A Description of the Size Structure of the 1993 Eastern Australian Winter Gemfish Aggregations and a Synthesis of Industry's Perspective on the Existing Stock Assessment

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Foreword

This project was initiated following contact made between the NSW trawler industry and myself in early 1992. The basis of our initial discussions was that significant sections of the fishery had reservations about the accuracy of the eastern gemfish stock assessment made by the Fisheries Research Institute (FRI), Cronulla. Having been previously consulted by sections of that industry, I was on record as supporting the FRI assessment. As my discussions with the industry progressed I began to understand their point of view more deeply and appreciate that their arguments had some merit.

The contention at that time was whether fishermen, by changing their fishing patterns, can affect the size of the gemfish caught. A crucial aspect of this claim is the belief that the size of gemfish vary during the season and between different areas in a predictable way, and that this could introduce bias to the size based stock assessment. This project was framed to test whether or not the size of eastern gemfish varied in the predictable way fishermen claimed.

Early in the process of project development it was made clear to me by the Australian Fisheries Management Authority that they supported the project. It was made clear to me that the project's value was perceived in terms of aiding and developing communication between all members of the industry: fishermen, managers and resource scientists.

To this end, I have structured this report in four sections. Section 1 deals with the main objective of the program - to test whether or not the size of eastern gemfish varied in the predictable way fishermen claimed. Section 2 was prepared by Dr G.Wright, an anthropologist who has worked internationally with resource harvesting industries. He participated as an scientific observer but agreed to conduct formal interviews in order to survey industry's point of view about the fishery. Section 3 documents some general observations about the environmental context of the gemfish run in relation to its timing and biology. The final section contains concluding comments and discussion.

I am grateful to and wish to acknowledge the various sources of funding that made it possible for me to undertake this field based project. These sources include Mr Antonio Musumeci of Wollongong, whose offer to advance purchase the research catch of gemfish on an as-is-where-is basis under the stricture of a 50t maximum research catch, ensured the further funding of the project. As the 38t research catch shows, the risk he undertook with that offer was considerable.

I am particular grateful to the Commonwealth funding of the Fisheries Research and Development Corporation (FRDC) and the Fisheries Resources Research Fund (FRRF) who made this project possible by contributing the bulk of support. Finally I must extend my thanks to the gemfish fishermen of south-eastern Australia, without whose support this project would not have been impossible.

Dr. J.D. Prince

Executive Summary

When annual catch reductions of eastern Australian gemfish (*Rexea solandri*, Gemphilidae) culminated with the fishery's virtual closure in 1992, fishermen insistently argued that the Fisheries Research Institute's (FRI) stock assessment (the data cited in support of restrictions) was methodologically biased.

Mr Kevin Rowling's (FRI) long-term program of measuring commercial catches of gemfish in the Sydney Fish Market showed that the size of fish caught began increasing in the late 1980s. This lead to the FRI stock assessment deduction that there had been poor recruitment to the cohorts spawned during the late 1980s.

The gemfish industry contended that the apparent change in the size of gemfish being landed was, at least in part, related to changes in fishing practice that occurred as the fishery developed, as quotas were introduced and the Total Allowable Catch (TAC) was reduced. A major premise of industry's argument was that gemfish are, throughout the winter spawning season, predictably distributed by size along and across the continental shelf. It is therefore possible, fishermen said, for changes in fishing strategy to change the size of fish caught - consequently skewing the FRI data. A secondary line to this argument was that, since the introduction of the TAC, the smaller and medium sized components of catches had been consistently dumped.

This project was conducted in order to test industry claims in relation to the eastern gemfish stock. The project was substantially funded by the Commonwealth Government through the FRDC and the FRRF.

Boats from Wollongong, Ulladulla, Bermagui and Eden participated in the two month fishing program, which was limited to a fifty tonne catch quota. Single boat and multiple (two and three) boat surveys were undertaken. The depth and duration of trawl shots were supervised by scientific observers who accompanied the vessels. These observers also recorded caudal fork lengths from samples of up to two hundred fish in each catch, sexed the fish and made observations as to their ripe or spent condition. Commercial by-catches (up to 200 kg) were also sampled on an opportunistic basis.

Significant aggregations of gemfish were sampled by the survey on four occasions: twice off Ulladulla at the beginning of July; and twice off Wollongong, once at the end of July and once in mid-August. Stratified multi-boat surveys were made of both events off Wollongong and of one Ulladulla event. In all, the survey caught 38 627 kg of gemfish, from which 10 061 individual fish in 103 samples were measured.

The survey confirmed the FRI stock assessment claim that the 60 - 80 cm class (which dominated catches between 1975 and 1987) is now the least abundant, supporting the deduction that the stock has suffered a period of low recruitment. This feature of the stock's

size structure made it difficult to quantitatively test some of industry's claims about size structure within aggregations. However, it showed that smaller male gemfish entered the spawning aggregations later than the females, supporting industry's contention that larger fish "run" first.

Another salient feature of the survey was the consistent variation between the size of fish taken from aggregations and those caught elsewhere. Aggregations were dominated by large (>80 cm), mature fish; whereas non-aggregation catches were dominated by small (<60 cm), generally immature fish. Northern port catches contain a higher percentage of large fish than those landed in southern ports.

From the evidence of this survey it seems unlikely that specific size classes of gemfish could be targeted with specific trawl shots. However, changes in fishing practices and the introduction of quotas may have influenced the data used by the FRI stock assessment to some lesser extent.

An interesting coincidence was observed between the timing and location of gemfish aggregations and the advection of cold water up the NSW continental slope.

Section 1: The Size Structure of Eastern Australian Gemfish Aggregations during Winter 1993

1.1 Introduction

The NSW trawler fleet is principally comprised of small, family-owned otter trawlers that conduct day trips from a string of ports between Newcastle, north of Sydney, and Eden, to the south on the Victorian border (Figure 1). The trawlers generally leave their home ports between 0300 - 0430 each fishing day and cruise towards the shelf break adjacent to their port (25 - 45km distance). The timing of the cruise is usually such that the first of two daily shots occurs at or just before sunrise. The second normally begins around mid-morning after retrieving, sorting and stowing the catch from the first shot.

Prior to the 1970s trawling mainly took place in less than 200fthm (400m - the standard unit of depth used in this report is fathoms because that is the unit still used by the industry) towards the edge but on top of the continental shelf. With the advent of better echo-location and positioning systems, and more powerful hydraulics, during the late 1960s and early 1970s (see Wright - Section 2, this report), these essentially shelf trawlers began exploring the rugged bottom down the edge of the shelf break.

During the 1970s the trawl fishermen around Sydney and Wollongong discovered large winter (June to August) aggregations of gemfish (*Rexea solandri*, Gemphilidae) along the NSW continental shelf break. Early gemfishing concentrated on the few known grounds around Sydney and Wollongong, but the industry soon discovered that gemfish aggregations could also be targeted below the shelf edge off most ports. Recorded landings of eastern gemfish increased rapidly during the 1970s, from below 200 t/annum in the early 1970s to above 4000 t/annum for the period 1978-81.

Fishermen normally arrive on their trawl grounds a little before they make their first shot. They use this time to echo-sound the grounds, observing the fish marks and the "deep scattering layer", a biological acoustically active layer which migrates diurnally up and down in the water column over the shelf break. This layer is apparently comprised of a diverse range of organisms and the fishermen call it the "feed layer". Recent sampling by CSIRO has determined that schools of plankton-eating jack mackerel (*Trachurus declivus*) comprise a significant proportion of the biomass in these layers (N. Bax, pers. comm). Depths or areas of the ground on or over which the most fish marks or the heaviest feed layer is observed will usually be selected to begin trawling. Fishermen associate good catches of gemfish and other species with areas and times when fish marks and the deep scattering layer are seen on echo-sounders near or touching the bottom over which they are trawling and sounding (Wright - Section 2, this report). Fishermen are quick to identify fish marks they think or hope may be gemfish, though they admit the species cannot be identified with any certainity using commercial grade echo-sounders. They readily agree that good gemfish catches can be made without any fish marks being visible on sounders.

Figure 1

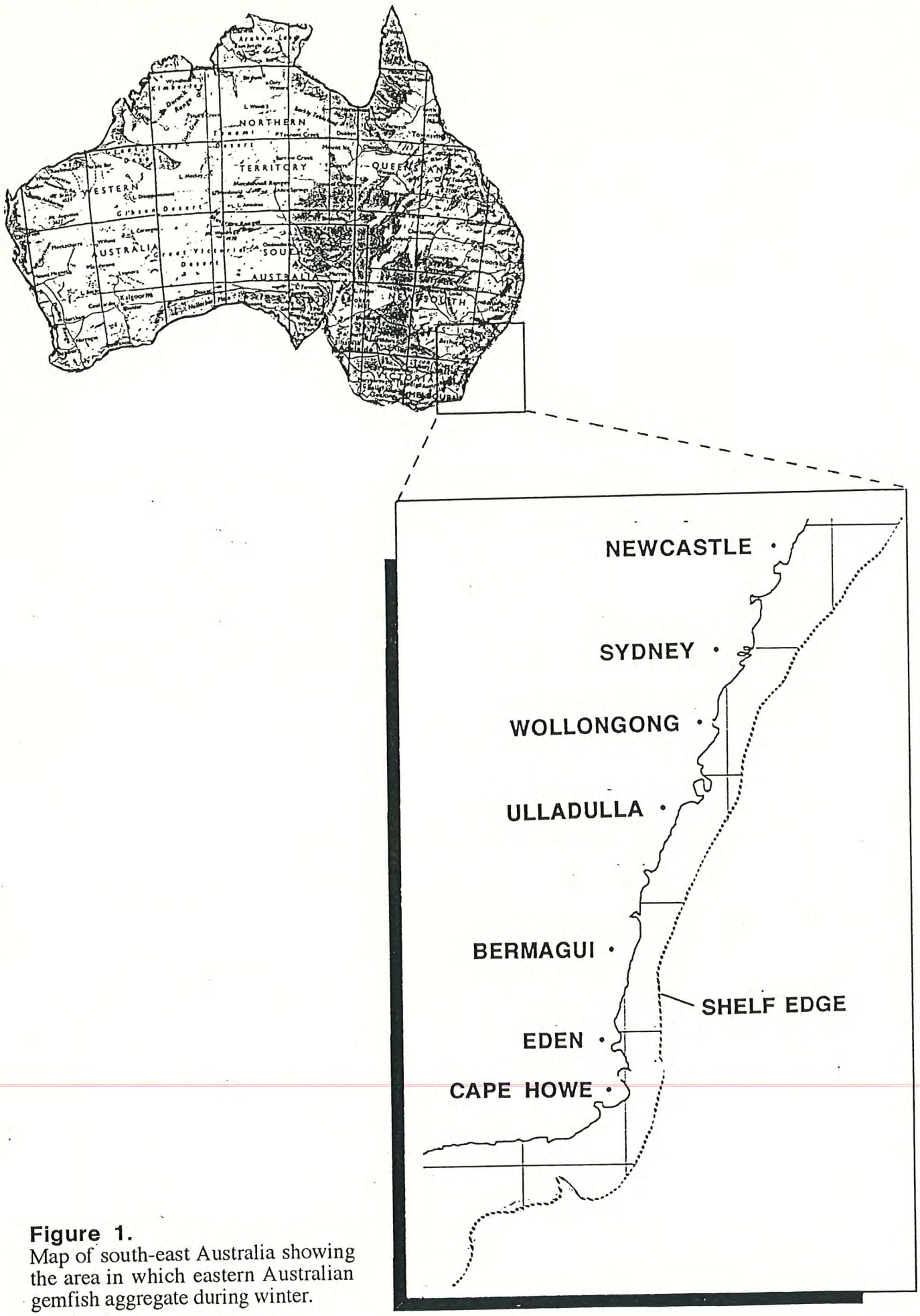


Figure 1.
Map of south-east Australia showing the area in which eastern Australian gemfish aggregate during winter.

Most fishermen believe that the gemfish schools approach the shelf edge from the south east and then move northwards along it (Wright - Section 2, this report). They associate the best catches with currents of cold water coming from the south. Because of their belief that the schools of gemfish move north along the break, fishermen generally trawl towards the south when fishing for gemfish. The trawl grounds are steep, narrow strips (2 - 4 km wide) of soft bottom surrounded by larger areas of untrawlable rough bottom. At the height of the gemfish fishery it was common practice for fishers to leave their home ports and move northward from port to port, following the progression of the gemfish season. The large number of boats that gathered to fish aggregations of gemfish were often forced to queue on the limited grounds prior to dawn and take their turn to "shoot".

According to experienced gemfish fishermen the "main run" of gemfish, where the best catch rates are expected, occurs in depths of around 200 fthm, shallower in the south and deeper in the north. The best catch rates are expected at that depth and industry claims that a broad spread of adult sizes can be found in the catch from that depth. Catch rates from waters shallower than the "main run" are lower than rates from inside the main run and the fish in the catch are purported to be smaller; catch rates from deeper than the "main run" are also lower than from inside the run and the fish are said to be larger. Fishermen also say that sizes vary from north to south, with fish in the north generally being larger.

Fishermen also claim that the gemfish move through the trawl grounds from south to north in three different "runs" (Wright - Section 2, this report). The first run is principally large fish, while the second, which occurs several weeks later, is comprised of medium size and smaller fish. Many fishermen say that this second run used to be the most important of the fishery but is now diminished, the first run is now the most significant. A third run of smaller gemfish occurs in some years and is called the "back run" because fishermen believe these are fish moving back from the north, having followed the main run north until it ended and presumably dissipated.

Interestingly, the arrival into spawning aggregations of larger mature fish prior to smaller mature fish has been observed for Australian salmon (Lenanton *et al.* 1991) and blue grenadier (J.A. Koslow pers. comm 1993).

1.2 Stock Assessment

The stock assessment of the Fisheries Research Institute, Cronulla, NSW (FRI) is based on a cohort analysis that estimates the strength of successive year classes of fish from the length of gemfish measured in the market.

The size of gemfish in the commercial catch has changed since Mr Kevin Rowling of FRI first began measuring the size of gemfish in the Sydney Fish Market in 1975. The length frequency distribution for the gemfish catch was originally uni-modal with a mean caudal fork length (LCF) of around 77 - 79 cm but began declining in the late 1970s. By 1980 mean

length had declined to around 75 cm, and it continued declining during the 1980s, by 1987 mean length had fallen to 71 - 73 cm (Rowling 1990).

This trend was initially taken to indicate that older gemfish were being fished down to low levels, while the number of young fish recruiting to the fishery each year was increasing. The stock was estimated to be around 50% of virgin biomass and the scientific advice was that further expansion of the fishery should not be allowed. The first TAC, introduced in 1988, was set at 3 000t to prevent further escalation of catches and to contain them around recent historic levels. The TAC was officially exceeded by about 500t. In 1989 the TAC was reduced and a system of Individually Transferable Quota (ITQ) was introduced.

Coincidently with the introduction of ITQ, the size of gemfish measured in the market began increasing. By 1992 the average size of gemfish being landed had increased to around 78 - 79 cm (Rowling 1993). Analysis of this trend suggested that recruitment to the gemfish stock declined sharply in 1988, despite the estimated spawning biomass of eastern gemfish remaining relatively high, around 40 - 50% of its virgin level. Low levels of recruitment have continued since 1988, apparently causing the size of the gemfish to continue increasing.

Since 1988 there has been a managed reduction in eastern gemfish catches, achieved through successive reductions of the TAC, down to approximately 200t by 1992. 1993 brought a zero TAC, with an experimental quota of 50 t being allocated for the 1993 Gemfish Research Project. Despite this catch reduction the FRI assessment predicts stock size will continue declining because of continuing low recruitment.

Industry has consistently expressed concern about the FRI assessment of stock levels based on analysis of fish size in the market. They believe that gemfish are distributed differentially by size, along and across the shelf, throughout the season, and that this leaves a size-based analysis open to bias (Wright - Section 2, this report). Industry's contention is that at least some of the change in the size of gemfish being caught is related to the changes in fishing practise which have occurred as the fishery has developed, quotas introduced, and the TAC reduced to zero.

The results of a FIRDTF funded project (88/126), which measured gemfish caught during 50 targeted commercial gemfish shots during and after the 1989 season, tend to support many of industry's observations about the gemfish aggregation. The study found that size, sex ratio and catch rates varied with depth and latitude. The study was hampered by the requirement to work within the constraint of strictly commercial operations and little significance was attached to the trends observed. A previous FRI study also compared the size of gemfish being landed aboard commercial trawlers and concluded that they were the same as those measured in the market at the same time.

The FRI assessment is based on a cohort analysis that estimates the strength of successive year classes of fish on the basis of the size of the fish in the market. When analysing trends

in recent year classes, without supporting estimates of population trends, the accuracy of the methodology is very dependent upon which assumptions have been made about the catchability of the fish in recent years (Sinclair *et al.* 1985). Sudden changes in fish catchability may bias the analysis (N. Hall, Pers. Comm. 1994).

If the size of gemfish varies predictably over the fishing grounds, changing fishing patterns could conceivably change the size of the gemfish being caught. If, for example, fishermen began to fish deeper, where they say larger gemfish are more prevalent, the vulnerability of large gemfish to fishing pressure might increase while the catchability of smaller gemfish might decline. This type of phenomenon has been found to bias estimates of herring stocks along the north-eastern seaboard of North America in the short to medium term (Sinclair *et al.* 1985). Potentially, this phenomenon could bias the existing assessment of the eastern gemfish stock.

