# Synthesis of industry information on fishing patterns, technological change and the influence of oceanographic effects on SEF fish stocks.

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FISHERIES
RESEARCH &
DEVELOPMENT
CORPORATION

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**OBJECTIVES:**

1. Synthesise and formalise SEF industry information about factors influencing fishing power, including construct a time series documenting the introduction of new technology.
2. Synthesise and formalise information about trends in fishing practices, targeting, by-catch and discarding rates, and influences on fishing practices.
3. Synthesise and formalise information about oceanographic factors influencing catches and catch rates of SEF species.
4. Generate ordinal time series for incorporation in General Linear Modelling of catch rate trends within the SEF1 database by SEFAG.
5. Generate hypotheses about trends in SEF catch rates that can be tested through targeted analysis of SEF1 database by SEFAG.
6. Improve SEFAG stock assessments and government/industry relations in the SEF.

**NON TECHNICAL SUMMARY:**

A total of 96 fishers from the South East Trawl Fishery of Australia were interviewed during two rounds of carefully structured interviews. During the interviews fishers were asked standardised questions about the fishing patterns, technological change and the influence of oceanographic factors on SEF fish stocks.

Despite harbouring deep frustration and distrust of the existing process of management and stock assessment' fishers welcomed the chance to describe their fishing experience and knowledge.

According to the trawl fishers the limited size of trawl grounds compared to the habitat occupied by the various species (5-30% of the area of shelf and slope) restricts their ability to target most species. While accepting that certain species such as orange roughy and gemfish can be highly targeted and need the

protection of single species quota most fishers believe the configuration of their fishery has limited potential for impacting most SEF species.

The major change in fishing technology to occur has been the evolution of nets from danish seine, through bottom hugging 'scratch nets', through to 'high lift' or 'cut away' nets equipped with "rubbers" or "bobbins". This has increased the effectiveness of fishing with regard to midwater pelagic species while decreasing fishing efficiency for traditional demersal species.

Because fishers repeatedly trawl the same restricted trawl grounds they claim that the introduction of Global Positioning Systems and colour echosounders has had relatively little impact on their relative fishing power.

The fishers say that the move to quota management has had a major impact, deterring fishers from targeting large quantities of single species. Income is now maximised by landing as many species as possible on as many days of the year as possible. They believe this trend has driven the general decline in catch rates observed across many SEF quota species. Fishers of the SEF also believe that oceanographic factors, principally water temperature, are extremely important in determining catch rates.

On the basis of this body of anecdotal information and an analysis of other data it is concluded that:

- The importance of midwater pelagic ecosystems and environmental variability in the SEF has not been fully recognised in the past.
- The concept of targeting needs redefinition within the SEF trawl fishery.
- The current methods of estimating and standardising catch rates are inadequate in reflecting trends in stock abundance.
- The wrong assumptions are being used to assess the population dynamics of many SEF species.

The project achieved all of its objectives with the exception of objective 4 which was to generate ordinal time series for incorporation in General Linear Modelling of catch rate trends within the SEF1 database by SEFAG.

That objective proved to be contentious, as some SEF fishers do not support making detailed technical data available to SEFAG at this point in time, because they lack confidence in how it will be used. As a consequence any data the project would have gathered would have been patchy and presented against the wishes of some project participants.

Keywords: South East Fishery, demersal trawl, fishing patterns, multispecies, stock assessment, catch rates, oceanographic influences

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# 1. BACKGROUND

In assessing the status of the fish stocks of the South East Fisheries (SEF) the South East Fisheries Assessment Group (SEFAG) relies heavily on the analysis of catch rate trends. The underlying assumption being that catch rates are primarily determined by the abundance of the SEF fish stocks and that consequently commercial catch rates can be used as indices of abundance.

In addition to providing the basis for quantitative stock assessment simply aggregated catch rates are also used as management performance indicators for most of the 16 quota species.

However it is known that this gross over simplification can lead to inaccurate stock assessment and there is wide spread criticism of the assumption. It is also broadly acknowledged that a wide range of factors influences the recorded trends in commercial catch rates of exploited species.

The difficulty faced by SEFAG has been in understanding recent trends within the fishery in sufficient detail for these other factors to be incorporated explicitly into stock assessments.

# 2. NEED

In its 1995-2000 research plan SETMAC's Research Sub-committee placed a high priority on:

- Understanding shifts in fishing efforts and practices, and
- Understanding the effect of oceanographic conditions on fish and fishing practices, together with
- Increasing collaborative work and communication with the SEF industry.

Consequently the main aim of this project has been to:

1. To help SEF scientists make better use of existing logbook data by explaining the main trends from the point of view of "a SEF fisher".

2. To extend the consultation process between government and industry by documenting and presenting the ideas and concerns of SEF fishers.

## 3. OBJECTIVES

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## 4. METHODS (WRIGHT)

This study was conducted in two main phases. In the first, Baelde and Wright travelled throughout the fishery, from Wollongong, to Beachport, visiting every port, and interviewing about 50 fishers. In the second, Baelde returned, with a detailed questionnaire devised by herself and Wright, and conducted a second series of detailed interviews. The questionnaire used in the second phase was based upon the information gained in the first. It was designed to build upon the information provided in the first round of interviews.

The purpose of the study was to discover the fisher's perception of the fishing environment in which they work. Our task was to document the range of factors which fishers consider to affect their ability to catch quota species and hence to effect their catch rate, measured in CPUE statistics. We were not required to show the actual effect of the strategies and techniques we have been able to describe. However, we have endeavoured to describe how the fishers perceive these to have an effect.

This study has deliberately proceeded from a human perspective; from the point of view of a set of human beings interacting with, and within, an ecological, cultural, social and economic system. This is necessarily different from a scientistic type of study which might seek to locate the fishers themselves as objects of the inquiry. There has not been any attempt to "randomise" or otherwise contrive a sample methodology through which to choose the people to be interviewed, rather we have spoken to almost everyone in the fishery.

This perspective can of course create difficulties with interpretation as people understand and perceive situations and phenomena differently to each other. Contradictory sources will be evaluated and understood differently by different researchers. In reporting the results of our research in this report we authors have not tried to reach agreement on the meaning of what we have been told by the Fishers of the SEF. Rather we have structured the report so that the integrity of the contributing works of scholarship is preserved and identifiable.

The methodology upon which this study is based has its roots in the observations of marine scientists, anthropologists and others, who have seen that fishers, in a wide variety of contexts, have a sophisticated understanding of the environment they depend upon to provide their livelihood.

The study's basic proposition, is that the trawler fishers of the South East Trawl Fishery operate in a manner which rests upon a significant understanding of the behaviour of the fish they are pursuing, and the environment in which they are operating. By understanding something more of the techniques by which the fishers run their operations, it is hoped that the assessment and management of the fishery will be enhanced.

This type of work began, in the South East Fishery during the 1993 gemfish season when Dr Guy Wright, an anthropologist, interviewed gemfish fishers about their observations of the environment, their fish practices and the social-political relationships within the fishery. He found that a wide range of factors, from inter-ethnic rivalries, to differences in sea water temperature, and the behaviour of acoustically reflective layers located by depth sounders, were considered by the fishers, to be quite fundamental to their capacity to catch fish (Prince and Wright 1994:52-53).

One of the phenomena reported by Prince and Wright is of fisher's perception that gemfish "backed up" against "tides" of warm water, often flowing seawards and noted by fishers (1994:52). Recent work by Prince, Griffin & Diver (1998) has shown that this observation seems to accurately report the influence that warm core eddies have on the progression of the winter gemfish run. They suggest that this phenomena, observed for many years previously by fishers, influences the availability for catching of gemfish (catchability).

That fishers observations of the marine environment should be found to be quite accurate when later comprehended by standard scientific techniques should be no surprise. Many fishers are highly intelligent people who spend virtually every day of their working lives on the sea making observations upon which their livelihoods, and their position in the social order at sea and ashore, depend. When they are not on the sea working, their propensity for giving intense consideration to their observations is phenomenal. This behaviour among *homo sapiens fisherman's* can be easily observed at any port or pub where two or more of these people meet. The discussion, the theorising, and the testing of theories is as intense as occurs in any scientific gathering.

Among non-Western groups of small scale fishers, the literature which describes the environmental knowledge of marine resources and also show how exploitation of these resources is mediated in ways that work as regulatory regimes, is now considerable.1 Prominent, and archetypical of this literature is Johannes' *Words of the Lagoon: Marine and Fishing Lore in the Palau District of Micronesia* (Johannes 1981), and related articles (esp. Johannes 1978). Johannes, a former CSIRO marine biologist, was able to show that Palau fishers had an impressive understanding of the marine environment, which often left Western scientific understanding looking impoverished. However, he also showed that intrusion of the market economy was having a drastic effect on both fishing knowledge, and the institutional apparatus of Palauan society which promoted fishing conservation (Johannes 1978, 1981:63-75). In subsequent studies there was a strong focus on debunking the Western myth of the common property nature of oceanic resources. Study after study showed that fishing people everywhere have developed institutions through which fisheries were managed, without interference from centralised governments.2

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1 James M. Acheson's review article "The Anthropology of Fishing" (Acheson 1981) described nearly 200 references to fisheries anthropology.

2 Of the more influential are collections edited by Ruddle and Akimichi 1984, Ruddle and Johannes 1985, and Cordell 1989. The most recent addition to this literature is an Australian collection just published, edited by Nicolas Peterson and Bruce Rigsby (Peterson and Rigsby 1998). The focus is primarily Aboriginal, but an article by Nonie Sharp discusses the origins of the common property myth in the politics of 17th century European imperialism (Sharp 1998).

A recent article, which makes the case that Western fisheries should look to these non-industrialised fisheries for better management models, lists 28 small scale fisheries which practice one or more of

- territoriality
- limited access
- seasonal limits
- technological limitations
- protection of breeding stock
- protection of the young
- size limitations
- conservation ethic
- protection against overcrowding

as means of limiting exploitation (Acheson and Wilson 1996:583). These groups have all made significant observations of the marine environment, and these observations have resulted in recognition of the need to generate restrictions to an "open commons" situation in order to preserve, or enhance, the capacity to continue relying upon the marine environment for economic reward.

Other work extended the basic premise of the work with non-industrial fisheries, to large scale fisheries, managed according to standard recruitment prediction models in large statistical blocks, such as the Grand Banks of Canada (e.g. Andersen 1972, 1979, 1988) and Iceland (e.g. Palsson 1982, 1988; Durrenberger and Palsson 1986). This work showed that even fishers working in large, predominantly distant water, fleets maintain control of fishing territory through a variety of means. These controls are "seen as pragmatic attempts to manage the conduct of fishing" (Palsson 1982:5).

A corollary of this work is a set of critiques of standard fisheries management and science. One line of critique argues for co-management of marine resources. Essentially this means that fishers should have greater say in the management of fisheries because

1. they have an obvious vested interest in the continuing productivity of the fishery,
2. they are almost certain to have developed institutions which can be drawn upon for more effective management, and
3. management without their cooperation is much more difficult than with their cooperation.

Acheson and Wilson point out that "Among maritime anthropologists it is axiomatic that fisheries scientists and those who use those resources hold different views about the way oceans work and thus have different ideas about how to manage them" (Acheson and Wilson 1996:579).

This certainly seems true of the South East Fishery (SEF) with which this report deals. During the preliminary fieldwork in July and August 1997, in which Baelde and Wright interviewed about 50 fishers from all ports between Wollongong and Beachport, it was clear that relations between the fishers and AFMA were a running sore. Fishers simply did not believe that the ITQ management system was serving their needs or preserving the fish stocks. A large number of cynical fishers spoke of "Rex Hunting" large lifts of quota species which they brought to the deck only to "kiss goodbye" as they sent the dead and dying fish back to the sea, because the system had made it uneconomic for them to land and report them.3 Some went so far as to speculate that the large numbers of ling present during the season, was due to the increased tonnages of dead quota species that had been discarded. A dangerous consequence of this situation is that fishers believe the ITQ system to be hopelessly compromised because it is based largely on logbook and landing data which fishers think bear little resemblance to the amounts of fish being killed.

Whatever the reality of the situation it is very clear, from this study and from countless previous studies of fisheries, that fisheries are highly complex systems which are not amenable to simple formulae. In recent years a number of anthropologists and economists have suggested that chaos theory may be a more appropriate way to conceptualise a fishery system than models premised on equilibrium theory (Smith 1991).

> a chaotic fisher is one in which the time path of abundance of individual species has no equilibrium tendency but varies unpredictably within certain limits. This contrasts with standard theory that assumes population abundance tends towards some predictable equilibrium value (Wilson and Kleban 1992:67).

Acheson and Wilson point out that

> in actual fisheries we are fortunate to be able to assess stocks within 30 percent of their actual size; we can only guess at community predation inter-relationships... Given our state of knowledge of interrelationships in fish communities and our real measurement capabilities, it is virtually impossible to predict the size of future stocks of fish. This means that in the real world, it is impossible to predict the outcomes ... of regulations to achieve maximum sustainable yield, or maximum economic yield, through measures such as quota (Wilson and Acheson 1996:584).

Big fish eat little fish at random, or at least in highly complex ways; fish are influenced by environmental conditions such as warm core eddies off NSW as discussed above; human fishers, are a highly variable input as they predate according to external factors such as their interpretation of sounder markings, the daily state of the market, the state of their quota holdings, and a great many other factors, as this study shows. In addition, it may be that individual species expand or contract in numbers, and in mass, as a result of alterations in

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3 Rex Hunt is a popular Australian television character who hosts a recreational fishing program in which he often kisses unwanted fish before returning them to the water.

the environment, some of which may be anthropogenic. As the fishers concern about the increase of ling as a result of high discard rates show, this is a reality which can be understood by fishers.

The chaos theorists consider that management should not be based upon the numerically derived output controls implicit in quota management, but upon more easily comprehended environmental factors.

> ...the goal of regulation would be to maintain critical life processes such as spawning, to prohibit fishing during certain parts of the life cycle, and to maintain areas essential for the well-being of these species (such as breeding grounds, migration and nursery areas). This can be accomplished by rules concerning fishing locations, fishing areas and techniques.... it is exactly this approach that is taken in tribal and peasant societies .... the emphasis is on maintaining the variables that affect fisheries systems - not the amount of fish taken. The goal is not to attempt to control yields of fish but to maintain the system in a state where the normal range of variability is preserved (Wilson and Acheson 1996:585).

# 5. RESULTS "SYNTHESIS OF INDUSTRY INFORMATION ON TRAWLING" (BAELDE)

## 5.1 Introduction

The value of catch rate analysis has been questioned for a long time both by the scientific community and the fishing industry. Fishers have pointed out that changes in their way of fishing greatly affect scientific analysis of catch rate. However, scientists generally have only a limited understanding of how fishing is done. In this study, extensive interviews with fishers were conducted to gather detailed descriptions of their fishing practices and changes over time.

It is important to say here that fishers' willingness to volunteer information on their fishing practices should not be taken for granted. Unpopular management decisions have created deep frustration and distrust in the industry; while limited and poor communication of scientific results used in the setting of TACs has further deepened fishers' incredulity. It is not the point of the present report to comment on whether or not industry's perceptions are justified, but it is worth mentioning that fishers' discontent was always in the background during the interviews.

Despite all this, fishers' response to the present project was very positive and nearly all of those who were approached agreed to take part in the interviews. Fishers welcomed a chance to describe their fishing experience and knowledge.

Any attempt to assimilate fishers' experience accumulated over many years is an ambitious task. Interviews were run with fishers from all sectors of the SEF, but given the time constraints of this short project, this report is limited to the examination of bottom board trawling for market fish. The trawl sector has been under an ITQ management system for several years and this is reported to be the major factor influencing fishing practices. Information gathered from other fisheries (danish seine, orange roughy, hook and mesh-net fisheries) will be reported at a later stage. Also, only those aspects of industry knowledge that are relevant to catch rate analysis are reported here.

## 5.2 Interview protocol

The project started with a 5-week round of interviews with fishers to first identify what were the important issues to be addressed. Discussions with fishers were run by Pascale Baelde (fisheries scientist and consultant) and by Guy Wright (anthropologist). A total of 49 people were interviewed, individually or in groups, and including skippers, boat or company owners from both the trawl and non-trawl sectors. Based on these discussions, a questionnaire was then designed (see appendix) for a second round of more thorough interviews run by Pascale Baelde. The questionnaire was adapted to the various fishing methods accordingly.

Fishers were asked to describe their fishing equipment (electronics, nets) and their use; they were also asked to describe temporal and spatial trends in their fishing patterns.

The questionnaire was used during face to face interviews with individual fishers to somehow standardise the investigation and ensure that the same questions would be put to every fisher interviewed. Face to face interviews were preferred to mail questionnaires because they are the best way to maximise the response rate and they also provide a good opportunity to build up mutual recognition and trust.

As many fishers as feasible were approached in the major SEF ports during the second round of interviews which took 3 and an half months to complete. Particular effort was put into talking preferentially with skippers and 47 of them (from the trawl and non-trawl sectors) were interviewed.

Also, to avoid locking discussions around purely scientific concerns and thus missing out on as yet unknown source of information, the interviews were flexible and the questions were kept open. This was to give fishers the opportunity to follow their line of thought freely, expanding in whichever direction their particular knowledge and concerns led them.

For reason of confidentiality, this report also remains fairly general, avoiding elaboration on contentious issues and respecting trade secrecy when necessary. The main point of this work is to describe fishing practices, not to make judgements on their appropriateness. If such debate becomes warranted, then it will need to be properly addressed through specific and targeted consultation with industry.

In that sense, some fishers may find that the report does not go far enough or does not tell them anything new. However, they need to understand that this report aims essentially at better informing scientists on what fishing is about so that logbook information can be used in a more appropriate way and meetings between scientists and industry can become constructive.

This report does not pretend to be a complete description of fishing practices and of factors influencing fishing efficiency. It is a synthesis of the most significant aspects of fishing practices discussed during the interviews. This report is an attempt to show the differences between the conceptual frameworks in which scientists and fishers operate. To improve text clarity, it intentionally falls short of giving practical details.

## 5.3 Fishing Technology

### Bottom trawl nets

Net design is a well guarded trade within each port. Some fishers work out their own designs and make their own nets, but most fishers rely on a local net maker.

When board trawling developed off NSW, the fishers there designed several demersal nets, each specialised in catching particular species. The most typical of these nets are the eastern gemfish nets which are designed to fish hard on the bottom and at low speed, with a wide and low net opening (around 3-4m high) and long wings to herd the fish. Eastern gemfish nets are big nets capable of handling large quantities of fish. Specialised gemfish nets are rarely used today because of the severe decline in the stock abundance.

As the abundance of some species declined (as in the case of gemfish) and the catches of other species were limited by quota, fishing practices evolved from initially targeting large, single-species catches to now catching mixed market species. At the same time, bottom trawling extended to rougher grounds.

This led in the early 1990s' to significant changes in the design of bottom trawl nets, most markedly in southern NSW and in Victoria (where board trawling developed later). Today, the bottom trawl nets used in the SEF are mostly multi-purpose nets (also referred to as 'high lift' nets) designed to catch a wide range of species. Fishers also use another type of nets (often referred to as 'scratch' nets), the design of which is derived from the gemfish net. The two types of nets and their use are described below in more detail.

## 'High lift' nets

'High lift' nets are small compared to early bottom trawl nets. They have a high opening (5-6m high), short (or 'cut-away') wings and bigger mesh size, and are usually fitted with large rubber disks. With their reduced bottom contact, they are designed to be towed over rough bottom at fairly fast speeds to catch a variety of species forming aggregations at some distance off the bottom.

Several designs have been developed from this general 'high lift' design, and some fishers pay particular attention to fine tuning the rigging of their nets to changing fishing conditions. To understand well how nets behave in the water is regarded as a major component of a fisher's skills.

## 'Scratch' nets

'Scratch' nets have kept some of the characteristics of the gemfish net, although they are smaller and have a slightly higher head line. Compared to the high lift nets described above, scratch nets have a wider and lower head line and longer wings, and are usually fitted with smaller rubber disks. They have a greater bottom contact and are designed to be towed closer to the bottom at lower speeds to herd fish dispersed on the bottom. Off NSW, where clear and muddy grounds predominate, these nets are fitted with chains.

Although both high lift and scratch nets can be used on clear and rough grounds, high lift nets are more often used on rough grounds and scratch nets on clear and safe grounds. Also, with their larger rubber disks and shorter wings, high lift nets are less efficient at catching dispersed species or species closer to the bottom which are caught more efficiently with scratch nets. High lift nets and scratch nets are used for two different type of fishing operations which will be described later.

## GPS-Plotters

Fishers started using the Global Positioning System (GPS) progressively from the mid-1980s, at a time when it was only operational for a few hours a day. By the early 1990s' most fishers had acquired one, and today the performance of GPS and associated equipment is continuously improving.

There is no doubt that, over the last decade, GPS-plotters have greatly facilitated fishing operations in the SEF by giving fishers more accuracy on the grounds. However, it is not so clear in what ways they affect fishing efficiency. According to fishers themselves, GPS-plotters do not necessarily increase the fishing efficiency of already efficient/skilled fishers, but rather improve fishing efficiency of less skilled fishers. It is often said that today young and inexperienced skippers can go fishing with some success at the swap of a floppy disk, as they just have to follow the dotted lines on plotters. It is the capacity of GPS-plotters to record, memorise and transfer information that is making them so essential to fishing. GPS-plotters do not increase catch rate of *individual* shots as such.

By continuously recording the position and speed of the boats, a GPS allows fishers to better work out the effect of currents on their route. Compared to using radar and land marks, navigation and setting of the nets on the bottom have become much more accurate, with fishers wasting less time positioning their boats exactly over fishing spots. More accurate navigation also gives fishers more incentives to move between grounds when necessary.

Better accuracy on the fishing grounds has major effects on fishing behaviour. Bottom trawling initially developed on clear and safe grounds, but over time fishers have learned to fish closer to rough grounds where some species are more abundant. The navigational accuracy provided by GPS-plotters, together with the ability to record the position and shape of trawlable and non-trawlable grounds, allow fishers to work closer to rough and risky grounds without excessive net damage. As GPS-plotters became common in the fishery, fishers also replaced chains on the foot line of their nets with rubber disks to limit net damage on these rough grounds.

In the end, GPS-plotters have extended trawlable grounds, not so much in terms of opening new grounds, but rather in terms of extending the limits of known grounds toward more risky, but still trawlable, areas. They also allow fishers to work grounds that were previously too difficult to trawl, such as gutters and edges of canyons.

Some fishers say that, although not denying that GPS-plotters have increased fishing efficiency in some ways, their importance is over-rated today. Other factors are at least as important, such as having adequate nets and boat power.

Also, no matter how sophisticated the fishing equipment fishers have, local knowledge and 'know how' always keep the best fishers a step ahead.

## Colour echo-sounders

Hardly any fisher uses black and white echo-sounders today, although they are often reported to give a better ground definition. The cost of paper rolls for the last fishers attached to their black and white sounders has eventually tipped the balance towards colour echo-sounders.

The importance of echo-sounders for fishers seems to have been supplanted by GPS-plotters. Before GPS-plotters, echo-sounders were used to help locate a fishing spot by following the contour of the bottom. With the positioning accuracy they get from GPS-Plotters, fishers tend to not check the bottom on their echo-sounders as much.

Today, colour echo-sounders are mainly used to look for 'life' (feed layer and fish marks) in the water and near the bottom, but even this appears to be of limited help to fishers in finding most commercial species (see section on feed layer and fish marks below).

Net monitors are much more useful to fishers than echo-sounders, although it is an expensive piece of gear rarely used for market fishing. Most of the fishers who were formally engaged in the orange roughy fishery have net monitors and some use them when chasing schooling species. Net monitors give a better definition of the fish when they are near the bottom compared to the definition given by colour echo-sounders. Also, the ability to see the fish just in front of net allows fishers to manoeuvre the nets and herd the fish inside more successfully.

## Rubber disks

To be able to trawl closer to the more productive rough grounds with limited damage to the nets, fishers started replacing chains with rubber disks in the mid-1980s. At the same time, increased access to GPS-plotters further facilitated the 'opening' of such grounds to trawling. Today, nearly all fishers have at least one of their nets fitted with rubber disks. The size of the disks ranges from 6 to 14 inches, depending on the type of bottom fished (larger disks, usually fitted on bigger nets, also require more boat power).

Although rubber disks are used to limit net damage, they also give some fishers the incentive to take increasing risks to access fish on rougher grounds. Fishing on the 'bad bottom' is balancing a personal/business choice between the costs of repairing or replacing nets and the benefits of greater catches in general.

***Non-trawlable reefs***

During the interviews, asking fishers to describe how rubber disks have helped them work over harder bottom revealed it to be quite a sensitive issue. This was most certainly related to current debates amongst industry on the potential impact of such fishing practices in terms of bottom degradation and increased fishing pressure on the stocks.

Fishers wanted to make it clear that the rubber disks they use do not allow them to fish over reefs or 'cray bottom'. At best they can only come close to them. Rubber disks have facilitated fishers' access to only certain types of rough bottom, such as slabs (sand stones) on the continental shelf break, gravel on the deeper continental slope, edges of canyons, etc. Most rough grounds exploited today are the ones on the continental shelf break. Fishers interviewed also wanted to point out that only a few of the largest of the SEF's orange roughy trawlers used the controversial steel bobbins to trawl over very hard bottom.

## 5.4 The Fish and their Environment

During the interviews with fishers, a lot of information has been gathered on various aspects of the biology and behaviour of individual species and on some environmental factors that influence fishing. The information mostly reflects individual fishers' believes and experiences and is very scattered and anecdotal. For example, the interactions between fish catchability and optimal environmental conditions as described by fishers are extremely complex, varying between species, times of the year, areas, and of course between fishers. There was not enough time during this study to synthetise such information in a clear and meaningful way.

It became obvious during the interviews that the nature of fishers' knowledge differs significantly from scientists' biological concerns and questions. Fishers' knowledge is indeed directly shaped by its usefulness to fishing. For example, fishers need to understand and predict the movements of the fish, but they do not particularly need to know the biological reasons behind the migrations of the fish. Once it has been scientifically established that a species gather seasonally over a particular area to spawn or feed, fishers still have to work out where the fish are on a day to day basis. Also, fishers have little opportunity to gather information on the maturation of the gonads for example, or on the feeding habits of the fish because most species are not gutted at sea.

However, fishers' knowledge about the fish they catch and the environment they work with provides very useful insight into some aspects of the fish/fishers interactions that are mostly unknown from scientists. Information on the behaviour of individual species includes inter-annual, seasonal and daily movements, fluctuations in abundance, preferred type of grounds and depths, schooling patterns (eg. density and distribution of schools), swimming speed and patterns of net avoidance, short and long term responses to fishing pressure, change in size of fish between seasons and fishing grounds. Information on the environmental factors that influence fishing mainly revolves around 'water conditions' (eg. water temperature, direction and strength of currents and tides, 'richness' of the water) and their seasonal fluctuations, and also around the phases of the moon.

The effect of the moon is certain, at least in keeping fishers, and some scientists, talking! Discussions about it are always colourful, a mixture of very strong believes, total incredulity, pet theories of the week, and whispered allusions to some heavily guarded trade secrets. Such animation around the topic suggests that there is some reality in what fishers' believes, and whether or not the effect of the moon on fishing has been over-rated, the information gathered during this study is worth further investigation.

The majority of fishers say that the temperature of the water is what influences fishing patterns and fishing success most. Most fishing activities in the SEF (except off Tasmania) depend on the cold waters coming from the south in winter. Fishers often comment that when fish aggregate near the bottom, they are more dependent on a particular body of water (cold and rich in feed) than on the bottom itself.

It is the temperature of the water near the bottom that is most important, but fishers do not have the equipment to measure and record it as yet (except for the few fishers using net monitors). They rely on their understanding of current patterns on the surface of the sea to know where to find the right body of water. The combined knowledge of the temperature requirement individual species and of the water dynamics is another important aspect of fishing skills.

## Regional and seasonal trends in ground productivity

Only very general trends discussed by fishers are reported here to help understand the regional differences in fishing practices that will be described later.

Fishers often say that good fishing goes with cold water and rough, broken bottom. The productivity within the SEF is largely determined by the mixing of northern warm waters with cold and nutrient-rich sub-antarctic waters running northerly each winter. Overall in the SEF, most productive fishing occurs in winter and within the area benefiting most from the influence of sub-antarctic cold waters, between East Bass Strait, southern NSW (south of Bermagui) and Flinders Island. The richness is further enhanced by the extended and diverse fishing grounds occurring between the continental shelf break and upper slope (there are of course other more localised 'hot spots' throughout the SEF area).

Fishing is generally poor in summer because of the influence of warm and nutrient-poor tropical waters running south. Fishing at that time of the year is limited to catching the more resident types of fish over the continental shelf or over the upper slope, below roughly 600m (300 fathoms).

By contrast, grounds off central NSW (from Ulladulla north) are markedly less productive than grounds further south. There, the beneficial influence of cold waters in winter is not as strongly felt, while the negative influence of warm waters in summer is greatest. Furthermore, trawlable grounds are mostly made of long stretches of clear and muddy bottom, with some non-trawlable reefs, and are generally not as productive as the rough, but trawlable grounds further south.

In Western Bass Strait, although winter months are still the best fishing months, the winter-summer change in productivity does not seem to be as marked as on the east side of the SEF. The productivity of this area is believed to be limited by the small extent of trawlable, but rich, grounds.

It is difficult to compare the productivity of the southmost part of the SEF, off Tasmania, to other areas because (except for the winter fishery for blue grenadier on the west coast) market fishing in Tasmania has developed only recently and fishers are still 'gathering evidence'. Market trawl fishing off Tasmania is developing mainly off the east and south coasts, where, contrary to other SEF areas, fishing is better in summer than in winter. This information is confounded, however, by the fact that Tasmanian weather conditions in winter are often bad, while fishing in northern areas (where most fishers working off Tasmania come from) is best in winter.

### *Greater productivity on rough grounds*

Fishers generally agree that, for many species, rough and broken grounds are more productive compared to the clear grounds on which demersal trawling initially developed. They believe that rough grounds create local current dynamics which attract food, which in turn attracts fish.

They say that catches are better on rough grounds because it is where the fish prefer to stay. The success of fishing 'on the clear' is said to be too dependent on the fish coming across the path of the nets during their movements. In their view, fishers 'miss' the fish more often when fishing on the clear.

However, other fishers are concerned that rough grounds could be the last refuge from trawling for fish and that too much fishing pressure there could be detrimental to the stocks in the long run. It is also unclear whether fishers' perception of increased catches on rough grounds comes from a perception of decreased catches on clear grounds. The apparent higher productivity of rough grounds could also relate to their more recent exploitation.

## 5.5 Feed layer and fish marks

### Behaviour of the feed layer/fish marks

A 'feed layer' is a mixture of macroplankton and various species of fish concentrating in a horizontal layer in the water column, most likely sitting on a thermocline. There are normally two feed layers sitting on the two major thermoclines in the sea, a shallow feed layer in about 10m (5 fathoms) and a deeper one in about 200m (100 fathoms). It is the deeper feed layer which is of interest here because of its importance to fishing. It is most likely a major source of food for commercial fish and thus probably influences their daily and seasonal migrations.

Fishers pick up the deep feed layer on their echo-sounders before daybreak as a horizontal band high in the water column which, as a general rule, moves down toward the bottom in the early hours of the morning. The feed layer can sometimes be seen to go back up the water column later in the afternoon. The reasons and mechanisms behind this daily phenomenon are not well understood, but they govern most fishing activity between the shelf break and upper slope. Also, in 200m, the deep feed layer is about at the same level as the continental shelf break and contributes to the enrichment of this part of the sea bed.

The feed layer generally seems to be richer (as suggested by its thickness in the water and its density) in winter than in summer, although this seasonal change is most obvious off central NSW.

### Identification of feed layer/fish marks

Fishers can sometimes distinguish fish aggregations, or 'fish marks', from the 'feed' on their echo-sounders for species forming dense aggregations. This is particularly the case in winter during the spawning runs of some species. Whether the fish that are caught are associated with the feed layer or are attracted by it and aggregating from somewhere else is debated within the industry, and most likely depends on the species. For some species, schools can be seen 'dropping off' from the feed layer on their way down to the bottom.