This project was designed to test industry's assertions about the influence fishing practice may have on the size of fish caught and to gauge the potential bias this may introduce into the existing gemfish stock assessment.

The primary objective of this project was to quantitatively assess the claim, of the NSW gemfish industry, that the observed trends in fish size in the commercial gemfish catch can be partly explained by changing fishing patterns and by the distribution of size classes of gemfish within the winter aggregations. The project's secondary objective was to synthesize industry information about gemfish and to describe the 1993 winter gemfish run.

1.3 Methods

This project was developed and conducted in collaboration with the NSW gemfish industry.

Fishermen in the ports of Wollongong, Ulladulla, Bermagui and Eden were enlisted to support and participate in a coordinated program of surveying the gemfish depths off each port. Two types of surveys were conducted from each port; single boat surveys and multiple boat surveys. The former were conducted simply to monitor the amount of gemfish on the trawl grounds while multiple boat surveys were targeted at aggregations when they were thought to be present. Most survey trawl shots were restricted to around 1h duration although longer shots were occasionally completed when the abundance of gemfish on the grounds was thought to be low.

Participating vessels generally completed two shots each day of surveying, the first commencing around dawn (approx. 0600 - 0700) and the second commencing around mid-morning (0900 - 1000). On rare occasions a third shot was conducted around midday. Because the fishermen were allowed to determine which vessels participated, no standardization of vessel power or net type was possible. Vessel size varied from 15 to 25 m and vessel power varied considerably. The nets were the standard "market-fish nets" being

used by the fleet at the time of the surveys, although these tended to vary to some extent from boat to boat.

Four Wollongong vessels participated in the surveys. The larger vessels - *Giuseppa*, *Santa Rosa* and *Illawara Star* - conducted the multiple boat surveys while the smaller, *San Diego*, conducted the single boat surveys. Eight vessels participated in Ulladulla, including the larger *Gracie P*, *Marina Star*, *Torina M*, *Charissa*, and *Shoalhaven*, and the smaller *Santa Maria Star*, *Shaylene B* and *San Giuseppa*. In Ulladulla participating boats rotated through both multiple and single boats surveys. At Bermagui two smaller vessels, the *Shelley H* and the *Dee Jay II*, participated in turn in surveys. Only one multiple boat survey was conducted from Eden using the vessels *Consolato*, *Terrace Star* and the *Osprey IV*, all larger vessels for the current NSW trawl fleet.

One scientific observer accompanied the participating vessels to the trawl grounds and supervised the trawl shots. During multiple boat surveys, shots were conducted synchronously with vessels steaming parallel with each other trawling in different depths. Vessels were equipped with Global Positioning Systems (GPS), echo-sounders, radios and radar, which allowed scientific personnel to monitor the position of all boats at all times. The depths and exact GPS bearings of all shots were recorded by participating skippers and reported to scientific observers by radio.

The approximate species composition of all catches was recorded. The total weight (to the nearest 0.5 kg) of gemfish in each catch was weighed upon unloading. The length composition of the gemfish in each catch was measured aboard participating vessels or upon landing, catches from individual shots being kept separate within the holds of vessels until landing. In catches of less than 200 fish the caudal fork length of every fish was measured. A haphazard sub-sample of 200 fish was measured from larger catches. Apart from initial samples, measured fish were also sexed and observations on the number of running ripe or spent fish were also recorded. Qualitative notes about stomach contents were also recorded, although no formal data on diet were collected.

Commercial catches landed in the survey ports were also sampled on an opportunistic basis. Skippers and crews were interviewed about the circumstances surrounding each catch to ascertain the degree of sorting or grading that may have altered the size composition of these catches. The commercial industry operated under a 200 kg by-catch arrangement during the 1993 spawning period, which made it illegal for fishermen to land in excess of this amount. Catches of less than 200 kg were generally landed without sorting or grading, but excessive catches resulted in 200 kg of larger fish being selected to land. Interviews attempted to ascertain what method of sorting had occurred. As these commercial catches belonged to fishermen rather than the research program, sexing, which may damage the catch, was rarely conducted on these samples.

The research program was originally planned to run for six weeks from the middle of June to the end of July 1993. However uncertainty about funding and administration of the program

delayed the start until July 1. Because of the late and extended nature of the 1993 gemfish season it was also deemed necessary to continue the program until the beginning of September.

The Mix analysis (McDonald & Green 1985) was used to describe the length frequency data. The Mix analysis seeks to describe any histogram as a mixture of distributions described individually by their means, the proportion of the overall histogram they constitute and the spread or deviation (sigma) of each distribution. The variability within the data and the overlap of age classes prevented the analysis from converging on unique solutions to the histograms consistent with the known growth rates of gemfish. Consequently the analysis was constrained to using mean lengths at age ($\pm$ 4 cm for 2-4+ year classes; $\pm$ 2 cm for >5+ year classes) consistent with published growth studies (Rowling 1990). The parameter sigma was allowed to vary in steps of 0.25 between 0.5 - 2.5 as dictated by the shape of the histograms, and distributions were held normal.

It should be recognized that constrained in this way the Mix analysis is largely descriptive, providing qualitative, rather than quantitative, descriptions of the proportion of a histogram contributed by a range of age classes. Little reliance should be placed in the estimated proportion of the oldest age classes (>11+) or the mean length of the youngest age classes (2 - 4+).

1.4 The 1993 Gemfish Season and Gemfish Research Program

1.4.1 Introduction

This description is largely based on short reports periodically provided to the Australian Fisheries Management Authority (AFMA) during the gemfish project. I have refrained from extensively re-working the material because I wish to convey some sense of the development of ideas and impressions during this program. My intention in this is to convey to the reader some of the evidence, information, experiences and thought processes which underlie the ideas documented later in this report.

1.4.2 The 1993 Gemfish Season and Project

The 1993 Gemfish project began on **Tuesday, 29 June 1993**, when I arrived in Sydney to commence the program. My first goal was to meet with fishermen in the three intended principle ports: Wollongong, Ulladulla and Eden. These meetings brought forth complaints that the project should have started two weeks earlier as the first run of gemfish had either passed or almost passed.

At the meeting in Wollongong fishermen were very supportive. Wollongong initially wanted to start immediately with a full 3-boat survey because the gemfish "were around". They believed the initial run of big fish was already moving up the coast. I was given reports and shown records which indicated that small catches (50 - 500 kg) of juvenile gemfish (39 - 45 cm) were taken as early as 6 May. The significance of these catches is that, unlike in the

south where small gemfish can be taken in traces year round, small gemfish are only taken across the northern main trawl grounds during the winter gemfish season. However, there were some indications that these early trawl catches were taken around the Kiama Hill, where aggregations of gemfish arrive earliest, and persist for longest in this area. The drop-line fishermen who fish the canyon say that they can catch these juvenile fish for most of the year in this area.

Large dumpings of gemfish (approximately 10 t) were also reported to me as having occurred in the last few days of June and this prompted Wollongong to request an immediate survey. Fish were also reported as being caught off Eden.

It was impossible for me to implement immediate requests for surveys as I needed to organize the other ports and establish the infrastructure to co-ordinate them in surveys.

At our initial meeting on **Wednesday, 30 June 1993**, the Eden operators were not overly enthusiastic. Most of the larger vessels that had become involved in the project were fishing a considerable distance south of Eden around the Horseshoe, a large canyon complex which bites into the eastern continental shelf between Flinders Island and Cape Howe. Their normal fishing trips were 3 - 5 days duration and the stipulation that a research catch could not be aboard a vessel with a commercial catch meant they would have to break their normal weather dictated cycle. Because their fishing is also more profitable than vessels operating north of Bermagui the Eden operators were, in effect, being asked to give up $5000 a day fishing to participate in the gemfish project for $1700 a day. They were also insistent that the gemfish season off Eden is earlier and shorter than anywhere else. In Eden the gemfish season is generally finished by 7 July each year.

Eden is the most weather prone port on the NSW coast and operators pointed out that surveys would have to accommodate this factor. It was also pointed out (not for the last time) that, unlike years when they fished commercially for gemfish, this year they did not know where or when gemfish were on their different grounds.

The Eden operators supported an immediate three-boat survey over the next weekend (using the shore-leave of the crew between extended commercial trips), followed by one or two more before moving the southern transect north towards Bermagui and using Bermagui boats.

It became obvious that simultaneous all port surveys would be very difficult to implement using Eden.

I returned, **Thursday, 1 July,** to meet the fishermen at Ulladulla, establish a central base and to welcome and establish my staff. In Ulladulla the fishermen enthusiastically supported the program but the area had been experiencing a warm northerly current and the fishermen had not noticed any gemfish around. They favoured commencing with a single vessel survey of the main trawl grounds off Ulladulla.

Saturday, 3 July: The first survey of the project was conducted on the first Howe ground (northern most), south of Eden and east of cape Howe. The skippers predicted that few gemfish would be caught and they were right.

Six short (1.5 h) trawl shots were conducted in 150, 160, 170, 190, 200, and 220 fthm. The total catch from all shots was 421 kg.

Only a few large fish (>60 cm) were caught. The smallest fish (40 - 50 cm) were more prominent (87% by number) on the shelf (<170 fthm), mixed with some 50 - 60 cm fish. The 50 - 60 cm fish were more important (39%) in deeper catches, 170 - 220 fthm. There were no mature females amongst the 40 - 60 cm fish, although most males were mature. The only >80 cm gemfish were mature females, which were mature but not in season.

The fishermen claimed that, from what they could tell, one run of fish had already passed through the Eden grounds. Recorded catches from the previous two weeks and the lack of gemfish caught in the survey supported this view in their opinion. They also maintained that catches made around canyons at the extreme south of the Howe grounds indicated that the next run was building up in the south. The fishermen blamed the warm northerly current that was prevailing at that time for the lack of gemfish.

Cumulative Gemfish Catch: **421kg**

Sunday, 4 July 1993: The first three-boat, six-shot survey off Wollongong was conducted. The depths sampled were 160, 165, 180, 180, 200, 200 fthm and the total catch was small, 1024 kg.

Larger fish (>80 cm) were more prevalent than at Eden, numerically dominating the catches (36%). A few (10%) 60-80 cm fish, mainly between 160 and 190 fthm and 54% small (<60 cm) gemfish. A greater proportion of smaller fish in shallower shots. The largest catches (487 & 205 kg) were made at around 180 fthm. The proportion of males in the catch declined with depth, as the proportion of big individuals increased.

Cumulative Gemfish Catch: **1 445kg**

Monday, 5 July 1993: A single boat survey was conducted from Ulladulla. Three shots were made in 200, 225 and 250 fthm. The deepest shot (1 h) produced 983 kg, and other shots were 230 and 128 kg respectively. Total catch for the day was 1 340 kg.

There were some (26%) small fish (<60 cm) in the two shallower shots, mainly males. The catches were dominated (64%) by large fish (>80 cm), mainly mature females. There was a greater proportion of small fish in shallower shots.

An opportunistic sample of a commercial catch was also made. The skipper of the

commercial vessel claimed to be landing his entire gemfish catch for the day (<200 kg), the shot was made in 120 fthm on the same grounds as the survey shots. Of the 33 fish caught, 27 were small (<60 cm) and the remaining 6 fish were 80 - 90 cm.

These traces of gemfish in Ulladulla created immediate interest in the port and the fishermen requested that a three-boat survey be organized for later in the week.

Cumulative Gemfish Catch: **2 785kg**

Tuesday, 6 July: A single vessel survey was conducted from Wollongong. Two shots were made in 190 and 215 fthm and the catch was mainly (79%) <60cm fish. Total catch was 70 kg.

Commercial boats fished around the survey vessel on the same trawl grounds. No gemfish were caught in 75 or 240 fthm but a few gemfish were taken in 160 - 190 fthm. The catch was mainly fish <60 cm. Gemfish were also taken in 140 - 145fthm where a few 70 - 90 cm fish were taken together with <60 cm fish.

Cumulative Gemfish Catch: **2 855kg**

As a result of these surveys Wollongong fishermen wished to delay any further three-boat shots from Wollongong.

Wednesday, 7 July: The Eden boats were back in port due to bad weather. There was no prospect of any Eden survey for the next few days. Weather also postponed the three-boat survey initially planned for Ulladulla that day.

The postponed Ulladulla survey occurred the next day, **Thursday, 8 July**. The main Ulladulla ground, often called "the paddock", was again used and six shots were completed in 160, 180, 190, 200, 220, 250 fthm for a total catch of 8 873kg.

The largest catch, of approximately 4 t, was taken in a 1 h shot in 200 fthm. Large catches, 1.0 - 2.7 t for 1 h trawling, were also taken in 190, 220 & 250 fthm. These catches were dominated (46%) by gemfish >80 cm, but all size classes (40 - 110 cm) were represented. Small fish (<60 cm) were numerically the next most abundant (40%) size class; 60 - 80 cm size classes were least abundant. The length frequency histograms for the catches from the varying depths were the most uniform observed up until that point of the project.

Some spawning activity was evident with approximately 3 - 5% of large females either running ripe or in a partly spent state. These female reproductive states had not been observed in previous samples.

Several opportunistic samples of commercial catches were also made. Approximately 200 kg of gemfish that a skipper claimed came from an unsorted catch of relatively

uniformly sized fish was measured. The catch had been made in 220 fthm on the "the paddock" around where the surveys were conducted. The measured fish were between 68 and 88 cm - the size classes which had been numerically weakest in the surveys.

Another fisherman claimed to have discarded a 300 kg shot of similar medium size fish because they had their 200 kg trip-limit filled with larger fish. That catch was made in about 160 fthm in the survey area.

Cumulative Gemfish Catch: **11 728kg**

A single boat survey planned for Wollongong on **Friday, 9 July**, was cancelled due to poor weather conditions. The Wollongong fishermen were also reluctant to survey because their own fishing suggested gemfish were scarce off Wollongong at the time.

Some opportunistic sampling of commercial catches was conducted in Ulladulla. Fishermen were interviewed about their catch and details of the shots obtained to ascertain if valid length frequency data could be collected. Catches were sampled only where it was ascertained that grading and sorting had not occurred. Fishermen were extremely aware of the aggregation of fish then off Ulladulla. Most of their commercial activity was orientated towards trying to catch other species (principally mirror dory), which school around the gemfish aggregation, while avoiding the gemfish aggregation itself.

Catches of small fish (<60 cm) mixed with a few large females, some spent, were recorded from 240 and 120 fthm, deeper and shallower than the main aggregation. At the southern end of the grounds fished from Ulladulla (south of "the paddock"), a further catch of relatively uniformly sized 70 - 90 cm fish was reported taken in 195 fthm, apparently to the south of the main aggregation.

On **Saturday, 10 July**, there were no surveys planned and opportunistic sampling of the commercial fleet out of Ulladulla continued. Gemfish catches had declined on the main Ulladulla grounds. Some small catches of <60 cm gemfish were taken, particularly in shallower depths (<150 fthm). The fisherman claimed that what they regarded as the initial run of gemfish had now moved north from Ulladulla. Most skippers now expected another run of gemfish to start appearing and building up on the grounds to the south of Ulladulla.

A further catch of relatively uniformly sized 70 - 90 cm fish was reported (and measured) from the south of the main Ulladulla grounds.

On **Sunday, 11 July**, four boats conducted a single boat and three-boat survey simultaneously on trawl grounds north and south of Wollongong. Trawl shots were made at 150, 160 (north), 165 (south), 180, 200 (north & south), 220 and 230 fthm (north). A small 322 kg catch was taken with the seven 90 minute trawls. It was principally comprised of 40 - 55 cm and 75 - 90 cm size classes.

A single boat survey was also conducted on **Sunday, 11 July**, from Ulladulla. Three 1 h shots were completed on the main ground in 175, 190 and 200 fthm. The total catch was 195 kg and covered all size classes from 40 - 90 cm, the few larger fish being taken in the deeper shots.

Cumulative Gemfish Catch: **12 245kg**

On **Tuesday, 13 July**, a three-boat survey was conducted from Ulladulla. Six 1 h shots were completed in 180, 190, 195, 200, 200, 230 fthm. Catch rates of gemfish were universally low and the total catch was only 276 kg.

The catch was principally of the size classes 40 - 55 cm and 70 - 95 cm. The larger fish were in the deeper water shots.

Cumulative Gemfish Catch: **12 521kg**

On **Thursday, 15 July**, a three-boat survey was conducted from Wollongong on trawl grounds to the south where a large accidental catch of gemfish had been made the previous day during commercial fishing for mirror dory. Mr Kevin Rowling (FRI) accompanied this survey. Six 1.5- 2.0 h shots were completed in 170, 180, 190, 200, 205 and 220 fthm. A total gemfish catch of 2 610 kg was taken.

Catch rates were considerably lower than the previous day's commercial by-catch, although a significant mirror dory catch was made. All size classes (40 - 100 cm) were represented in the catch. The catch was principally (46%) large fish, with 14% of 60 - 80 cm and 39% of >60 cm fish.

Cumulative Gemfish Catch: **15 131kg**

Since the original surveys in Eden, weather conditions had prevented further surveys from there. Consequently, Bermagui boats had been enlisted into the project. On **Monday, 19 July**, the first survey was conducted from Bermagui. Because the trawl ground off Bermagui is relatively narrow, two boats were used rather than three. On the first survey, shots were completed in 190, 200, 220, 230 fthm. The total catch was 1 105 kg, almost exclusively (98%) small gemfish (40 - 60 cm), very similar to the catch taken in the only Eden survey.