Generally speaking, however, fishers have limited faith in their ability to identify the species in aggregations by using the colour or shape of fish marks visible on echo-sounders. In most cases, it is the local knowledge of fishing grounds and of the seasonal occurrence of fish that allows some prediction of what species are on the grounds.

It is also worth noting that colour echo-sounders with different output power give different definition, which affects fishers' interpretation of what they see on their screens.

## 5.6 Fishing Practices

### 'High lift' fishing

High lift fishing is the major component of the SEF market fishery and its related fishing practices are described in some detail below. This type of fishing refers mainly to winter fishing when fishers actively concentrate their effort on the spawning runs of several species between the continental shelf break and upper slope.

## Targeting

Only the orange roughy fishery can be considered as a true target fishery: a fish mark has to be found on top of a hill before the net is dropped on the fish school in a scooping motion. Once a mark has been found, the success of actually catching the fish in the net depends essentially on the skipper's experience. Poor shots often result from the skipper having missed the marks, rather than from the fish not being there. And poor fishing days refer mostly to days when fish marks can not be found, or are not close enough to the bottom to be targeted.

Fishers are eager to demonstrate that, when market fishing, they do not *target* the fish as such. Their sensitivity to this targeting issue is related to its link with the controversial issue of dumping. In simplified terms, the perception from outside the industry is that if fishers are able to target a species, then they should also be able to avoid it and thus should not have to dump unwanted catches. This report hopes to bring some light into the debate in the following paragraphs.

## What to catch and where

With a market demand encompassing diversified species and, furthermore, with quota limiting catches, making the right business decisions on what to catch and where has become an essential part of 'fishing skills'. Fishers have to make such decisions based on a complex combination of information on market prices, quota holdings/availability/leasing prices, fish availability, and also on the composition of other fishers' catches. In fishers' experience, trends in market demand, quota holdings and fish availability too often pull in opposing directions.

Communication between fishers is an important part of trawl fishing, as in many other fisheries, and it seems to have increased since the quota system was put into place. While the exchange of information may flow more or less freely, on 'a give and take' basis between some fishers, a few fishers, and particularly the best ones, are rather secretive about their fishing activities.

Most species of fish move around continuously and working out where the fish are, or may be, is critical for fishers. They do not like to go fishing totally 'green' and they need some information before hand on what to expect. They maintain a day to day knowledge of what is going on the grounds using their own experience and using other fishers' experience whenever available.

Fishers sometimes use information on other fishers' catches to follow in their steps, but in most cases they use such information to decide which species to catch that are not yet on the market. Market prices are very much geared to supply and demand. Also, catches are generally better on 'fresh', or 'spelled', grounds that have not been fished for some time. So, fishers try to be first on these fresh grounds to have the advantage of a few trawl shots ahead of other fishers.

### Mixed species catches

Fishing patterns are more and more revolving around the need for fishers not only to land a mix of species, but also to spread their landings throughout the year as much as possible. For most fishers, the good old days when they could in one season catch *and* land large quantities of only few species have gone, a legacy of stock declines and market and management constraints.

Fishers have several ways to increase the diversity of their catches in individual shots. As seen previously, they have designed high lift nets that are more versatile and can be used over the richer rough grounds. By fishing through a higher portion of the water column, high lift nets catch several species that swim at some distance off the bottom, and also, albeit less efficiently, some of the species that are more attached to the bottom.

Fishers also work particular depths or grounds where the distributions of various species are known to overlap, or they sometimes trawl over a wide range of depths during one shot. They can also pick up more species by increasing the distance trawled or, with the help of GPS, by finishing a shot over the edges of canyons.

However, the essential way for fishers to catch a mix of species is to travel more between grounds, catching different combinations of species in different shots. Some fishers also resort more and more to catching non-quota species.

## 5.7 Fishing time and searching time

### The 'morning shot' and the feed layer

Bottom trawl nets, by design, can only catch fish when they aggregate near the bottom which many SEF species do on a daily basis, apparently in unison with the morning descent of the feed layer. The first shot, or 'morning shot', is generally regarded as the most successful shot when market fishing.

Despite this well talked about association between the first shot and the morning descent of the feed layer (and associated fish species), fishers in fact spend little time at sea, if any, checking for the presence or abundance of the feed layer. As mentioned before, a large part of 'searching 'for fish is spent on the phone 'sharing' some sort of 'collective' experience with other fishers.

Fishers see no clear relation between the presence or abundance of feed layer/fish marks and their catches because of the difficulty in identifying what they see on echo-sounders. At best, the presence of 'life' in the water is a good sign for fishing and lifts fishers' hopes, but it is no guarantee of good catches (a thick feed layer can be just made up of small non-commercial fish). On the other hand, good catches are also made sometimes when there is no trace of 'life' at all in the water. Speculation on the relationship between the presence and composition of the feed layer and catches is an ongoing frustrating experience for many fishers.

For the morning shot, fishers generally go straight to a chosen spot and shoot the gear regardless of finding 'life' in the water. By experience, they know that having the net accurately and quickly on the bottom at the right time is more important than actually searching for fish.

## Daytime shots

Shots in the middle of the day are usually less productive than the morning shot. Depending on the success of this first shot, and on other constraints such as quota holdings and market prices, fishers may repeat the shot on the same ground or move to another ground. During the day, fishers tend to search for fish marks more actively than in the morning, particularly if chasing schooling species. However, if running out of time, they often end up shooting the gear regardless of finding a mark. Here again, the presence of 'life' is a bonus but not reliable enough to 'waste' fishing time looking for it.

## The 'dark shot'

At the end of the day, fishing tends to improve again during the so-called 'dark shot'. Fishers shoot the nets on the bottom about one hour before dark. For both the morning and the dark shots, it is during twilight conditions that fish seem to be the most vulnerable to bottom trawling.

## 'Scratch' fishing

Scratching, as suggested by the word itself, usually refers to fishing at times when catches are expected to be poor, such as during night time or during summer. As already said, annual market landings rely mostly on the winter spawning runs of several species between the shelf break and the upper slope. Fishing becomes less productive on a daily basis when these species lift off the bottom at night time, and on a seasonal basis when they 'disappear' from the grounds at the end of their spawning activity (some species never seem to disappear totally though).

While most of the small, day time operators return to port at the end of the day, larger operators who stay at sea for several days keep fishing during the night to maximise their fishing time. They usually carry on night fishing on shallower (continental shelf) or deeper (below 300 fathoms) grounds. They use scratch nets to make 1 or 2 long shots (up to 7-8 hours) through the night and catch small quantities of fish dispersed on the bottom. These long shots are generally made on safe, clear grounds.

In summer, much fishing effort is diverted onto inshore grounds. While small boat operators are bound to local grounds, large operators change area and go fishing further south. The importance of such fishing mobility in the SEF is discussed below.

## 5.8 Need new definition of 'targeting' for the market fishery

When fishing for market species, short of being able to target the fish themselves, fishers have learned to target the rougher grounds where the fish are more likely to be. Fishers do not trawl totally blindly either and they have some idea of what they are likely to catch on a given ground at a given time. Over the years, they have learned about the seasonal and daily movements of the fish and, as discussed earlier, they also use individual and 'collective' fishing experience.

However, they are rarely totally sure of what the fish are doing and they do get surprises at times in terms of the species caught or their relative proportions. Accidental catches are a reality. Some are welcomed, others are not.

Under a quota system, fishers not only have to decide what species to catch, but they also may have to avoid catching some other quota species. This is not an easy matter for some species which naturally have a wide depth distribution and a tendency to mix with others, or in the case of species showing high year to year fluctuations in abundance.

Most fishers say that it is now part of their fishing practices to 'run away' from concentrations of some quota species to avoid unwanted catches. There are typically two situations where fishers need to run away from fish. After catching some quantity of a particular species on a ground, fishers may have to leave the ground even though they could catch more fish (and would have before the implementation of the quota management). The other situation is when fishers want to avoid any catch of a particular species at all (such as eastern gemfish).

Although it is possible to avoid some species to some extent by avoiding particular depth ranges or particular grounds, fishers pointed out that in most cases, they can only run away from already, and accidentally, caught fish. Here again, it is previous fishing experience on a ground that informs fishers of what species is likely to be caught.

The need to run away is more or less constraining depending on the species distribution and the fishers' personal quota situation, but it happens more frequently in the second half of the year when a large portion of TACs and personal quota has been caught.

It is necessary here to rethink the definition of targeting because of its consequences for the analysis of catch rate. Again, fishers target particular grounds rather than the fish themselves, with consequent limited control over the species composition of catches.

## 5.9 Variation in fishing practices within the SEF

Fishing practices are not uniform within the SEF, and vary most markedly between business operations with different structures and fishing needs. Some of the fishing practices discussed so far are reviewed here for the two major SEF business categories described below.

### The two major business categories

Fishers, categorised here as skippers who are engaged more or less full time in market fishing in the SEF, can be grouped into two broad categories of fishing businesses. First, the family businesses, run by fishers who operate small to average size boats (from less than 20m to just above 20m in length) on daily trips at sea. These fishers usually own and skipper their boats and have relatively small quota holdings. Most of them work off the NSW coast, with also a few working off East Bass Strait.

The second category encompasses the 'company' fishers. These are hired skippers or business partners in companies usually having large quota holdings attached to several boats. The boats involved are relatively larger (between about 20m and 25m) and most are based in southern NSW and Victoria. It is quite common for hired skippers to change boats within or between companies. Their fishing skill/experience is a tradeable commodity.

The contrast between these two types of fishing businesses results essentially from the rapid development and decline of the orange roughy fishery between the mid-1980s and early 1990s. At the start of this fishery, when input management was in place, boat-units from small boats (mostly from NSW) were amalgamated into large boats capable of fishing the orange roughy grounds. After the decline in the orange roughy fishery, these large boats shifted to market fishing.

### Influence of quota holdings on catch patterns

Because of their larger quota holdings, fishing companies are usually under less constraining quota limitations. They are also sometimes under fewer market constraints by having their own fish processing factories. For some of these operators, the need to catch the right species in the right quantities at the right time is not as crucial as for operators with more restricting quota holdings. However, owners of larger boats have to pay higher running costs and fees for their large quota holdings and, as a consequence, often put pressure on their skippers to catch large quantities of fish. If landing the fish at the market, low market prices often have to be offset by large catches.

### Fishing effort

According to logbook data, fishing effort (hours trawled) has increased significantly over the last decade in the SEF but landings of market species have not increased. The first concern here, in terms of stock assessment, is whether this increase in fishing effort reflects a decrease in fish abundance. Asking fishers for their perceptions about changes in the abundance of individual stocks was another sensitive issue that many fishers were reluctant to discuss. Comments on fish abundance mostly reflected fishers' individual quota requirements (whether for an increase or a decrease). However, not all information on changes in stock abundance provided by fishers was 'economically' biased. Again, increased and truthful collaboration from fishers would need them to have a better understanding of the stock assessment process.

Fishers also provided information on the role that the ITQ management system is playing in increasing fishing effort. It was often mentioned for example that since fishers were given quota, they actually have to catch them if they cannot sell or lease them satisfactorily. Also, many company skippers under constant pressure to catch quota have increased their fishing effort by spending more days at sea, working on a 24 hour basis. This increase in night fishing over the last few years is possibly contributing significantly to the overall increase in fishing effort in the SEF. Large operators also tend to work more under bad weather conditions, and some boats operate continuously with two skippers working in shifts.

Small boat operators have also increased their fishing effort, but not quite for the same reasons and not to the same extent. They are also under constant pressure to catch fish, but, as said earlier, more in terms of catching diversified catches. To catch the right amount of the right mix of species on a regular basis in fact requires fishers to spend more time at sea, always 'on the go', to take advantages of fluctuations in market demand. In the end, they seem to spend more, and longer, days at sea than they used to a few years back.

It must be remembered too that part of the fishing effort recorded in logbook relate to shots primarily aimed at non-quota species, even though they may include small quantities of quota species.

In terms of the number and duration of shots, fishers make on average 2 to 3 shots during daylight of about 3-4 hours duration (ranging from 1 to 4 hours). They tend to make more shots in summer and less in winter because of the change in day length. Night shots (and more generally 'scratching' shots) are usually longer, and fishers make 1 to 2 shots for up to 7-8 hours. The differences in the duration of shots between 'high lift' fishing and 'scratch' fishing has to do with the differences in distribution patterns of the fish, from aggregated to dispersed.

A significant aspect of the increase in fishing effort in the SEF is the increase in boat power. More boat power increases fishing efficiency by allowing fishers to tow bigger and higher nets at greater speed and thus to cover more ground (and volume of water) by unit of time. Fishers boost the power of their boats by increasing the power the engine(s) and by fitting larger propellers and nozzles. Thus far, the increase in fleet power remains unquantified.

### Fishing mobility and fishing options

Large company boats are also much more mobile and they travel a lot throughout much of the SEF. This mobility opens more fishing options to them as they can follow the seasonal north-south changes in ground productivity.

During the best winter months, most small and large operators work within the most productive area between southern NSW and north Flinders Island. Small operators usually work local grounds around their ports during single day-fishing trips. Larger operators spend 3 to 5 days at sea travelling to various grounds along the shelf break-upper slope contour in the day time, and 'scratching' on shallower or deeper grounds at night. It is sometimes recognised that 'company skippers' have less experience on local grounds than the more established small operators.

In summer, when fishing become less productive in this area of the SEF, fishing options are more limited for the small operators bound to their local grounds. They concentrate most of their fishing effort on inshore grounds. Whereas, over the last few years, large operators have adapted their fishing patterns to this seasonal change in productivity. In summer, they go fishing on southern grounds, particularly off the east coast of Tasmania, on 5 to 10 day fishing trips. Some of them will return to their main port after each trip, while others will stay in Tasmania for a few months before returning to northern grounds in winter.

The summer situation is particularly bad off northern NSW where fishers have even fewer fishing options than anywhere else in the SEF. This is due to the generally lower productivity of their local grounds, to the distance away of more productive southern grounds and to the small size of their quota holdings in general (deep water prawn, which are available in summer, do not constitute an attractive fishing option for fishers because of current handling difficulties and market problems).

# 6. DISCUSSION, ANALYSIS & HYPOTHESIS GENERATION (BAELDE)

## 6.1 Consequences for catch rate analysis

Trends in catch rate could send the wrong message on fish abundance if changes in fishing practices and fishing efficiency are not taken into account. Talking with fishers about their fishing patterns clearly showed that analysis of catch and effort data needs to be better adapted to the dynamics and diversity of practices within the fishing fleet.

## 6.2 Limitations of the current use of logbook information

Current data aggregations based on SEF statistical areas, depth strata or seasons are a crude way to use logbook information which does not reflect the structure and dynamics of the fishery. Data that are not truly comparable are lumped together to analyse trends in catch rate. Also, as pointed out by fishers themselves, the information recorded in logbooks does not say anything about the intricacies and motives behind fishing practices. Analysis of logbook information is further hampered by the sometimes questionable quality of recorded data.

Aggregations of catch and effort data must be done in more sophisticated ways and need to make more use of qualitative information on the fishery. In this section of the report, some of the major factors governing the fishing practices described earlier are reviewed with respect to their impact on the analysis of catch rate.

## 6.3 Business aspects of fishing under a quota system

As a rule, TACs are not fully caught at the end of the year, and far from it for several species. In scientific terms, this is a concern because it could reflect a decline in fish stocks. However, fishers say that they fish for dollars, not fish, and are eager to demonstrate that whether TACs are caught or not relates essentially to business decisions they have to make when dealing with market demand and quota availability. The availability of the fish is just one of the components to deal with in a complex decision making process.

Small quota holdings are sometimes less likely to be caught than larger quota holdings because the likelihood to quickly overcatch some species limits fishers' operations.

## 6.4 Fishing practices and catch rate

### Maximising quota holdings tends to drive catch rate down

In general under quota limitations, fishers have adapted their fishing practices to the need to maximise their holdings. And different groups of fishers have different fishing practices in relation to their specific quota situation and type of businesses.

To maximise their quota, fishers tend to spend more time at sea to catch a mix of species that suit both market demand and quota holdings than to catch whatever species is the most available.

Furthermore, to spread their landings throughout the year, fishers sometimes keep their quota for some species in order to catch them outside their normal season and so obtain better prices on the market. Catch rate differs significantly between fishing spawning aggregations in winter and fishing more dispersed fish at other times of the years, with no relation to change in the stock abundance.

These fishing practices today are most likely to drive fishers' overall catch rate down. The need to occasionally 'run away' from fish aggregations and potentially good catches would also artificially drive the catch rate down.

This however is not true for all fishers in the SEF and individual operator's business constraints and needs influence their fishing practices, and thus their overall catch rate.

## 6.5 Effect of fish behaviour on catch rate

### Mixing of species on the grounds:

There is a well debated contradiction in the ITQ quota system being based on individual species while many of these species are mixed on the same grounds, at least to some extent. This is probably one of the major problems with the current single species approach to catch rate analysis which disregard the mixed nature of catches. The distinction between targeted and non-targeted shots in a multi-species fishery, specially when fishers have only limited control over what they catch in terms of species composition and relative proportions, seems rather pointless.

### Fish response to fishing pressure:

Catch rate analysis also needs to integrate the fact that fishing patterns are governed by a succession of depletions/recoveries of the fish which operate at various temporal and spatial scales. It is well known that catch rate generally decreases as fishing progresses on a particular ground or during a particular period and fishers try to adjust their fishing accordingly.

Fishers stopped fishing on a ground when catches have decreased to non-economical levels, which can take from a few days to a few weeks depending on the species, the type of ground and the intensity of fishing pressure. Then, after some time, the fish come back on the ground and fishing resumes. That is why fishers always try to be first on 'fresh' grounds that had a spell from fishing.

Fishers also describe how changes in their individual fishing activity immediately affect the fishing activity of other fishers working in the same area. This is the case for example when one boat stop fishing for a while for maintenance purpose. This suggests that, at least at a local level, there is some sort of a balance between the fishing grounds 'carrying capacity', the fish (short-term) resilience to fishing pressure, and the intensity of fishing effort.

## 6.6 Changes in fishing efficiency

### Technological improvements and boat power :

The impact of GPS-plotters on fishing efficiency need to be examined in details at the local level. GPS is perhaps more likely to have increased the proportion of low to average catch rate values than the proportion of high values.

The general increase in boat power in the SEF is also changing the value of one unit of effort (one hour on the bottom).

### Fishing more productive grounds:

Fishing on the more productive rough grounds has increased over the years in the SEF, facilitated by GPS, rubber disks and more appropriate net design. The difference in fish productivity between rough and clear grounds need to be investigated and integrated in catch rate analysis.

Also, large operators are more mobile (within or between areas) than small operators, which gives them the ability to move to most productive grounds. How such fishing practices affect their catch rate needs to be examined.

### Differences between 'high lift' fishing and 'scratching':

'High lift' and 'scratch' fishing are totally different fishing operations that result in hardly comparable catches in terms of size and species composition. They need to be distinguished when analysing logbook data, specially because some species are caught during both types of operations.

### Fishers' skills:

The impact of individual fishers' experience on catch rate analysis has been long recognised, but left in the 'too hard basket' because of the difficulty to quantitatively measure it. It is in fact necessary to consider fishing skills as a non-quantifiable 'package' belonging to individual fishers. The nature of fishing efficiency has changed over time under market and quota limitations, and fishers competing with others by comparing catch sizes are getting fewer.

The increase in communication between fishers is apparently facilitating a form of 'collective searching' and, as such, improving fishing efficiency. The impact of this on catch rate would be very difficult to measure, but it should not be dismissed.

# 6.7 Concluding Discussions (Baelde)

## Socio-economic factors associated with quota management:

In the same way as fish stocks have been regarded for a long time as separated from the influence of the environment they live in (mainly as a matter of necessity), fishing practices are still understood today as fish and fishers 'eyeballing' each other, independently from other social and economic influences.

However, an ITQs system is designed in such way that economic forces and the servicing of debts and costs associated with fishing override biological concerns. Economic forces translate into fishing practices and, for catch rate analysis to be relevant to stock assessment, it must include a fair understanding of these economic forces. The distinction between the social, the biological and economical in fisheries assessment and management are artificial and detrimental in the long run.

## Need sustained collaboration with industry:

This short study has confirmed the great benefit that can be gained from collaborative work between scientists and industry. To put it crudely, the operational logic in fishers' mind on their way to catch fish has not much to do with the analytical logic of scientists counting dead fish on the wharf. The value of catch rate as an index of stock abundance can be improved if used in conjunction with industry' experience and perspectives. Fishers detain much valuable information from their day to day experience with the resource, and by learning more from them what fishing is about fisheries scientists can develop more appropriate analytical methods.

Consultation with industry is a much needed non-data gathering type of research. It requires a change in state of mind from everyone involved and cannot simply be legislated into being. Consulting with industry is not only about gathering information but also about providing information and feedback to the industry. One of the most important results of the present study is that it demonstrates that there is a lot of good will within the industry to contribute to the consultation process. Strategies must be actively worked out to facilitate sustained collaborative work and to better integrate fishers' knowledge and scientific knowledge.

# 7. DISCUSSION, ANALYSIS & HYPOTHESIS "FISHERIES ECOLOGY AND SOCIO-ECONOMICS IN THE SEF" (PRINCE)

## 7.1 Introduction

In my experience fisheries scientists often hide behind our lack of detailed data and knowledge, saying that we don't know anything because it has never been scientifically studied. But in doing this we seem to forget that these scientifically accurate answers leave fisheries managers and fishers relating to each other in a vacuum.

If we fisheries scientists are not the best people to provide working assumptions or "guesstimates" about the scientifically unknown context of the South East Fishery, then who is? We are the trained experts and there is a wealth of information available in the observations of knowledgeable fishers. My purpose here is to begin sketching detail into the knowledge vacuum of SEF fisheries ecology. My aim is to begin constructing a new understanding of the South East Fishery, which over time can be tested by analysis and observation, and then modified or built upon.

When writing a document it is easier to edit than to start a blank page. It seems to be the same with science. The process of building knowledge speeds up if there is a coherent idea that can be focussed on and criticised. Through this document I hope to assemble a coherent and different view of the South East Trawl Fishery. What follows is my "guesstimate" about the nature of the SEF. I knowingly go beyond what can be scientifically proven at this stage in the hope that this will sharpen the focus of discussion, research, assessment and management in the SEF.

### Multi-species Management in the SEF

In strictly biological terms, fisheries management in a multi-species ecosystem such as the SEF involves two major issues:

1. Sustainably managing the physical impact of fishing upon the ecosystem, and
2. Sustainably managing rates of fishing mortality upon the fished species.

In the context of the SEF demersal trawl fishery the former issue should be managed by preserving habitat outside the trawl grounds. If the areas reserved from fishing is reasonably large compared to the area being fished, and representative of the full range of ecosystems, permanent habitat change within restricted fishing grounds need pose no threat to biodiversity values.

My focus here is on fishing mortality which in the SEF is managed through a system of ITQs which was implemented for 16 species in 1992 to control species specific fishing pressure.

### Catchability & the Ability to Target Species

There are over 100 commercial species in the fishery and the impact of trawling will be different for each species.

In the equations of fisheries dynamics:

$$F = q \times e$$

Fishing Mortality (F) is proportional to fishing effort (e) and catchability (q)

Fishing pressure or fishing mortality (F) is not just proportional to the amount of fishing that occurs (e), but it is a product of the catchability of each species (q) when they are fished.

Catchability is the forgotten word in the context of the SEF. In many fisheries catchability is studied intensively before trends in catch per unit effort are calculated and used to estimate trends in abundance. But in the Assessment Groups of the SEF we virtually never talk about catchability.

Catchability is how vulnerable a species is to the particularly type of fishing equipment used and it is generally expressed as the proportion of a species total population that is captured with each unit of fishing pressure, in this case an hours trawling.

Catchability is determined by the interaction between the fishing technology which in this case is applied uniformly across the multiple species, and the varied behaviour of the many SEF species.

## 7.2 Demersal Trawling in the SEF

Despite the relatively recent introduction of mid-water trawl net technology to the SEF remains predominantly a bottom or demersal trawl fishery.

Demersal trawl nets are dragged along the seabed. Demersal trawls work by herding fish and concentrating them in front of the mouth of the net, as the fish tire from swimming in front of the net, they are herded back down the belly of the net into the cod end where they are caught (Figure 1a&b). It is widely appreciated that fish are herded across the bottom by the sweeps and bridles (Figure 1b), but the vertical herding of fish down out of the water column is less recognised (Figure 1a). Within SEF scientific circles it has been implicitly accepted that most of the species being caught are demersal, spending most of their life cycles close to the seabed. The implicit assumption has been that it is their demersal life cycle that makes them catchable with bottom trawls.

## Pelagic Midwater Species

In contrast many fishers in the SEF believe they fish an ecosystem, that extends out of the deep-midwaters of the adjacent oceans into the shallow waters of the Continental Shelf and Slope. Many of them believe that their bottom trawls only fish a small part of this ecosystem. As they say "the fish go up in the air" into the midwaters 100s of meters above the bottom, while their bottom trawls are only a few meters high.

The fishers of the SEF believe that for most of the time the fish they catch cannot be caught by their nets either because they are not over their trawl grounds, or because they are too high above the trawl grounds to be caught in the net. They believe that favourable oceanic and climatic conditions, moon phase, and fish behaviour at times bring concentrations of midwater fish down to the trawl grounds. They believe that it is only at these times that the fish are vulnerable to their nets.

They have developed these opinions by watching their echosounders fishers and studying the behaviour of acoustically reflective "feedlayers". Two echograms recorded during the Industry Surveys of Eastern Gemfish (Prince *et al.* 1998) are shown in figures 2 and 3 to illustrate the type of evidence SEF fisher's observe on a daily basis.

### *Feedlayers*

Figure 2a-d illustrates the normal morning decent of such "feed layers" as observed by the Santa Rosa A off Wollongong on 14 July, 1997, between approximately 06.00 and 07.05 local time. In the echogram the heavy line of the bottom can be seen running from left to right at 350-400m. The depth from the surface is given on the right hand axis, 50m gradations are marked.

Two heavy feedlayers are evident from 06.00 and 06.20 (Figure 2a), one above 50m and one between 200 and 300m. The deeper 250m layer seems to receive a "rain" of marks into it from the surface. Both layers concentrate and begin descending. The surface layer apparently fades after having descended to around 100m, by 06.40 (Figure 2b) only the background surface splash is left making a mark in the surface waters. By this time the deeper layer has also thinned and descended to around 300m. Figures 2c&d show the deeper layer descending to around 350m and to within 50m of the substrate of the trawl ground.

Integration of the strength of acoustic returns from above 400m in echograms such as this one shows that total acoustic biomass in the water column declines daily around daybreak by around 90% (Prince et al. 1998 - FRDC 97/147).

As described above by Baelde SEF trawl fishers, hoping that the feedlayer will contain commercial species, fish the shelf edge trawl grounds around dawn coinciding their shot with when they expect these "feed layers" to descend onto the grounds.

A similar impression of the midwater nature of many SEF species is provided by figure 3 which shows an echogram featuring a prominent acoustic mark typical of redfish. The high acoustic reflectivity, and characteristic shape of marks make redfish one of the few SEF species which can often be identified acoustically. This echogram was made as a vessel steamed from east to west across the shelf slope towards the shelf. The heavy bottom line can be seen rising from below 300m at the left and almost reaches 200m on the right.

A "feed layer", probably relatively pure redfish, can be seen stretching horizontally from left to right just below 200m. On the right the feedlayer intersects with the bottom line and attaches to the bottom line in several places.

Where the mark interacts with the substrate the bottom line is particularly thick and intensely red. This shows that the acoustic mark is on the bottom in 'foul' or untrawlable ground. Over the soft bottom the mark is 50-100m above the bottom. From echograms like this the fishers reasonably infer that these fish are mainly found in midwater and preferentially interact with reefy bottom rather than the soft bottom of trawl grounds. They would also expect that a trawl shot across the trawl ground below that mark would catch little if any redfish. However if the mark dropped lower in the water column and onto the trawl ground they would expect redfish to be caught.

### *Deep Sonic Layers*

Oceanographers around the world call these acoustically reflective midwater layers the "Deep Sonic Layer" or the "Deep Scattering Layer". The "Deep Sonic Layer" stretches in horizontal bands across the midwaters of the Tasman Sea and all the world's oceans. Off south eastern Australia the RAN maps its density on a weekly basis because they are used to hide submarine.

But it is only recently with the advent of submersible vehicles that fisheries ecologists have begun to observe and understand a little about the biology and ecology of the oceanic midwaters (Robison 1995). The midwaters of the world's ocean provides the largest habitat in the world and it has long been thought to be a relatively empty void. But in fact it contains highly dynamic ecosystems structured by the ephemeral growth of pelagic jellyfish (Robison 1995).

The "Deep Sonic Layer" is an acoustic reflection off an extensive midwater ecosystem containing many species. The layers migrate vertically several hundred metres on a daily basis in response to light conditions, diving during the morning as the sun rises and rising as the sun sets (Robison 1995).

John Stevens of CSIRO using archival tags placed in school sharks (FRDC 96/128) has recently documented an example of these diurnal migrations from the SEF (Figure 4). Within the SEF school shark are an occasional incidental catch from demersal trawling, they can also be targeted with bottom set nets and baited hooks.

As with many SEF species there has been long standing debate between fisheries scientists and fishers about whether school shark are pelagic or demersal? Without scientific evidence to the contrary fisheries scientists have emphasised the demersal nature of the species. Fishers refuted this stance by recounting observations of school sharks on the surface over deep water during the night.

By April, 1998, three archival tags had been retrieved and their data down loaded. All the three sharks displayed pronounced diurnal vertical migrations diving around dawn every day and ascending around sunset. The largest vertical migrations were between the surface and 500m. All three sharks also seem to have spent significant periods beyond the continental shelf during their times at liberty and all three apparently moved out over the shelf to recover from the disturbance of tagging.

Diurnal vertical migrations have been well documented for squid (Nakamura 1993) and in the environment of the SEF (Nowara & Walker 1998). But we SEF scientists have been slow to realise the full importance to our fishery of the extensive oceanic midwater habitat that begins at the edge of the continent.

### *The Growing Importance of Pelagic Midwater Species*

Much of the recent history of development in this fishery can be viewed as an expanding realisation of the extent to which the SEF's principle finfish resources are pelagic rather than demersal.

The NSW State Government, originally developed the SEF during the first two decades of the twentieth century using steam powered otter board trawlers. These original steam trawlers were replaced, between the World Wars, by privately owned danish seine vessels.

The danish seine technique involves placing a large ring of net around an area of soft bottom and then drawing the net together by moving slowly forward either by winching forward on an anchor or by inching forward under power. The slow movement of the danish seine net across the bottom is extremely efficient at herding demersal species together and into the cod-end. However compared to an otter board trawler fishing at the same place and time, the slow danish seine nets catch virtually no pelagic midwater fish because they easily evade the net.

Demersal otter board trawling was re-introduced to the SEF during the early 1970s and most vessels rapidly converted over to otter board trawling. By the late 1970s there was just a small fleet of danish seiners operating in eastern Bass Strait.

Ever since the conversion of the SEF from danish seining the fishery has gradually been growing more aware of the resources occupying the midwaters of their fishery. The change from danish seine to the traditionally designed bottom hugging demersal nets began this process for the trawlers. The so called "traditional net", "scratch net" of "spag net" was originally the cod end of a danish seine adapted for faster towing.

Initially towing speeds were relatively slow, below 2 knots for some species. The traditional net was modified during the gemfish boom of the 1970s and 1980s to maximise the catchability of gemfish. But this still required slow towing speeds and a low billowing profile in the wings, mouth and belly

It has been the intervention of the quota system which has driven the most recent phase of gear development. The growing deployment of high-flying, light cut-away nets with rubber foot lines and higher towing speeds continues to make trawling more effective at fishing pelagic midwater species, while reducing the fishing efficiency on low swimming demersal species (Figure 5). The aim of the fishers deploying it being to optimise mixed species catches rather than catches of any single species.

### *How can Pelagic Midwater Fish be Caught on the Bottom?*

Many SEF species share a range of common characteristics which adapt them to foraging upwards through the water column under low light conditions (Robison 1995):

- Their eyes are set on the upper surface of their bodies facilitating searching in front and above the fish,
- Their body shape is adapted to minimise visibility through being dorsally or ventrally flattened, and
- Their counter shaded body colourations, white below with red/orange, silver, black, or dark blue also minimise visibility under low light conditions.