Cumulative Gemfish Catch: **16 236kg**

General Comments Drafted on Monday, 19 July

By Monday, 19 July, it seemed apparent that the earlier spate of significant gemfish catches was finished. Incidental catches of gemfish from commercial boats had dropped off, few if any boats were landing their 200 kg trip limits in any port. No port was enthusiastic about continued surveying at that time, largely because of the lack of gemfish but also because the boats wished to use the period without gemfish to fill market fish quotas.

Low catch rates of gemfish occurred across all depths with small size classes of gemfish (<60 cm) predominating in catches. However, a strong north-south size trend was visible in the few catches being made. Larger fish >70 cm were only taken from Ulladulla north. In the north, around Wollongong, catches were principally made up (in terms of weight) of a few large fish. Off Bermagui the catch was dominated by large numbers of small fish.

Industry could not agree as to exactly what stage the gemfish season had reached. Some, arguing that the season was late, were still expecting the next "main run" of gemfish. A second group argued that the main part of the season had finished and that the first run of gemfish had not been detected. Some, who held the second view, argued that the first run of gemfish had occurred before the project, but others of this persuasion argued that because few boats had been on the shelf one of the runs had passed undetected during the project.

A strong body of opinion, however, also maintained that the next run was 1-2 weeks away and simply later than normal. Most of the proponents of this theory explained it in terms of 1993's lunar cycle, which had 13 lunar months rather than 12; the full moons of June, July, August were very early in the month. Some fishermen said they associated the main gemfish runs with the sixth and seventh full moons of the year. This body of opinion remained confident that the next run of gemfish would occur around the next full moon and would be largely comprised of the 65 - 85 cm fish which, to date, had been under-represented in the samples, as predicted by FRI.

On **Tuesday, 20 July**, a trawl owner from Eden suggested that a landing of gemfish coming ashore from the grounds around the Horseshoe may be of interest to me. On inspection they turned out to be mainly 50 - 60 cm fish with 10-15% by weight large (80 - 100 cm) fish.

A single boat survey was conducted off Wollongong. Shots were completed in 195 & 200 fthm for a total of 134 kg. In the first shot only 17 kg of 40 - 60 cm gemfish were taken, in the latter 80 - 100 cm females dominated.

Cumulative Gemfish Catch: **16 370kg**

On **Friday, 23 July**, I was again asked to inspect a box (35 kg) landed in Eden as part of a 200 kg trip limit. The box was part of a discarded shot taken on the Second Howe ground. The fish I examined were from the under-represented size classes (60 - 80 cm) - mature ripe males and immature females. It was claimed that they collected enough larger (80 - 100 cm) fish from the catch to fill their 200 kg trip limit but that most of the weight in the catch (which they discarded) were of the size they retained for my inspection.

On **Sunday, 25 July**, a survey planned for Wollongong was cancelled due to poor weather.

Reports of dumping south of Eden continued. Fishermen were in regular contact because they believe the fish being dumped were the missing size classes.

During the latter half of July, as the larger Eden operators were principally fishing spawning aggregations of warehou on the southern side of the Horseshoe in 150 fthm, the level of gemfish by-catch began increasing. The proportion of gemfish taken incidentally amongst the warehou increased to a peak around 20 July and the following week before declining. Before and after this event the catches of warehou in this area contained few fish besides the targeted species. No targeted shots were performed on the nearby "hake ground" or gemfish ground for fear of it resulting in a large gemfish catch. Thus no reports are available about the presence or absence of fish in that vicinity. Fishermen have the opinion that larger quantities of gemfish would have been in the vicinity of the gemfish ground. By 4 August incidental gemfish catches had declined to very low levels around the Horseshoe. Smaller trawlers fishing directly east of Eden reported some catches around the end of July and the beginning of August but these had also declined by 4 August.

No official surveys were conducted on these gemfish aggregations due to the organizational difficulties outlined. Some landed fish were measured and some observations of the size of the gemfish caught at this time were made by staff of the Scientific Monitoring Programme. The catch was described to me by skippers, crew and owners as being numerically dominated by 40 - 60 cm fish but with large amounts of 70 - 80 cm fish. In weight it was dominated by these medium size fish. One small entire catch was landed without grading (it was claimed), was measured and found to be of medium (70 - 80 cm) size fish. Photographic evidence of the earlier large catches supported the suggestion that the single measured catch was representative of those earlier catches.

On **Monday, 26 July**, the delayed three-boat survey off Wollongong was completed. Six two hour shots were completed in 185, 190, 200, 205, 210 and 215 fthm. Significant catches were made during the shots commenced around noon and 12 038 t of gemfish was landed.

Catch rates were around 150 - 250 kg/h in the morning and 1 200-1 500 kg/h in the later shots. Seventy percent of the gemfish were large (>80 cm) but 70 - 80 cm were also noticeable (18%) in the catch composition. Plans were made to conduct surveys off Ulladulla where there were reports of large amounts of feed building up on the gemfish grounds. But there were very few catches of any commercial species being made on the shelf edge off Ulladulla.

Cumulative Gemfish Catch: **28 408kg**

Tuesday, 27 July: The planned surveys off Ulladulla were postponed due to a reluctance on the part of skippers to participate because of a perceived lack of gemfish on the grounds. Surveys were conducted from Bermagui. Only 250 kg were caught, almost entirely (95%) 40 - 60 cm non-breeding fish. There was only a scatter of larger size classes.

Cumulative Gemfish Catch: **28 658kg**

Wednesday, 28 July: A single boat survey was conducted from Ulladula. Only 170 kg were

caught from shots in 225 & 205 fthm. The catch from the earlier shot was almost entirely 40 - 60 cm fish. In the later shot a scatter of larger fish (65 - 100 cm) were also taken, including some males.

The deepest shot (225 fthm) was similar to the previous day's catch off Bermagui but with a better representation of the older year classes. A shallower shot (205 fthm) contained only 40 - 60 cm fish. The catches of all the other boats that had fished the shelf from Ulladulla were also examined, most had fished shallower than 205 fthm. The catch of those that had gemfish was similar to our uniform 40 - 60 cm catch. One reported shot from 285 fthm had yielded no gemfish.

Cumulative Gemfish Catch: **29 248kg**

Thursday, 29 July: Two survey shots from Bermagui. Similar small catch as to before; 102 kg.

Cumulative Gemfish Catch: **29 350kg**

Sunday, 1 August: In Wollongong a trip limit of 200 kg was landed commercially and opportunistically sampled. The catch was taken from a larger shot (approx. 900 kg) made in 195 fthm; it was mainly (57%) 60 - 80 cm fish, modal length 77 cm. No sexing was conducted.

Monday, 2 August: A single boat survey was conducted from Wollongong. The total catch from a single 3 h shot in 200 fthm was 290 kg. Broad representation of all size classes in the catch (40 - 105 cm). Lowest numbers (13%) in 60 - 80 cm size class, small (46%) and large fish (41%) more prominent. Males 70 - 85cm were conspicuous by their presence, comprising 32% of the >60 cm gemfish.

Survey shots off Bermagui in 170 and 230 fthm. Gemfish catch only 210 kg. Principally (95%) 40 - 60 cm fish. A few (4%) 60 - 80 cm fish.

Incidental gemfish catches measured aboard vessels fishing for spotted warehou south of the Horseshoe. Catches of gemfish very low, almost exclusively (90%) 40 - 60 cm fish. A scatter (8%) of 60 - 80 cm fish.

Cumulative Gemfish Catch: **29 640kg**

Friday, 6 August: A single shot off Bermagui in 200 fthm. Only 18 kg caught, 40 - 50 cm fish. One mature female 74 cm fish still to spawn.

Complete ungraded catch caught from near the Horseshoe measured. Similar catch to those measured previously, almost entirely 40 - 60 cm fish, a few 60 - 80 cm fish.

On **Saturday, 7 August**, three dropline boats were organized to survey the gemfish around

the Kiama Hill, an area that had been producing consistent catches of gemfish. The three vessels completed 6 - 7 drops each but only landed 49 kg of 70 - 95 cm fish. This result was generally interpreted by industry as indicating particularly low levels of gemfish in the broader area.

By **Friday, 13 August**, however, the dropliners were again reporting large amounts of gemfish around the Hill at Kiama. A single drop-liner was used to survey the fish in the Kiama Canyon and caught 384 kg in 3 - 4 drops, 78 - 98 cm fish. These fish were coming into spawning condition, as was evident by the partial hydration of some gonads.

On **Sunday, 15 August**, a commercial landing of gemfish was opportunistically measured at Wollongong, principally 70 - 95 cm fish with a broad mode between 80 - 90 cm. The following day the Wollongong trawlers again reported catches of gemfish and requested a research survey to be organized.

This survey was conducted **Wednesday, 18 August**, from Wollongong. Four two hour shots and one four hour shot were conducted. Catch rates were highest 479 - 1 620 kg/h in the afternoon (1245 - 1445) in 205 - 220 fthm, and lowest (70 - 75 kg/h) in the morning (0810 - 1030) in 205 & 210 fthm. A total of 633 gemfish were measured and a catch of 8 086 kg was taken, principally (53%) >80 cm fish with a modal length of 85 - 90 cm. Relative to earlier catches there was a stronger representation (28%) of 60 - 80 cm gemfish. In one catch there was a clear secondary mode at 77 cm. These catches also had a higher proportion of male gemfish (37 - 45%). Approximately 13 - 15% of females were running ripe.

Cumulative Gemfish Catch: **38 177kg**

On **Friday, 20 August**, four shots were conducted off Wollongong in 190, 205, 220 & 235 fthm. The total catch was only 245 kg. Only 14 fish larger than 60 cm were caught, principally males 70 - 90 cm in length.

Cumulative Gemfish Catch: **38 422kg**

From Ulladulla southwards no significant catches of gemfish were reported during this period. Around Wollongong and further north, gemfish catches apparently declined after 20 August, remaining low until at least 26 August.

The last survey of the gemfish project was conducted on **Saturday, 25 August**, from Bermagui. Commercial catches made near the survey were also measured. Both survey and commercial catches were small. The survey catch of 205 kg was principally (84%) 40 - 60 cm, with a scatter of 60 - 80 cm fish. The small commercial catch, a by-catch of ling, was uniformly 76 - 92 cm fish with a modal length of 81 cm.

Cumulative Gemfish Catch: **38 627kg**

On **Sunday, 26 August**, commercial catches taken during ling fishing off Bermagui were examined. The catches were small, principally 73 - 85 cm fish.

Around **28 August**, however, fishermen targeting mirror dory north of Sydney, began reporting significant incidental catches of gemfish. Around **1 September**, several significant commercial landings were made. Catches made from these aggregations were measured in Sydney and Wollongong. All fish (even the few 40 cm females) were in full spawning condition, running ripe or spent. This was the only time female gemfish this size were seen in a state suggesting they were participating in spawning aggregations. All size classes were represented, including 60 - 80 cm fish, although this size class was numerically weaker (19%) than the 40 - 60 cm (35%) and >80 cm size classes (35%).

The catches were approximately 36% male, with the males having distinctively bi-modal size distribution, a major mode at 50 cm and a secondary mode at 79 cm. The modal length of female fish was 88 - 91cm. Most fish were in an almost fully spent condition. Only about 7% of females looked entirely spent with no ova left in bloody, contracted gonads. Only 4% of females were still running ripe and only a few fish appeared to be in ripe but unspawned condition. Most fish appeared noticeably slabby for the first time in the season, with bone structure being clearly visible through the skin.

A commercial drop-liner catch from the Kiama Canyon was also examined at the same time and found to have modal lengths at 76 and 84 cm.

Catches declined along all parts of the coast after this period and significant gemfish landings were not reported again until October when boats fishing along the shelf between Tasmania and Victoria reported incidental catches of immature gemfish.

End of field work 1993.

Total Research Gemfish Catch: 38 627 kg

1.4.3 Summary of Eastern Gemfish Winter 1993 Aggregations

During the 1993 gemfish season significant aggregations of gemfish or "runs" were apparently detected by industry or research surveys on the following occasions and locations:

Early/Mid June	Eden	Unconfirmed reports of catches.
June 29 - July 2	Wollongong	Several significant dumpings.
July 5 - 8	Ulladulla	Large survey shots. Commercial by-catches.
July 18 - 25	Horseshoe	Large incidental catches on warehou grounds.

July 26	Wollongong	Survey catches approx. 12t.
July 30 - Aug. 2	East of Eden	Commercial catches reported.
Aug. 16 - 20	Wollongong	Commercial catches reported. Survey catch of approx. 8t. Commercial catches also reported north of Barranjoey.
Aug. 28 - Sept. mirror	North of Sydney	Commercial catches of gemfish amongst dory targets.

1.4.4 Structured Sampling of Gemfish Aggregations

Gemfish aggregations were sampled on four occasions:

July 5	Ulladulla.
July 8	Ulladulla.
July 26	Wollongong.
August 18	Wollongong.

Stratified multi-boat surveys only sampled the final three of these occasions. Although outside the scope of this project, preventing structured surveying, samples were also measured from commercial catches made around:

September 1	North of Sydney.

1.5 Results of Gemfish Measuring

1.5.1 Size Structure in Survey Catches

A total of 10 061 gemfish in 103 survey samples were measured during the 1993 gemfish project. Figure 2a shows the aggregate length-frequency histograms for all samples pooled on the basis of raw numbers within each sample (ie large samples have greater influence on the aggregate than smaller samples). Small gemfish (40 - 60 cm) numerically dominate (46%) the pooled samples, with the >80 cm size classes being the next most abundant size class (40%) and the 60 - 80 cm fish least abundant (14%).

The greatest and most consistent variation between catches was determined by whether or not aggregations or "runs" of gemfish were fished during surveys (Figure 2b&c).

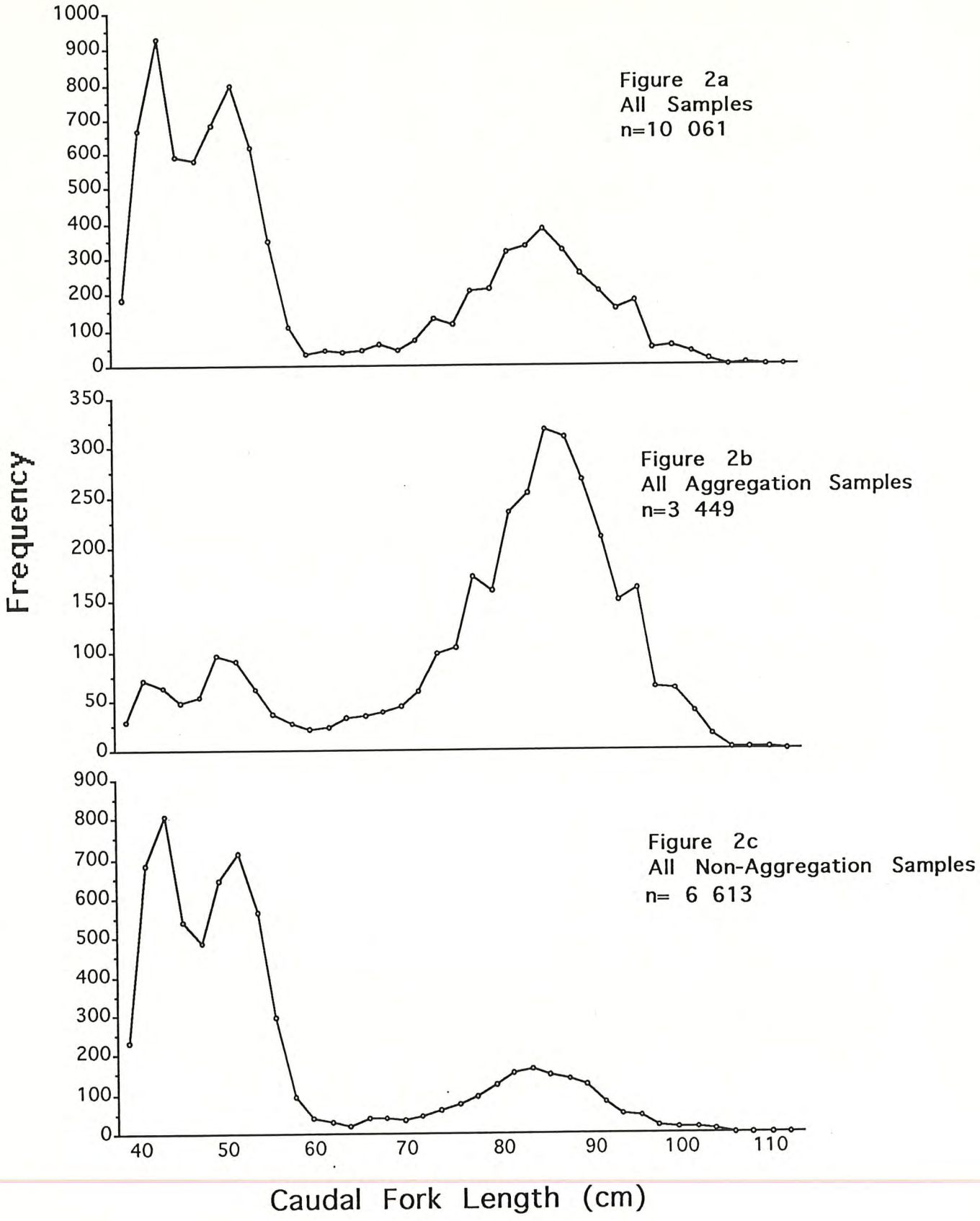


Figure 2.
Aggregate length-frequency histograms for gemfish, (**a**) all samples pooled on the basis of sample size; (**b**) samples from aggregations; (**c**) non-aggregation samples.