Down to below 1,000m midwater fish and squid predominantly feed by silhouetting prey against the surface gloom. Living almost permanently in the dark they use the cover of the dark to hide from both prey and predators alike. These midwater predators approach their prey stealthily from below and make short final lunges out of the dark (Robison 1995).

The sperm whale which hunts through the same oceanic midwater environment, uses similar techniques, silhouetting prey from below with their acoustics, they approaching stealthily from below just by cooling the spermacetti in their head and increasing their buoyancy (Clark 1979).

While the midwater species characteristically feed by slowly swimming upwards their flight response is to dive down away from the potential threat, they instinctively seek safety in the darkness below them (Robison 1995). It is probably this diving response that makes SEF species vulnerable to being caught in demersal trawls. As some SEF fishers say, "the trawl ground is the third wing of the trawl net".

Spread out through the sparse midwater environment hunting stealthily in the dark midwater fish probably first perceive the approach of a trawl net through their vibration sensitive lateral lines feeling first the noise of the vessel approaching and passing above them. Next would come the feel of vibrating warp wires rapidly approaching. This being the dawn shot most of the fish would already be slowly diving away from the light. The noise of the vessel with warps would be enough to hurry the descent of midwater fish through the water column. Guiding the fish deeper and deeper towards the path of the net.

The approach of the doors would be felt next through their vibration and would probably be perceived for what they are two large and threatening objects, approaching at speed. The reaction of the midwater fish in front of the net would be to dive faster, accelerating to be below the level of the boards when they pass. Fish towards the edge of trawl path would also begin moving laterally away from the path of the approaching boards. Others perceiving that the boards are passing below them and far enough might slow their dive to remain above and outside the path of the boards. These are the fish that have been frightened out of the path of the approaching net.

But as the boards approach the wedge formed by the warps will concentrate a group of diving fish in front of the net. These fish will be diving relatively rapidly as the boards approach, but instead of escaping away down in front of the boards they will run abruptly and unexpectedly into the bottom. With their instinctive flight response thwarted these midwater fish are probably dazed and confused when they hit the bottom in the path of the approaching trawl. Their first response is probably to concentrate in the middle of the trawl path and swim towards the net in an attempt to pass the boards quickly while maintaining the maximum possible distance from the boards.

However having passed the boards the fish would rapidly become aware of the approaching sweeps, bridles and mouth of the net. These will cause the fish to turn and start swimming in front of the net. Despite having the physical ability, midwater species are probably reluctant to dart away over the net's headline because it is counter to their instincts. Safety comes from diving even if diving is no longer possible. Herded along in front of the trawl and towards the central mouth of the net the tiring fish slowly drop back into the mouth of the net, and eventually, back to the cod end where they are caught.

Thus the catchability of many SEF species is probably related more to their diving behaviour than their use of demersal habitats.

## 7.3 Catchability in the SEF

Two critical factors determine the catchability of a species (Figure 6):

1. Their distribution of the species relative to the area being fished. Species living outside the trawl ground will by definition be invulnerable to fishing pressure applied to the fishing grounds.

2. Their propensity to aggregate on the Fishing Grounds. A species that is obligated to aggregate within the fishing grounds will be vulnerable to over exploitation even if most of its life cycle is spent outside the fishing grounds.

Amongst the many species landed by the trawlers of the South East Trawl there is a wide range of behaviour and life cycles.

## Demersal or Pelagic?

Species such as flathead, ocean perch, morwong, whiting are relatively demersal probably spending the vast majority of their life cycles within 10m of the bottom. However they are all known to swim freely at some stages, even flathead have been observed swimming close to the surface in several hundreds of meters. But these demersal species would be expected to rest and sit on the bottom.

At the other end of the spectrum species such as the warehous, gemfish, southern frost fish (ribbon fish), mirror and john dories clearly spend most of their lives swimming hundreds of meter above the substrate. In contrast to the demersal species pelagic midwater spend little time near the bottom.

There are also species that lie between these extremes such as ling, redfish and orange roughy. For these species there is evidence that they use both the benthic and midwater environments extensively.

## Benthic Habitat Preferences

There are two basic bottom habitats in the SEF (Figure 7): mobile sediments with sparse ephemeral growths or reefy habitat with permanent benthic growths providing habitat with complex structure (i.e. sponges, bryozoans, and corals). In some places a succession of encrusting species can apparently colonise and stabilise areas of softer bottom. In these areas sponge gardens may grow on a concretion of older benthic growths which provide a calcareous layer over soft sediments.

Species such as ling, flathead and whiting all clearly thrive in soft bottom environments. Ling dig burrows, into which they retreat, they lay their eggs in a gelatinous mass that they stick to a rock. Flathead have a flattened body shape, as their name implies, they bury themselves in sand and lie in ambush for prey swimming close to the bottom. Whiting have sensitive lips which they use to sift through sediments for burrowing invertebrates.

Other SEF species such as morwong, redfish, blue warehou display strong preferences for living, or schooling in reefy habitats. Morwong are generalist bottom feeders that apparently spend little time in the midwater. They use their tough rubbery lips for grubbing around sponges and turning stones searching for their invertebrate prey. In contrast redfish and warehou apparently forage extensively through the midwater; redfish preying on crustaceans, squid and fish and blue warehou on pelagic jellyfish. But both these species also aggregate close to the bottom around certain reefs. This behaviour may be in response to the aggregation of food species, or perhaps to conserve energy by resting in area of slack water.

Highly pelagic species like blue grenadier, john and mirror dory apparently display little or, no preference for types of substrate. These species probably forage through several hundred meters of the water column for prey species that are entirely pelagic and have virtually no interaction with benthic habitats. But this pelagic life style can still render them vulnerable to being caught occasionally either when feeding or forming spawning aggregations close to the bottom over the trawl grounds.

The behaviour of each SEF species determines how catchable they are with demersal trawls. Species will be highly catchable when a high proportion of their population aggregate close to the bottom over the trawl grounds. Conversely species in which most individuals never enter the trawl grounds will have a low catchability

## The Extent of Trawl Grounds

Interacting with the behaviour of the many SEF species is size and location of the trawl grounds in comparison to the habitat occupied by the different species.

In the SEF trawling only occurs within limited areas of the continental shelf, slope and associated seamounts contained within the fishery. Trawl grounds can only be developed where the underlying substrate is soft or smooth enough not to snag the footline, or rip the belly of the net.

Trawl grounds were initially developed on the naturally soft, smooth substrates, but there has been a tendency for the fishery to develop further trawl grounds around and at the edges of the original naturally occurring trawl grounds. Where trawl grounds are developed over the softer reefs, formed through the concretion encrusting growth, the complex structures growing on the substrate are removed and the soft reef is broken down (Figure 8).

This initial change in the habitat is likely to favour species which prefer soft substrates, at the expense of species that prefer reef and sponge garden habitats. The recent Kapala Report (Andrews *et al.* 1997) documents this phenomena. It reports finding that since the trawl grounds were developed off NSW the abundance of soft bottom species such as ling and flathead on the trawl grounds has been little changed by trawling, while the biomass of demersal reef species on the trawl grounds is greatly reduced.

But having developed the trawl grounds and changed the nature of the benthic habitat trawling relies on fish swimming into the trawl grounds. Where large areas exist outside the trawl grounds, trawling will have little impact on species that preferentially pass their life cycle amongst sponges and corals outside trawl grounds.

Through the SEF the vast majority of the benthic habitat lies outside the trawl grounds. But currently the only published estimate we have to document the extent of trawl grounds is that provided by the recent Kapala Report (Andrews *et al.* 1997), which estimated that off NSW approximately 30% of the shelf break area was trawlable. This would be an extreme figure if applied to the SEF in general because the history of trawling outside NSW is much more limited. Off western Tasmania my discussions with fishers suggest that trawling only affects about 5% of the bottom <1000m.

### The Height of Trawls Ground

Despite the catchability of pelagic midwater species bottom trawls can only catch fish when they are swimming near the bottom. The trawl fishers of the SEF fishers use their echosounders to magnify the bottom 4-6m of the water column. This being the height of the headline on their nets, they think the fish are only catchable up to that height.

No estimate exists as to how high in the water column bottom trawls of the SEF might fish.

But the diving nature of pelagic midwater species described by Robison (1995) suggests that to some extent the trawl warps herd fish down out of the water column. This probably extends the effective reach of the trawl gear further than the fishers assume. The height from which species can be herded down into the path of the net will probably be highly species and size specific. As an initial guess we might suppose that the trawls herd down a proportion of fish swimming as high as 20-40m above the trawl ground. This trawl 'catch' zone above the trawl grounds forms a third dimension to the trawl ground which in our conception now extends both laterally and vertically (Figure 8).

But as with the lateral extent of the trawl grounds the height of the trawl grounds is limited compared to the area occupied by the fish. At the edge of the continental shelf in 200-400m the trawl catch zone probably has an effective height of only 12-25% of the water column. As with the lateral extension of the trawl grounds trawling will be relative ineffective at fishing pelagic midwater species that spend time extensively outside the effective area of the fishery (Figure 9a&b).

## 7.4 Towards a New Definition of Targeting in the SEF

In comparison to other fisheries trawl fishers in the SEF are limited in their ability to hunt and target the fish throughout their range and life cycle is extremely limited.

The choice for a SEF trawl operator in directing fishing pressure so that landings are optimised is limited to allocating effort:

1. across the seasons
2. across the trawl grounds within range of their operation, and
3. where available trawl grounds allow, across depth strata.

## Depth Selection

Catches of most SEF species are characteristically associated with trawl grounds within specific depth ranges. Juveniles of species are usually caught shallower than the adults and are generally extended over a wider range of depths (Figure 10). Catch rates for a species tend to be highest towards the middle of the adult distribution, but the largest individuals are generally caught at the lower end of a species depth distribution.

Consequently trawl fishers can to some extent select a species and size assemblage by choosing the depth of the trawl ground.

Having selected a depth, choosing between trawl grounds and seasons can determine in which of three distribution phases fish are potentially caught:

1. Aggregations
2. Background scatter, or
3. Seasonal Dispersion

## Targeting Aggregations

At the high extreme of catch rates and catchability many SEF species form dense aggregations when feeding or breeding.

In fact it can probably be assumed that almost all SEF species form breeding aggregations. However for many of these species fishers and scientists remain unaware of where and when these aggregations occur.

This highlights that catchability is an interaction between fishing gear and fish biology. The aggregation of some species may not be catchable with existing fishing gear and so remain unobserved and unknown. This is best illustrate with ling whose breeding aggregations apparently occur in untrawlable areas. It is only in recent years that non-trawl fishers have discovered and begun fishing large annual aggregations of spawning ling (Figure 11).

The nature of an aggregation is extremely important in determining how vulnerable a species is to exploitation. Fishing spawning aggregations generally makes a species more vulnerable to overfishing than fishing feeding aggregations. This is because the timing and location of spawning aggregations is generally more predictable than with feeding aggregations. But it is also because every member of a species must pass through the spawning aggregations at some stage of their life cycle making them vulnerable to capture. In contrast feeding aggregations may contain a much smaller fraction of a population. Some individuals of a population may rarely if ever join feeding aggregations and so remain relatively invulnerable to fishing.

The behaviour of aggregations also affects catchability and thus vulnerability to overfishing. The breeding aggregations of orange roughy (Figure 12) are extremely predictable occurring at virtually the same location and time each year.

In contrast the breeding aggregations of blue grenadier, eastern gemfish (Figure 13) and mirror dory (Figure 14) are more mobile and dynamic. Each season their aggregations move along considerable lengths of the shelf break making it more difficult for the fishermen to predict their location.

The warehou's (Figure 15) and tiger flathead (Figure 16) also predictably form breeding aggregations near the bottom over some trawl grounds. However while the location of their spawning aggregations is apparently relatively stable within each year, it is relatively variable within each region between years.

The visibility of aggregations also varies between species affecting catchability. Blue grenadier, orange roughy, and spotted warehou form relatively pure aggregations that are highly visible with echo-sounders making them easy to find and target. However with mirror dory, gemfish and flathead their aggregations are often formed with many other species from which they are normally indistinguishable. With gemfish and mirror dory the presence or absence of schools can only be determined by fishing.

Redfish illustrate another variation (Figure 17). They form highly visible and stable aggregations along the NSW shelf edge in winter. However these aggregations cannot be reliably targeted every year because they often remain high in the water column. It is only when they come to the bottom over the trawl grounds that they become catchable (Figure 3).

## Incidental Catches from the Background Scatter

The catch of most species in the SEF is highly seasonal and for most of the year catch rates are extremely low. For species such as blue grenadier and eastern gemfish adult fish are only caught during their short winter breeding seasons. We don't know for certain where there are outside the spawning season but they are probably disperse so widely through the midwater environment adjacent to the fishery that their presence is virtually undetectable on the trawl grounds.

In other species the disappearance is not so complete and some low incidental catch from the background scatter is possible throughout the year at the right depth. Fishers often refer to catching this background scatter as "scratch fishing" or "scratching around".

Orange roughy provide a convenient extreme example of this phenomenon (Figure 12). While mainly taken from short (approximately 1 hour) trawl shots targeted at large visible schools around sea mounts when catches of 30 tonnes per shot and more are possible. Small incidental by-catches (up to 100-200kg) of orange roughy can also be caught from the background scatter, along with deepwater sharks during long (5-6 hour) deep night time trawls.

## Fishing Seasonal Dispersions

Between the extremes of aggregations and background scatters most SEF species also exhibit a distribution phase which I call here a "seasonal dispersion of fish". Within a season and area catch rates may increase significantly above the normal "background scatter" but still remain much lower than would be expected from fishing an aggregation. The increase of catch rates at these times may occur predictably in the same areas or depths without the appearance of discrete identifiable aggregations of that species.

A seasonal dispersion may form as the prelude or aftermath of spawning aggregations or when species gathers to feed on some concentration of food.

Breeding dispersions of eastern gemfish are fished before and after the winter breeding season, as are sub-adult feeding dispersions during summer. Sub-adult blue grenadier are also fished in summer feeding, and winter breeding dispersions outside their main winter spawning grounds. Thus these two species are caught by trawlers in both dispersions and aggregations.

Some species such as ling (Figure 11), morwong (Figure 18) and john dory (Figure 19), can only be caught by trawlers in seasonal dispersions or background scatters. Ling apparently form breeding aggregations in untrawlable areas, while morwong and john dory are not known to form aggregations.

## The Price of Fish and Fishing Practises

Fishers of the SEF do not necessarily fish for each species when the highest catch rates might be expected.

Fishers fish for money not fish. They view the different species in terms of price received in the market, the volume that they can be caught in relation to the availability of quota, and the expense incurred. On this complex basis fishers seek to optimise their multi-species catches.

In understanding this situation it is useful to categorise the SEF species according to their relative values in the market, and the catchability of the species.

### *Low Priced Species*

Low priced species include small redfish, blue grenadier, silver trevally, flathead and ocean perch and mirror dory.

Many of these species form large seasonal aggregations. Prior to the introduction of quotas most operators would have targeted these seasonal aggregations and landed large volumes that would have made up for the low prices received from the market. However at around or below $1.00/kg fishers can easily loose money landing these species under the quota system. Handling fees for the landing, transport and sale of fish often amounts to 30-40c/kg, while the lease price, which to some extent represents the opportunity cost of filling the quota, is another 30-50c/kg. This leaves little margin for making money and makes landing the species a risky venture for fishers.

Consequently these species are now only fished in aggregations by the few fishers with large quota holdings of these species and/or the infrastructure necessary to make profits using economies of scale. Most fishers avoid the major aggregations of these species, or are forced to high-grade their catches to make their catch worth landing. Attempting to maximise the return from quota holdings low priced species are now landed by most operators as an incidental catch of fishing for other species. High grading and discarding of these species is relatively common.

### *Medium Price Species*

Medium priced species include small blue warehou, spotted warehou, morwong and, ocean perch, flathead and redfish. The price of most of these species is highly variable and depresses easily during the peak of seasonal availability when the markets may glut. While at times medium priced species will determine fishing patterns in the SEF, increasingly operators avoid fishing the peak aggregations of these species preferring to take them as an incidental catch.

### *High Price Species*

Orange Roughy, gemfish, ling, john dory and blue warehou, all fall into this category in the SEF. Because of their value these high priced species are rarely discarded.

There is almost always a market for these highly priced species and consequently they are normally fished to the full extent allowed by trawl gear and TACs. This is not great extent in the case of john dory because of its dispersed nature. But orange roughy and gemfish both form large aggregations which can be effectively targeted by trawl fishing. While trawl catches of blue warehou and ling can be maximised by fishing their seasonal dispersions during the right season, in certain depths and regions.

### *Fishing Strategies Maximise Nett Incomes not Catch Rates*

Even if trawlers can effectively target a species, the extent to which it is targeted will be determined by the collective fishing strategies of the fishers. Fishers will work to optimise the catches of the most valued species. The fishing strategies deployed to optimise incomes from the most important species will determine the nature and level of catches of other less important species.

These observations are supported by an analysis of Tables 1 & 2 and Figure 20.

Table 1 summarises the 1997 landed catches for the 16 quota species both in terms of catch and as a percent of the Total Allowable Catch. While reporting the figures for 1997 the table the situation reported has been relatively stable since the introduction of ITQs in 1992. It can be seen that generally TACs do not seem to be limited catch levels. Only the TACs for roughy (east), spotted and blue warehou, and ling were above 80% filled. While TACs for nine species are less than 50% filled.

Only in the case of roughy (south) and gemfish (east) can an argument be mounted that low stock abundance determines this level of TAC under-run. In the case of the other species their low value results in little directed fishing and lower than allowed catches.

Discarding estimates indicate that fishers catch too much of these low value species rather than too little. Table 2 presents estimated discards from SEF trawlers operating in NSW during 1996 as detailed by Liggins (1997). Here I present just the largest discards of commercial species, together with the estimated discards of the 16 quota species. I have not included the full species list. It can be seen that discards are principally of non-quota species and quota species for which TACs were not limiting. This is fish with little commercial value because it cannot be sold at profit in the fresh fish markets of Melbourne and Sydney.

This is confirmed by looking at the size distribution of quota species which are dumped Figure 20. Again I have selected data from Liggins (1997) to illustrate the point. The figure shows the size of discarded and retained redfish, ocean perch, tiger flathead, spotted warehou. Note that it is the smaller sizes being discarded. Size classes of fish that cannot be sold for a profit in the fresh fish market.

The SEF fishery is principally directing its fishing effort at targetable, higher value species for which TACs are substantially met Roughy (east), spotted and blue warehou, ling and redfish. Generally speaking, and with a few obvious exceptions, the other species in the SEF tend to be an incidental catch of fishing for these principal species.

## The Nature of the Mixed Bag

Anthony Jubb of Bermagui is fond of saying, "You scientists don't understand the nature of our mixed bag. And ya need to!"

Fishers of the SEF say that the introduction of ITQs in 1992 has had a major effect in this way. Prior to ITQs fishers could maximise incomes by maximising landings. Where species could be targeted in aggregations they generally were and fishers responded to the low prices received by increasing landings.

In today's ITQ system there is an opportunity cost associated with filling quota, and income is maximised by ensuring good prices are received for the catch.

Many fishers claim the income from quota holdings are maximised by landing relatively small mixed species catches on as many day of the year as possible. The fresh fish markets of Sydney and Melbourne require variety and mark down the price of large single species landings.

The traditional demersal species morwong, flathead and whiting which for most of this century comprised most of the market are no longer highly favoured. They have been largely displaced by the midwater warehous. Flathead were heavily targeted in shallow water during their summer spawning aggregations by the original state owned steam trawlers, the danish seine fleet and the modern trawler fleet. During the 1990s this fishing practice has almost died out. Increasingly flathead are landed as incidental catches from other types of fishing.

## 7.5 Environmental Variability and Seasonality in the SEF

The fishers of the SEF believe that environmental conditions, primarily water temperature and deep currents, are more significant in determining their catches and catch rates than the actual abundance of the stocks. They also believe that for most species environmental conditions are more fundamental in driving future recruitment trends and stock sizes than the abundance of spawning adults.

So what are the main influences on the ecology of the SEF? What environmental factors should we expect to influence the abundance and catchability of SEF species?

In contrast to the fishers of the SEF, fisheries biologist have tended to emphasise the importance of the demersal habitats and the productivity of shelf waters. A recent and still unpublished study of SEF ecosystems (FRDC-94/040) by Nic Bax of CSIRO was designed to study nutrient flows into the SEF through the benthic environment of the shelf. However results from that study apparently show that the nutrients in SEF species are fixed initially by oceanic phytoplankton, rather than the sea-grasses and estuaries in the coastal environment. This suggests that SEF food chains have oceanic sources and extend out of the offshore environment of the Tasman Sea, into shelf and coastal waters.

Koslow (1997) postulates that some mechanism exists for gathering together dispersed oceanic productivity, or else the known orange roughy stocks of the SEF would starve. This is because local sources of productivity along the shelf edge are estimated to be insufficient to supply the relatively high energy demands of known roughy populations. His assumption is that roughy remain around the sea mounts for food to be gathered up and brought to them.

In contrast it seems more likely that the fish themselves are the mechanism which gathers the dispersed oceanic productivity of the SEF. Together with many fishers I believe that many SEF species spend most of their life cycles dispersed widely through the midwater habitat of the Tasman Sea foraging on dispersed oceanic production through their daily vertical migrations (Figure 9a&b). Whatever the mechanisms which concentrates the Tasman Sea's productivity for SEF fish, it seems increasingly apparent that it is the ocean adjacent to the SEF that is feeding SEF species and not the inshore and coastal environment.

But then what is the source of the oceanic production feeding the SEF ecosystem? After all, as we all know very well, Australia has none of the large upwelling systems on which large fisheries are based in other parts of the globe.

## Fishing the Productivity of the Sub-Tropical Convergence

Over the last two decades small seasonal upwellings have been widely noted around Southern Australia. See for example Rochford's (1977a &b) descriptions of these systems off NSW and Victoria, and Lewis' (1981) description of the wind driven seasonal upwelling of South Australia shown in figure 21. In 1986 Gibbs *et al.* suggested that the major source of nutrients controlling productivity in the region of the SEF is the upward mixing of deep water along the continental shelf. In 1990 Edwards postulated that "Upwellings could hold clues to fish patterns" in Southern Australia, while by 1991 Rochford was asking the Australian scientific community whether the term "upwelling" needed a stricter definition for the Australian context.

The association between these ephemeral "upwellings" or "deep mixing events" and plankton blooms has been extensively discussed in Australia's scientific literature (see Rochford 1958, 1975, 1984; Humphrey 1960; Newell 1966; Grant 1971; Boland 1979; Godfrey *et al.* 1980; Pearce & Boland 1982; Huyer *et al.* 1988; Cresswell 1994; Hallegraeff & Jeffrey 1993). Many of these authors have discussed in general terms their likely importance for commercial fisheries. Hallegraeff & Jeffrey (1993) noted that elsewhere around the world the dynamics of fish stocks were influenced by phenomena similar. But without any information they could only postulate that this would also be the situation in the SEF.

From my studies it appears that this source of productivity has profound effects on the dynamics of SEF stocks and that understanding the influence is critical to designing effective strategies for management and research.

More is known about the Tasman Sea off southern NSW than about any other area of the SEF because that area has been most heavily studied and most heavily fished.

Two principal bodies of water dominate the Tasman Sea. The warm East Australia Current (EAC) flowing southwards from the tropics, and the cold deeper nutrient rich waters of sub-antarctic origin. Across the Tasman Sea these water bodies converge and mix along the Tasman Front. The Tasman Front is just one part of the Sub-tropical Convergence formed globally between the sub-antarctic waters and various streams of tropical surface waters. West of Tasmania a similar Sub-Tropical Convergence Zone influences the SEF. But this convergence is between the Leeuwin Current which flows out of tropical surface waters northwest of WA, and the sub-antarctic waters (Creswell & Petersen 1983).

Along the Tasman Front the water the deep mixing of these two water bodies enriches the water column and the convergence zone is characterised by high levels of phytoplankton production (McClatchie *etal.* 1995). With satellite imagery of the Tasman Sea using the band of light absorbed by phytoplankton the Sub-tropical Convergence is visible as an permanent band of enhanced oceanic productivity stretching east west around 44-45°S (Figure 22). Where the sub-Antarctic waters mix with the light and warmth of the various tropical surface waters they support rich frontal blooms of phytoplankton. These concentrations of phytoplankton in turn support concentrations of pelagic jellyfish, deep midwater crustaceans, pelagic fish and molluscs, birds and marine mammals.

As shown by the imagery of figure 22 the location of the Sub-tropical Convergence and its associated band of enhanced phytoplankton production is not stationary, but moves seasonally north and south, between Sydney in spring and south-east of Tasmania in Autumn.

The driving forces behind this oscillation are not fully understood (Ridgway & Godfrey in press) but deep mixing of the water column is common along the continental shelf as the Tasman Front seasonally oscillates north and south. The degree of mixing is not large or powerful on an international scale rather it is small and ephemeral. Never-the-less seasonal blooms of phytoplankton are associated with the deep mixing (Jeffrey & Hallegraeff 1990, Gibbs et al. 1991) and the blooms measured off southern NSW contained the highest phytoplankton densities measured in Australian marine waters (Jeffrey & Hallegraeff 1990).

A number of factors (Cresswell 1994) have been observed to influence the deep mixing of the water column likely to promote phytoplankton blooms. These three principal factors are:

1. the southward flowing EAC deflecting a northward flowing bottom boundary layer of water inshore and up the continental slope (Pearce & Boland 1982), and
2. undercurrents being driven onto the shelf by the edges of eddy systems Huyer *et al.* (1988).
3. along shore continental winds.

Recognising the influence of these environmental factors on the productivity of the Sub-tropical Convergence and the fish stocks of the SEF makes sense of many of the stories told by the fishers of the SEF. But the interaction between fish fauna and the environment of the SEF appears to be complex acting at numerous levels and over a range of time scales.

### *Long Term Productivity*

Analysis of the landing statistics from a range of south eastern Australia show that abalone, lobster, scallops, squid, tuna, shark and SEF finfish all concentrate around the same hotspots of productivity; Jervis Bay, Montague Island, Cape Howe, Flinders Island, Tasman Peninsula, Maatsuyker, King Island, Portland and Kangaroo Island. These are regions where the deep mixing associated with the movement of the Sub-tropical Convergence Zone is most intense, and where seasonally the ephemeral midwater food chains produced by this mixing are richest. Around these areas the food chain is regular enriched by the incursion of deeper water.

This can be illustrated with figure 21 which shows wind driven upwelling along the South Australian coastline. Both the distribution and magnitude of long term landings of abalone, rock lobster, southern shark and trawl fish along the SA coast coincide with the relative areas of cold 12°C water seen upwelling along the coastline in this image.

These hotspots for fisheries coincide with abrupt topographical features (canyons, bluffs, sea mounts etc) on the edge of the continental shelf which apparently intensify mixing rates. McClatchie et al. (1995) describe similar phenomena in New Zealand waters and have shown that intensified mixing around similar topographic features forms permanent hotspots for both biodiversity and fisheries production.

### *Annual Variability in Recruitment*

Fishers constantly report cycles of years, that they associate with environmental variability and there is an increasing body of scientific evidence within state agencies and CSIRO to support these claims.

The collection of SEF1 data only began in 1986 so it is not immediately evident in our catch figures that this occurring. However previous studies of morwong and flathead show that cycles of good and bad recruitment have occurred previously in the SEF. Recent analyses of eastern gemfish, blue grenadier and blue warehou also indicate considerable variability in recruitment around the underlying relationship between breeding stock and recruitment (e.g. Punt 1996).

Harris et al. (1988) first published on this idea in the mid-1980s noting cycles in the long term production of a range of species which they attributed to the dynamics of the Sub-tropical Convergence and phytoplankton production. Ron Thresher of CSIRO has observed that during the late 1980s the recruitment of gemfish apparently declined coincidentally with the density of plankton in the Tasman Sea and the intensity of zonal westerly winds. His analysis has not been updated, nor to my knowledge has it been published, but as suggested by

Hallegraeff & Jeffrey (1993) the linkage between the survival of plankton eating larval fish and the productivity of the Sub-tropical Convergence, seems likely to influence the abundance of many SEF species.

### *Medium Term Species Composition*

When the SEF1 catch statistics for any port, or vessel with a stable fishing pattern are examined considerable variability in species composition is observed between years. This is apparently due to variability in the position of the Sub-tropical Convergence and the fact that the faunal assemblage of the SEF differs markedly north and south of the Sub-tropical Convergence.

When the Sub-tropical Convergence pushes south of any particular port catches of cold water or southern species (such as warehous, morwong, blue grenadier) decline while the catches of warm water or northern species (such as mirror and john dories, flathead, silver trevally and redfish) increases.

Figure 23(a-d) shows composite images of sea surface temperatures off southern NSW during the winter 1994 to 1997 and illustrates the variability of convergence zone between years. It can be seen that through this area of the SEF SSTs were relatively high in 1994 and 1997, and low during 1995 and 1996. Consequently in Ulladulla and Bermagui catches of warehou increased during 1995 and 1996 but declined back towards longer term levels in 1997 (Table 3).

In the SEF catch composition is variable oscillating between warm and cold water assemblages.

### *Catchability: Seasonal - Daily - Hourly*

In addition to the affects already described, on a seasonal, daily and hourly basis the environment of the SEF also seems to influence the density of many SEF species on the trawl grounds and thus their catchability.

The trawl fishers of the SEF trawl repeatedly over the same ground trapping fish against the bottom with their nets. Large areas of the shelf remain untrawlable and many of the SEF species move freely through the water column. So in comparison to other fisheries, the fishers have an extremely limited ability to hunt and target fish. The fishers believe that they are highly dependent on favourable conditions bringing midwater pelagic fish down into the path of their bottom trawls.

Fishers describe seasonal north-south “runs” for many SEF species during which catch rates reach their seasonal peaks sequentially along the shelf break. The timing of these runs coincides with the seasonal oscillation of the Sub-tropical convergence. On the eastern seaboard of the SEF fish 'run' to the north during winter, and to the south in summer. The behaviour of the SEF fleet follows these 'runs' and larger vessels, capable of following the 'runs', fish around southern Tasmania in summer and between Cape Howe and Flinders Island during winter.

The nature, location and timing of frontal features around the trawl grounds are thought to influence the timing and location of feeding and breeding aggregations, together with their density and proximity to the bottom over the trawl grounds. The 1997 Industry Gemfish Survey described a coincidence between gemfish aggregations and thermoclines over the trawl grounds indicative of turbulence and water mixing on the bottom.

The fishers of the SEF also maintain that environmental conditions affects the catchability of SEF species on a daily and hourly time scale. Light intensity and current conditions are thought to have the major influence on these time scales. The midwater marks, which SEF fishers try to trawl when they are close to the bottom, begin to dive around daybreak and rise again when light intensity starts to decline after midday. So in many parts of the fishery the fishing practice is to begin trawling around daybreak as these feed marks approach the bottom. Robison (1995) has documented the diving behaviour of midwater ecosystems in response to rising light intensity.

## 7.6 The Socio-Economic Status of the SEF

During the course of this study it was often a challenge to get fishers talking about the biological nature of the SEF fish stocks. Generally fishers viewed these aspects of the fishery as of extremely low priority. Their concerns centered on the economic trends underlying the fishery. While being outside the terms of reference for this study, we would be remiss if we did not formalise this body of concern as it is of such overwhelming importance to the fishers of the SEF.

The trends which the fishers believe should concern the managers of this fishery are generally not biological but economic

### Stable Catches

Excluding eastern gemfish and orange roughy, the overall level landings of quota species have remained relatively stable around 15,000t since at least 1986 and probably considerably longer but we do not have statistics to test this statement (Figure 24a). Moreover figures for non-quota species show that they have also remained relatively stable at around 20% of the level of landings of quota species (Figure 24b).

### Stable Prices and Fixed Income

Of major concern to SEF fishers is the fact that the prices received by operators have also been stable or declining in real terms. Figure 25 shows the estimated mean annual price received ($/kg), averaged across the entire annual landings of a medium size operator in Eden who claims to have maintained a relatively stable operation since the early 1980s. His average price received has been around $1.30/kg since 1986 while better handling practice and technological improvements have allowed considerable gains to be made in fish quality.

This price stability is probably because supply to the fresh fish markets of Melbourne and Sydney has been rising faster than demand over the last couple of decades. The technology which has allowed the SEF to improve fish quality have also enabled fishers from northern and western Australia, and New Zealand to access the market. The market now expects to handle a much wider range of species and the popularity of the traditional SEF species, flathead and morwong, have declined.

Figure (26) shows the trend since 1989/90 in total cash receipts for the three sectors of the SEF (danish, inshore, offshore) estimated by ABARE economic surveys. This essentially shows the result of stable landings and flat prices. For the inshore, or market fishing fleet total cash receipts have remained between $400-500,000 since 90/91.

## Rising Hours Trawled & Increased Costs

At 110,000 hours the time spent trawling in 1996 was another record (Figure 27). From 1986 when around 90,000 hours were reported in SEF1 returns, effort at first declined to around 70,000 hours by 1992. Since the introduction of ITQs in 1992 the hours trawled have risen steadily. Effort has increased through the average trawl shots getting longer, as the number of shots has remained relatively stable below 40,000 shots.

The stability of landings together with increasing effort levels drives catches per hour spent trawling to decline. Assuming that the abundance of fish stocks is proportional to catch rates SEFAG assesses these trends as indicating declining stock abundance. But the stability of catches and the long history of trawling in the SEF suggest that the resource is actually relatively stable.

As discussed above, fishers explain that ITQ management provides incentive for fishers to fish multi-species dispersions of fish with longer less targeted shots. Prior to the introduction of output controls fishers fished for larger catches dominated by a single species. "Now the aim is to land as many species as possible, on as many days as possible, to play the market."

From the economic perspective increased hours trawling means increased running costs. Figure 28 shows the trend since 1989/90 in fuel costs for SEF operators as estimated by ABARE economic surveys. For the inshore, or market fishing, fleet total fuel costs have almost doubled since 89/90 and are currently around $80,000/annum. But it is not just fuel costs, other costs have more than doubled (Figure 29) and fishers complain specifically about the escalating number and level of government fees they pay.

With catches for most species stable and prices unchanged or declining in real terms, increasing hours of operation and generally rising costs, translates into a steady erosion of economic viability which is being felt by every SEF operator. Figure 30 shows ABARE's estimates of receipts minus costs, for the inshore fleet it has been below $50,000 since 94/95. This represents a return of just 5% on the SEF operators investment (Figure 31).

## 7.7 Stock Assessment in the SEF

The fishers of the SEF have very little confidence in existing stock assessments.

In my judgement this has two main causes:

- Inappropriate aggregation of catch rates
- Inappropriate fisheries models

These two problems seriously compromise the integrity of stock assessment in the SEF so that it does not relate to the reality being seen on a daily basis by fishers.

### Inappropriate Aggregation of Catch Rates

Stock assessment in the SEF is highly dependent on the use of commercial catch rates reported in SEF1 returns as an index of stock abundance. This is increasingly recognised as being an unsatisfactory arrangement, but at present stock assessment in the SEF has few alternative means of monitoring biomass levels.

So far crudely aggregated catch rates for 7 of the 16 quota have fallen below AFMA's performance levels, arbitrarily set as within the bounds of historic catch rates. This steady fall in catch rates is causing concern amongst biologists and managers, some of whom consider it an indication that current management is not providing sufficient biological protection to the fish stocks of the SEF.

In contrast most fishers maintain that generally these trends contain little if any information about stock abundance, rather they reflect changing fishing patterns through the SEF. After all it is only the shots that are getting longer, the number of trawl shots is not rising as rapidly. What is the evidence for these competing view points?

Commercial catch rates are currently estimated using SEF1 returns in which fishers report shot by shot catch compositions. Generally stock assessment in the SEF has followed a strictly single species focus so the statistics are selected from the multi-species database using a routine which selects all shots with at least one kilogram of the species under assessment.

In this way the same raw effort trend is used as the basis for the assessment of many species. i.e. A shot that may originally have been made "out wide" to pick up a bit of ling when nothing else was around, will be selected in turn for the assessments of ling, redfish, mirror dory, blue grenadier, spotted warehou, flathead, royal red prawns and gemfish, because during winter there will be more than 1kg of all 8 species reported in the catch.

This selection criteria obviously also throws up the potential bias of not including zero catches that were intended to catch a certain species. But given the widespread distribution of the SEF species as a back-scatter I believe this potential for bias is actually relatively minor. Trace amounts of most species will occur in most shots even if they are relatively unsuccessful. Actual zero shots virtually only occur well outside the normal season or depth range of a species, or because of gear failure like "pinning-up".

The potential for bias that I believe to be much more influential in the SEF, comes from the extraction of single species data sets using the >1kg selection rule. This makes no distinction between differing "types" of fishing effort which take the same species from a range of dispersion patterns, seasons and depths. Our crudely aggregated catch statistics include fish that are captured from a wide range of fishing efficiencies from the background scatter, seasonal dispersions and aggregations.

In this situation it is obvious that systematic changes in fishing practice like those described by the fishers of SEF could well drive systematic changes in estimated catch rates unrelated to the underlying abundance of the species in question.

It has become normal practice in SEFAG stock assessment to try and standardise our catch rate data with General Linear Modelling (GLM). The aim of this is to standardise the data with regard to variables contained in the SEF1 database. The variables normally used are:

- Vessel Identifying Number - to account for differing fishing powers of vessels.
- Area - to account for the geographical distribution of the fish.
- Depth - to account for differing depth preferences of the fish.
- Season or month - to account for seasonal catchability factors
- Year - to account for specific year effects and changes in abundance.

In theory this approach should standardise for the types of factors described in this report, and it is often argued that it does. In practice the use of a GLM in the SEF usually accounts for relatively little (5-15%) of the observed variability and estimated trends are usually similar whether or not they are standardised.

The problem with the use of GLM in the SEF is that factors recorded in the SEF1 are inadequate for describing the actual variability of catch rates in the fishery. The consequence of this is that the systematic changes occurring due to changing fishing practice are picked up by the year variable in the GLM and interpreted as changing stock abundance.

## Inappropriate Fisheries Models

It is extremely interesting that, with the notable exceptions of orange roughy and gemfish, SEF1 catch rates are declining in proportion to the concurrent increase in effort levels. Landings from the SEF have remained stable throughout our time series (Figure 24). Thus catch rates are at historically low levels because a historically high number of hours are being trawled (Figure 27).

This basic proportionality between catch rate and effort is widely seen when one analyses the SEF1 database and it is not necessarily indicative of a fishery that is fishing down its resource.

When a resource goes into decline catch rates that are indicative of stock abundance would be expected to fall relatively independently of effort levels. Normally (according to classic models of fisheries) as stock abundances decline effort increases as the fishers attempt to maintain catch levels, and under the twin effects of increasing effort, and declining stock abundance, the decline of catch rates is almost exponentially.

But in the SEF some other type of fisheries dynamic is being exhibited.

In standard fisheries models fishing effort is assumed to be effective across the whole fish stock, either because the fishing grounds include the entire stock or because the entire stock passes through the fishing ground. But the proportionality of effort and catch rate in the SEF suggests that this is not valid. Rather this dynamic is suggestive of a fishery exploiting some limited part of a species' population with relatively limited impact on the abundance of the broader population. In this type of model the rate of recruitment to the fishery is relatively constant and related to the rate at which each species reoccupies the fishing grounds, which are repeatedly depleted by fishing.

In this type of system the ability of the fishery to impact the broader population will be related to the rate at which a species reoccupies the fishing ground, and the size of the fishing grounds relative to the area occupied by the stock. Where fishing grounds are small and movement rates are limited fishing will have severe local effects but little broad-scale effect. In this type of fishery increasing effort simply increases the competition between fishers for a fixed catch, catch rates decline and catches remain stable. Under this dynamic catch rates do not reflect overall abundance only the intensity of fishing within the fishing grounds. On the bright side these types of fisheries tend to be relatively robust to over fishing.

This could conceivably be the situation for species such as ling, ocean perch, redfish, blue warehou, flathead, morwong, redfish and probably a range of other SEF species. Because the extent of the trawl grounds is limited compared to the habitat occupied by these species, and their movement patterns are apparently localised some extent.

Interestingly the gummy shark fishery in the SEF also displays this same characteristic dynamic.

## General Comments

How should we proceed to determine which model is appropriate for describing our resource?

1. Better description and understanding of the SEF1 data basis data prior to estimating trends to be used as indices of abundance in population models, or formalising stock assessments.

2. Make more use of mapping to study the regional and seasonal variability of effort and catches together with the environmental variability of the SEF.

3. Make more use of the species composition data collected on SEF1 forms. Species composition data could help to categorise/standardise for type of fishing. It may also test the fishers' information gathered by this study. According to fishers' trawl shots should formerly have been dominated by relatively fewer species, and should now be evolving towards containing a more even representation of species.

One of the original objectives of this project (Objective 4) was to:

Generate ordinal time series for incorporation in General Linear Modelling of catch rate trends within the SEF1 database by SEFAG.

This is the only objective of this project that has not been achieved.

The objective proved to be contentious, as some influential fishers of the SEF do not support making detailed technological data available to SEFAG at this point in time, because they lack confidence in how it will be used. As a consequence any data the project would have gathered would have been patchy and presented against the wishes of some project participants.

We were, however, able to ascertain that the data could be reliably gathered although it would take a considerable amount of researcher time and considerable co-operation of the fishers who agree to act as sources for the study. Most operators are knowledgeable about the equipment they have used and currently use. Normally they only hold documentation of the purchase for the statutory period required by the Taxation Act. However they can normally link the purchase and installation with other events which they can date with documentation. In this fashion many, if not most fishers, could document to within several months their technological development within the fishery.

Most of the time required by such a project would probably be spent sitting and talking with fishers as they work back through business records. The level of effort this will take from participating fishers should not be under estimated. It is high enough to ensure that a simple questionnaire sent out impersonally will fail.

It should however be noted the generation of an ordinal time series for incorporating into GLMs will be seriously flawed if it fails to incorporate the impact of changing net design. This will require a species specific analysis of how changing net design has influenced catchability which in turn will require the specific attention of a qualified professional in net design. Perhaps such a desktop and interview project could be an initial phase of the proposed initiative to modify gear design and reduce unintended by-catch in the SEF. It is certain that such skills will be needed to interpret catch rate trends if further widespread gear modification is initiated in the SEF to reduce by-catches.

In fact SEFAG needs to reconsider the use of GLMs generally together with the full range of variables being used to explain the variability of catch rates in the SEF. This should occur before a study is mounted to collect detailed information from industry.

## 7.8 The Relative Need for Biological Protection

Most SEF fishers do not think the problems of the SEF are biological. They argue that the species vulnerable to over fishing (gemfish and orange roughy) have been successfully protected by the ITQ system. The principle remaining problems of the SEF are socioeconomic.

With an expected return for running an inshore trawler for 12 months of just 5%, or just $50,000, it is easy to understand why the fishers are of this opinion. And why they complain about paying annual management levies of $15-25,000/annum against this standard.

What is wrong with Australia's premier fresh white fish fishery? How can the fishery situated between the regions two largest fresh fish markets be going so badly wrong? Is this just the face of fishery rationalisation in the SEF? Or is the entire industry going to go bankrupt together? Why aren't more fishers retiring from the fishery and leaving the others to be more profitable? When is the human cost of rationalisation too great?

Above I have argued that the trends being observed for many species in the SEF suggest that the existing configuration of the trawl fleet makes them robust under exploitation. If this is the case SEF managers should be cautious about over managing the resource on the pretext of biological protection.

# 8. BENEFITS

Over the last decade the SEF has been characterised by high levels of conflict between fishers, managers and stock assessment scientists. Fishers have had little faith in the process of assessment and management, believing that it is out of touch with the reality of their fishery.

This project has begun the process of formalising these views and opinions about the SEF so that they can be recognised, analysed and incorporated into the process of stock assessment and management. The SEF has previously been viewed as a collection of single species fisheries. This project has assembled and presented a coherent overview of the SEF as a multi-specied resource.

During the project fishers being interviewed frequently commented that this project has been needed for many years and that it would enable scientists and managers to understand their fishery better, and improve relationships within the fishery, along with the standard of assessment and management.

The material produced by this study has lead to the recognition amongst the SEF scientific community that effect of changing fishing patterns and technology, together with oceanographic influences, need to be understood and incorporated into the assessment and management of the fishery.

The results of this project have already been used to set the context for:

- The recent Workshop on Introducing Flexibility to Management of the SEF
- Developing proposals for further research and analysis into the influence of oceanographic factors and changing fishing patterns on catch rate trends.
- New analyses of the SEF1 database.

# 9. FURTHER DEVELOPMENT

The issues documented by this project will be developed through the work of the SEF assessment groups and continuing debate about SEF management. Within the assessment groups the results of this study have focused debate as to how catch rates should be analysed, and discussion about the need to develop fishery independent survey techniques for SEF stocks. This has lead to the development of specific research proposals.

The Research Sub-committee of SETMAC is supporting the development of a proposal to hold a workshop entitled:

" Managing in the face of environmental influences - a workshop on the Environmental influences on SE Australian Fisheries"

The objectives of the workshop will be to:
1. Document and publish the current state of knowledge and perceptions (both scientific and anecdotal) on how environment influences are manifest in SE Australian fisheries.
2. Evaluate the implications of such influences for current assessment and harvest strategies.
3. Evaluate the potential benefits and possible approaches for incorporating environmental influences of SEF fish stocks into harvest strategies and stock assessments.
4. Develop an agreed direction for strategic research into this topic that will facilitate achieving management objectives in South East Australian fisheries.

The results of this study will be used to provide the background for this proposed workshop.

The Research Sub-committee of SETMAC is also supporting the development of a proposal to use SEF1 data more intensively to analyse the factors reported by this study. BRS has already begun analysing the change in species composition within trawl shots over time. Preliminary results apparently support the industry contention that catches now contain a broader mix of species. It is proposed that SEF1 data should be analysed in detail using GIS techniques overlaid with remote sensing data, principally SST and ocean colour. It is also proposed that alternative parameters be developed for potentially explaining the variability of catch rates in the SEF, and that the technique of General Additive Modelling (GAM) should be developed.

The Research Sub-committee of SETMAC is also supporting the development of a proposal to begin the design and feasibility testing of fishery independent survey techniques for general application in the SEF.

At the level of fisheries management, the recently held "Workshop on Introducing Flexibility to Management of the SEF" attained uniform public agreement that the existing management strategy needs reform, although there was less agreement on specific changes. However having reached agreement that change is needed, debate about the type of change will continue. The coherent over-view of the fishery documented by this project provides an appropriate context in which this debate can occur.

# 10. CONCLUSION

A total of 96 fishers from the South East Trawl Fishery of Australia were interviewed during two rounds of carefully structured interviews. During the interviews fishers were asked a series of standard questions about their fishing patterns, technological change and the influence of oceanographic factors on SEF fish stocks.

Despite harbouring deep frustration and distrust of the existing process of management and stock assessment fishers welcomed the chance to describe their fishing experience and knowledge.

According to the trawl fishers the limited size of trawl grounds compared to the habitat occupied by the various species (5-30% of the area of shelf and slope) restricts their ability to target most species. While accepting that certain species such as orange roughy and gemfish can be highly targeted and need the protection of single species quota most fishers believe the configuration of their fishery has limited potential for impacting most SEF species.

The major change in fishing technology to occur has been the evolution of nets from danish seine, through bottom hugging 'scratch nets', through to 'high lift' or 'cut away' nets equipped with "rubbers" or "bobbins". This has increased the effectiveness of fishing with regard to midwater pelagic species while decreasing fishing efficiency for traditional demersal species.

Because fishers repeatedly trawl the same restricted trawl grounds they claim that the introduction of Global Positioning Systems and colour echosounders has had relatively little impact on their relative fishing power.

The fishers say that the move to quota management has had a major impact on their fishing patterns and on catch rates. They claim that ITQ management deters fishers from targeting large single species catches. Income is now maximised by landing as many species as possible on as many days of the year as possible. They believe this trend has driven the decline in catch rates widely observed across SEF quota species.

Fishers of the SEF believe that oceanographic factors, principally water temperature, are extremely important in determining catch rates.

On the basis of this body of anecdotal information and analysis of range of other data it is concluded that:

- The importance of midwater pelagic ecosystems and environmental variability in the SEF has not been fully recognised in the past.
- The concept of targeting needs redefinition within the SEF trawl fishery.
- The current methods of estimating and standardising catch rates are inadequate in reflecting trends in stock abundance.

- The wrong assumptions are being used to model the population dynamics of some SEF species.

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## APPENDIX 1: INTELLECTUAL PROPERTY

No commercially valuable intellectual property has resulted from this research.

## APPENDIX 2: STAFF

Dr Jeremy Prince
Dr Pascale Baelde
Dr Guy Wright

| Quota Species | Catch 97 tonnes | % TAC Max | SEFAG Status |
|---|---|---|---|
| Roughy (east) | 2,063 | 105 | Fully Fished |
| Spotted Warehou | 2,785 | 98 | Unknown |
| Ling | 1,756 | 94 | Unknown |
| Blue Warehou | 794 | 85 | Unknown |
| Blue-eye Trevalla | 113 | 73 | Fully Fished |
| Redfish | 1,597 | 74 | Fully Fished |
| Gemfish (west) | 227 | 64 | Fully Fished |
| Ocean Perch | 423 | 59 | Fully Fished in NSW. Other Areas Unknown |
| Morwong | 1,206 | 56 | Fully Fished Southwest Underfished |
| Tiger Flathead | 2,677 | 55 | Fully Fished |
| Mirror Dory | 546 | 51 | Unknown |
| Blue Grenadier | 5,206 | 42 | Underfished |
| Gemfish (east) | 397 | 38 | Overfished |
| John Dory | 103 | 29 | Unknown |
| Royal Red Prawns | 295 | 27 | Unknown |
| Silver Trevally | 372 | 27 | Unknown |
| Roughy (south) | 454 | 21 | Overfished |
| Roughy (west) | 352 | 20 | Unknown |
| School Whiting | 754 | 16 | One Stock Fully Fished OtherStocks UnderFished |

Sources:
Catches from SEF2 Returns
SEFAG Status as of 1997 FAR

**Table 1**

| Species | Tonnes Discarded | % Wt Discarded | % of TAC Filled |
|---|---|---|---|
| Jack mackerel | 330 | 85 | No Quota |
| Redfish | 266 | 24 | 74 |
| Southern Frost Fish | 222 | 76 | No Quota |
| Blue Grenadier | 182 | 81 | 42 |
| Mirror Dory | 125 | 60 | 51 |
| Inshore Ocean Perch | 122 | 83 | 59 |
| Silver Dory | 114 | 70 | No Quota |
| Piked Dogfish | 101 | 48 | No Quota |
| Tiger Flathead | 81 | 14 | 55 |
| Spotted Trevalla | 73 | 10 | 98 |
| Offshore Ocean Perch | 32 | 18 | 59 |
| Jackass Morwong | 14 | 4 | 56 |
| Pink Ling | 7 | 2 | 94 |
| Blue warehou | 3 | 1 | 85 |
| Royal Red Prawn | 1 | 48 | 27 |
| John Dory | 1 | 1 | 29 |
| Blue eye-trevalla | 0 | 0 | 73 |
| Silver Trevally | 0 | 0 | 27 |

*Largest Discards of Commercial Species for 1996 Ulladulla and Eden Combined from Liggins 1996.*

# Table 2

| Port | Year | Silver trevally | Warehou - blue | Warehou - spotted |
|---|---|---|---|---|
| Ulladulla | 1994 | 76 | 0 | 0 |
| | 1995 | 78 | 15 | 2 |
| | 1996 | 66 | 16 | 4 |
| | 1997 | 66 | 1 | 1 |
| Bermagui | 1994 | 176 | 31 | 18 |
| | 1995 | 82 | 100 | 68 |
| | 1996 | 84 | 117 | 46 |
| | 1997 | 147 | 16 | 5 |

Source; SEF2.