When aggregations of gemfish were around the trawl grounds catch rates >250 kg/h were attained and the catch was dominated (>80%) by large and medium sized fish (Figure 2b & 3).

When aggregations of gemfish were absent and catch rates low, catches were dominated (74%) by immature 40 - 60 cm gemfish. Larger size classes of gemfish were present in catches made away from spawning aggregations (Figure 3), but in lower proportions (26%).

Survey catches from around aggregations were dominated by the large (>80 cm) mature fish.

Mature, medium size (60 - 80 cm) dominant in commercial catches from 1975 - 1987 (Rowlings 1990) were poorly represented.

Trends in length composition were most evident in catches made away from aggregations.

1.5.2 Size Composition of 1993 Non-aggregation Catches

1.5.2.1 Ports

The size composition of non-aggregation catches varied markedly between the ports used during the surveys (Figure 4a-c). The smallest size classes of gemfish (40 - 60 cm) were numerically strongest (>90%) in surveys conducted from Eden/Bermagui (south), and least abundant (55%) at Wollongong (north), while >80 cm gemfish were numerically most prevalent (40%) in samples from Wollongong, and least prevalent (<5%), in samples from Eden/Bermagui (Figure 5). The size composition of catches from Ulladulla tended to be intermediate between these two extremes.

1.5.2.2 Depth

In samples from Eden/Bermagui >80cm gemfish were only significant (>25%) in catches from depths >220 fthm (Figure 6a). All catches were dominated by small (<60 cm), mainly immature gemfish. Medium size gemfish (60 - 80 cm) were only significantly represented in surveys from depths >200 fthm.

Samples from Ulladulla showed the clearest trend with depth observed. The proportion of larger fish fell from around 45% in catches made deeper than 220 fthm to less than 15% in the shallowest (<180 fthm) depths (Figure 6b). Medium size gemfish were 10-15% of samples from depths >180 fthm. The proportion of small fish decreased from >85% in the shallowest surveys to <50% of the deepest survey catches.

The size composition of non-aggregation catches off Wollongong had the most homogenous size composition (Figure 6c) across the depth range surveyed (160 - 240 fthm). Large fish (>80 cm) were 25 - 45% of the catch, medium size fish (60 - 80 cm) were 10-15% and small (<60 cm) fish were approximately 50% of the catch across the depth range.

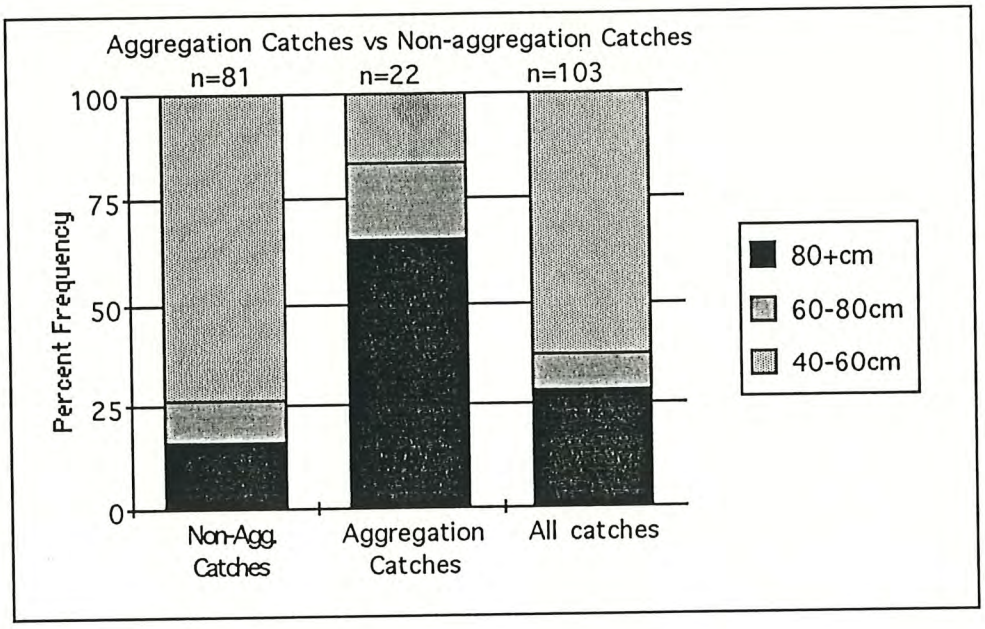


Figure 3.
The proportion of 40-60, 60-80 and >80cm gemfish in all samples, samples from aggregations and non-aggregation samples.

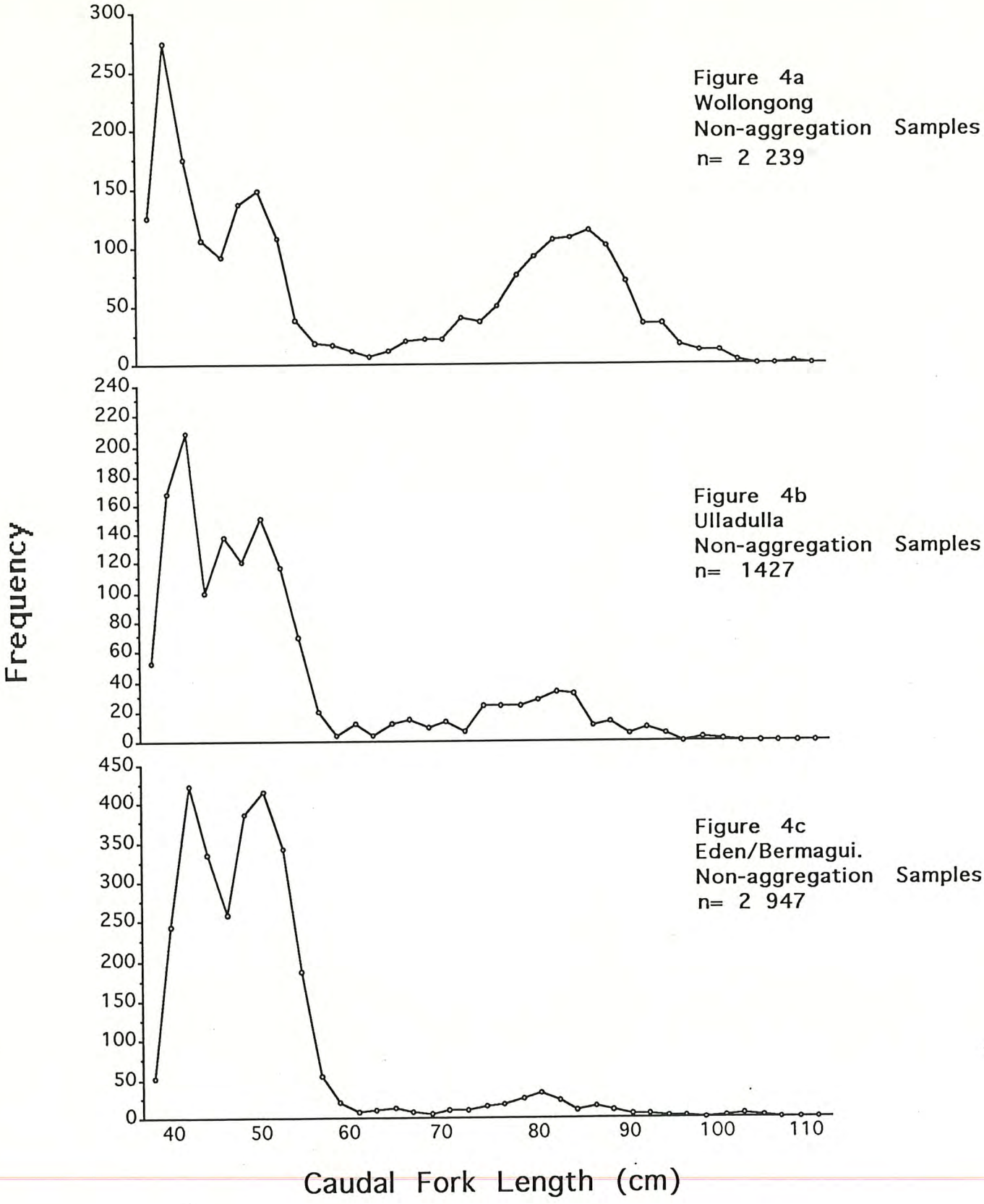


Figure 4.
Length frequency histograms for all non-aggregation samples from (**a**) Eden/Bermagui, (**b**) Ulladulla and (**c**) Wollongong.

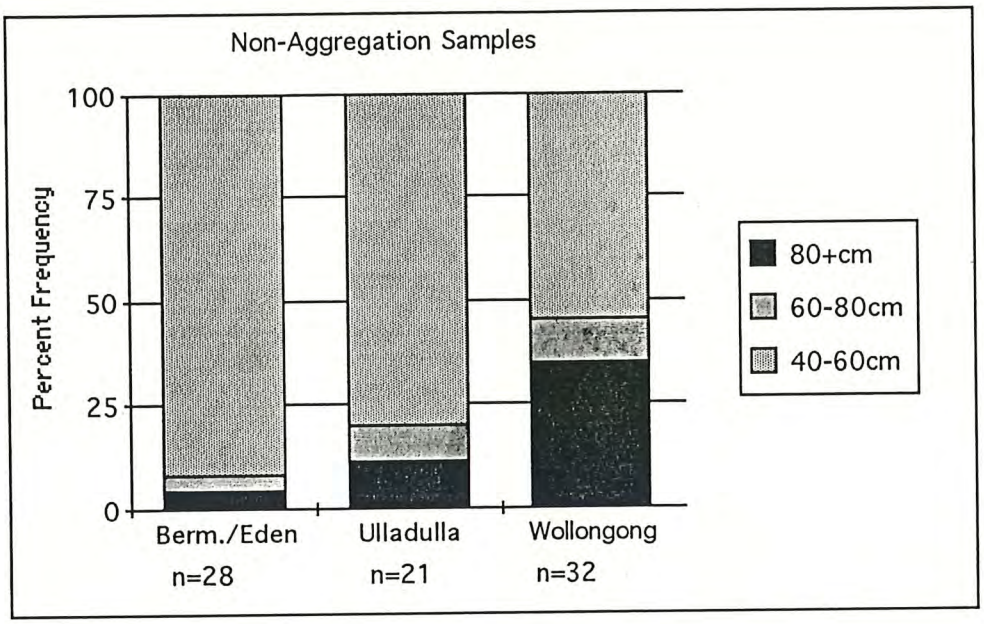


Figure 5.
The proportion of 40-60, 60-80 and >80cm gemfish in non-aggregation samples taken from Eden/Bermagui, Ulladulla and Wollongong.

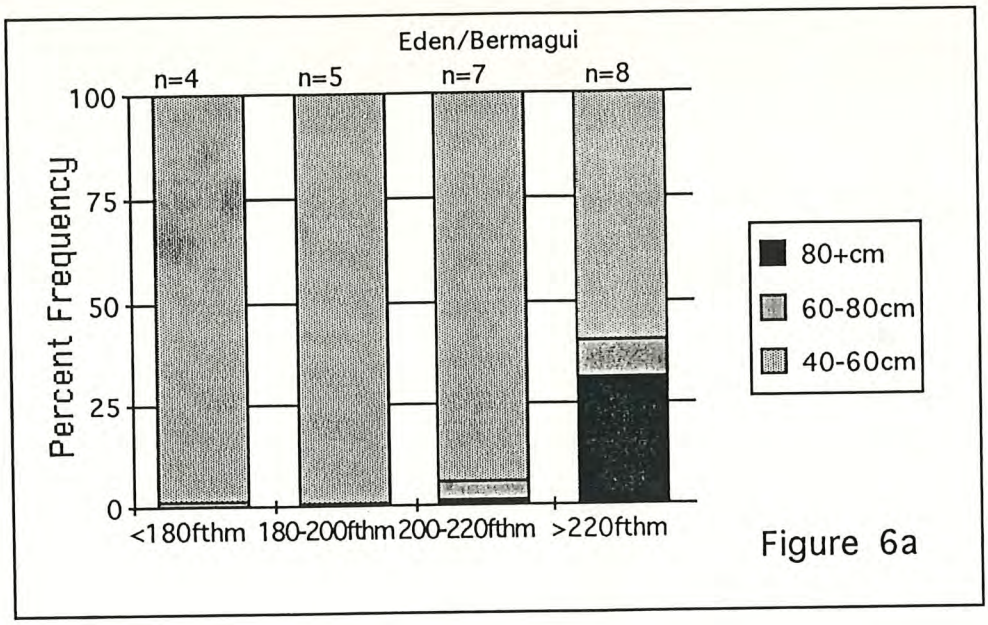


Figure 6a

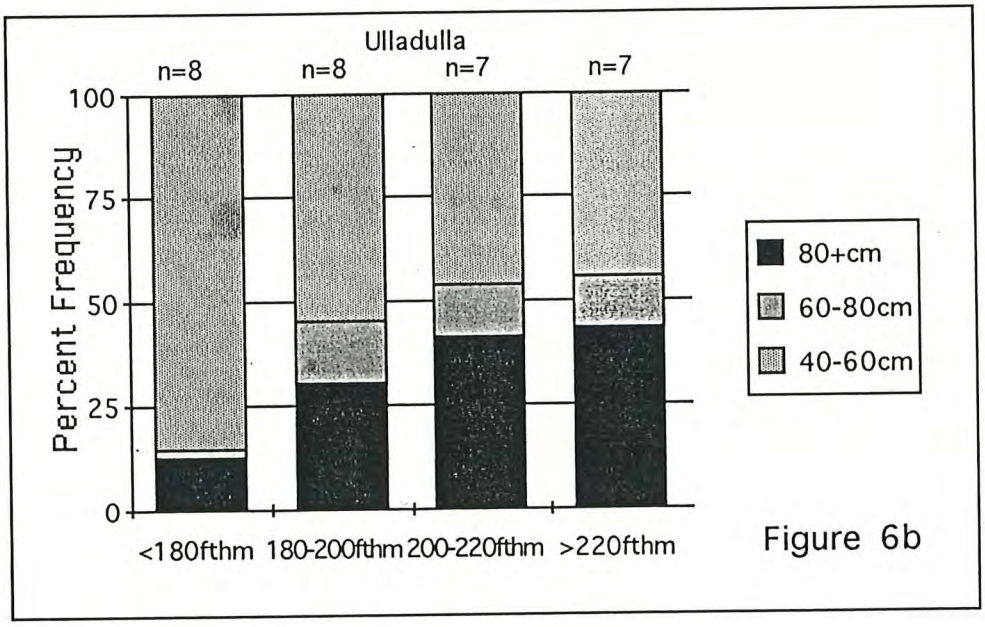


Figure 6b

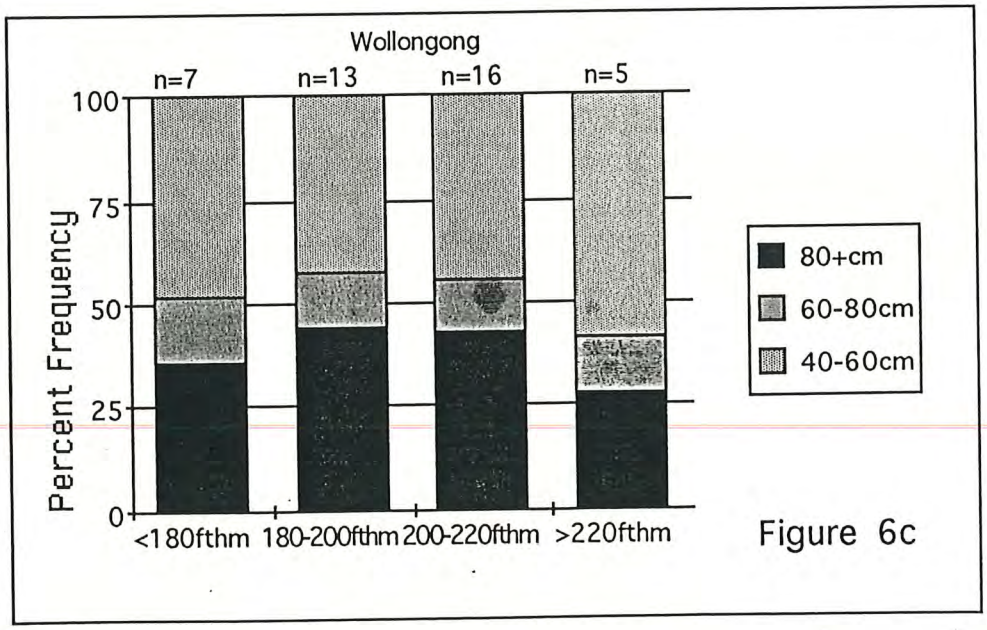


Figure 6c

Figure 6.
The proportion of 40-60, 60-80 and >80cm gemfish in non-aggregation samples taken in <180fthm, 180-200fthm, 200-220fthm and >220fthm, in surveys off (**a**) Eden/Bermagui, (**b**) Ulladulla and (**c**) Wollongong.

1.5.2.3 Time of Season

Until the last half of August samples from Bermagui/Eden were almost entirely (>95%) comprised of small 40 - 60 cm fish (Figure 7a). In the latter half of August >80 cm (50%) and 60 - 80 cm gemfish (15%) became a major proportion of samples. In combination with Figure 6c it can be seen that these fish were taken from depths >220 fthm at that time.

The proportion of >80 cm and 60 - 80 cm gemfish in samples from Ulladulla declined through July from approximately 60% to <5% (Figure 7b). Gemfish were rarely caught off Ulladulla after July.