Table 3

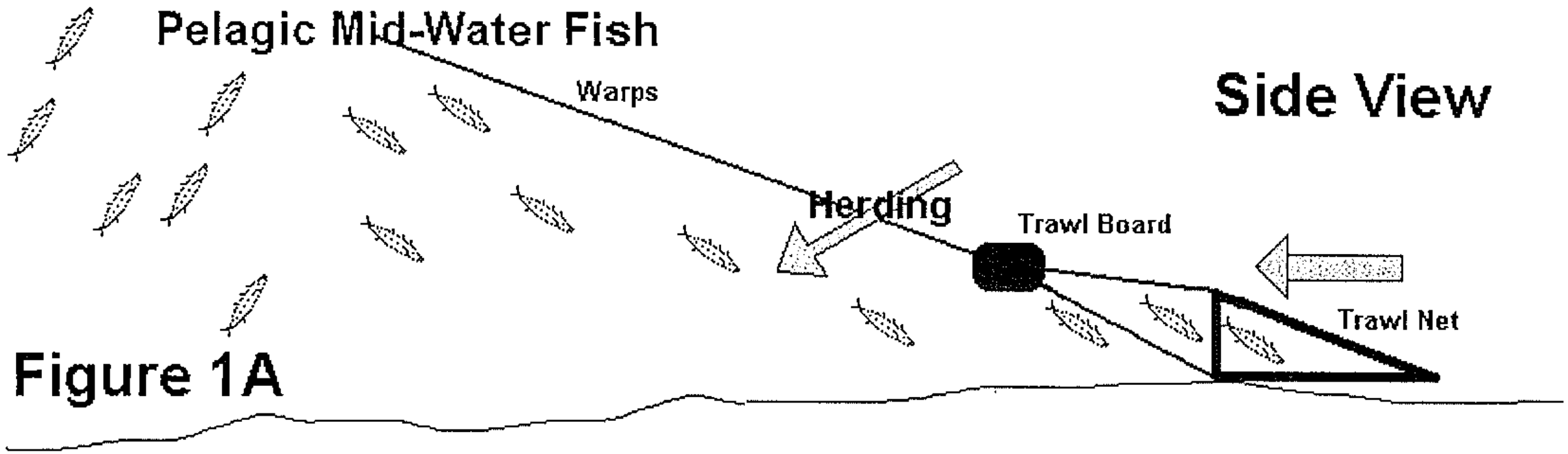



Figure 1A

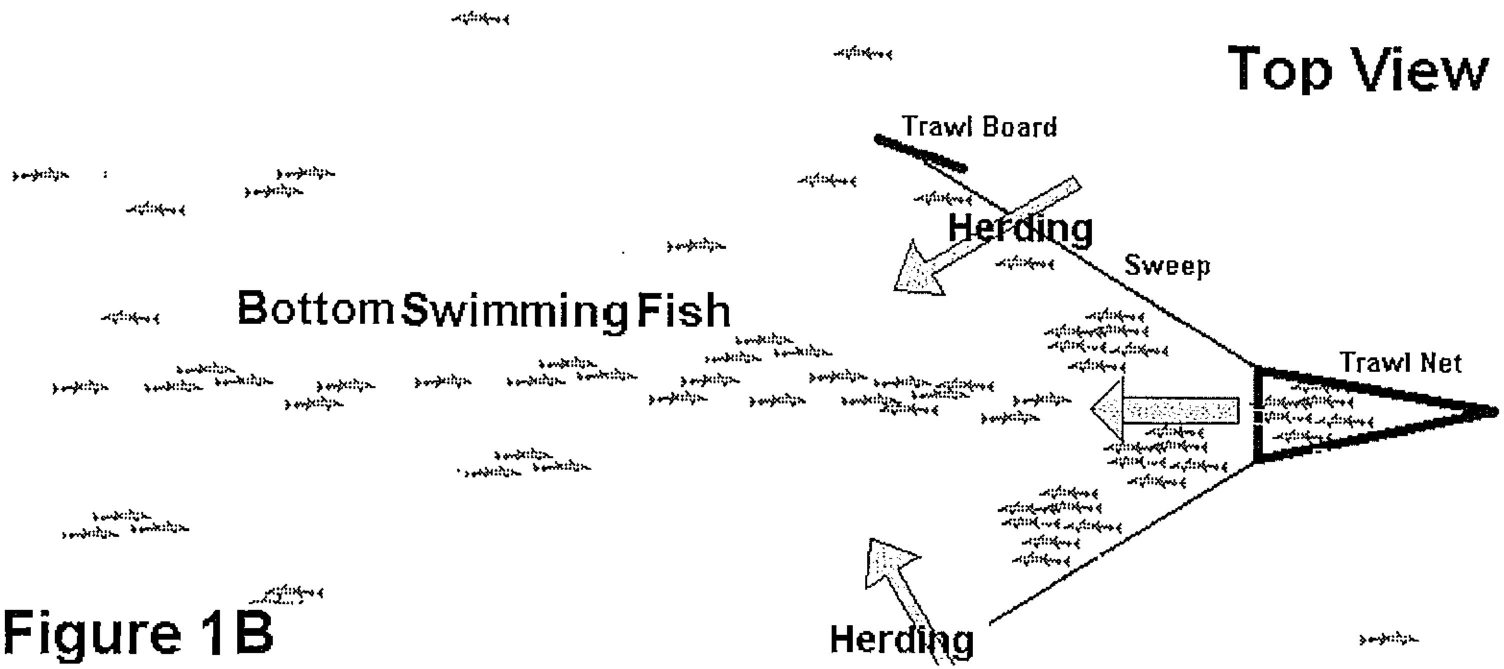



Figure 1B

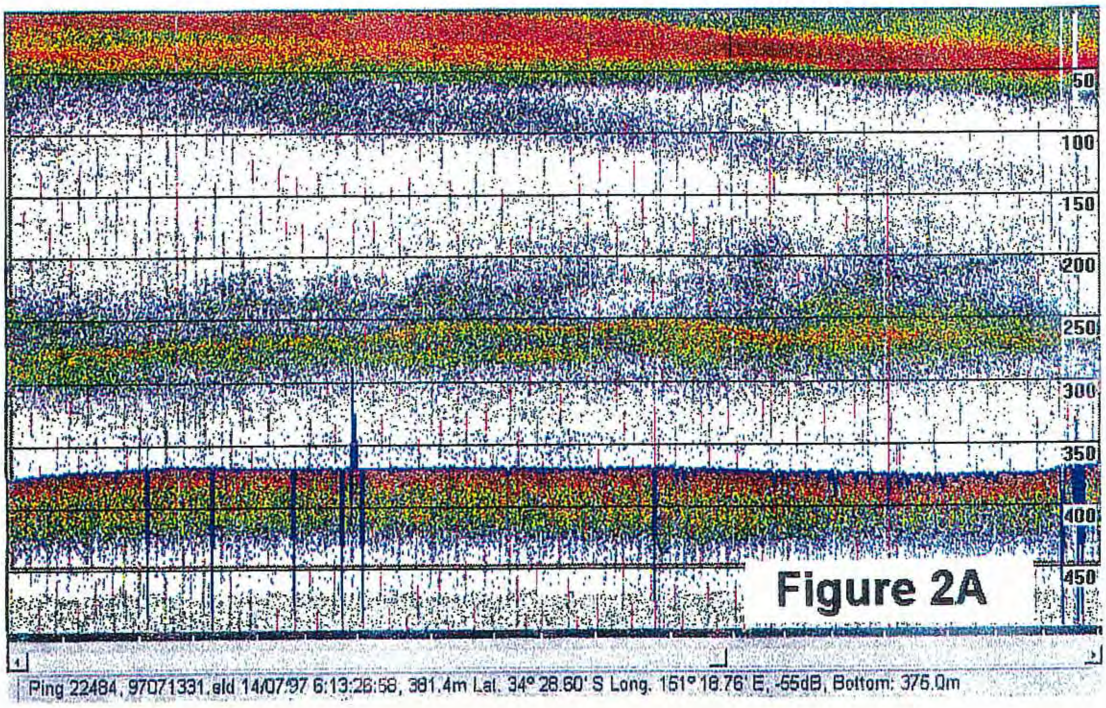



Figure 2A

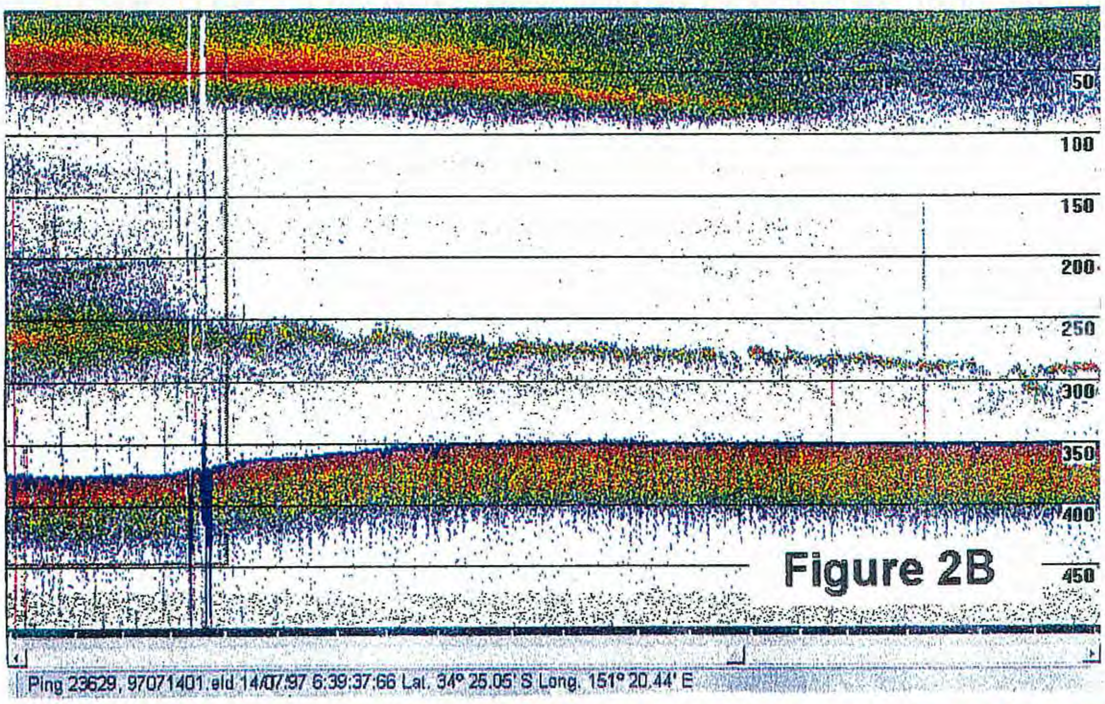



Figure 2B

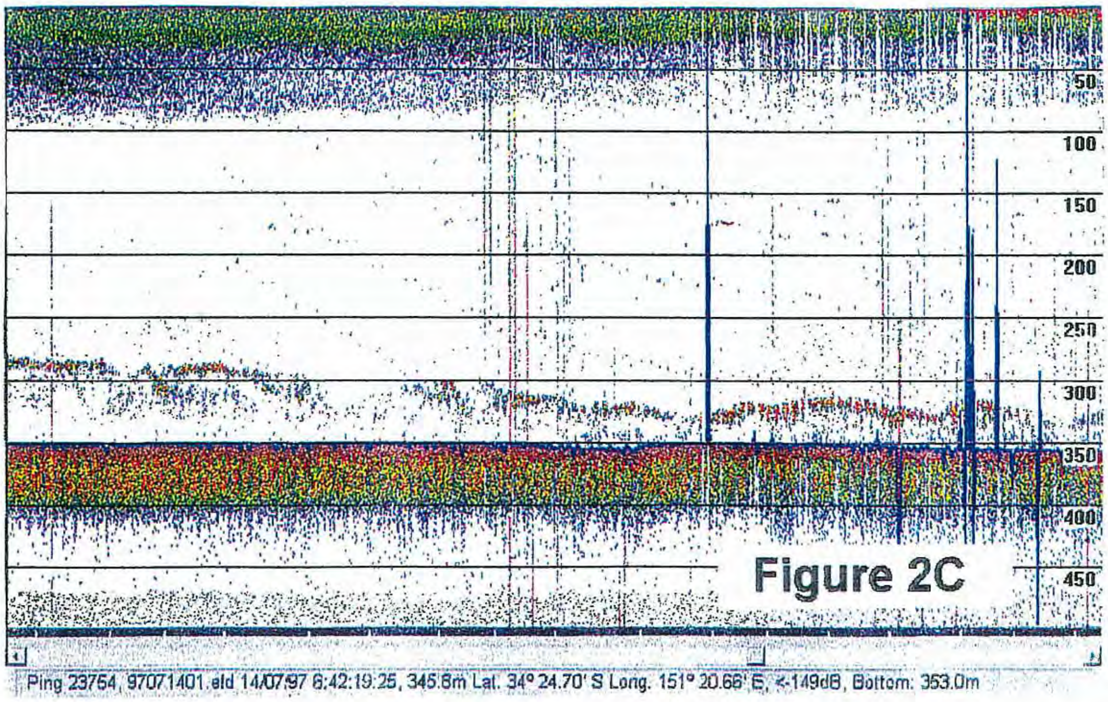



Figure 2C

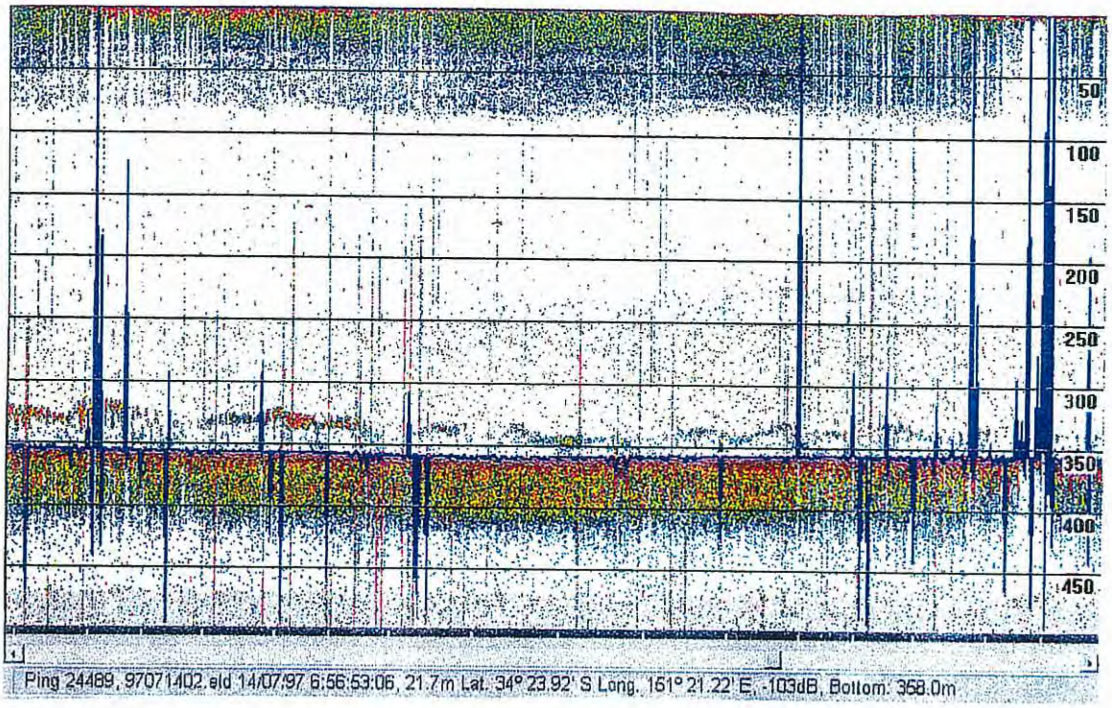
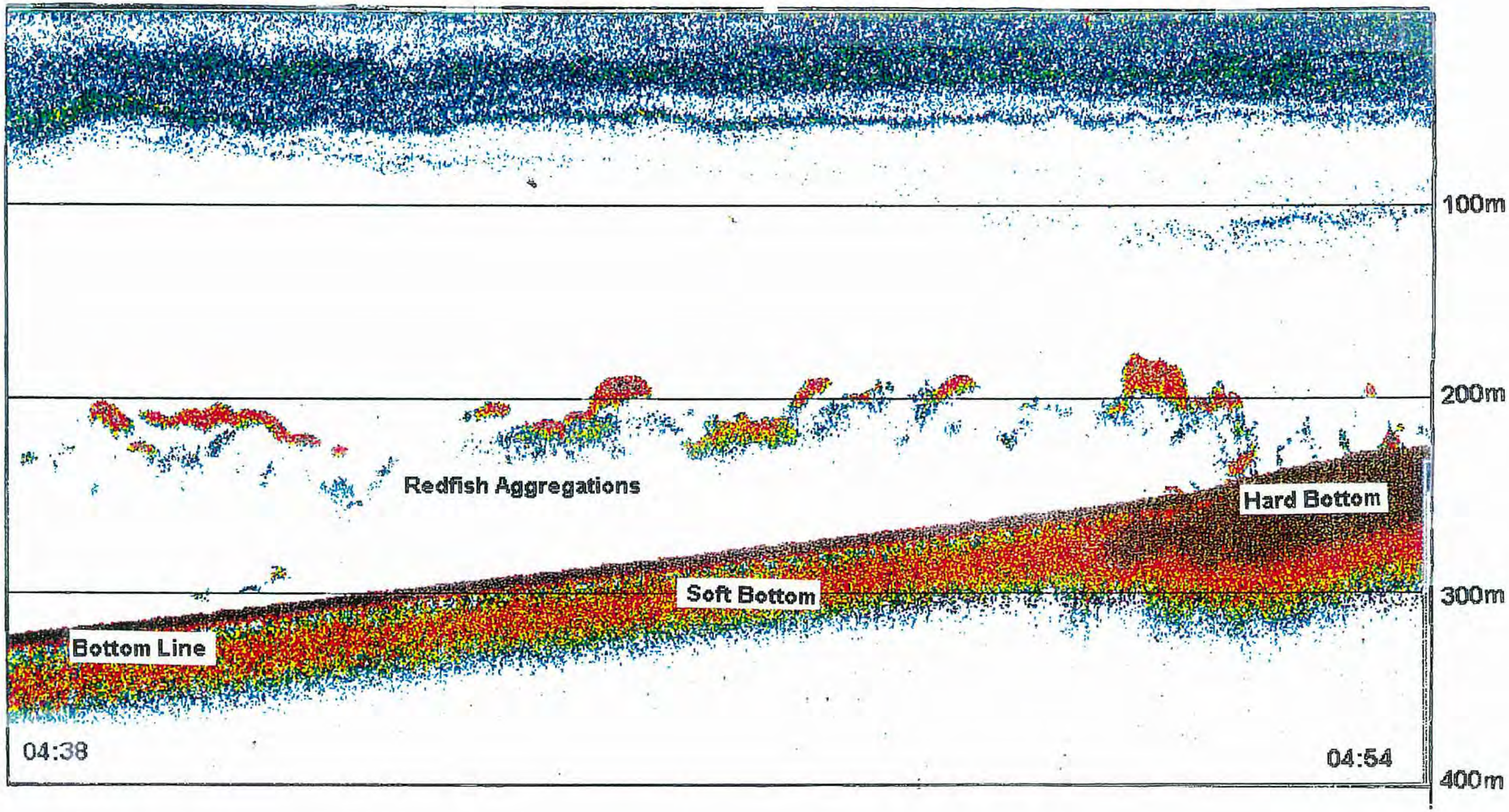

50
100
150
200
250
300
350
400
450
Ping 24489, 97071402.eld 14/07/97 6:56:53:06, 21.7m Lat. 34° 23.92' S Long. 151° 21.22' E, -103dB, Bottom: 358.0m

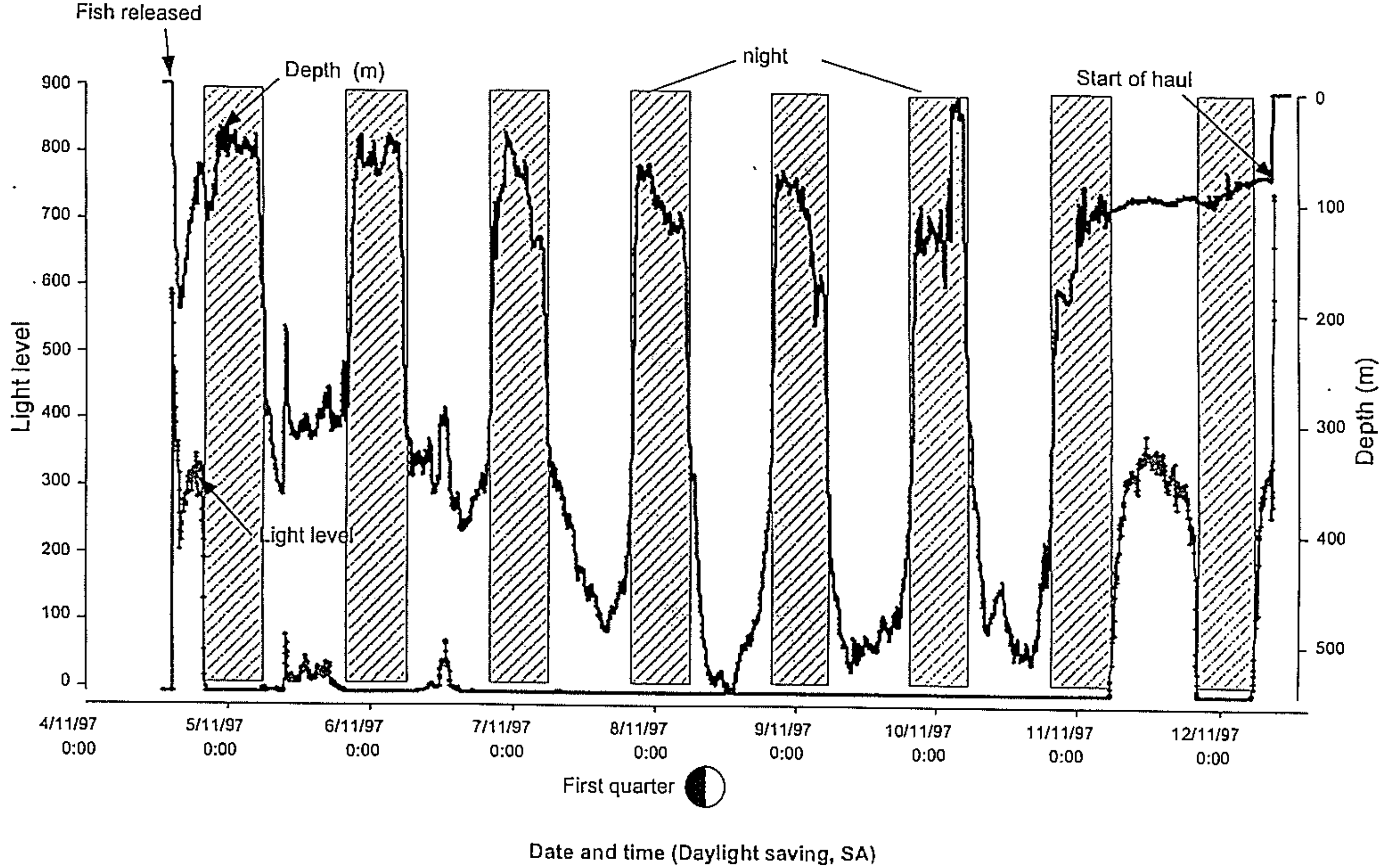
**Figure 2D**



100m
200m
300m
400m
Redfish Aggregations
Hard Bottom
Soft Bottom
Bottom Line
04:38
04:54


Figure 3

School shark, archival tag 1337, releaser' ' Nov 1997, 14:48, recaptured 12 Nov 1'97, 08:44.




# Figure 4

Courtesy John Stevens CSIRO FRDC 96/128

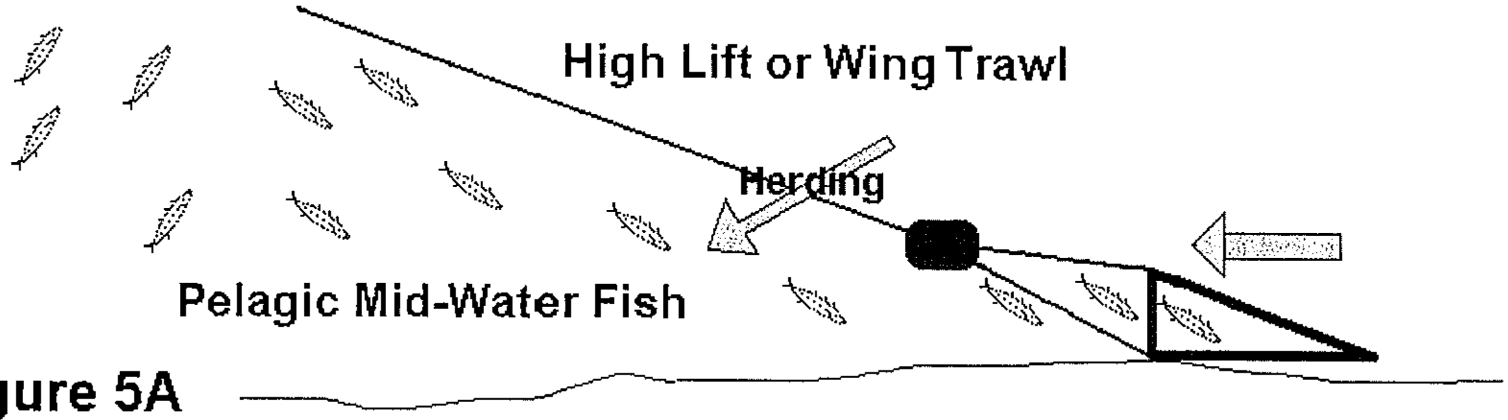



Figure 5A

Side Views

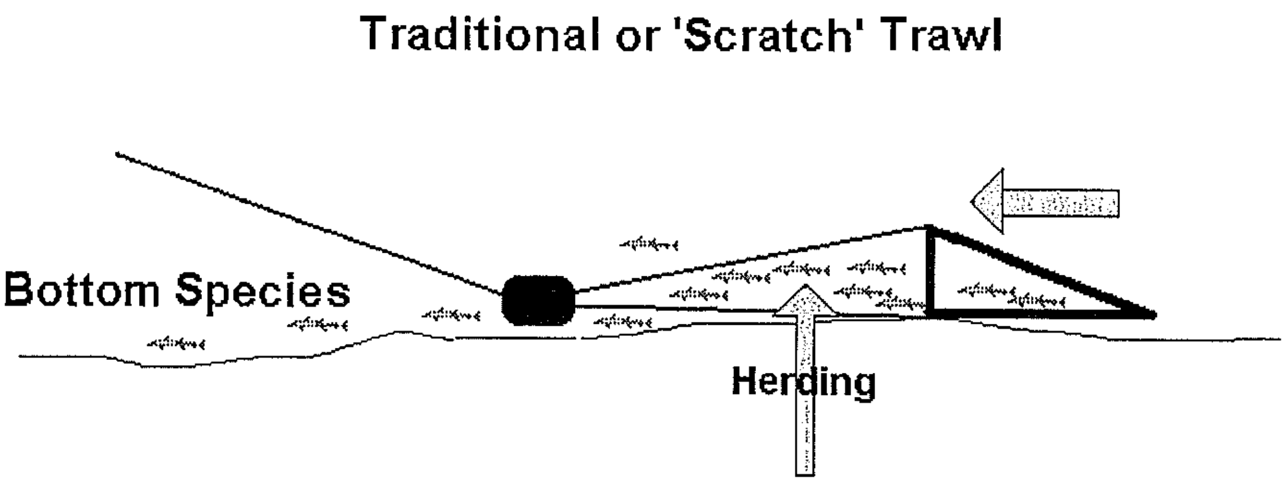



Figure 5B

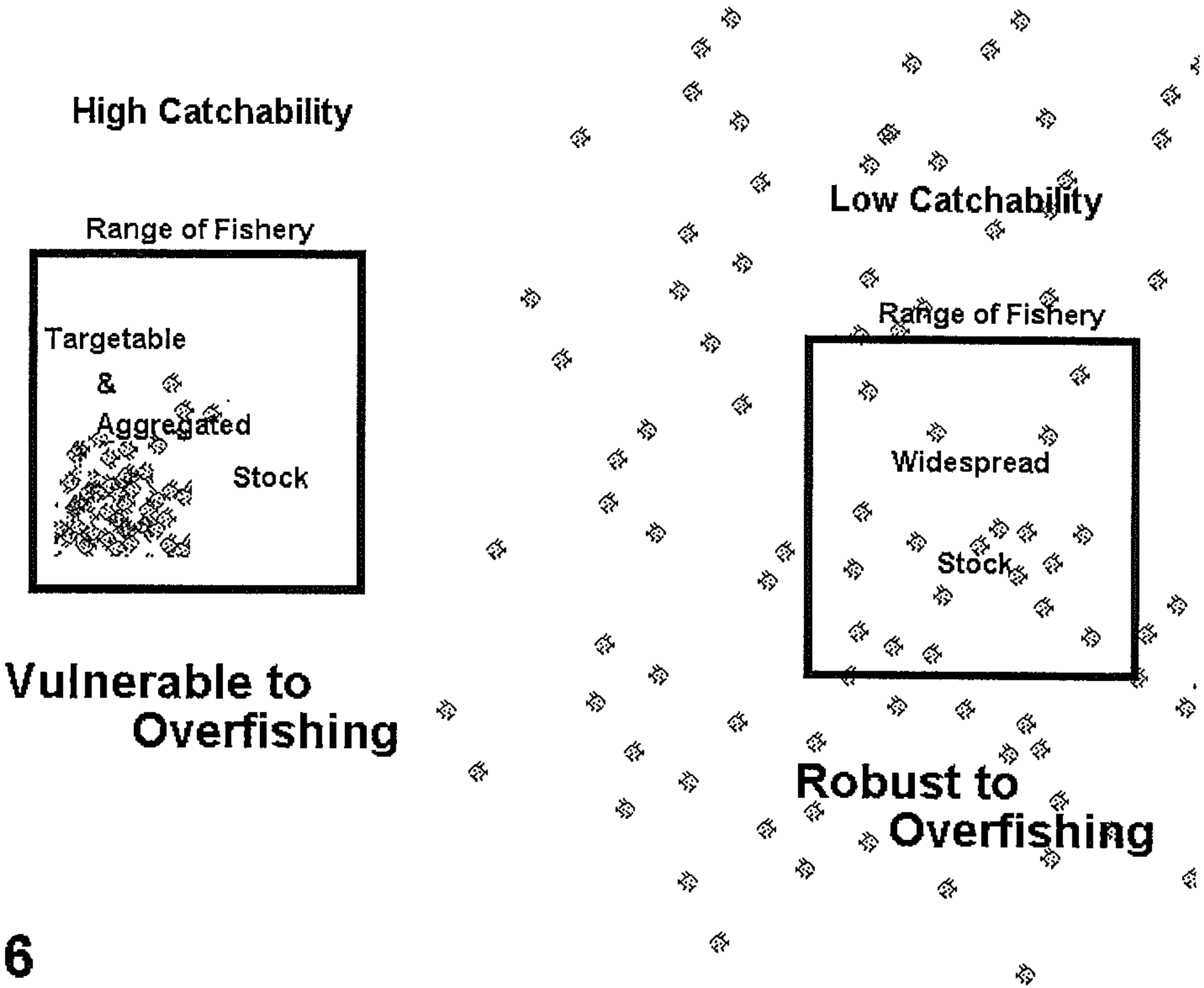

High Catchability
Range of Fishery
Targetable
&
Aggregated
Stock
Vulnerable to
Overfishing
Low Catchability
Range of Fishery
Widespread
Stock
Robust to
Overfishing

Figure 6

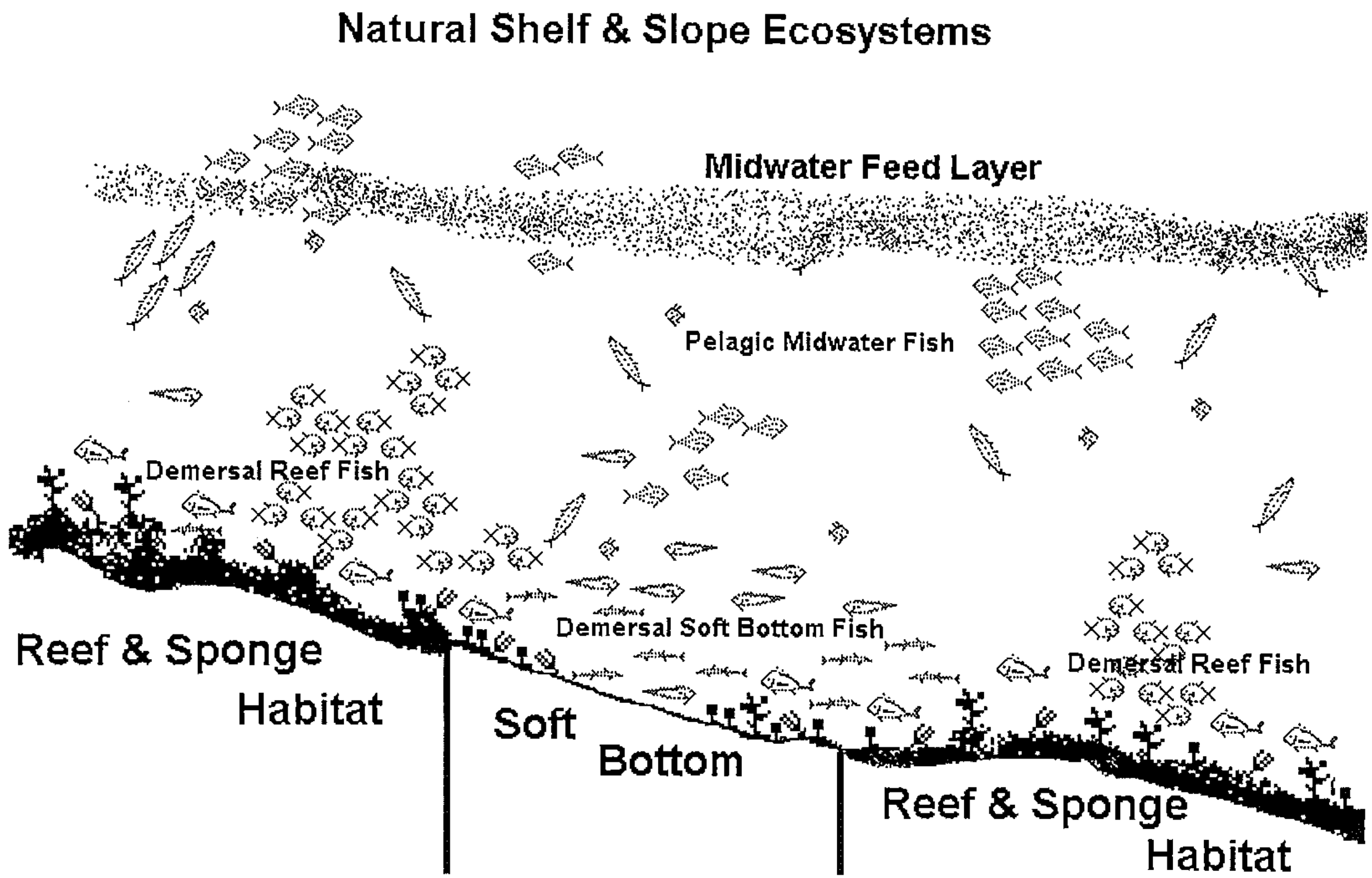

Natural Shelf & Slope Ecosystems
Midwater Feed Layer
Pelagic Midwater Fish
Demersal Reef Fish
Demersal Soft Bottom Fish
Demersal Reef Fish
Reef & Sponge Habitat
Soft Bottom
Reef & Sponge Habitat

Figure 7

Demersal Trawl Fishery

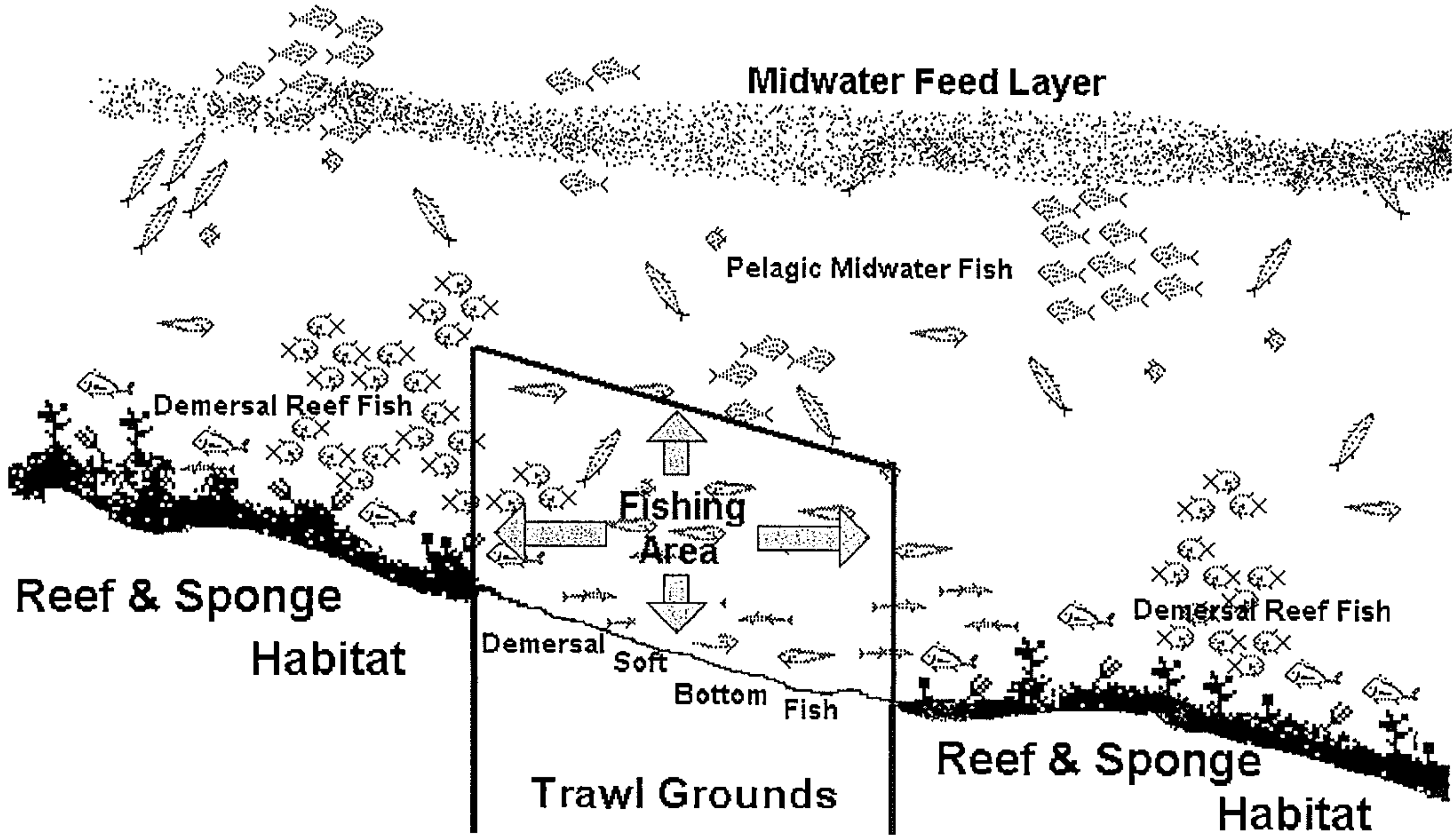



Figure 8

# Daily & Seasonal Movement in SEF

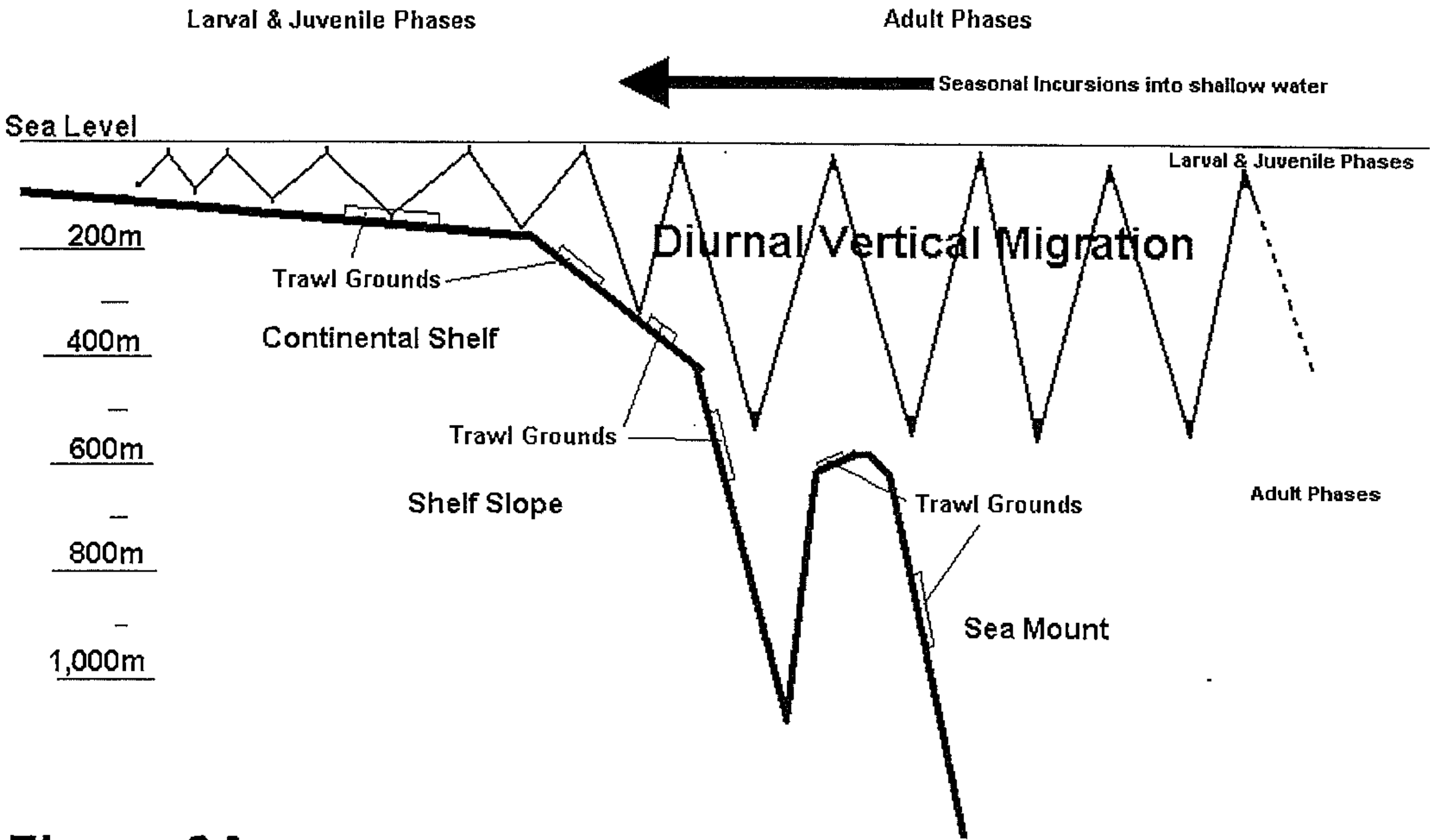



Figure 9A

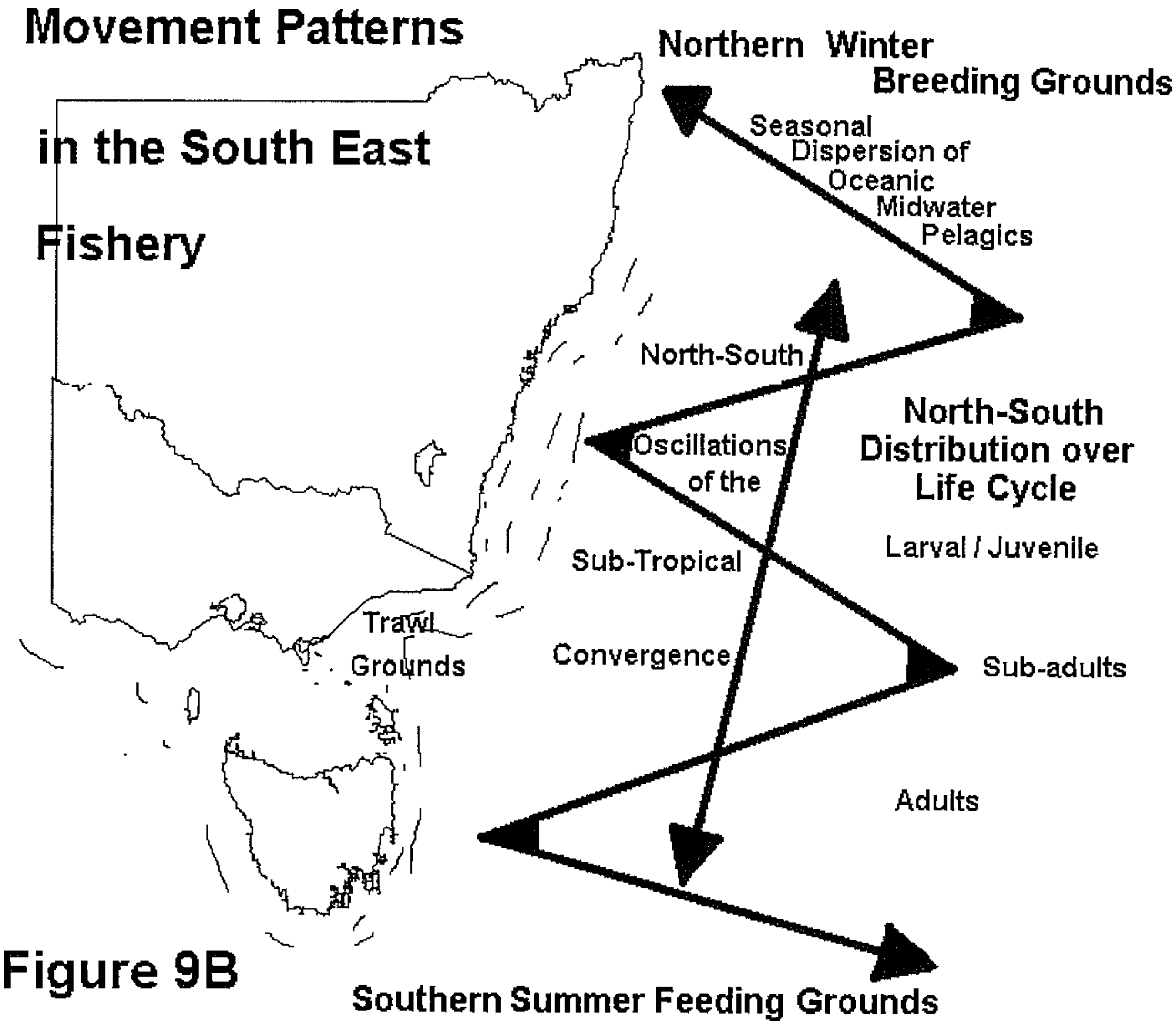

Movement Patterns in the South East Fishery
Northern Winter Breeding Grounds
Seasonal Dispersion of Oceanic Midwater Pelagics
North-South
Oscillations of the
Sub-Tropical
Convergence
Trawl Grounds
North-South Distribution over Life Cycle
Larval / Juvenile
Sub-adults
Adults
Southern Summer Feeding Grounds

Figure 9B

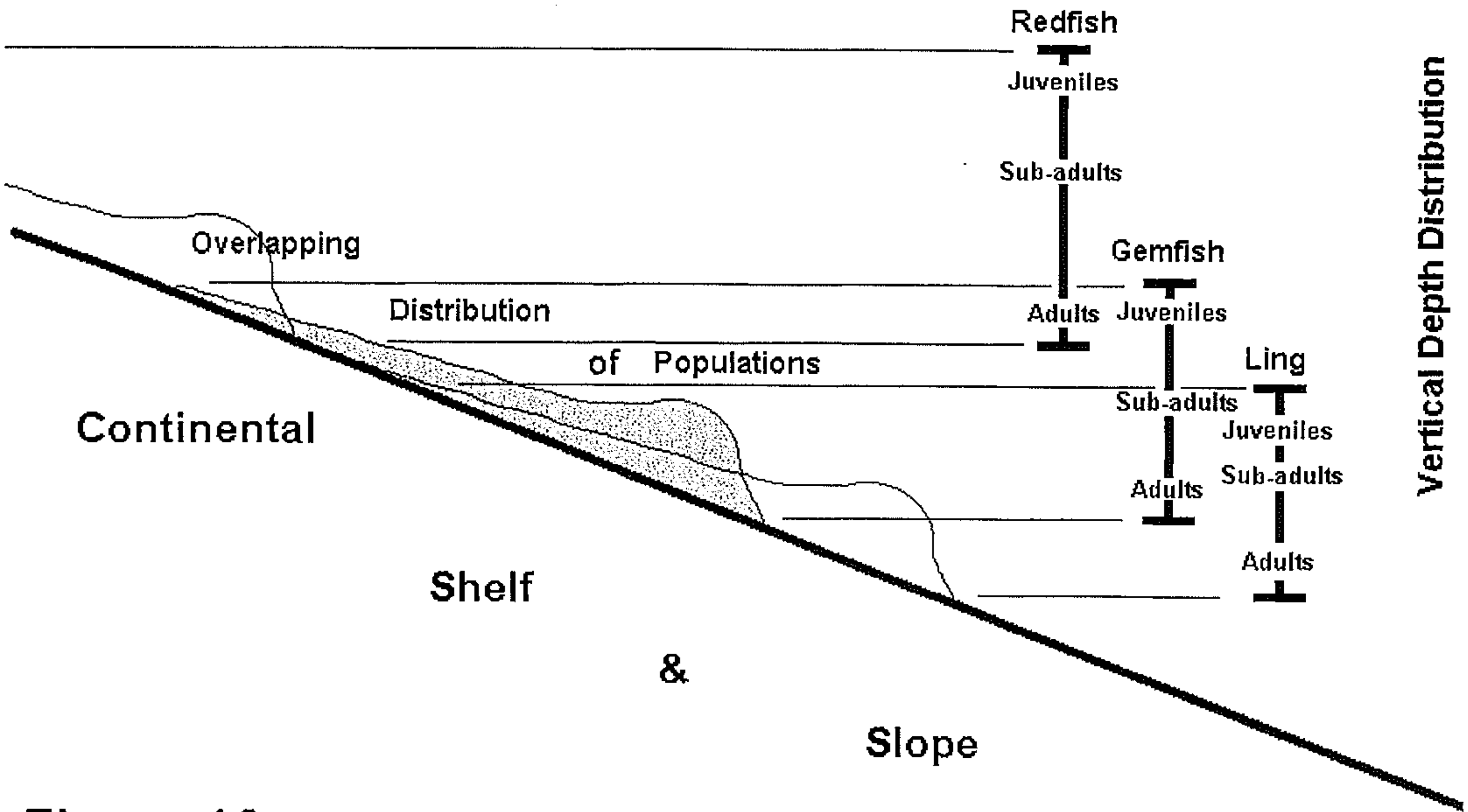

Redfish
Juveniles
Sub-adults
Adults
Gemfish
Juveniles
Sub-adults
Adults
Ling
Juveniles
Sub-adults
Adults
Vertical Depth Distribution
Overlapping
Distribution
of Populations
Continental
Shelf
&
Slope

Figure 10

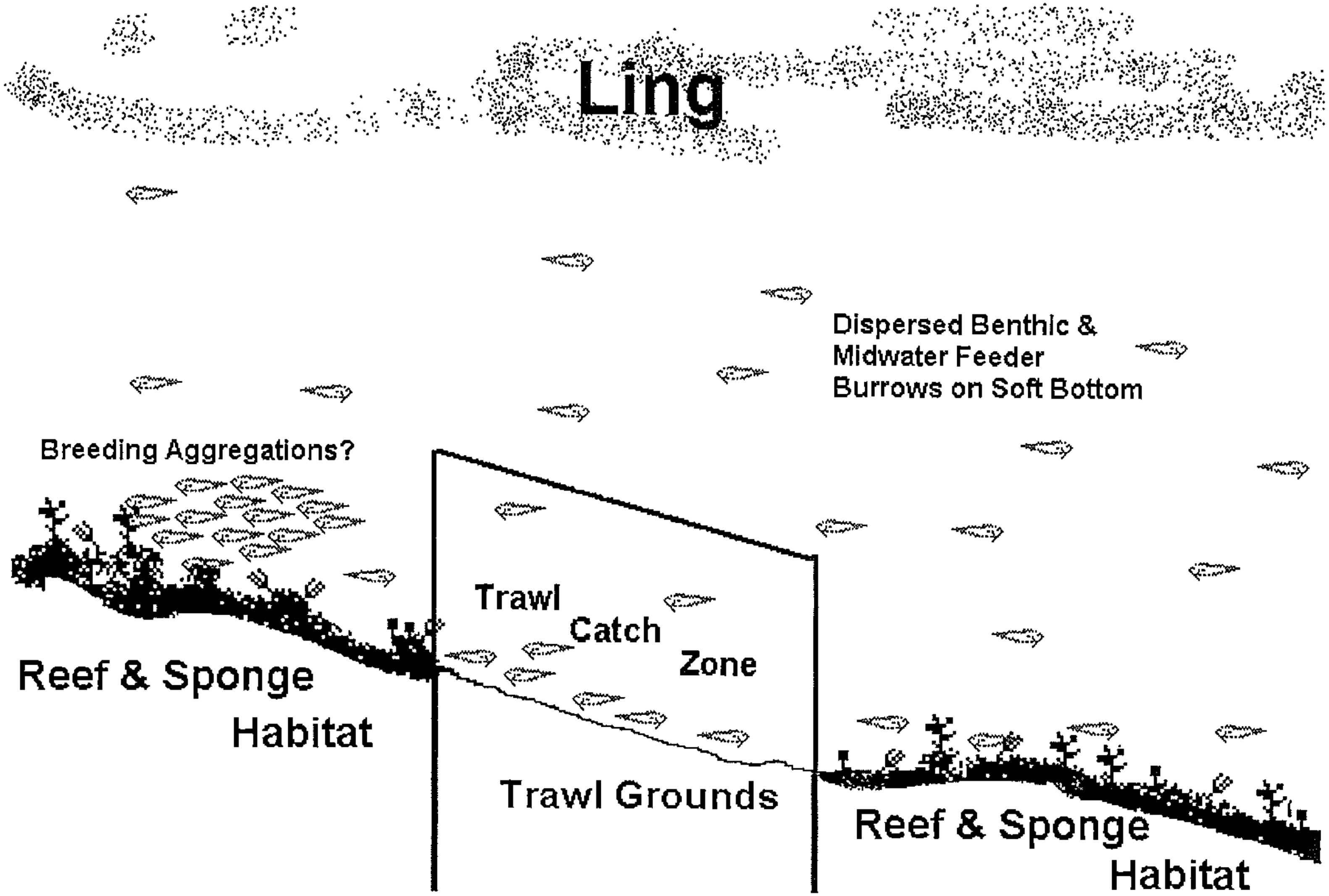

Ling
Dispersed Benthic &
Midwater Feeder
Burrows on Soft Bottom
Breeding Aggregations?
Trawl
Catch
Zone
Reef & Sponge
Habitat
Trawl Grounds
Reef & Sponge
Habitat

Figure 11

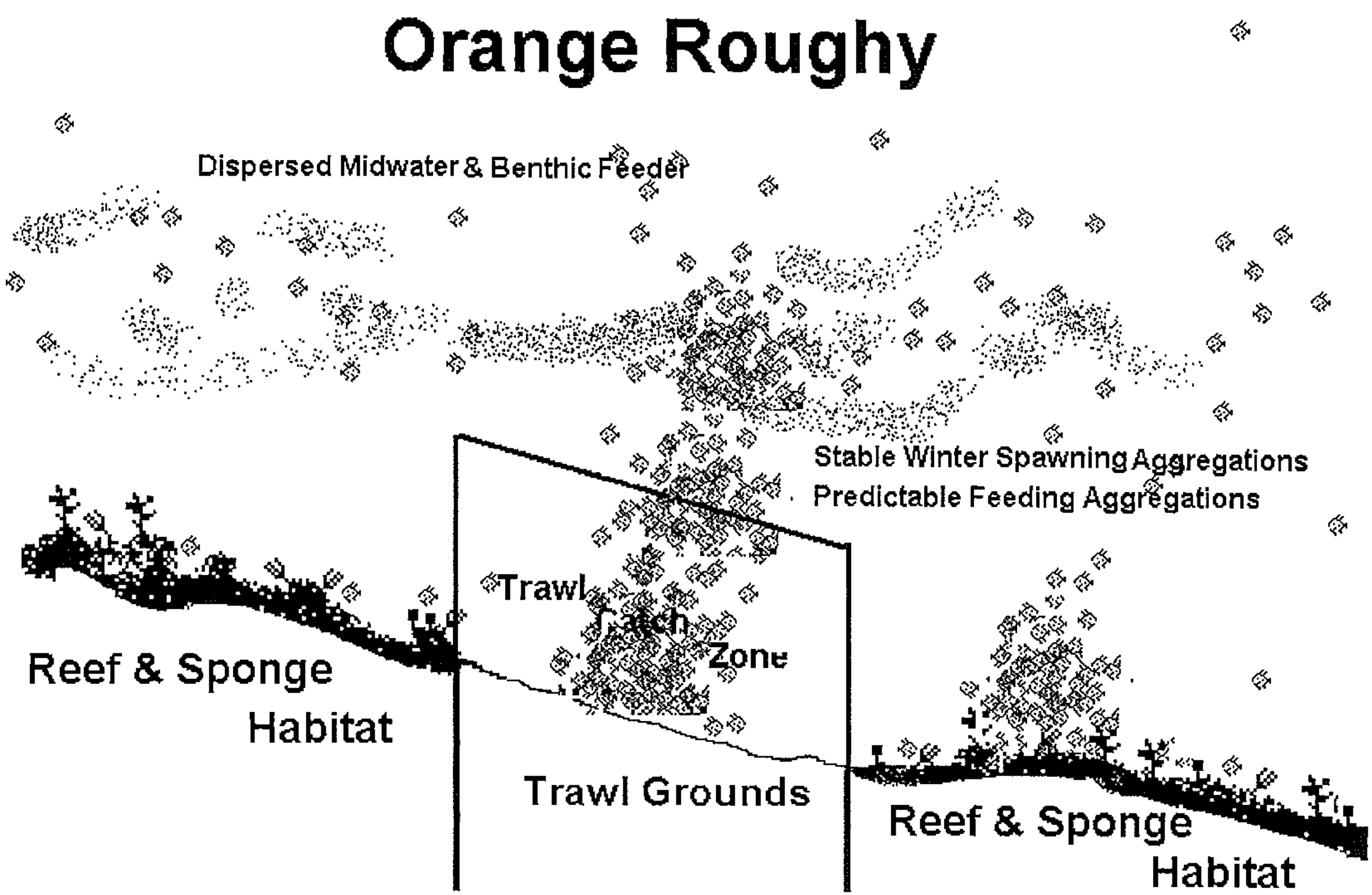

Orange Roughy
Dispersed Midwater & Benthic Feeder
Stable Winter Spawning Aggregations
Predictable Feeding Aggregations
Trawl Catch Zone
Reef & Sponge Habitat
Trawl Grounds
Reef & Sponge Habitat

Figure 12

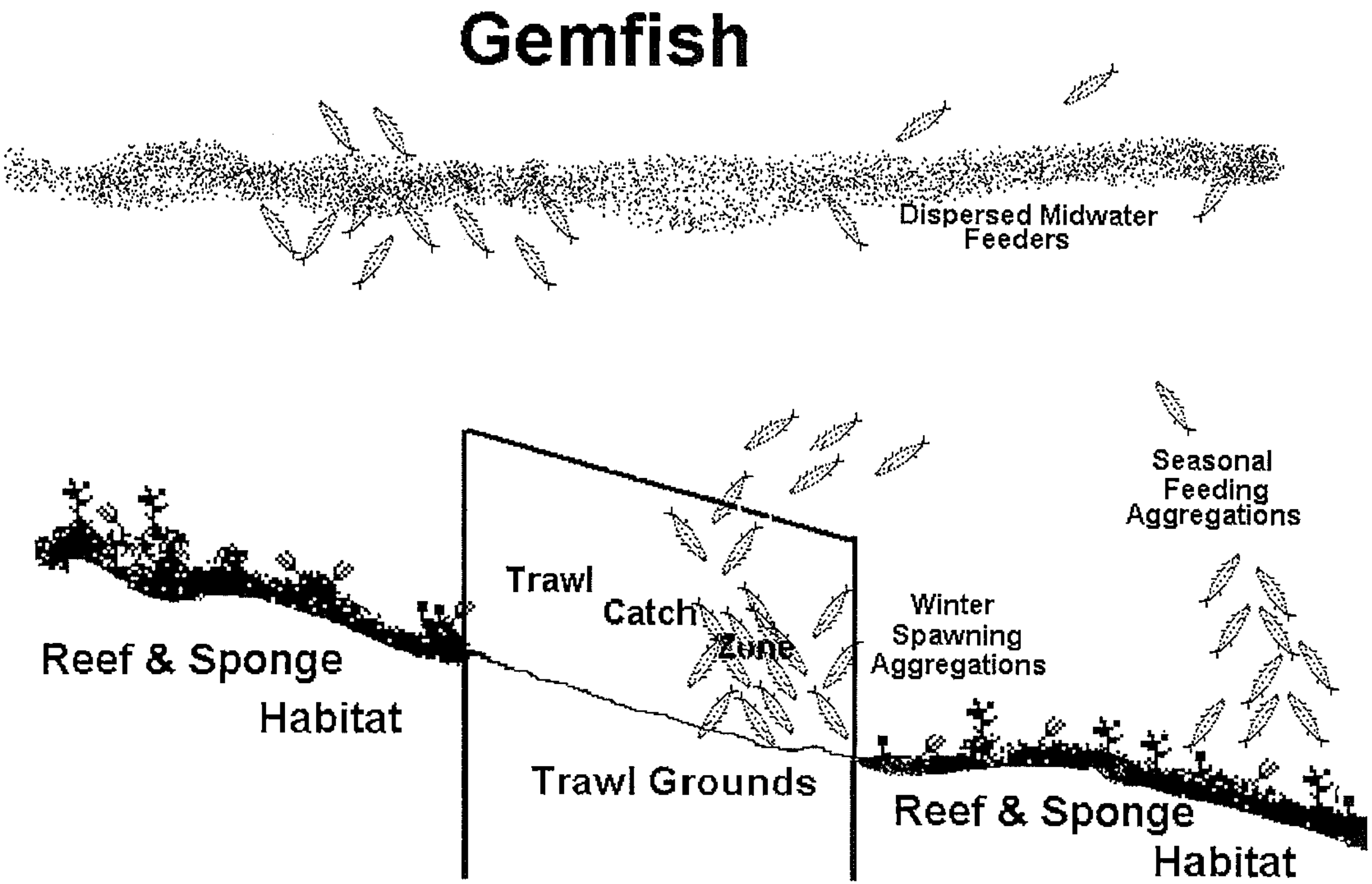

Gemfish
Dispersed Midwater Feeders
Seasonal Feeding Aggregations
Trawl Catch Zone
Winter Spawning Aggregations
Reef & Sponge Habitat
Trawl Grounds
Reef & Sponge Habitat

Figure 13

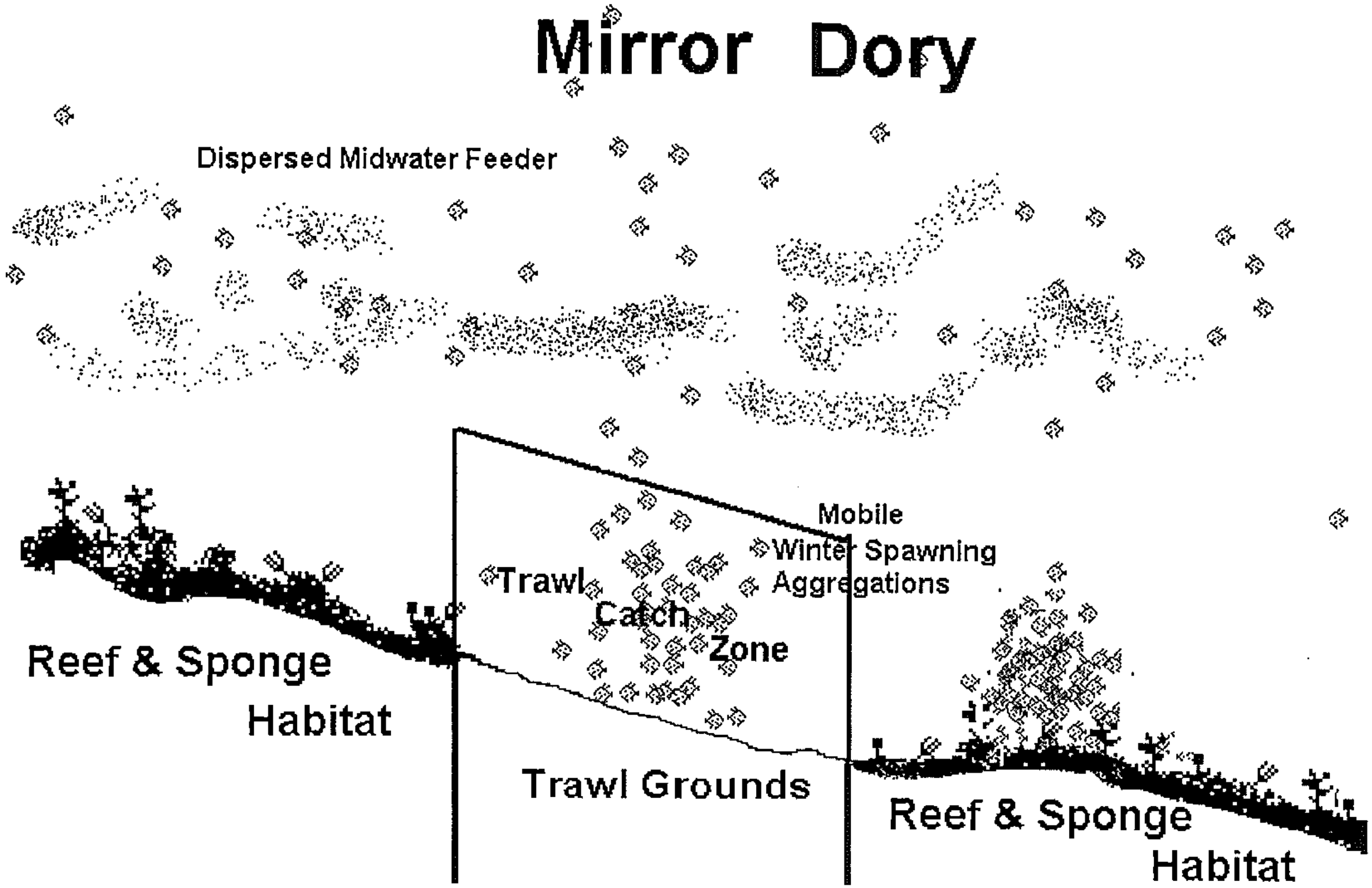

Mirror Dory
Dispersed Midwater Feeder
Mobile
Winter Spawning
Aggregations
Trawl
Catch
Zone
Reef & Sponge
Habitat
Trawl Grounds
Reef & Sponge
Habitat

Figure 14

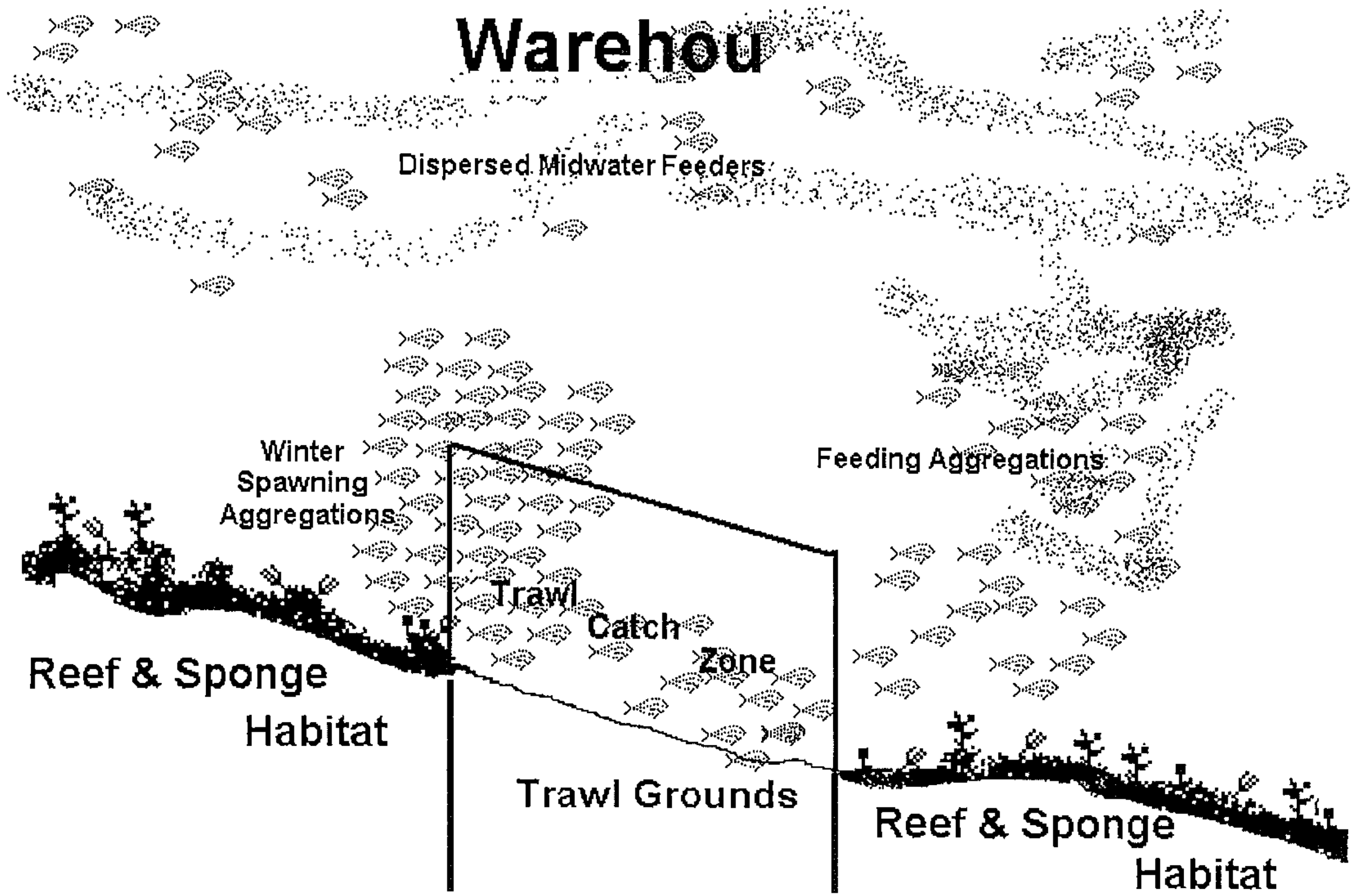

Warehou
Dispersed Midwater Feeders
Winter
Spawning
Aggregations
Feeding Aggregations
Trawl
Catch
Zone
Reef & Sponge
Habitat
Trawl Grounds
Reef & Sponge
Habitat

Figure 15

# Tiger Flathead

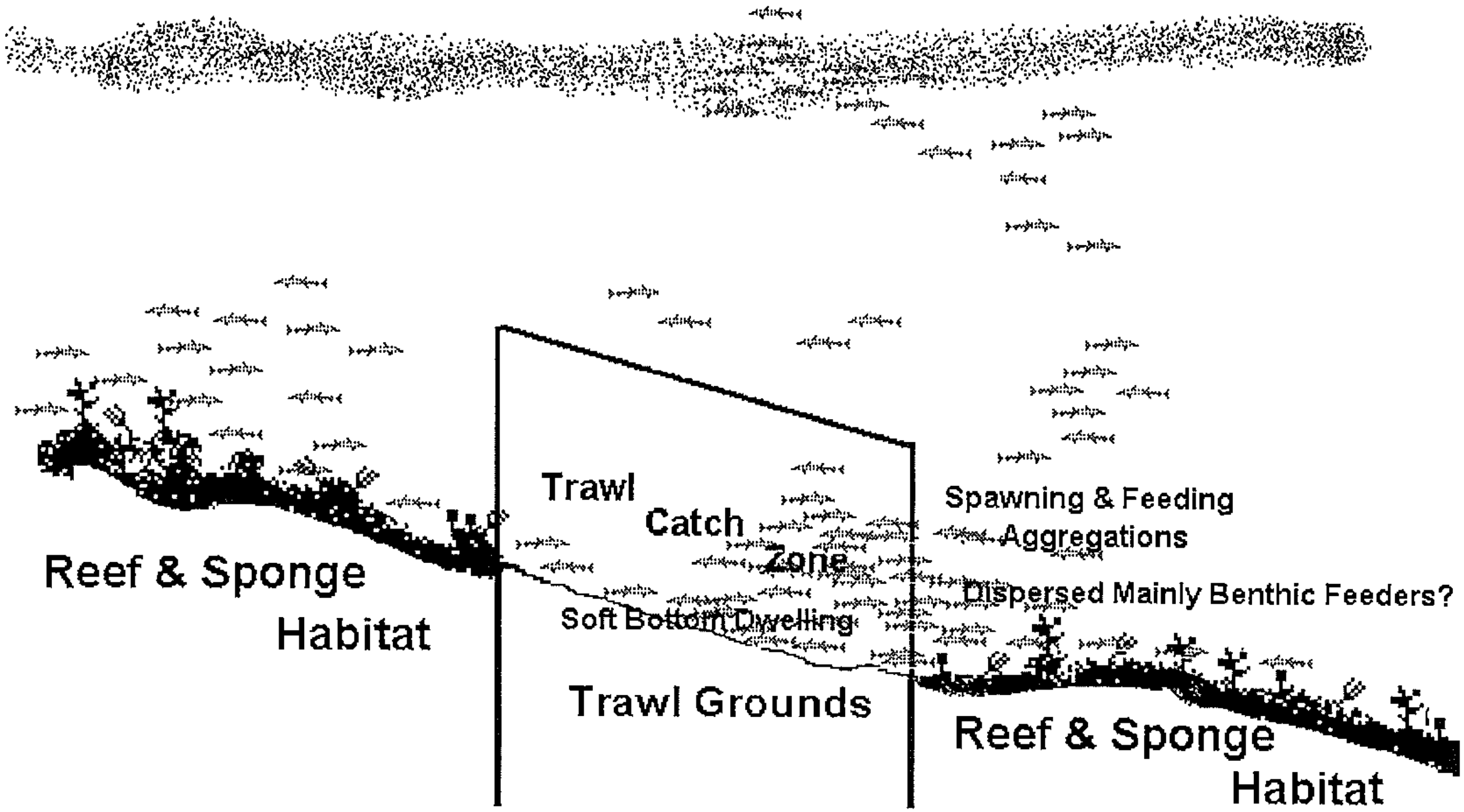



Figure 16

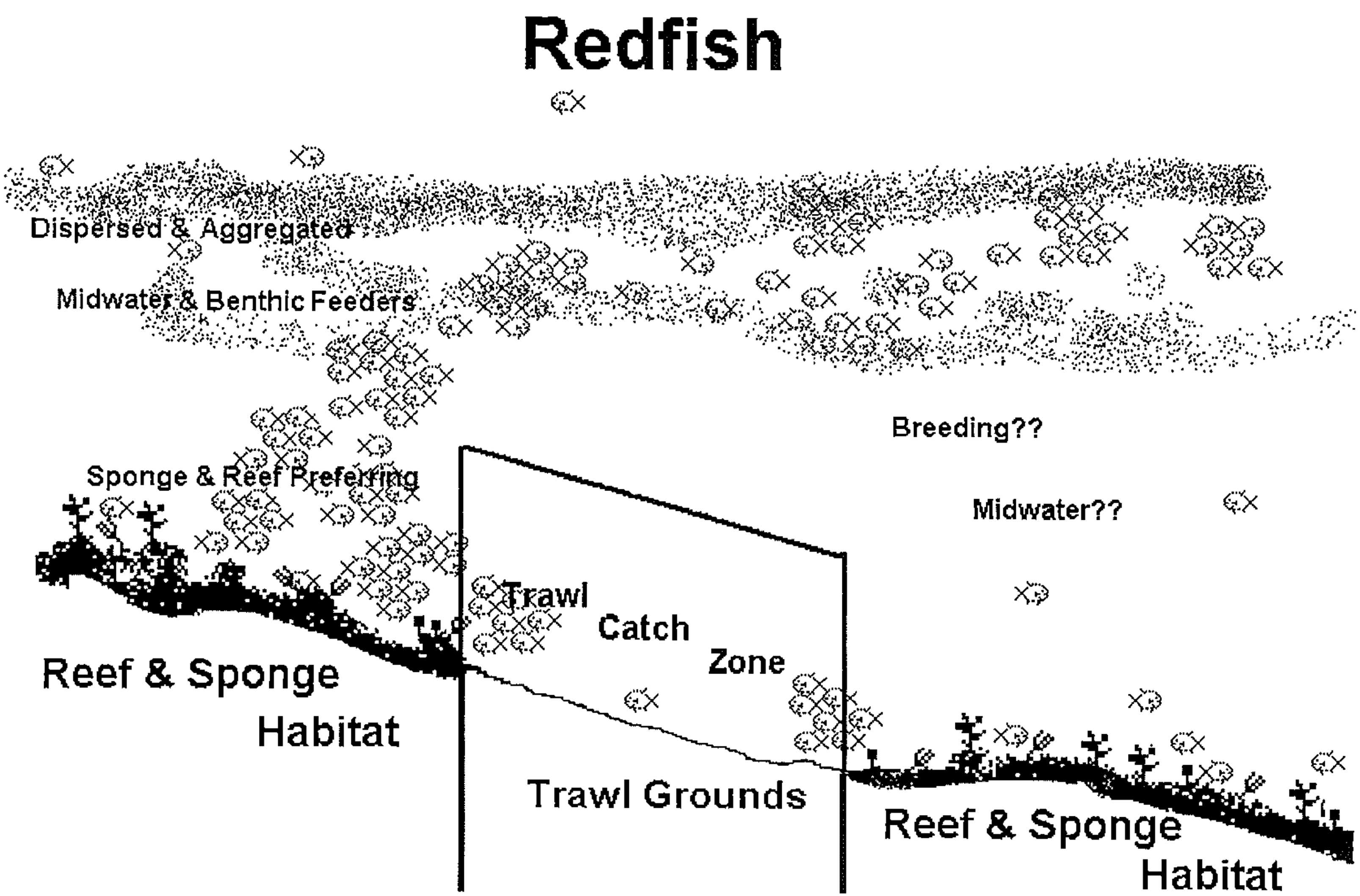

Redfish
Dispersed & Aggregated
Midwater & Benthic Feeders
Sponge & Reef Preferring
Breeding??
Midwater??
Trawl
Catch
Zone
Reef & Sponge Habitat
Trawl Grounds
Reef & Sponge Habitat