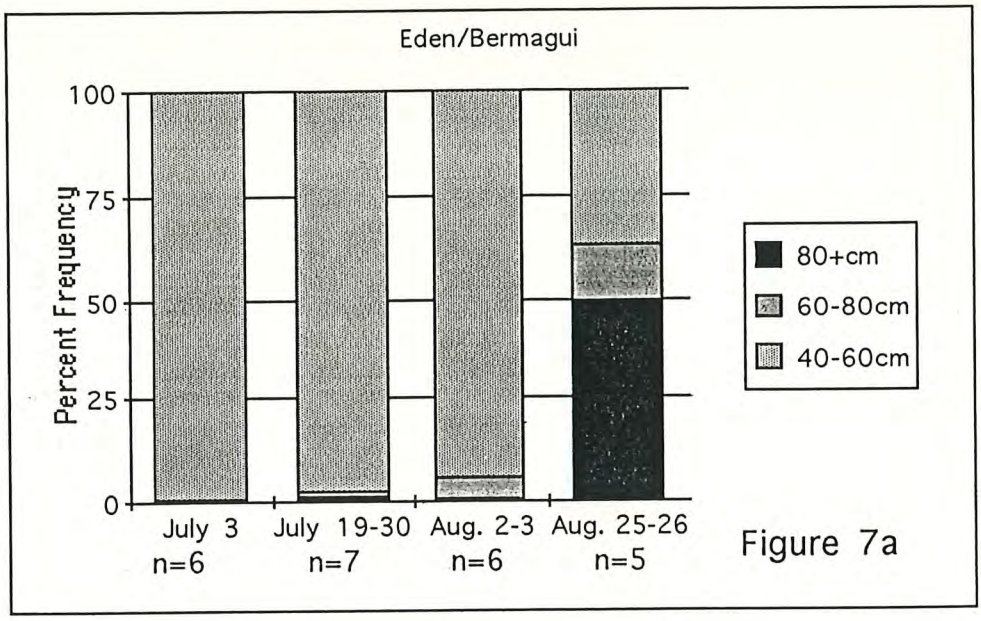
As with depth, trends in size structure were less obvious in non-aggregation samples from Wollongong than from other ports. The proportion of >80 cm fish rose slightly during July, from about 25% - 60% and remained high (40% - 60%) throughout August (Figure 7c). The proportion of smaller fish declined correspondingly from about 50% to 30%. With the exception of the beginning of August, when medium sized gemfish (60 - 80 cm) comprised 30% - 35% of survey catches off Wollongong, medium size fish comprised approximately 10% - 15% of the samples.

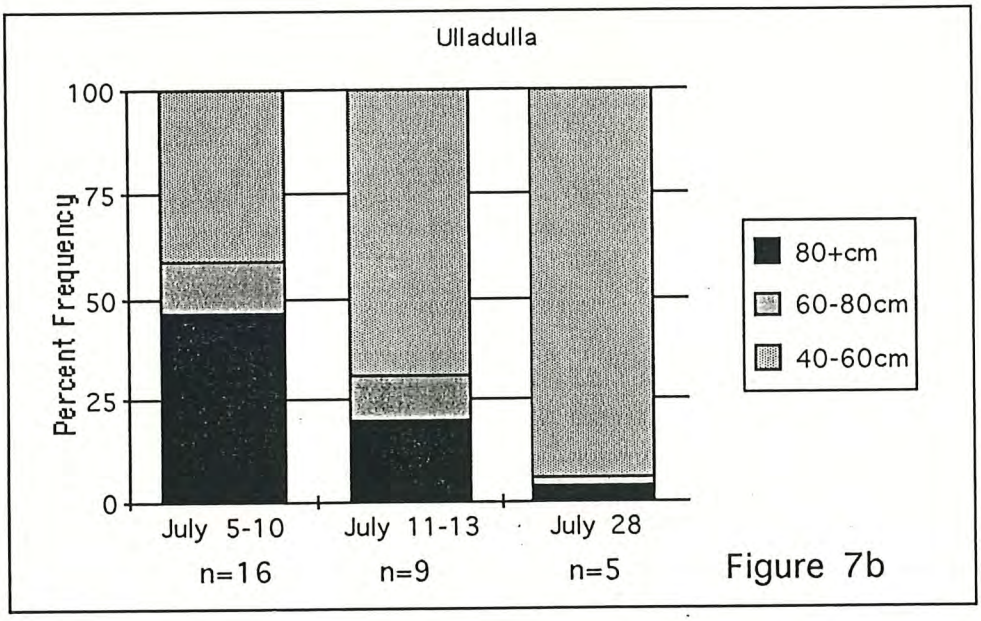
1.5.3 Size Composition of 1993 Aggregation Catches

A total of 3 449 gemfish were measured in samples from the 1993 winter gemfish aggregations (Figure 2b). Aggregations were principally (approx. 65%) comprised of large (>80 cm) gemfish. The modal length of the aggregated catches was 82-86 cm. Small fish (40 - 60 cm) and medium size (60 - 80 cm) gemfish were each approximately 20% of the catches.

A total of 2 202 of the gemfish measured were females (Figure 8a). Their length frequency histogram was basically unimodal with a modal length of 86 - 88cm. Only a few 40 - 60 cm gemfish were measured. The medium (60 – 80 cm) size classes were also poorly represented.

The Mix analysis, constrained to approximate the age-length key of Rowling (1990), suggests that 8 - 10 year-old female gemfish were most prevalent in the catch, with 7 and 11 year classes comprising a smaller but significant component (Figure 9a).





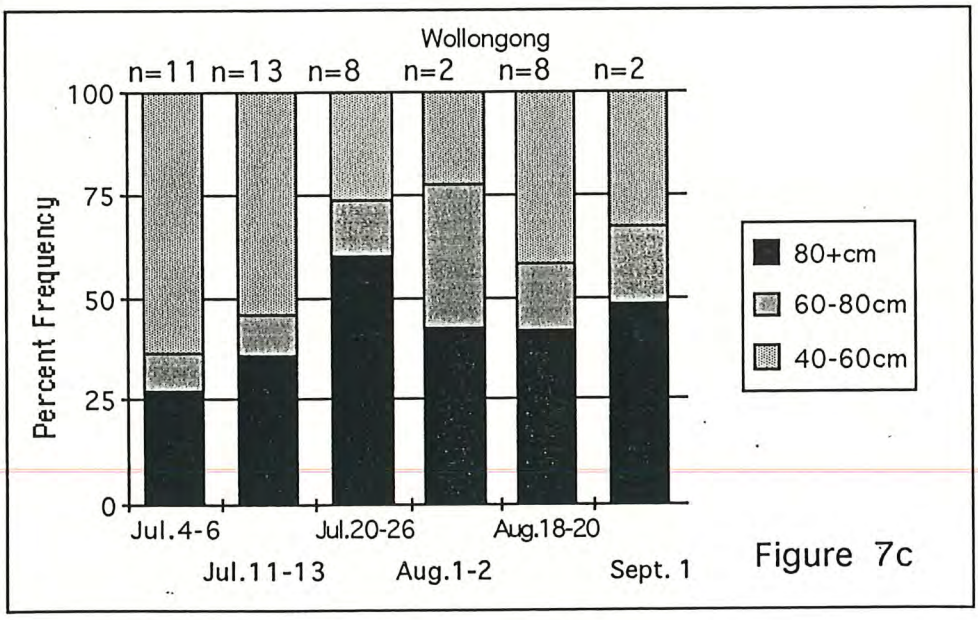


Figure 7.
The proportion of 40-60, 60-80 and >80cm gemfish in non-aggregation samples taken off (**a**) Eden/Bermagui during the periods 3 July, 19-30 July, 2-3 August, and 25-26 August, (**b**) Ulladulla during the periods 5-10 July, 11-13 July, and 28 July, (**c**) Wollongong during the periods 4-6 July, 11-13 July, 20-26 July, 1-2 August, 18-20 August, and 1 September.

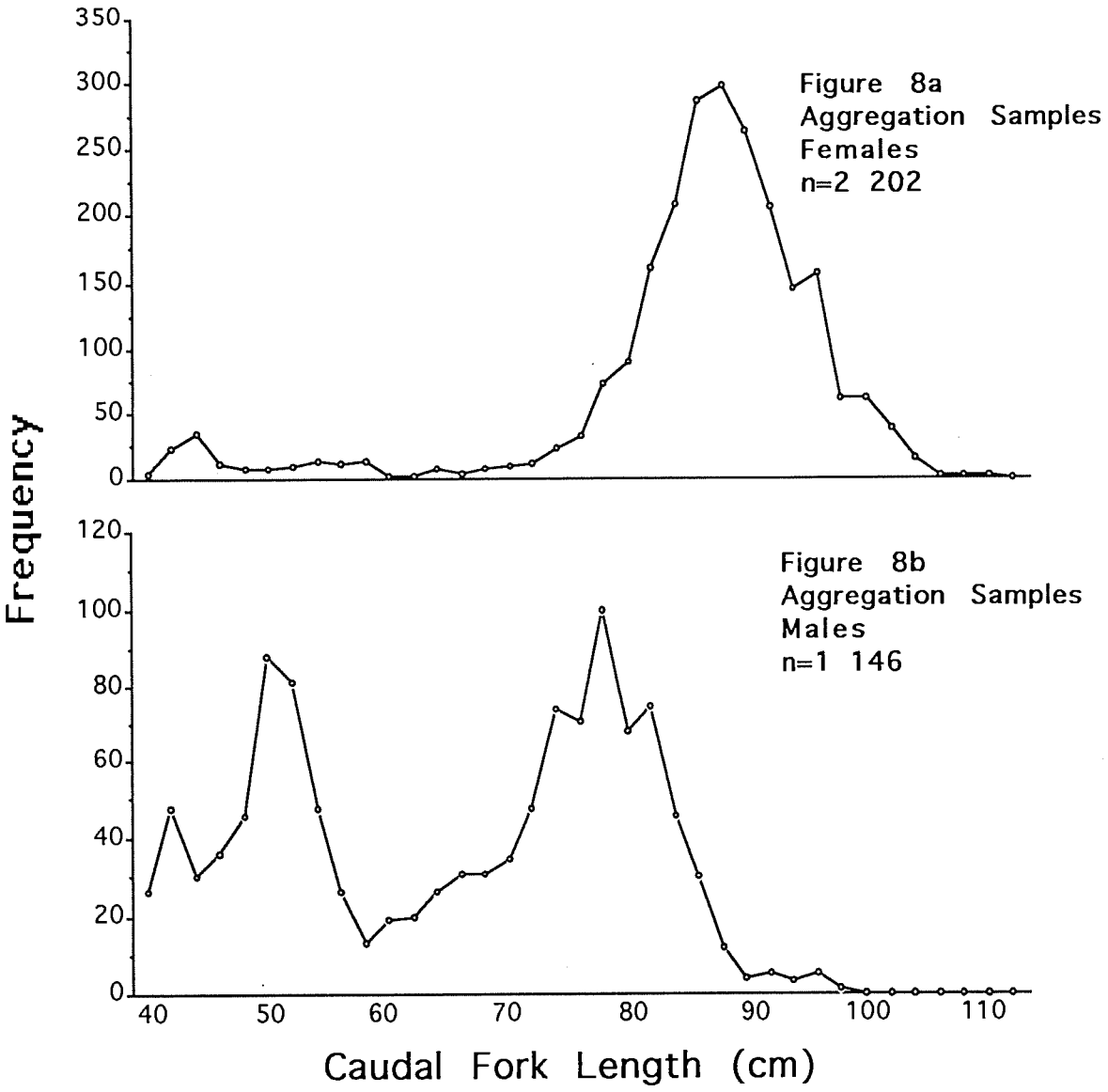


Figure 8.
Length frequency histogram of (**a**) female gemfish and (**b**) male gemfish sampled from aggregations.

Figure 9a

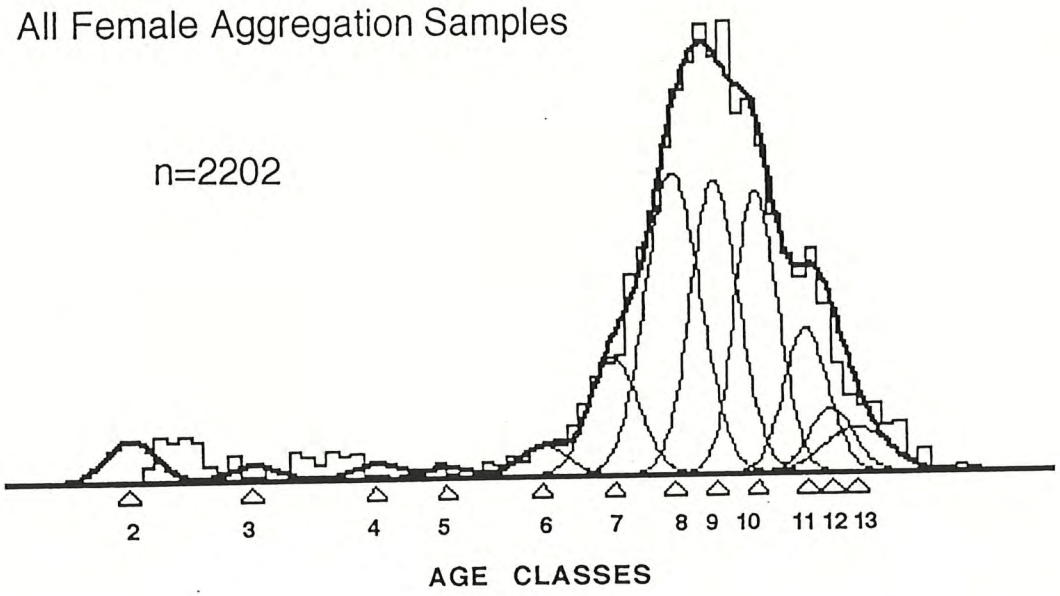


Figure 9b

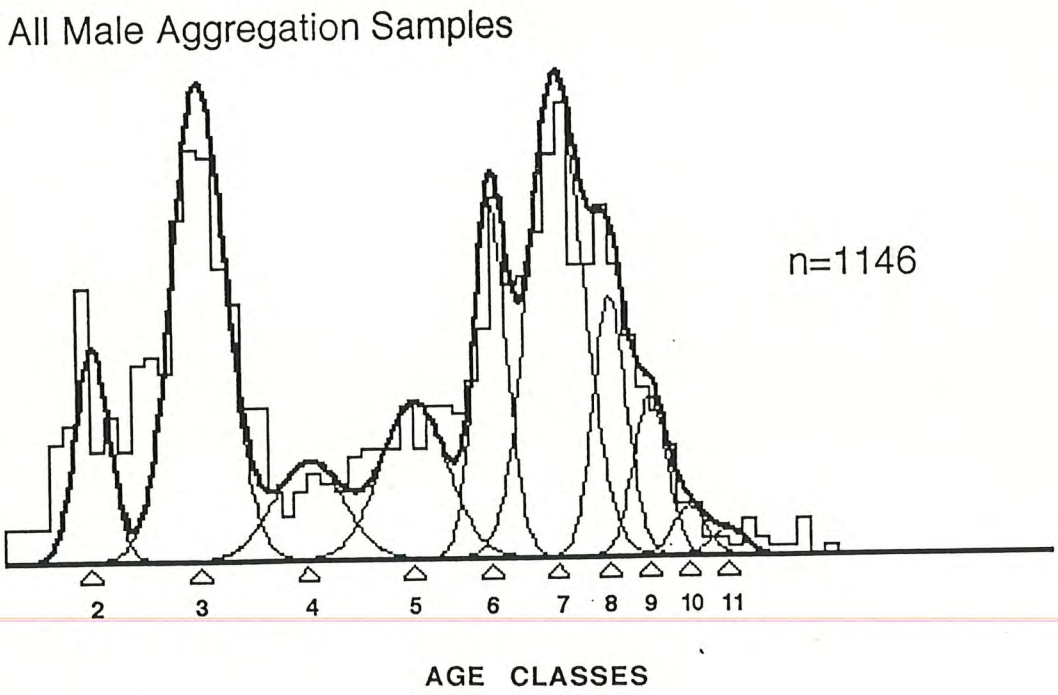


Figure 9.
Aggregate length frequency histograms of (**a**) female and (**b**) male gemfish sampled from aggregations, component age classes have been described using the Mix analysis constrained to documented growth rates (Rowling 1990).

A total of 1 146 male gemfish were measured in samples taken from spawning aggregations of gemfish (Figure 8b). The length of the primary mode in these samples was 76 - 78 cm, although an important secondary mode occurred at 52 - 54 cm. The 60 - 70 cm size classes were poorly represented.

Males numerically comprised 34% of the pooled aggregation samples and 29% of >60cm fish.

A constrained Mix suggests that 3 and 7 year-old male gemfish were most numerous in the samples, with the 5, 6 and 8 year classes comprising significant proportions (Figure 9b).

The aggregation samples collected varied considerably between shots, ports and over time (Figure 10a-e).

1.5.3.1 Variation in Size Structure of Aggregations through the Season

5 July, Ulladulla

A total of 313 gemfish were measured in samples taken from a single boat survey off Ulladulla on 5 July (Figure 10a). The three hour long shots were towed between 0730 and 1300 on the main Ulladulla trawl ground in 225, 200 and 245 fthm. Catch rates were 96, 184 and 1 053 kg/h respectively, significantly higher than previous 1993 catch rates for gemfish of Ulladulla. The catch rates and size structure of these catches prompted the Ulladulla fishermen to request a stratified survey for 8 July as they took them to indicate that spawning gemfish had begun to aggregate around the main Ulladulla trawl grounds.