Figure 17

# Morwong

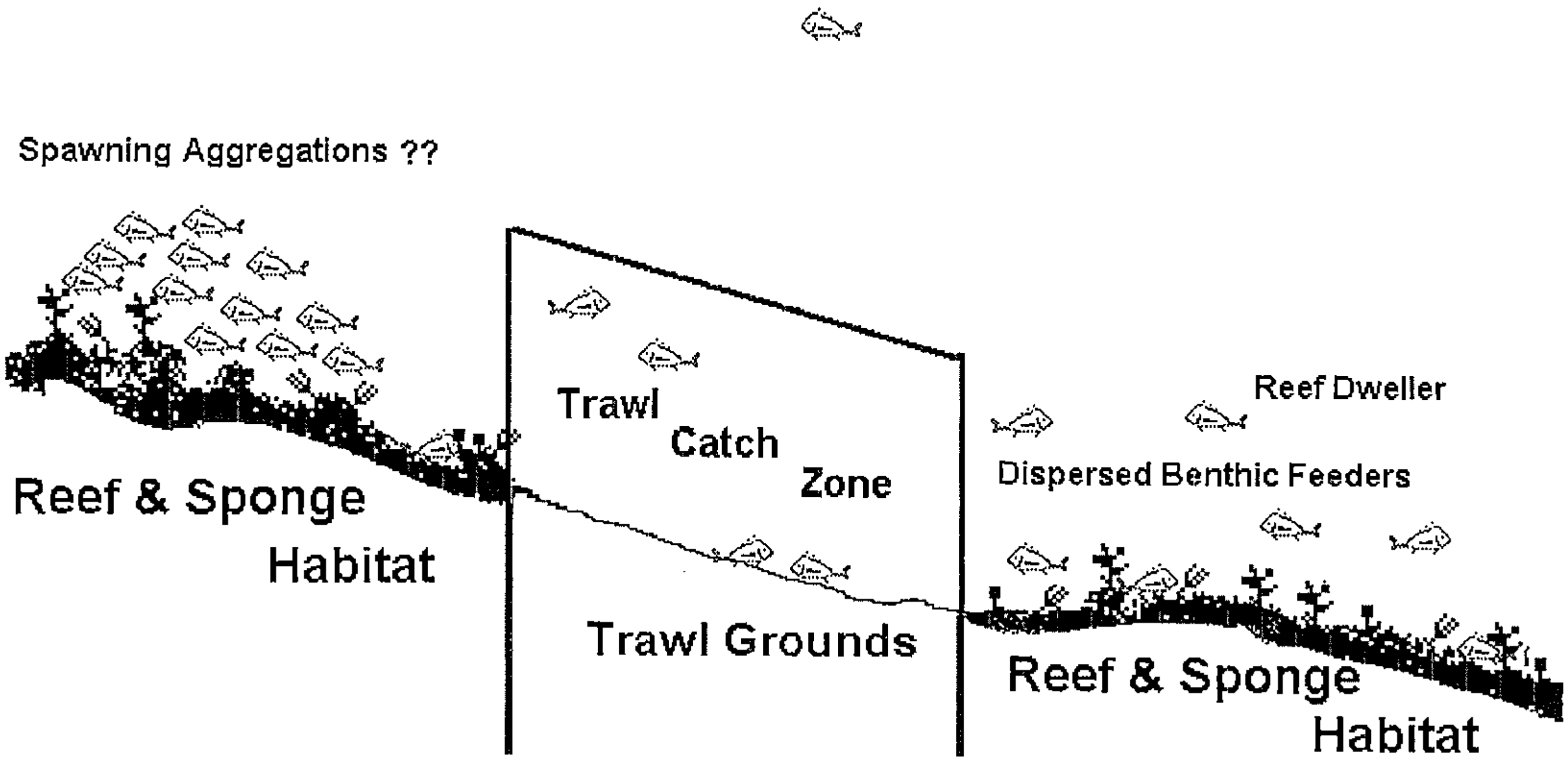



Figure 18

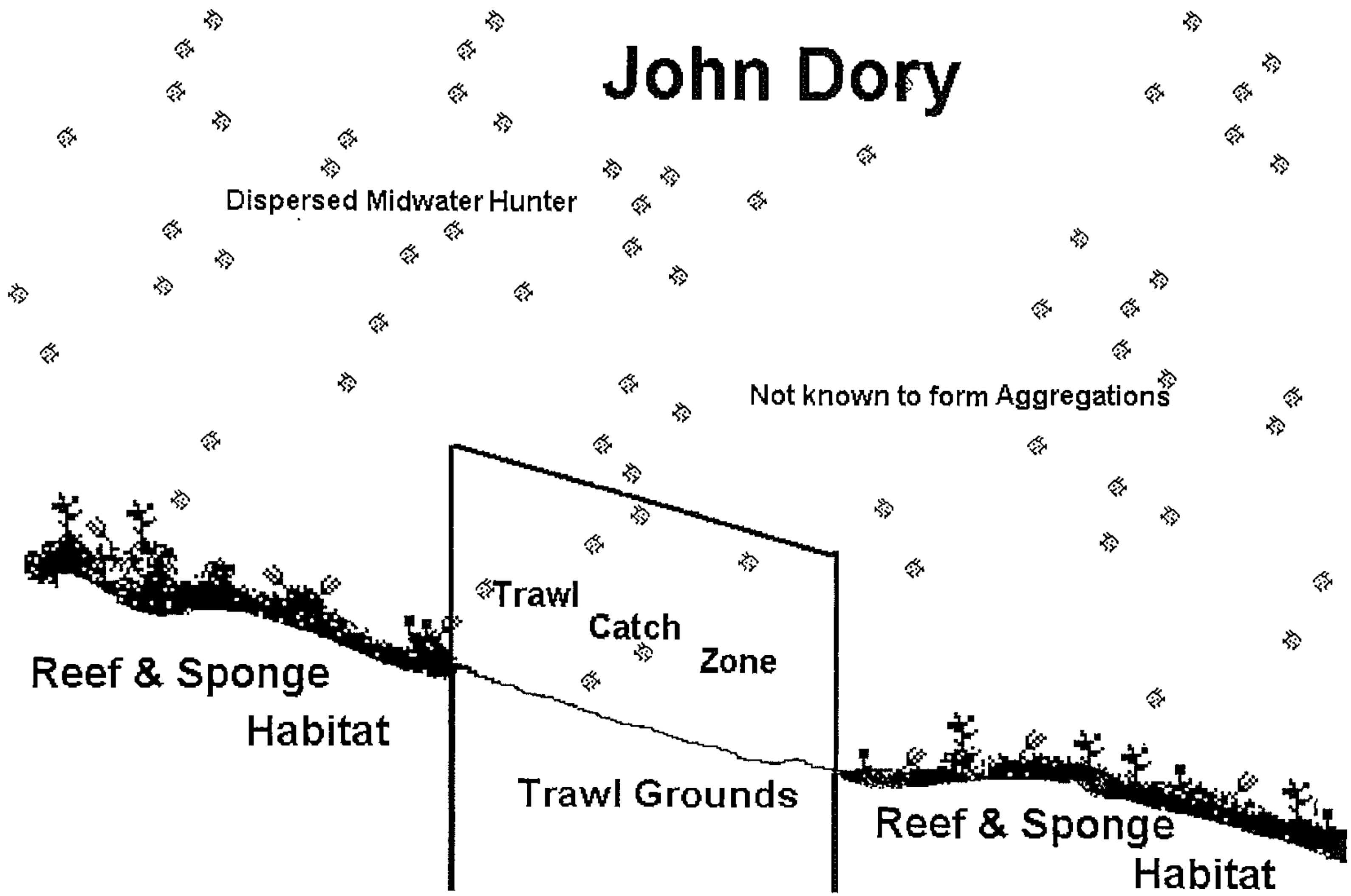
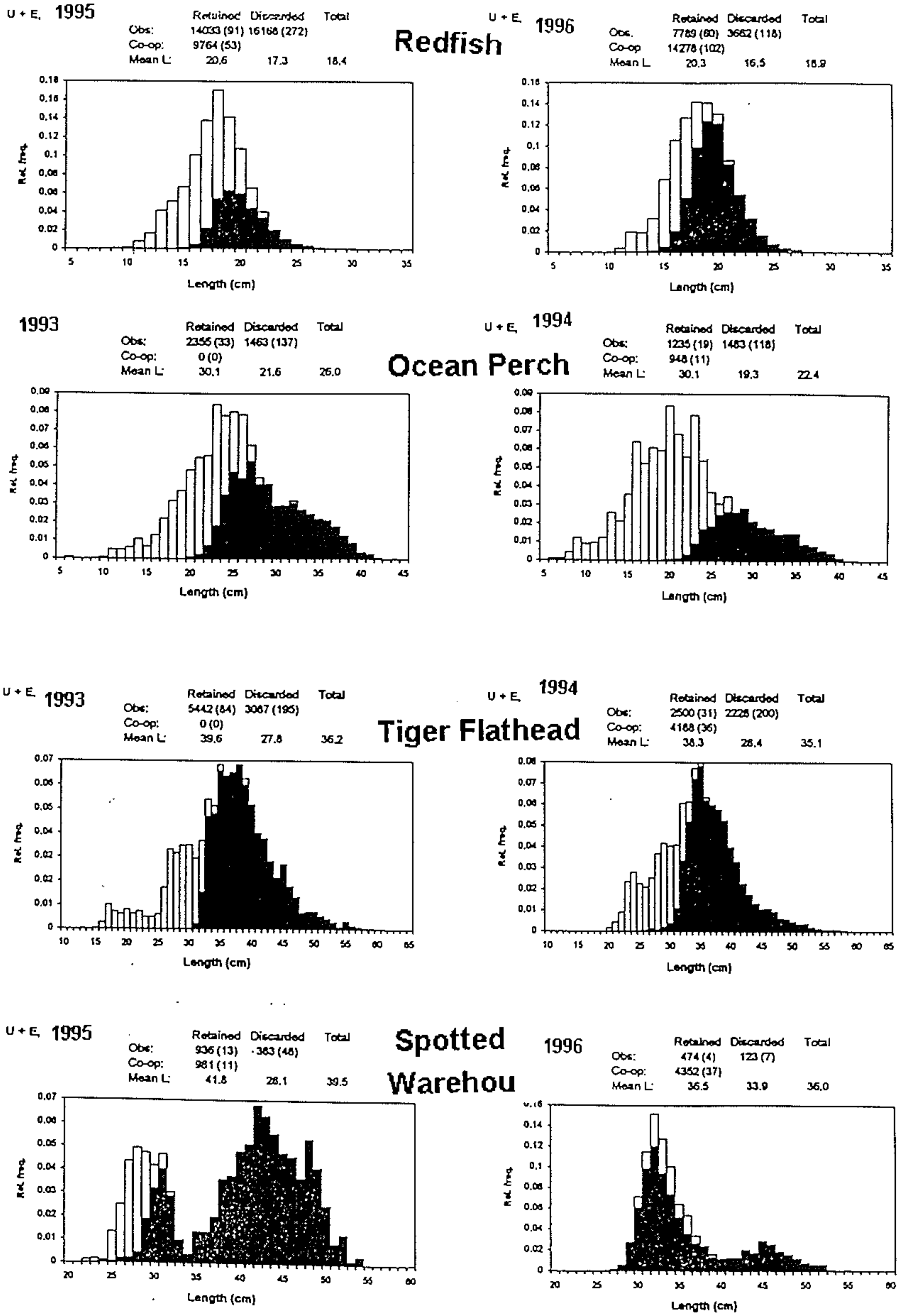

John Dory
Dispersed Midwater Hunter
Not known to form Aggregations
Trawl
Catch
Zone
Reef & Sponge
Habitat
Trawl Grounds
Reef & Sponge
Habitat

Figure 19




From Liggins 1997

**Figure 20**

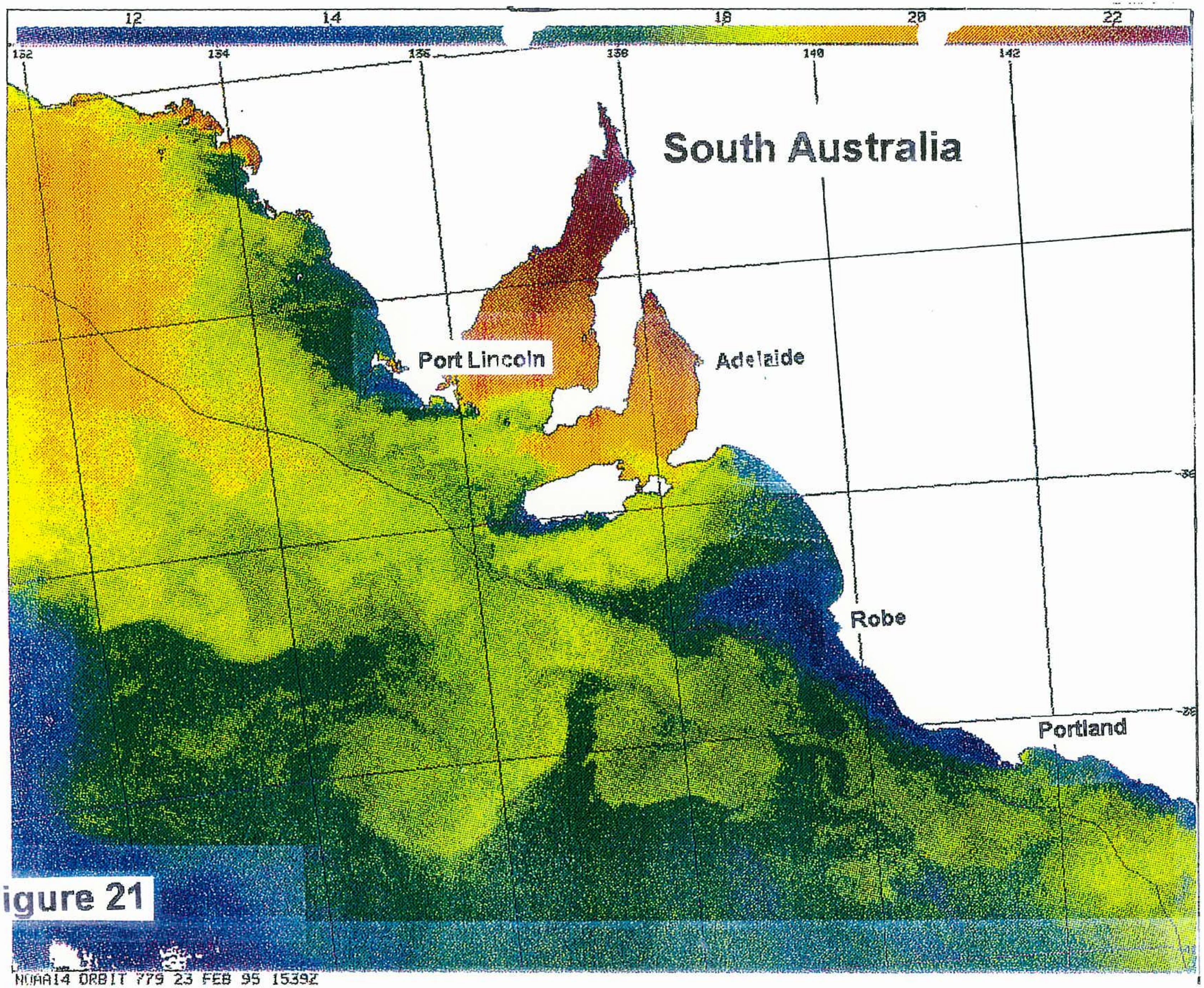

12
14
18
20
22
132
134
136
138
140
142
South Australia
Port Lincoln
Adelaide
Robe
Portland
NOAA14 ORBIT 779 23 FEB 95 1539Z

Figure 21

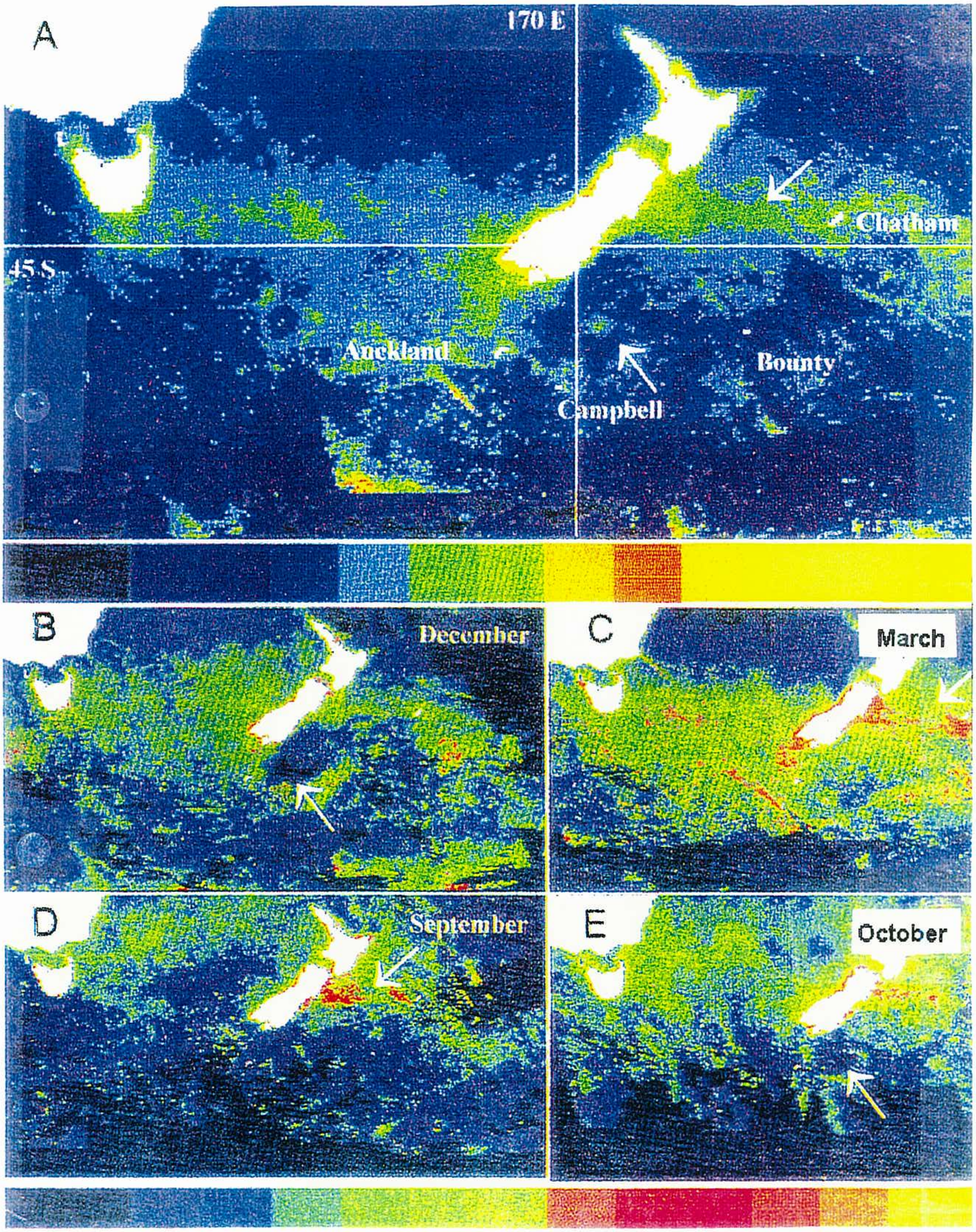

A
170 E
45 S
Chatham
Auckland
Campbell
Bounty
B
December
C
March
D
September
E
October

Figure 22

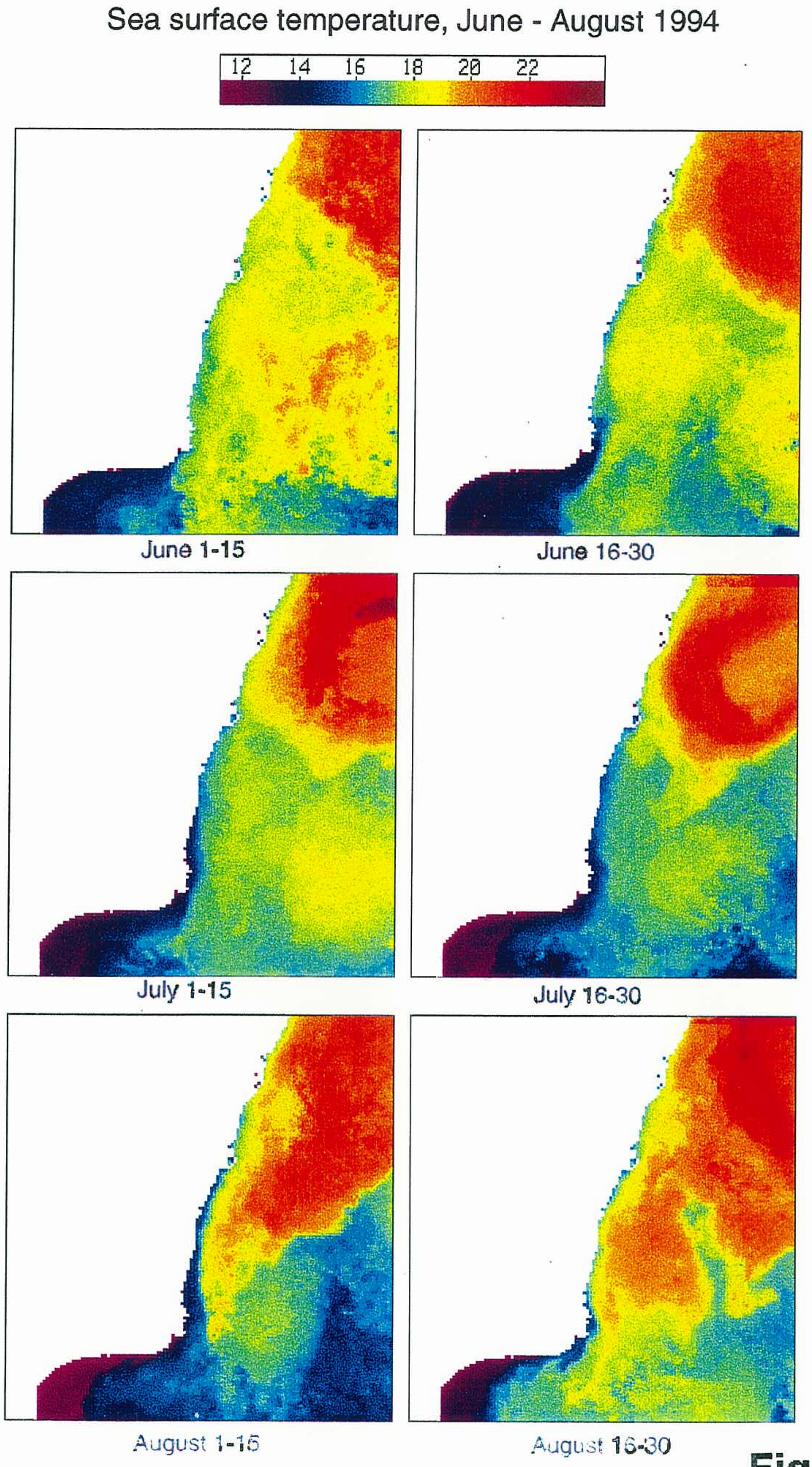

Sea surface temperature, June - August 1994
12
14
16
18
20
22
June 1-15
June 16-30
July 1-15
July 16-30
August 1-15
August 16-30

**Figure 23A**

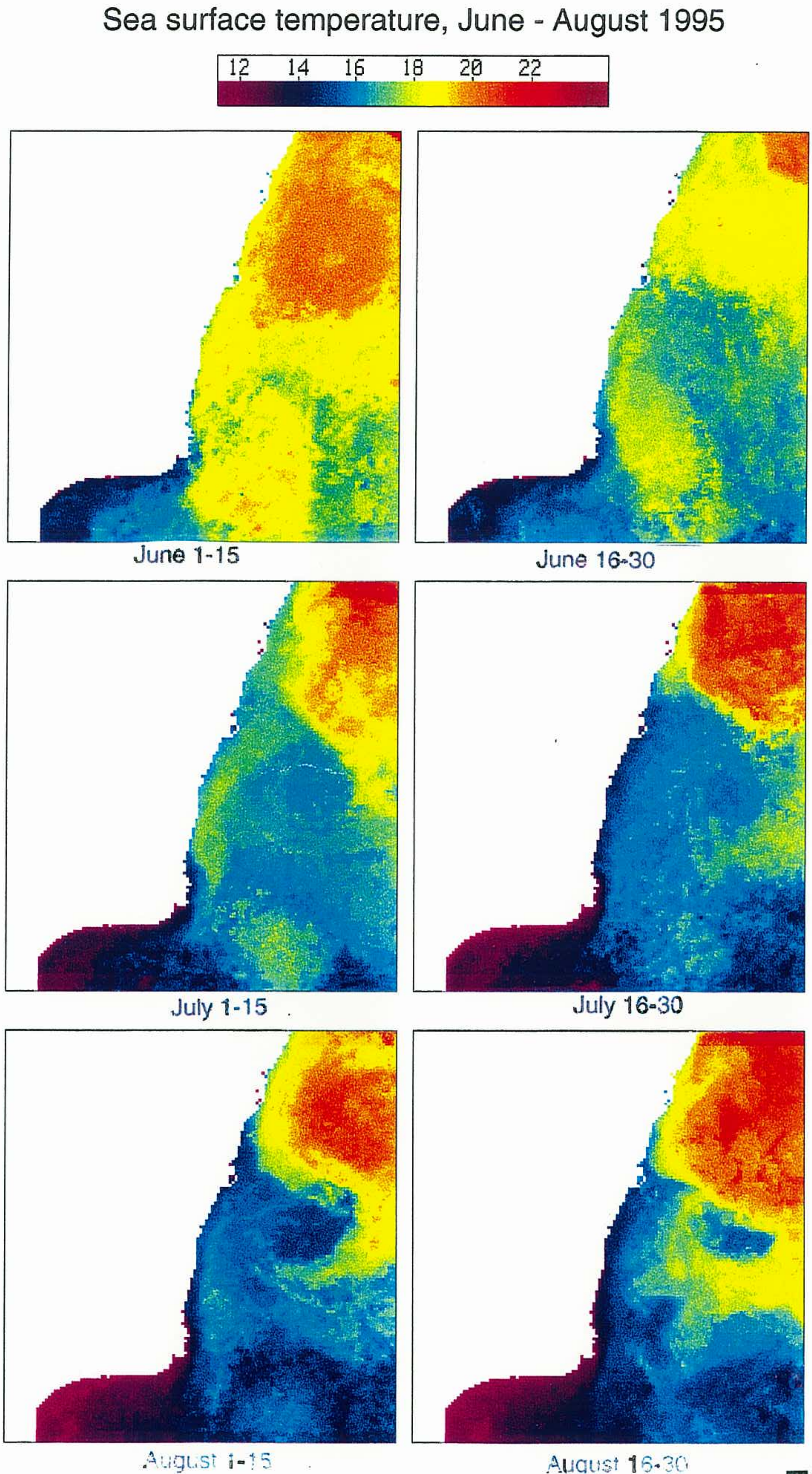

Sea surface temperature, June - August 1995
12
14
16
18
20
22
June 1-15
June 16-30
July 1-15
July 16-30
August 1-15
August 16-30