In contrast to previous survey catches off Ulladulla the largest size classes of gemfish (>80 cm) dominated (55%) catches rather than the smallest size classes.

The modal length of the 202 females measured was 84 - 86 cm. Constrained analysis with Mix indicates strong (66%) representation of 8 - 12 year-old female gemfish (Figure 11a) and some (18%) representation of 2-3 year-old females. Year classes 4-6 were poorly represented (16%) in the context of their prior dominance in spawning aggregation catches.

The 111 males measured were predominantly (77%) <60cm in length, corresponding to 2 and 3 year-old males (Figure 12a). Larger >60cm males, mainly 6-9+ comprised only 20% of the measured males. Four and five year-old size classes were particularly poorly represented.

While the size structure of the female catch contrasted with that of previous non-aggregation catches, the male catch structure remained consistent with previous catches of males.

While males were 36% of the samples (Figure 13a), only 13% of the gemfish >60 cm were male (Figure 13b) and >60 cm males only comprised 22% of the male catch (Figure 13c).

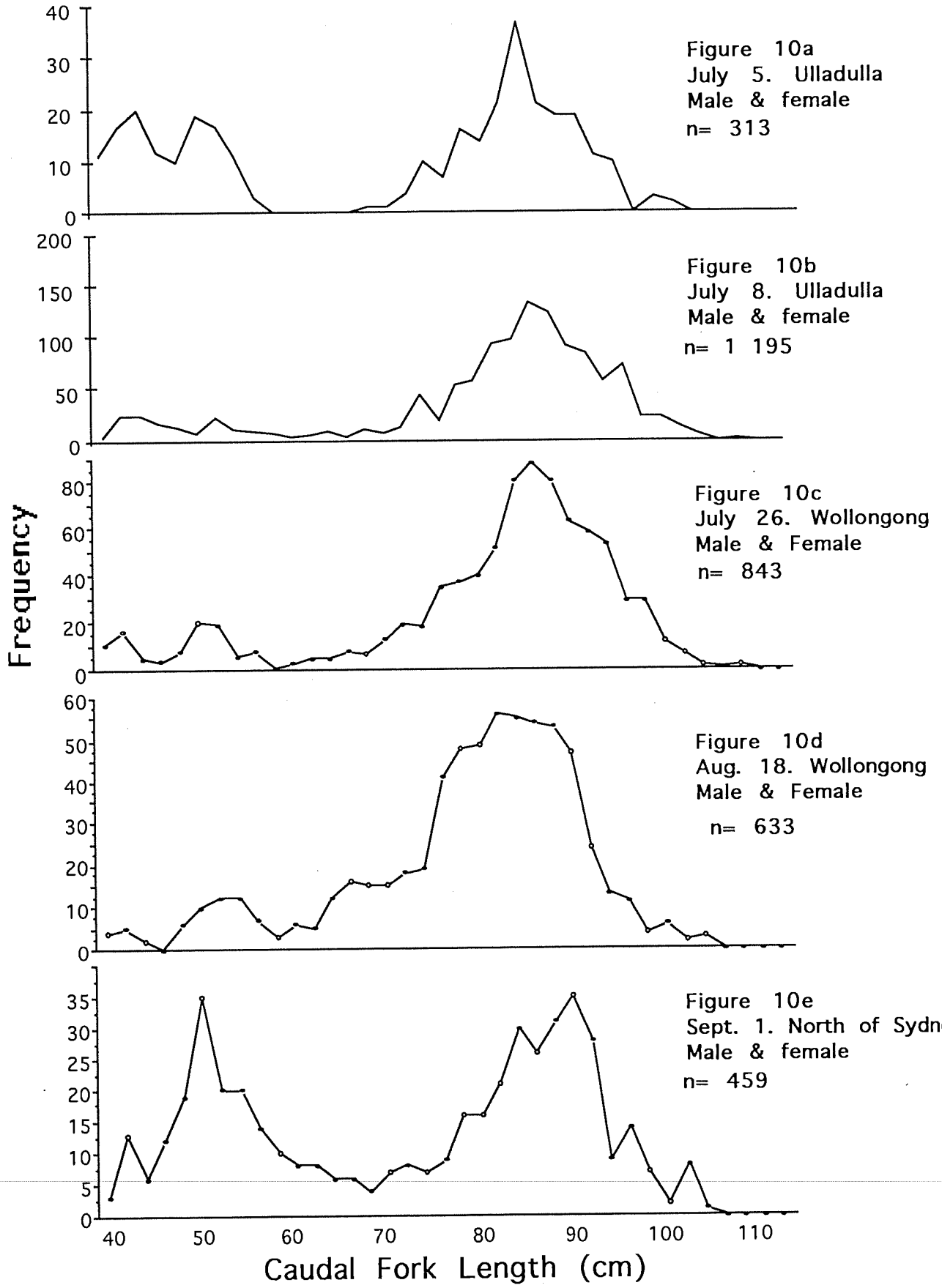
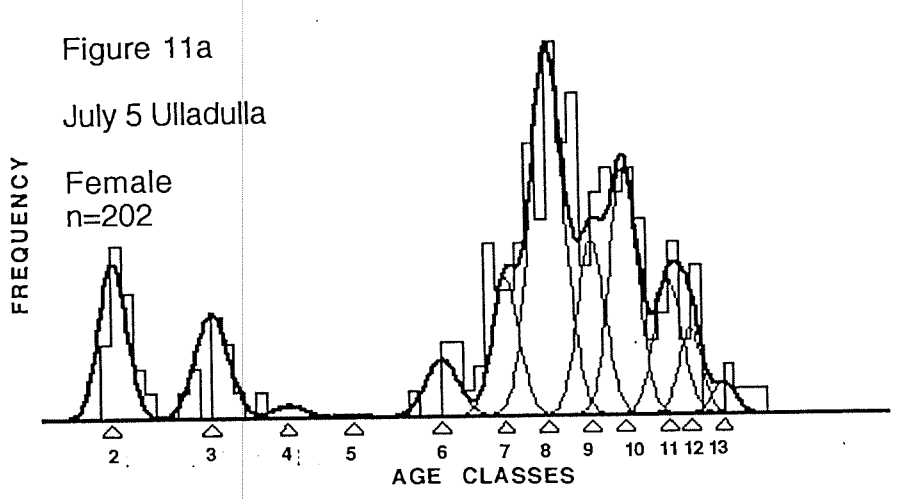
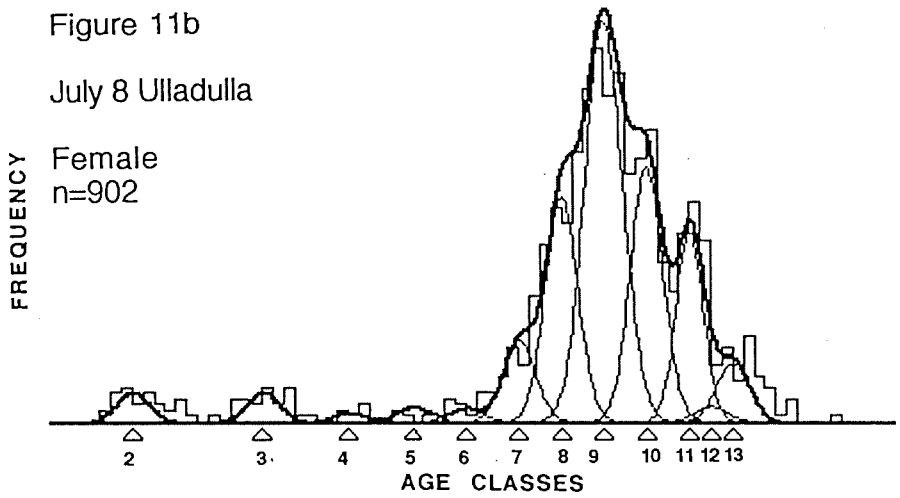
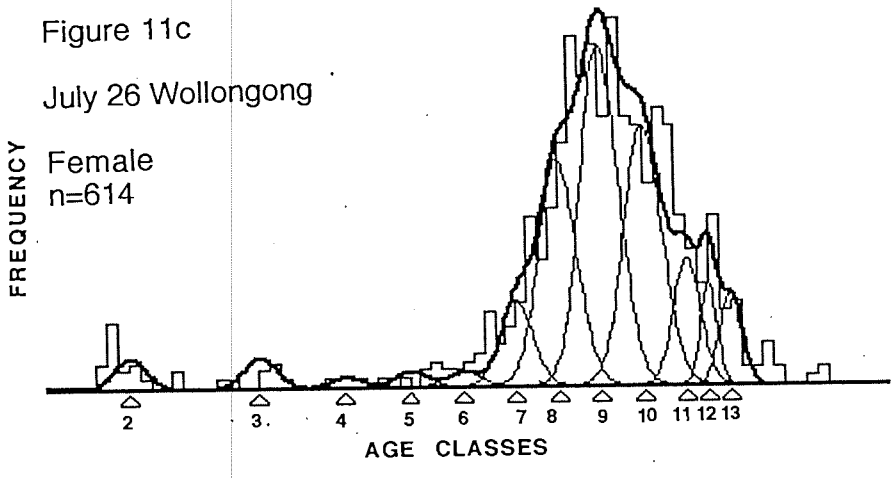
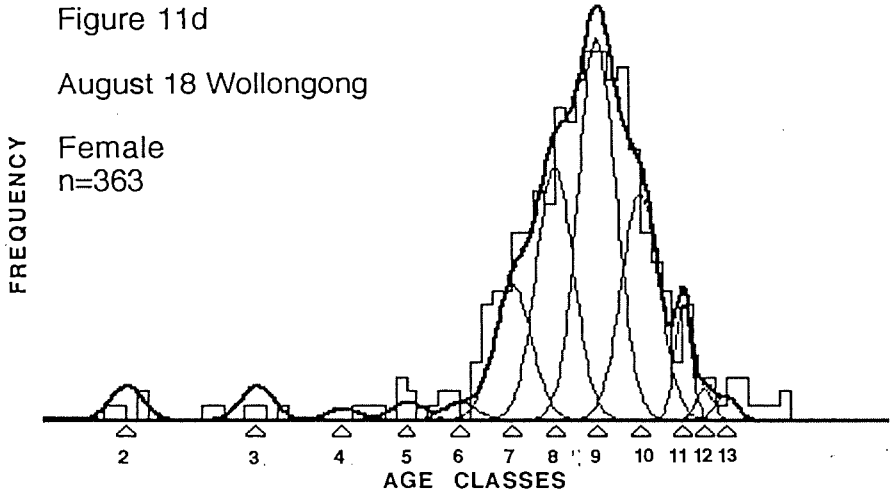


Figure 10.
Length frequency histogram of all gemfish sampled from aggregations off (**a**) Ulladulla 5 July, (**b**) Ulladulla 8 July, (**c**) Wollongong 26 July, (**d**) Wollongong 18 August, (**e**) North of Sydney 1 September, 1993.









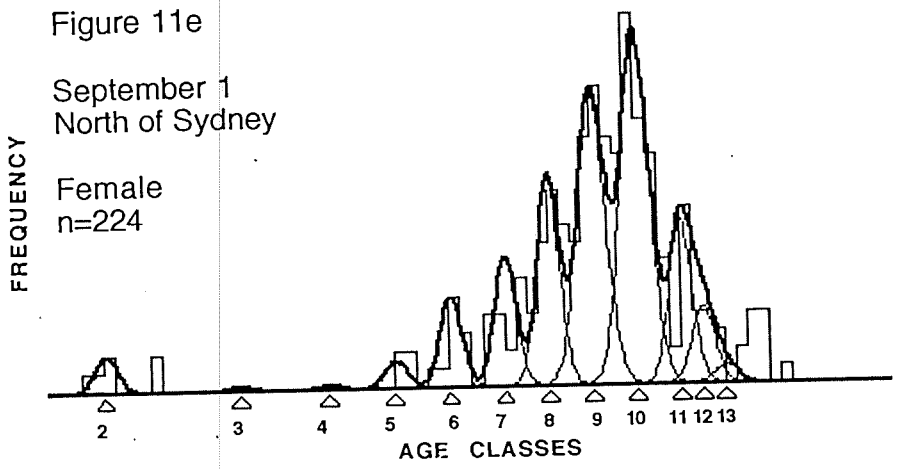
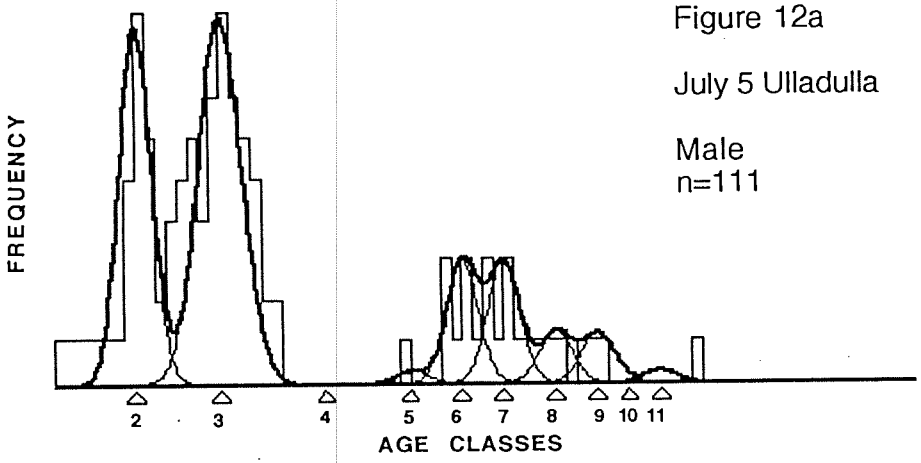
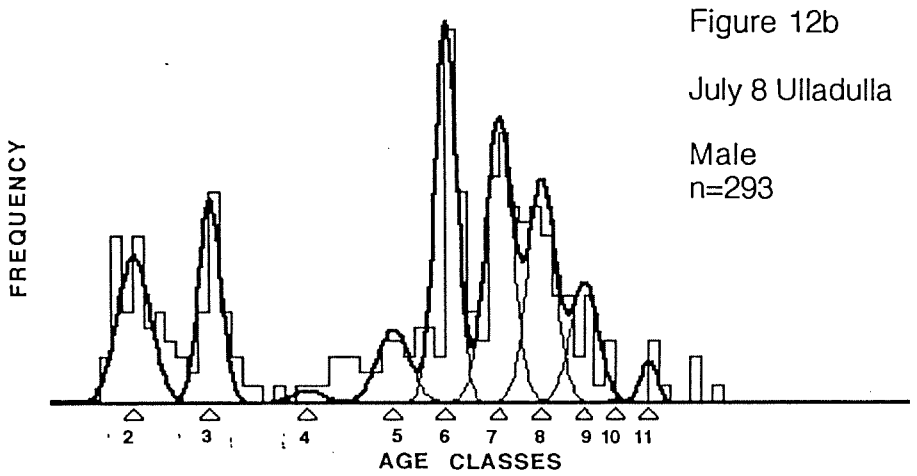
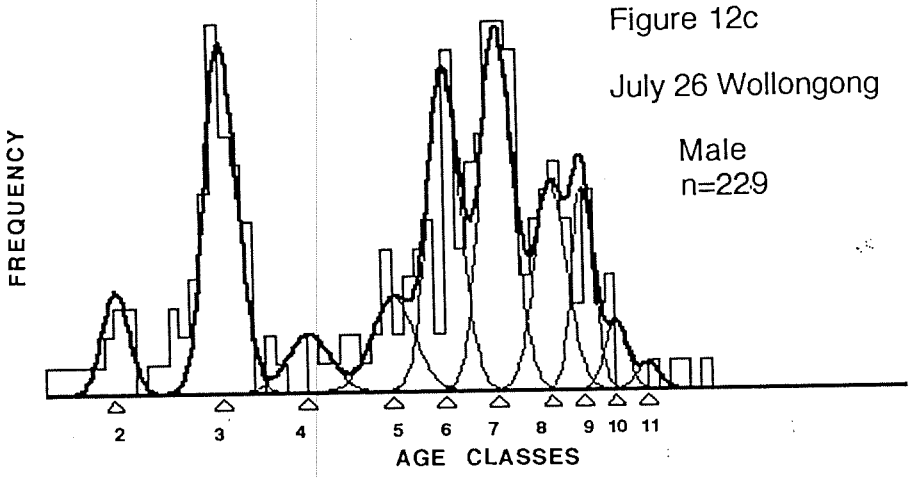
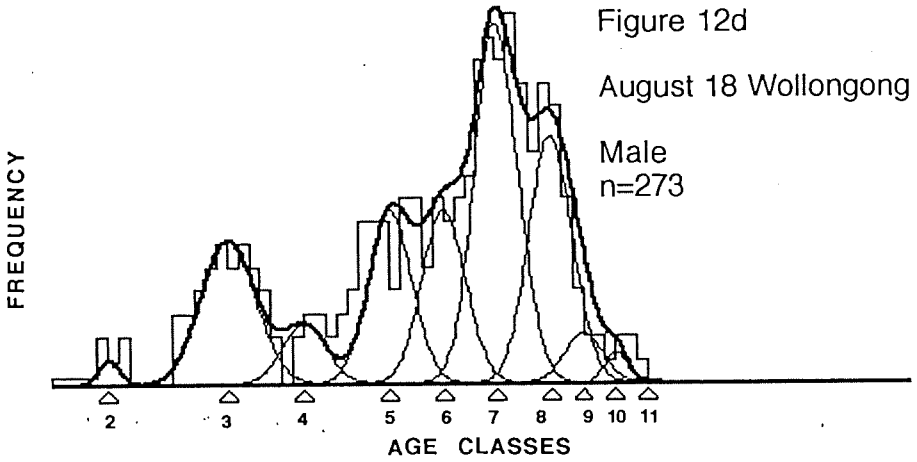


Figure 11.
Length frequency histogram of female gemfish sampled from aggregations off (**a**) Ulladulla 5 July, (**b**) Ulladulla 8 July, (**c**) Wollongong 26 July, (**d**) Wollongong 18 August, (**e**) North of Sydney 1 September, 1993 showing the component age classes described using a constrained Mix analysis.









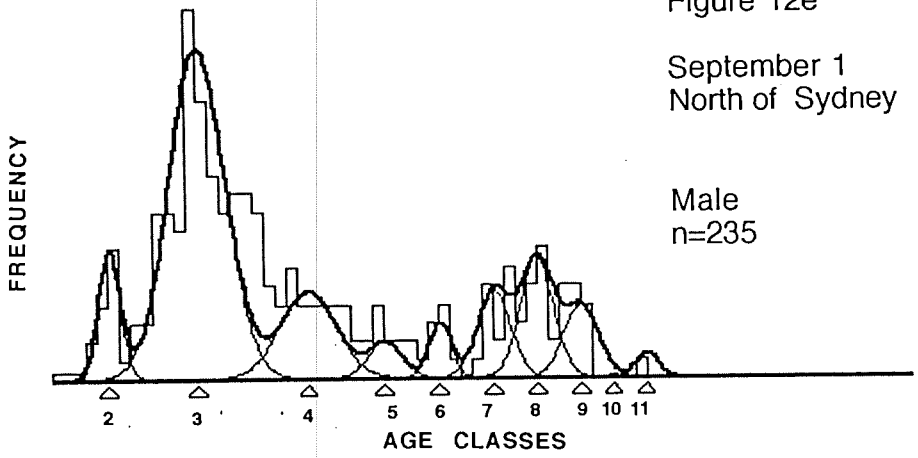


Figure 12.
Length frequency histogram of male gemfish sampled from aggregations off (**a**) Ulladulla 5 July, (**b**) Ulladulla 8 July, (**c**) Wollongong 26 July, (**d**) Wollongong 18 August, (**e**) North of Sydney 1 September, 1993 showing the component age classes described using a constrained Mix analysis.

Figure 13a

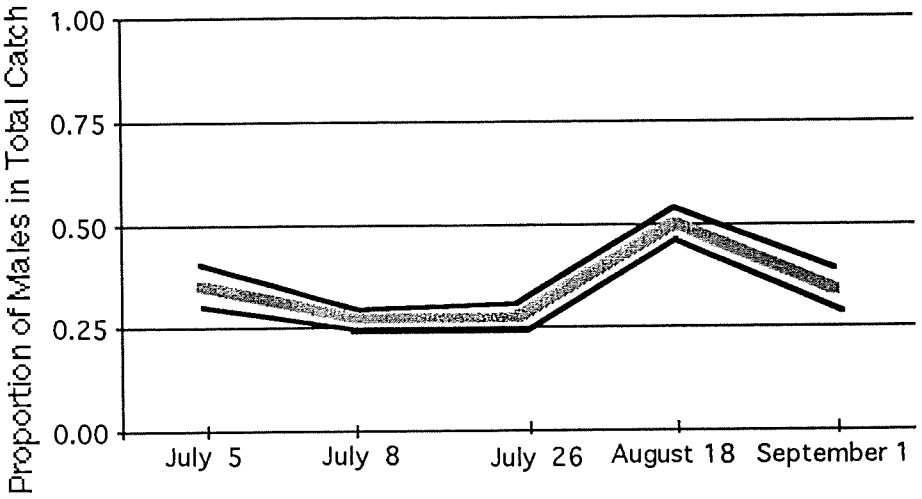


Figure 13b

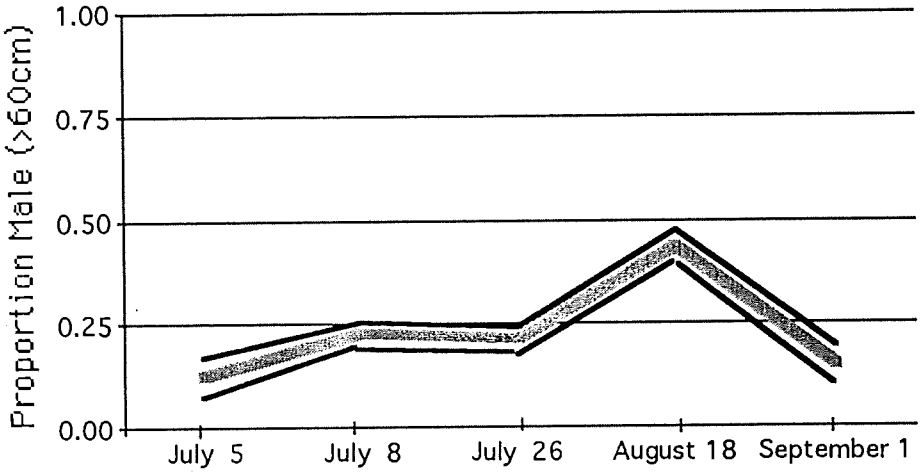


Figure 13c

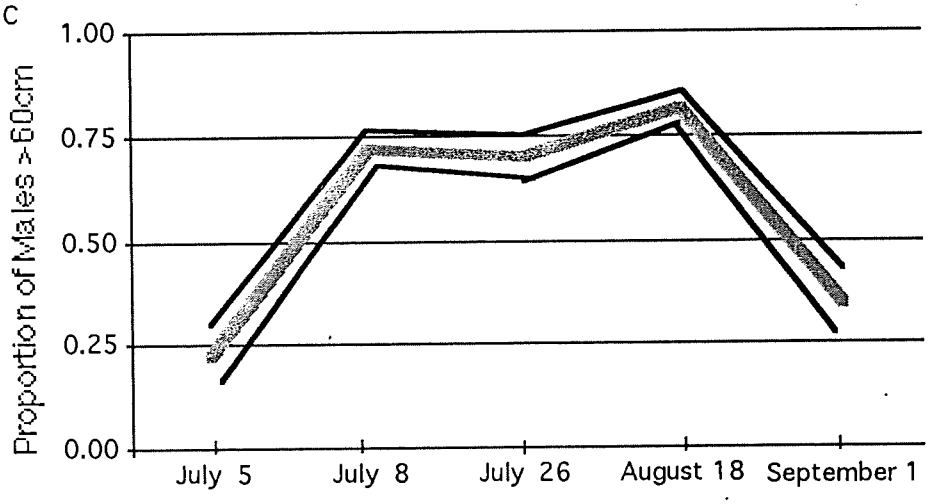


Figure 13.

The proportion of aggregation samples on 5, 8 & 26 of July, 18 August, and 1 September, (a) comprised of male gemfish, (b) the proportion of >60 cm gemfish comprised of males and (c) the proportion of male gemfish comprised of >60 cm fish. (95% confidence intervals shown)

8 July, Ulladulla

A total of 1 195 gemfish were measured in samples taken in six shots on the main trawl grounds off Ulladulla on 8 July (Figure 10b). Shots were conducted in 190, 200 and 220 fthm starting at 0730, and in 160, 180, 245 fthm starting at 1030. Catch rates were highest in the morning: 4 412 kg/h, 2 835 kg/h, 915 kg/h in 200, 190 and 220fthm, respectively. In the later shots the highest catch rate, 1 017 kg/h, was achieved in 245 fthm, 915 kg/h in 180 fthm and only 83 kg/h in 160 fthm.

The catches were numerically dominated (61%) by large 8 - 12+ females (Figure 11b). The modal length of the 902 females measured was 86 - 88 cm.

Over all size classes males were 28% of the catch (Figure 13a). As a proportion of >60 cm fish, males were numerically 23% of the catch (Figure 13b). However, in contrast to the previous 5 July catches, the 293 males measured were predominantly (71%) large (78 - 90 cm), 6 - 9+ fish (Figure 13c).

26 July, Wollongong

Six 2 h shots were conducted off Wollongong on 26 July. Catches rates were 150 - 250 kg/h in the first shots (start time: 0830) in 185, 195 and 205 fthm. In the afternoon shots (start time: 1200) in 205, 210 and 215 fthm, catch rates were higher, 1200 - 1500 kg/h.

A total of 843 gemfish were measured (Figure 10c). The samples were approximately 70% >80cm, 18% 60 - 80 cm and 12% 40 - 60 cm fish. The aggregated length frequency histogram looks extremely similar to that of 8 July from Ulladulla.

A total of 614 female gemfish were measured in these samples (Figure 11c). The size composition of these samples were similar to that observed off Ulladulla 8 July (Figure 11b) with a modal length of 86 - 88 cm (9+). The length classes 90 - 96 cm (10-12+) continued to be well represented.

A total of 229 male gemfish were measured (Figure 12c). The histogram was obviously bi–modal, with the larger mode at 76 - 78 cm (7+), and the smaller major mode at 50 - 52 cm (3+). Less prominent male modes were also evident at 72 - 74 cm (6+), and 82 - 88 cm (8 - 9+).

Males comprised 28% of the total samples (Figure 13a), 22% of fish >60cm (Figure 13a). As with the samples of 8 July the catch of males was principally (69%) of larger (>60 cm) rather than small (<60 cm) males (Figure 13c).

18 August, Wollongong

Four two-hour shots and one four-hour shot were conducted off Wollongong on 18 August. Catch rates were low in the morning (60 - 65 kg/h) in 205 - 220 fthm and highest 479 - 1 620 kg/h in the afternoon (start time: 1245) in the same depths. A total of 633 gemfish were measured.

were measured.

Medium size classes of gemfish (60 - 80 cm) were more prominent (28%) in these catches than in any others of the survey (Figure 10d) and the broad left hand shoulder that this imparts to the aggregated length frequency histogram puts the 18 August histogram in contrast to those of 5, 8 & 26 July.

A total of 363 female gemfish were measured in these samples and their modal length was 86 -88 cm (9+), similar to previous samples (Figure 11d). Close inspection of the histograms indicates that the larger (>90cm) size classes of females (>10+) are proportionally less abundant than in earlier surveys.

A total of 273 male gemfish were measured (Figure 12d) in these samples and the male modal length was 76 - 78 cm (7-8+). These were the only aggregation samples in which the 65 - 75 cm size of class of males (5-6+) was a significant (12%) component of the samples. Although, interestingly, these size classes were also relatively more abundant in non-aggregation and opportunistic commercial samples taken at Wollongong during the period 2 - 20 August (Figure 7a).

Males comprised 50% of the catch overall (Figure 13a) and 44% of fish >60 cm (Figure 13b), the highest proportion recorded. Of the males, 81% were >60 cm (Figure 13c).

1 September, North of Sydney

A total of 459 gemfish were measured from catches taken from the gemfish aggregations north of Sydney around 1 September (Figure 10e). These catches were not part of the structured surveys but part of commercial operations. Samples were measured as the two vessels that had fished the same aggregation unloaded. The fish had been loaded without sorting and were sorted as they were unloaded. A sample of each vessel's catch was measured prior to sorting and unloading.

The skippers estimated catch rates at around 2 000-4 000 kg/h.

The largest size class of gemfish (>80 cm) comprised 46% of the samples, the lowest proportion in catches from spawning aggregations. Mature, running ripe, small fish (40 - 60 cm) comprised the largest proportion (36%) of spawning catches observed.

A total of 224 female gemfish were measured (Figure 11e), principally ranging from 75 - 100 cm (6-12+). Their modal length was 90 cm (10+).

A total of 235 males were measured (Figure 12e). The largest proportion (48%) of these fish was 50 - 52 cm (3+). Relative to previous catches there was also strong representation (13%) of 60 - 65 cm gemfish (4+). The 6-9+ (70 - 80 cm) which dominated males catches 8 July, 26 July and 18 August were poorly represented amongst the males (26%).

13b). The males in the catch were mostly small (<60 cm), only 35% of the males were >60 cm.

1.5.3.2 Variation in Size Structure of Aggregations by Depth and Shot

Depth stratified sampling of gemfish aggregations only occurred on three occasions: 8 & 26 July, and 18 August. Figures 14 - 16 show the length frequency histograms for males and females from the individual shots within each of these stratified samples. Constrained Mix analyses have been performed for samples of approximately 100 individuals or more.

On the basis of these limited samples little depth related size structure could be discerned. There is some trend towards smaller gemfish being more prevalent outside the main gemfish depths of 190 - 210 fthm. The larger catches from the central depths were generally relatively uniformly composed of larger fish, while small catches contained a broader range of size classes.

The data from 18 August most clearly show this trend and also illustrate the diurnal variability of the aggregations (Figure 15). On that day shots were repeated in the morning and the afternoon in 205 and 210 fthm. The morning shots recorded small catches, including <60 cm fish, while the afternoon recorded larger catches with few <60 cm fish.

Aggregations were never simultaneously sampled off different ports so nothing can be concluded about variability between ports. However, the similarity of the length frequency histograms and sex ratios collected on 8 July off Ulladulla and on 26 July off Wollongong suggest that these were the same or at least similar bodies of gemfish.

1.6 Discussion

1.6.1 Size Structure in the 1993 Gemfish Run

The onset of the annual winter gemfish season off southern NSW is recognised by industry as the increase of background levels of gemfish (as recognized by catch rates) in 180 - 220 fthm. At this time other winter species such as mirror dory also begin to be taken. The increase in background levels of gemfish in early winter is observed in all ports south of Sydney, but not necessarily with exactly the same timing.

In 1993, the size distribution of winter gemfish caught outside the main aggregations was clearly bi-modal. The dominant mode was comprised of immature 40 - 60 cm fish (2 - 3+), the lesser mode was principally of larger 75 - 90 cm fish (7 - 12+). In these catches most of the older fish were mature but not in spawning condition, a few fish were in condition and a few spent fish were also observed.

Figure 14.
Length frequency histograms for males and females for each shot during the stratified survey off Ulladulla, 8 July, 1994. Where sample size approximate 100 or greater component age classes have been described using a constrained Mix analysis.

Figure 15.
Length frequency histograms for males and females for each shot during the stratified survey off Wollongong, 26 July, 1994. Where sample size approximate 100 or greater component age classes have been described using a constrained Mix analysis.

Figure 16.
Length frequency histograms for males and females for each shot during the stratified survey off Wollongong, 18 August, 1994. Where sample size approximate 100 or greater component age classes have been described using a constrained Mix analysis.