Figure 23B

Sea surface temperature, June - August 1996

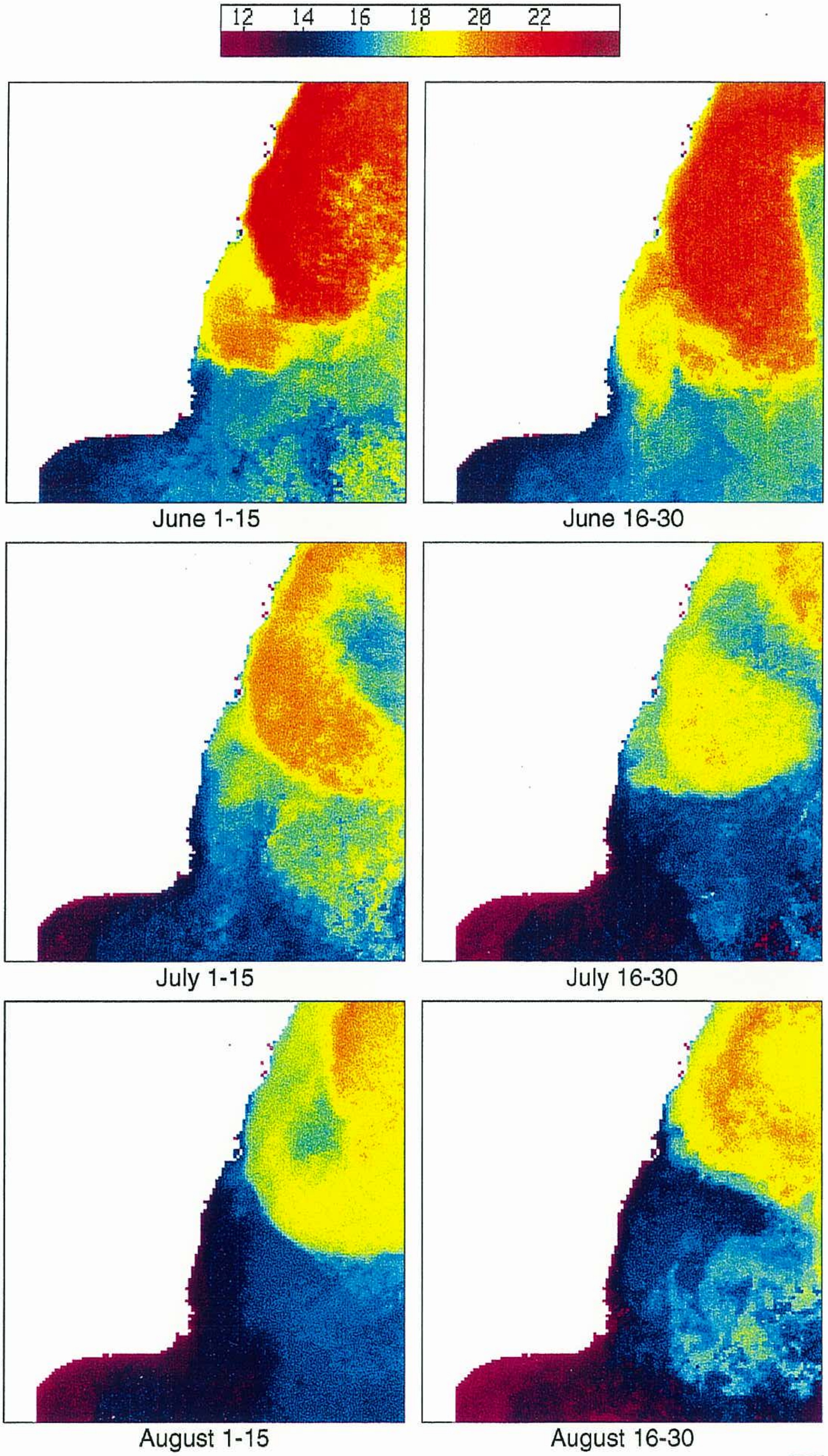



**Figure 23C**

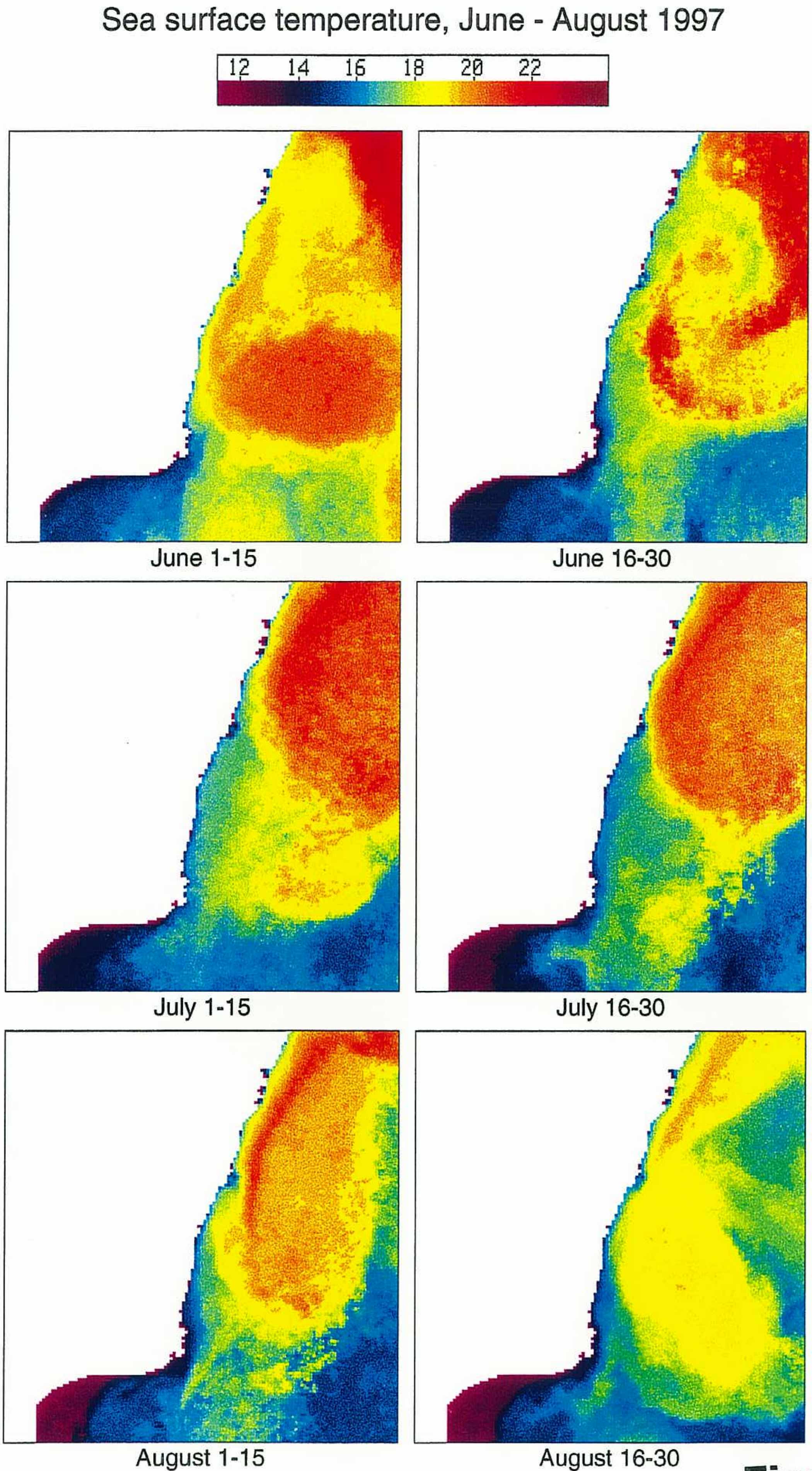

Sea surface temperature, June - August 1997
12 14 16 18 20 22
June 1-15
June 16-30
July 1-15
July 16-30
August 1-15
August 16-30

**Figure 23D**

Annual retained catch of orange roughy and other quota species recorded in trawl sector logbooks, 1986 to 1996. Source 1997 FAR - SEFAG.

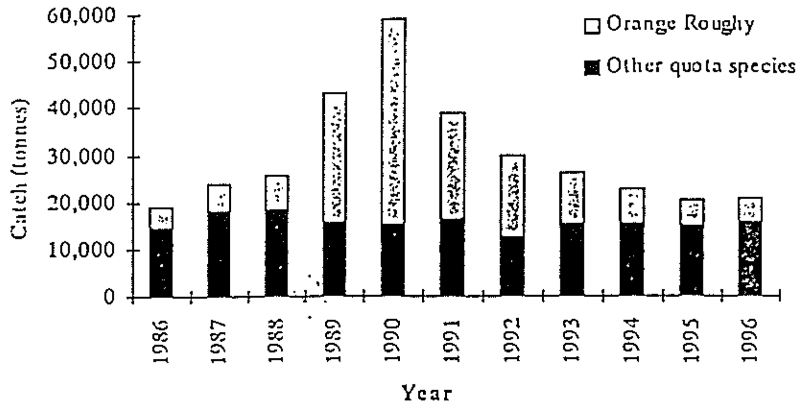



**Figure 24A**

Proportion of annual retained catch of quota species (excluding orange roughy) and non-quota species recorded in trawl sector logbooks. Source 1997 FAR - SEFAG.

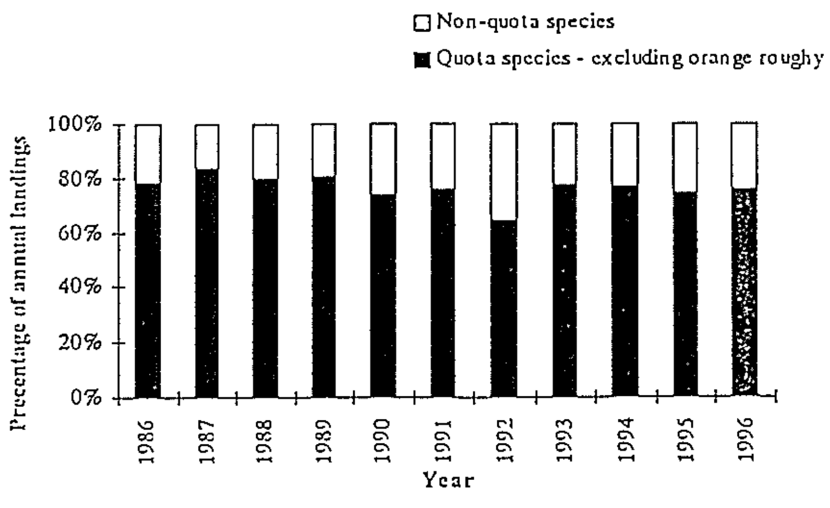
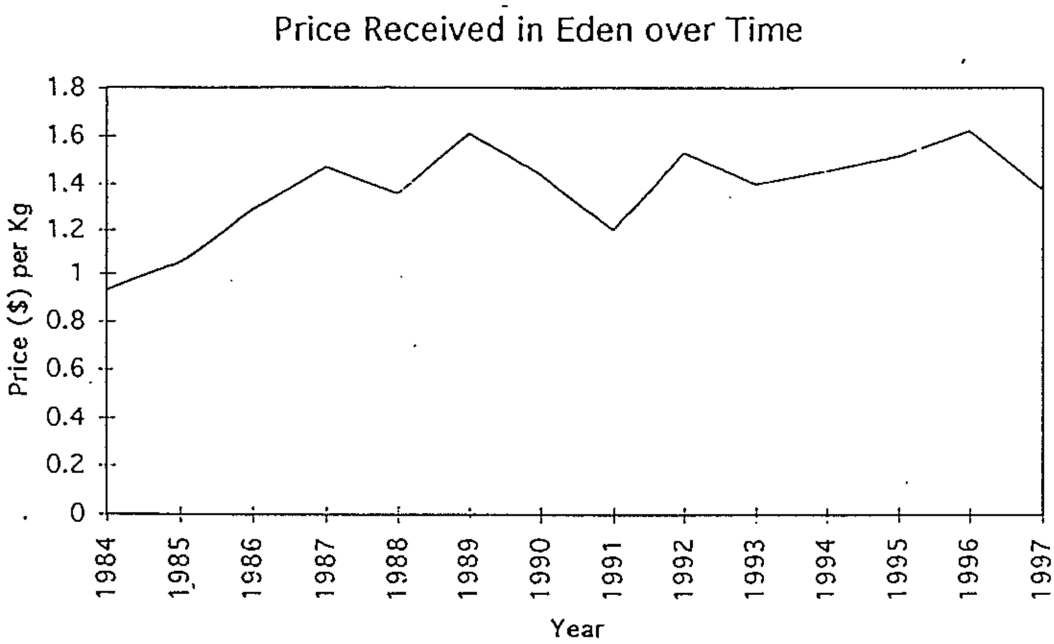
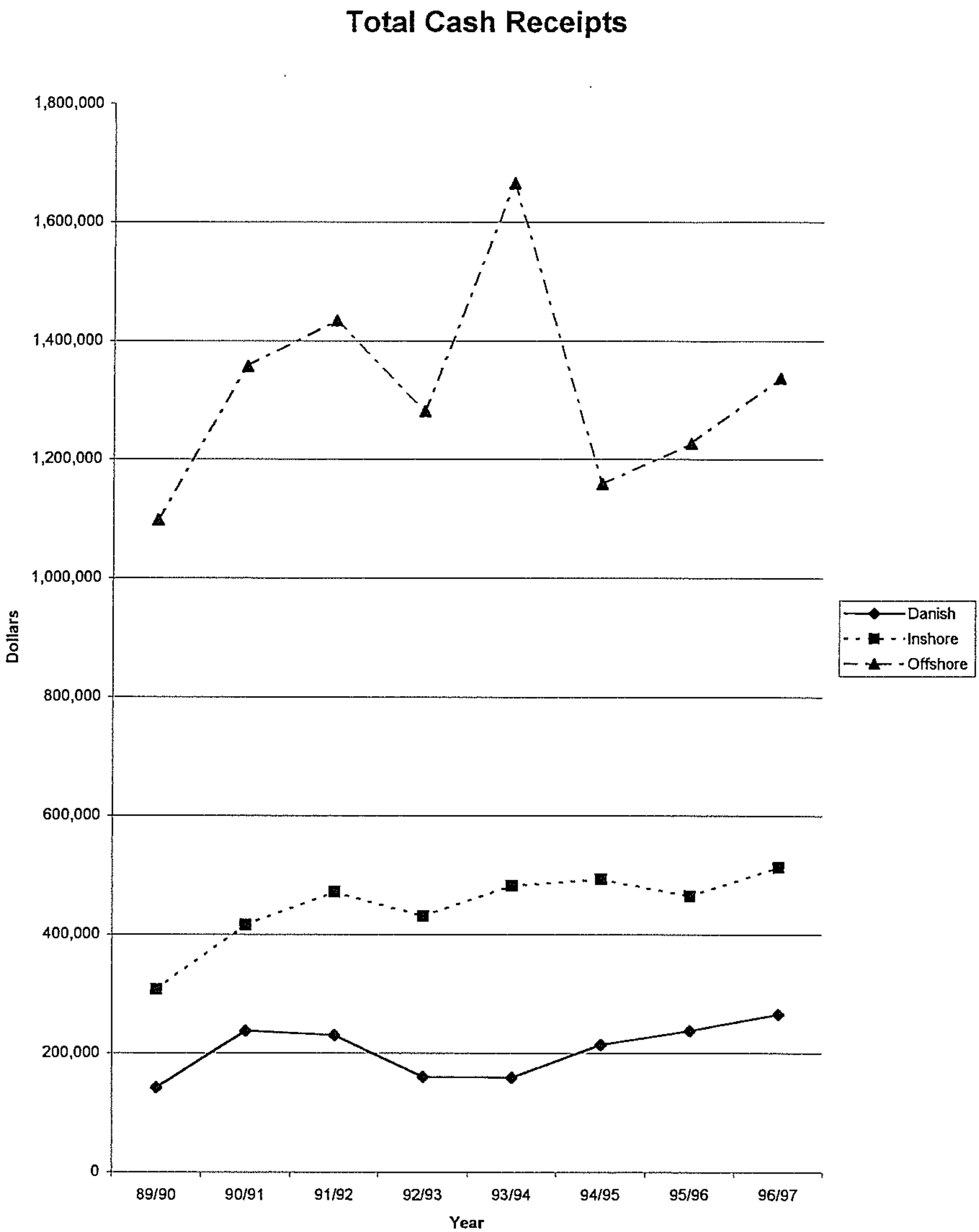



**Figure 24B**



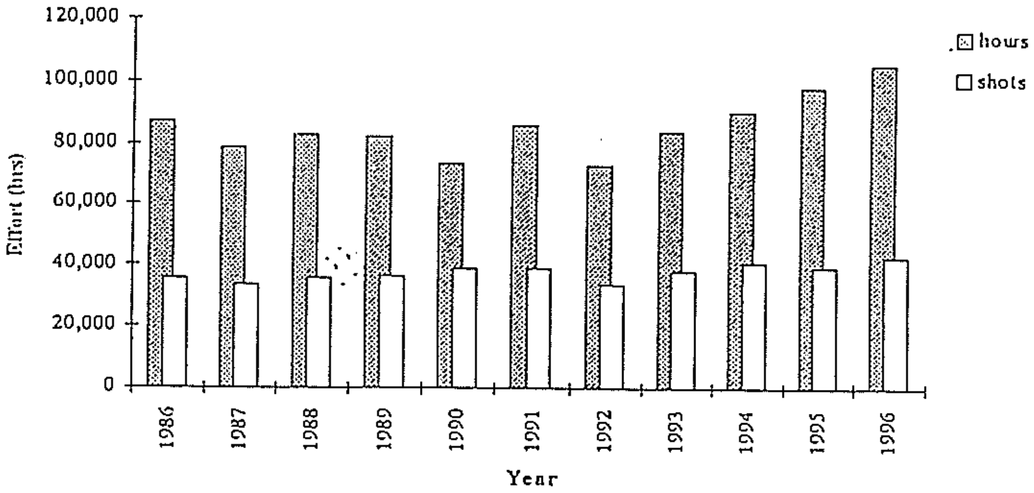
Price Received in Eden over Time
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Price ($) per Kg
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
Year


**Figure 25**



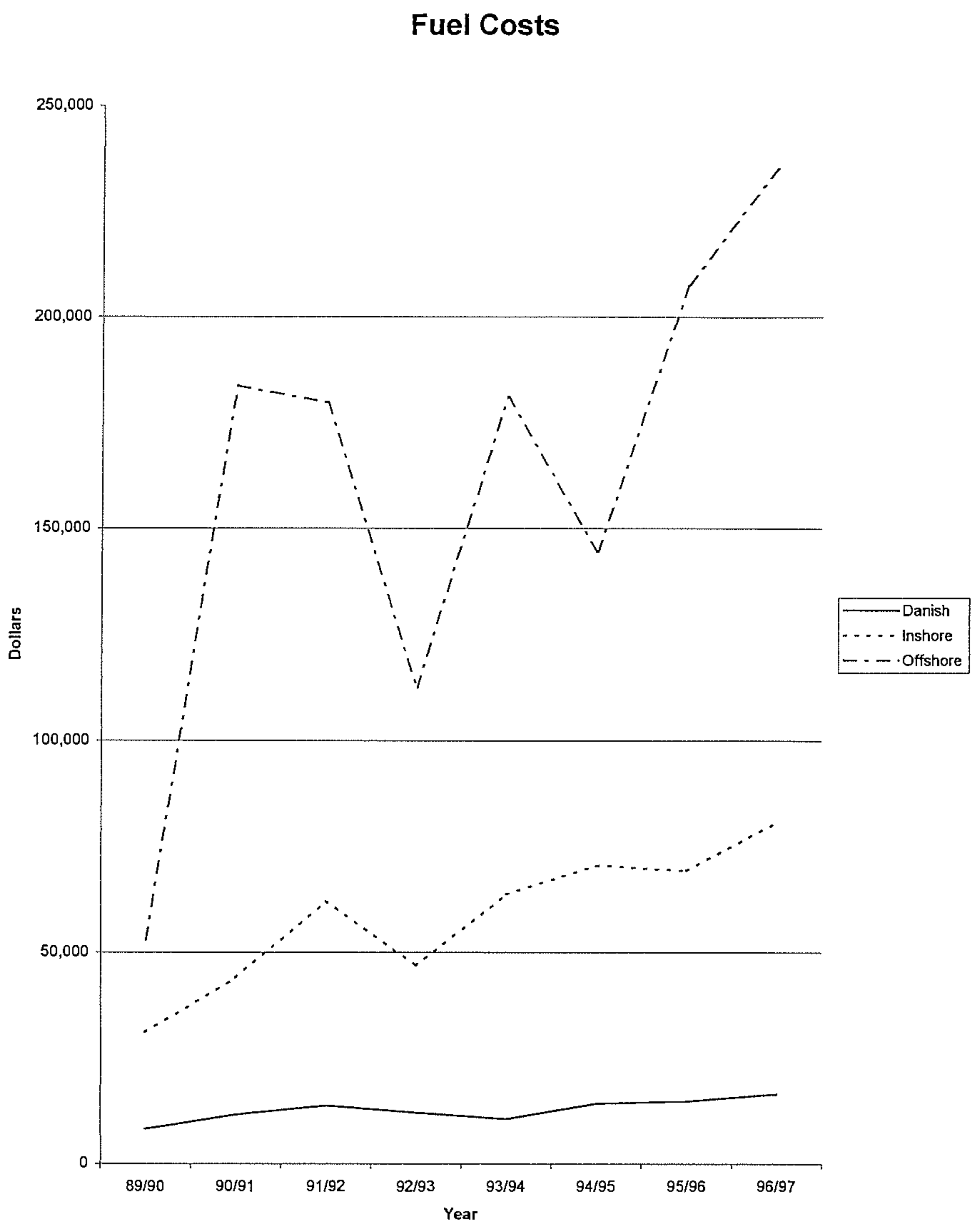
Total Cash Receipts
1,800,000
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Dollars
89/90
90/91
91/92
92/93
93/94
94/95
95/96
96/97
Year
Danish
Inshore
Offshore


Figure 26




Effort trends in the SEF. Source: SEFAG 1997 Fishery Assessment Report

**Figure 27**



Fuel Costs
250,000
200,000
150,000
100,000
50,000
0
Dollars
89/90
90/91
91/92
92/93
93/94
94/95
95/96
96/97
Year
Danish
Inshore
Offshore


Figure 28

## Costs without Fuel

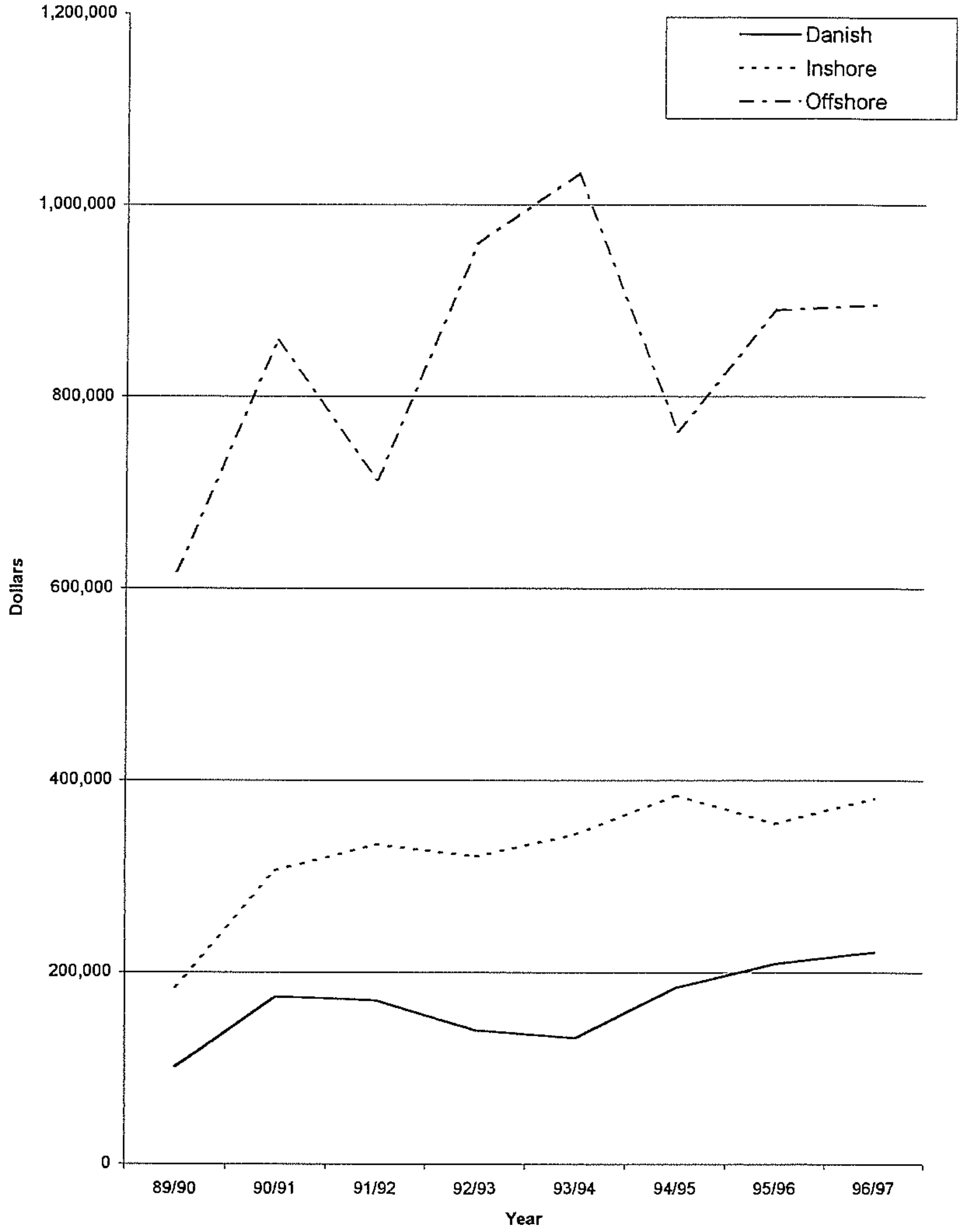



Figure 29

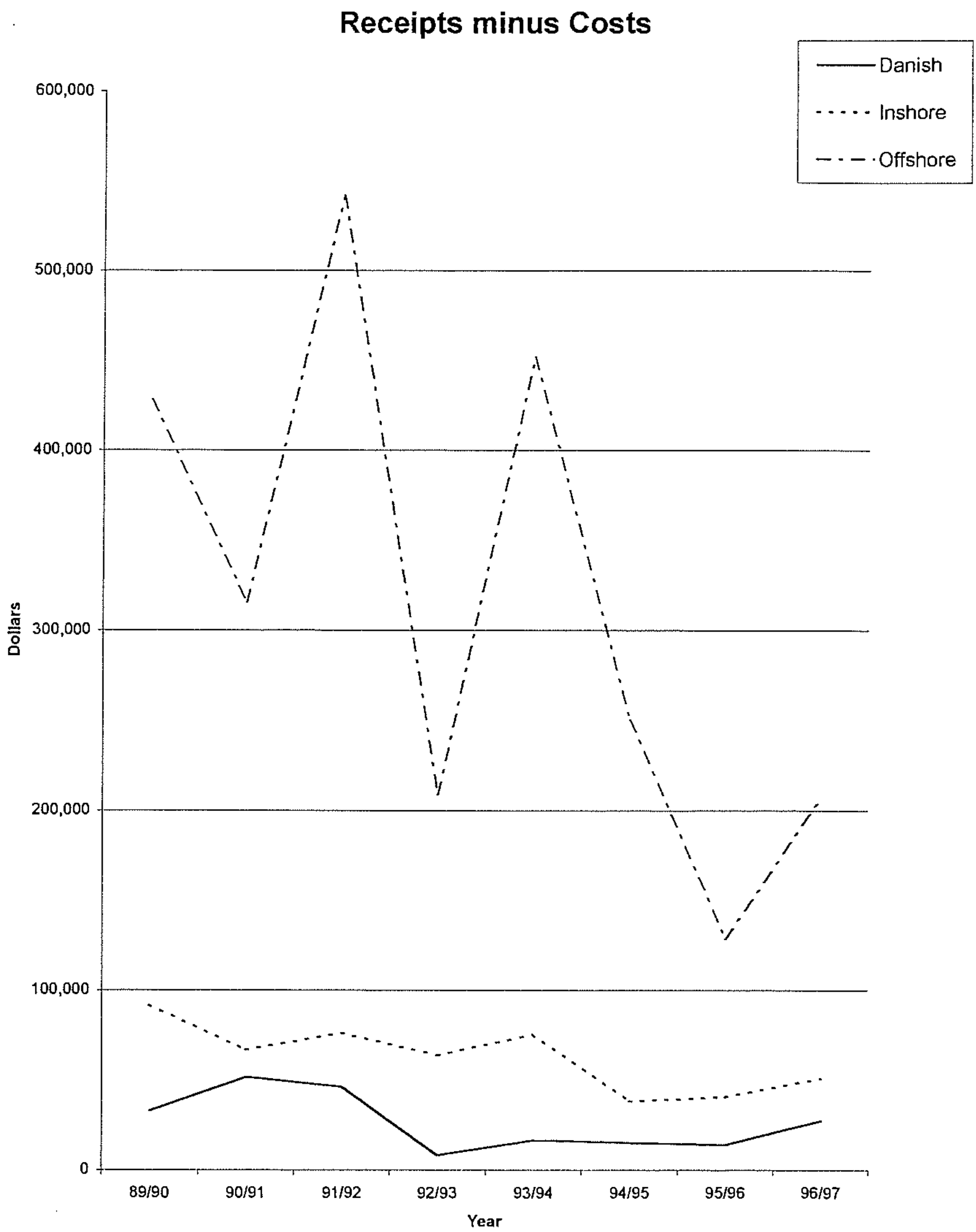
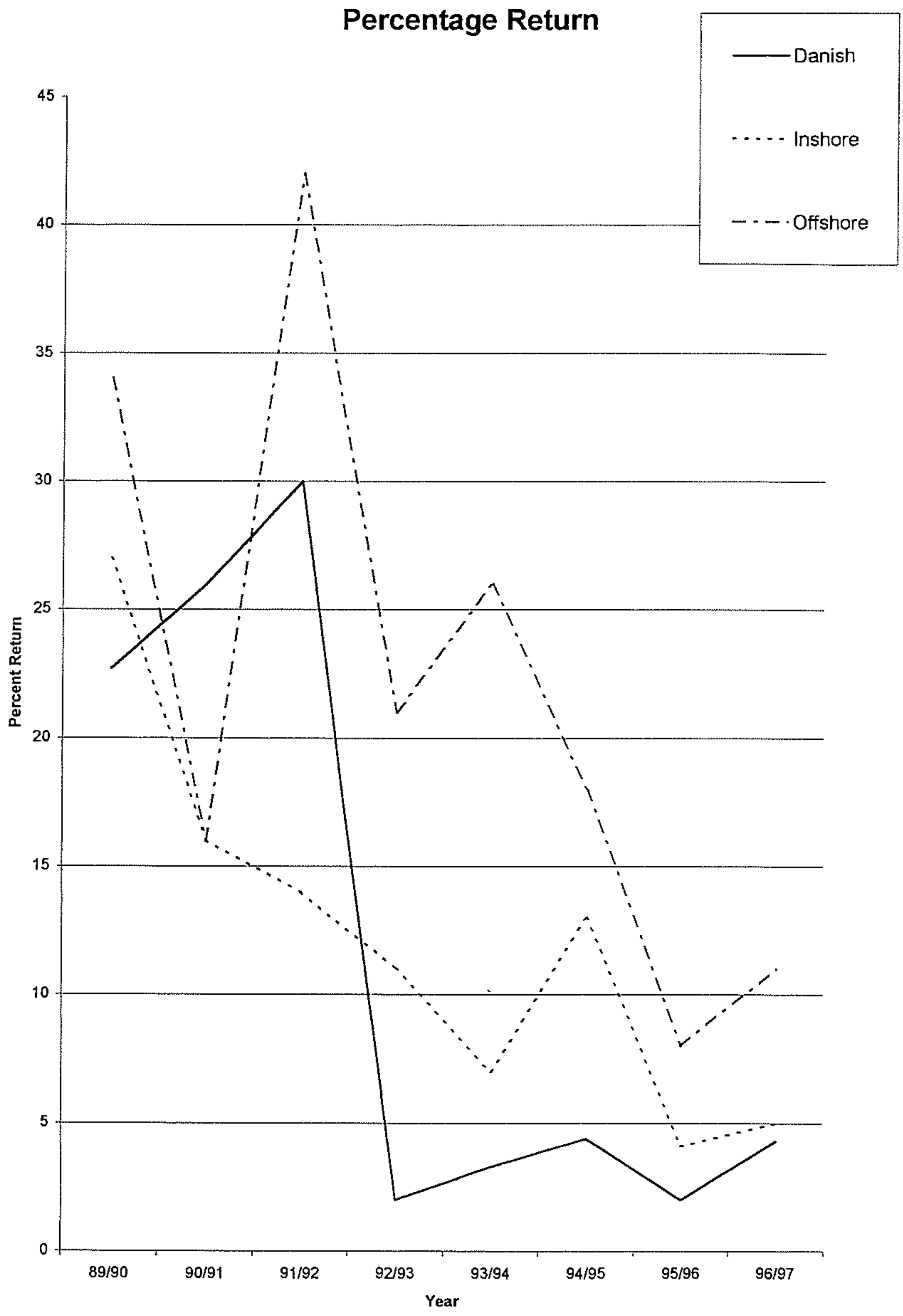

Receipts minus Costs
Danish
Inshore
Offshore
600,000
500,000
400,000
300,000
200,000
100,000
0
Dollars
89/90
90/91
91/92
92/93
93/94
94/95
95/96
96/97
Year

Figure 30



Percentage Return
Danish
Inshore
Offshore
45
40
35
30
25
20
15
10
5
0
Percent Return
89/90
90/91
91/92
92/93
93/94
94/95
95/96
96/97
Year


Figure 31