Figure 14 July 8 Ulladulla

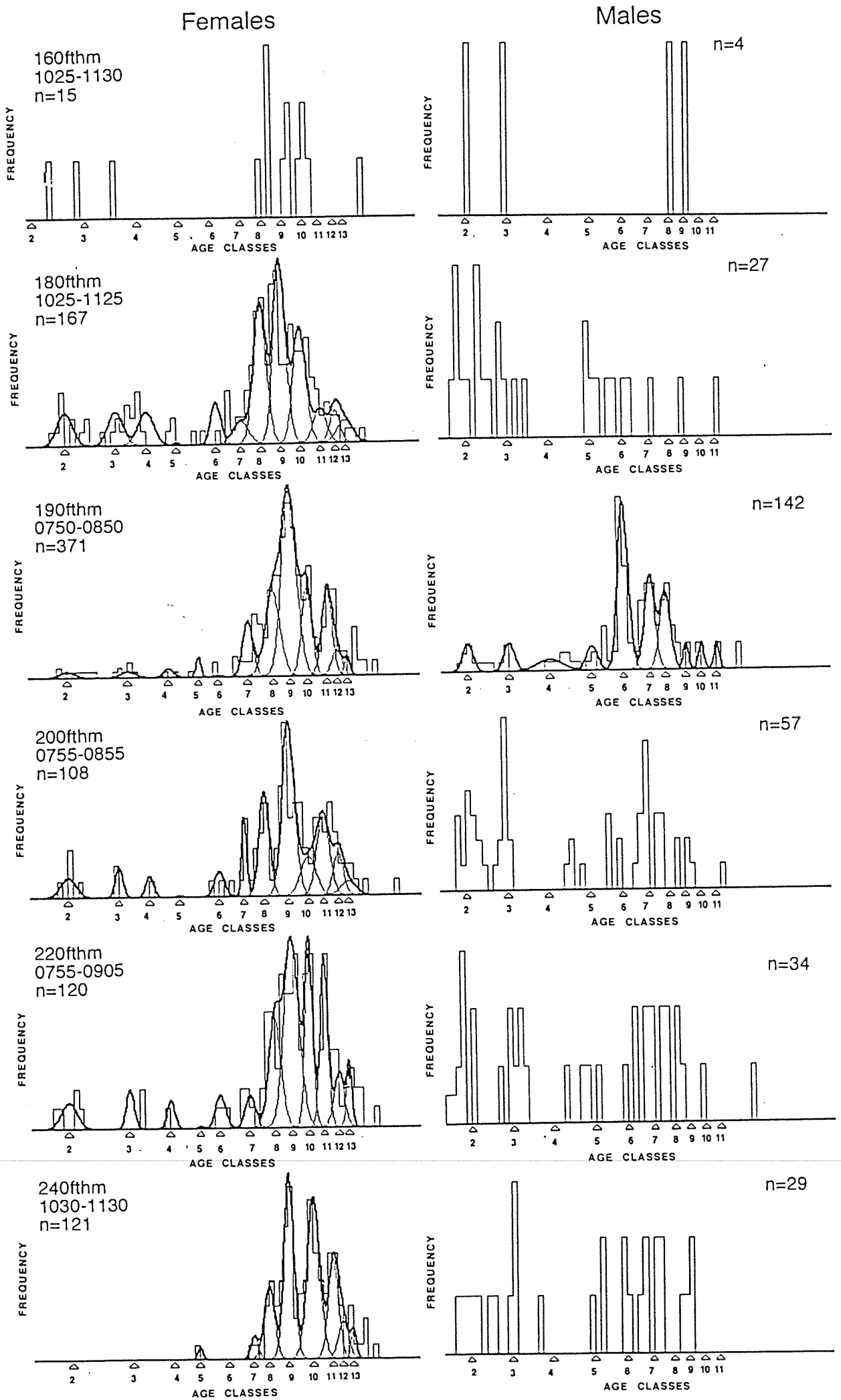


Figure 15 July 26 Wollongong

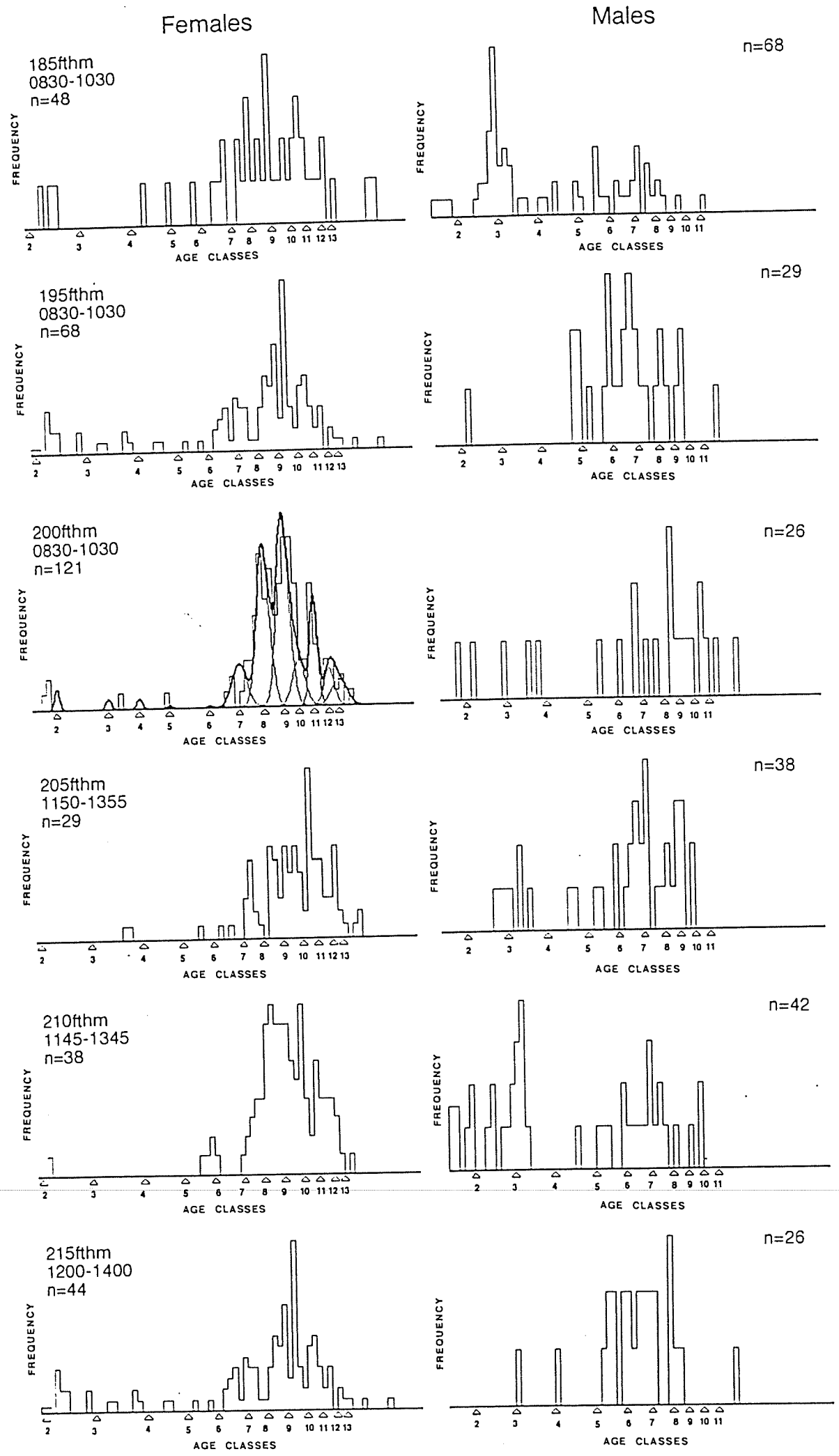
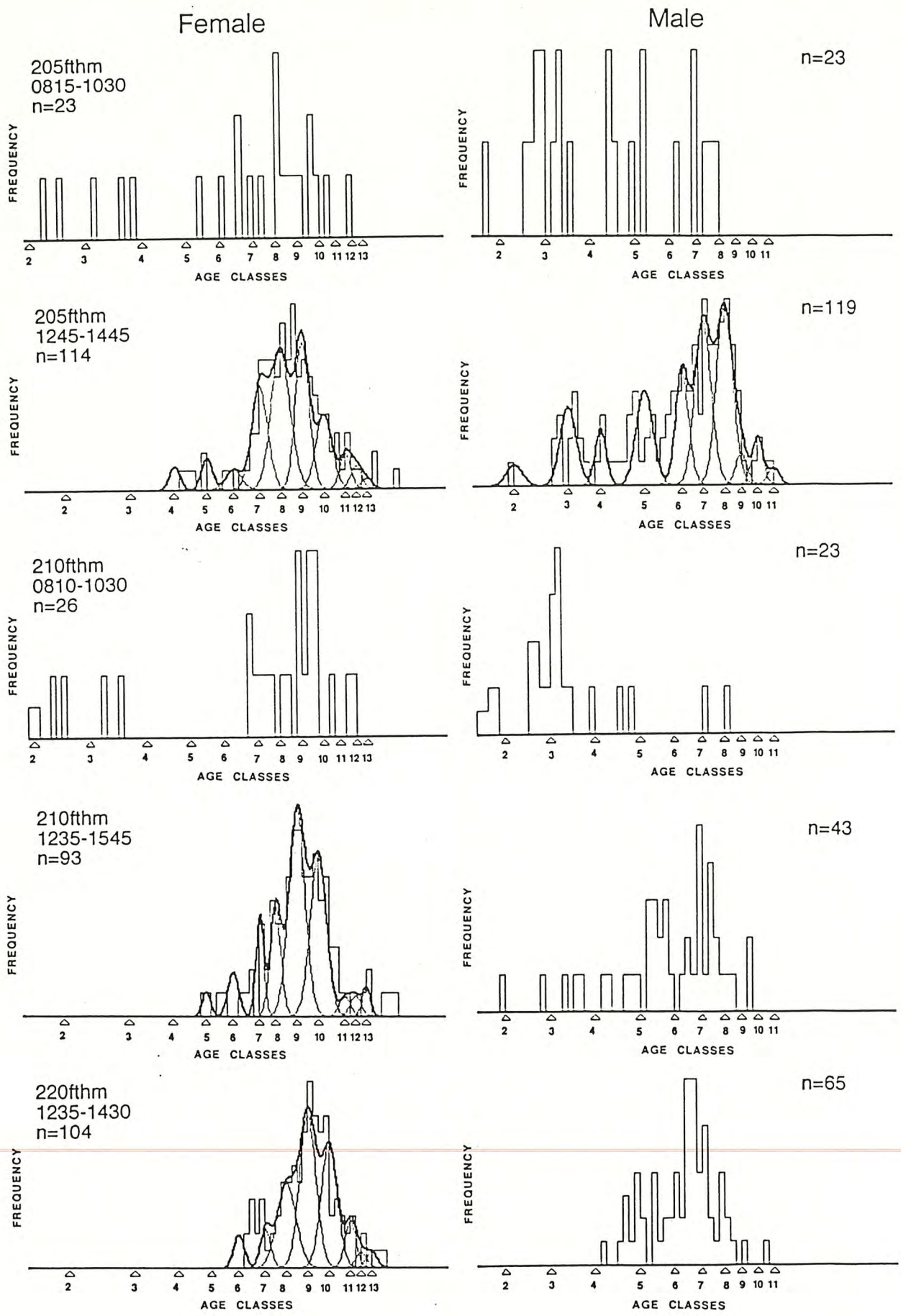


Figure 16 August 18 Wollongong



Aggregations of gemfish were sampled during 1993 off Ulladulla (5 & 8 July), Wollongong (26 July, 18 August) and north of Sydney (1 September). However, depth stratified samples were only obtained on three occasions: 8 & 26 July, 18 August.

In the context of this study it could be asked what objective basis has been used for selecting these surveys, rather than any others, as being representative of gemfish aggregations rather than the background population? These dates and locations have been selected because it was only on these surveys that catch rates exceeding 150 kg/h were achieved, and on each of these surveys at least one survey shot recorded catch rates in excess of 1000 kg/h.

In general the size structure of aggregation samples was relatively stable over all the survey shots, however this is not to negate the fact that shot by shot catch rates and size structure varied greatly. Both the main modes observed in non-aggregation samples were also observed in aggregation samples. In contrast to the background population of gemfish, aggregation catches were principally (approx. 65%) comprised of large (>80 cm) gemfish. Small (40 - 60 cm) and medium size (60 - 80 cm) gemfish were each approximately 20% of the catches.

The consistently poor (approx. 20%) representation of the 60 - 80 cm gemfish is noteworthy. During the 1970s - 1980s these size classes dominated catches.

1.6.2 Temporal Variability in the 1993 Eastern Gemfish Run

The limited number of samples on actual aggregations restricts the ability of these results to quantitatively describe structure of any type within the aggregations over time and space. On the surface the results apparently indicate aggregate stability over time and space despite evident variability between shots. But because of their restricted nature it must be expected that a result suggesting no size trends will be easier to support with these data than a result indicating systematic trends over time and space.

In 1993 the size composition of individual catches did not appear to vary smoothly around some average composition or along depth gradients. Instead, variability seemed to be stepwise or quantum in nature. Large size (>60 cm - principally >80 cm) gemfish either dominated catches, or a background scatter of all size classes was present with small, mainly male, gemfish (<60 cm) predominant.

This stepwise statistical property of variability in the size proportional data is difficult to analyse quantitatively. The quantitative analysis of size structure in the gemfish fishery is also complicated by the strongly bi-modal nature of the stock's size structure at the present time. This prevents the comparison of simple mean sizes and the use of other simple statistical tests based on the assumption of normal distributions. With so few visible trends, exhaustive quantitative analysis was not considered warranted.

None of which is to say that there are no interesting features in the data.

The most significant variation observed in the aggregation catches involved the size structure and proportion of the male gemfish participating in aggregations (Fig. 13a-c).

The 5 July length frequency histograms show that a previously undetected group of large female gemfish had moved onto the main Ulladulla trawl grounds. However, of the mature, fully recruited size classes (>60 cm) males were only 13% (Fig. 13b), and just 22% of the male gemfish measured were >60 cm (Fig. 13c).

On 8 July the large >60 cm males were detected in increased amounts on the same trawl grounds; comprising 23% of the >60 cm fish caught, and 71% of the males caught. These larger males remained the dominant (69%) size groups of males on 26 July and 18 August (81%). The proportion of males in the >60 cm catch peaked at 44% in the surveys of 18 August and, interestingly, these elevated proportions of mature males were also detected in the background population of gemfish off Wollongong during most of August.

These data, showing that the proportion of mature males within the catch rose through until 18 August, suggest that mature female gemfish moved onto the trawl grounds before the mature males in 1993.

By 1 September the proportion of >60 cm individuals in the male catch had declined to 35%. As a proportion of the total >60 cm catch males fell to 16%. The ratio of >60 cm females to <60 cm females also fell, suggesting that by 1 September mature gemfish of both sexes had begun moving away from the aggregations by that time. This supposition is consistent with the observation that most of the gemfish in that aggregation were almost fully spent, which suggests that the spawning season had been virtually completed by that stage.

Male gemfish are smaller than females at any given age and because of this the mature male population will on average be smaller than the female population. The observation that female gemfish arrived on the trawl grounds before male gemfish implies that larger mature gemfish arrive on the grounds before smaller mature. While this was observed to have only a marginal influence on the aggregated size structure of the catch in 1993, this finding does support the assertion of NSW industry that larger gemfish arrive on the NSW shelf earlier in the spawning season than smaller gemfish.

Industry's claim of a first and second run of gemfish, with the first being larger fish and the second more of a mixture of sizes, can undoubtedly be explained in terms of the larger female gemfish arriving on the trawl grounds prior to the smaller males.

Variability in the size of spawning fish during the spawning season has been observed in a number of other species, including Australian salmon (Lenanton *et al.* 1991), west coast Tasmanian blue grenadier (T. Koslow, CSIRO. pers. comm.) and, perhaps most pertinently, northern New Zealand gemfish (Langley *et al.* 1990).

1.6.3 North-South Variability in Size

There was a clear north-south size structure in the background population of gemfish during July and August 1993. Off Wollongong, in the north, >80 cm gemfish were numerically most abundant (55%) and least abundant (<5%) off Eden - Bermagui, in the south. This confirmed the observations of industry (Wright - Section 2, this report) and those of Rowling (1990).

However, within these data there is too little spatial spread to make this comment with regard to catches taken from spawning aggregations.

1.6.4 Variability in Size by Depth

Data gathered by this study with respect to depth variability are the most equivocable. Away from spawning aggregations a trend with depth was sometimes visible. Small 2 - 3+ fish were generally taken above the edge of the shelf (above 160 - 180 fthm), extending into shallower water (towards 100 fthm) in reduced numbers. Outside of aggregations larger, mature fish were generally taken below 180 fthm.

Little evidence of depth related size structure could be found during the runs of gemfish. Fine scale temporal and spatial variability was observed but little coherent structure could be discerned from the data. Small gemfish tended to dominate in catches from depths not occupied by the main aggregation.

1.6.5 Targeted Fishing by Size

This project was established to examine claims that through their fishing pattern fishermen could influence the size of gemfish being caught. These claims were stated so strongly in some situations as to suggest that fishermen might virtually target specific sizes of fish.

The results of this study found little predictable size structure to the gemfish aggregations and it seems certain that little targeting of specific size classes within these aggregations could have occurred in 1993.

These results suggest that broad scale changes in fishing practice such as north-south or shallow-deep effort shifts, or the concentration of catching into the beginning or end of the season by management regime, should be expected to impact the size composition of overall catches to some extent. Given the evidence of these surveys, however, any claims that specific size classes of gemfish can be targeted with a specific shot are apparently well overstated.

On the basis of these results, the overall size structure of the Eastern Australian gemfish stock documented by FRI over recent years must be accepted as approximating the actual size structure of the stock.

This being said, it is likely that if the size structure of the gemfish were more normal the size trends described by industry may have been more visible. This project looked for trends in

the proportion of 60 - 80 cm fish relative to the abundance of >80 cm fish but concluded that 60 - 80 cm gemfish are generally in low abundance. Logically, the overall lack of 60 - 80 cm gemfish will preclude trends involving this size class from being observed. In other words, the trend could not be observed in 1993, even if it normally exists, because the size class giving rise to the trend is at present so poorly represented in the stock.

1.6.6 Implications for the Existing Stock Assessment

While these results can be interpreted as providing support for industry's observations that the size structure of the gemfish stock varies temporally and spatially, it remains evident from these results that these affects have not obscured the broader population trends in the gemfish stock.

In this respect, it should be noted that while not identical the histograms prepared as a part of this study are similar to those prepared by Kevin Rowling of FRI in 1993, using market measuring data.

These histograms are uncharacteristically bi-modal in relation to historic catches from this winter fishery. The most prominent modes occur around 50 cm and 80 cm. The 60 - 80 cm size class, which dominated catches through all but the most recent years, was poorly represented in all survey catches. While the ratio of the different size classes varied considerably between shots, even the survey catches with the highest proportions of these "missing" medium size fish had primary modes at either 50 cm or 80 cm. It is probable that some commercial by-catches had primary modes in the 60 - 80 cm size range, however the failure of the survey to detect this size structure indicates that while schools of this size class may exist they a few in number compared to other size classes.

From this size structure it is clear that levels of recruitment have varied considerably through the history of the fishery. Recruitment variability is evident both in the relative lack of 60 - 80 cm gemfish, in comparison to previous years, and the large numbers of 50 - 60 cm gemfish recorded in survey catches. The length frequency histograms of survey catches are consistent with the view that recruitment of eastern gemfish was poor between 1987 and 1989.

On the positive side, 2 - 3 year-old gemfish are now strongly represented in catches, suggesting that recruitment may have returned to more normal levels.

Section 2: Anthropological Participation in the Gemfish Research Program

2.1 Introduction

The notion that there could be an anthropological contribution to the gemfish project resulted from the perception, by the fishermen and by Dr Prince, that the gemfish "story" was as much about the people who catch the fish as about the biological problems with the fish stocks. Many of the fishers were particularly concerned that they should be given the opportunity to have their perceptions of the gemfish problem documented. Fishers had views about the behaviour of gemfish, and they also had views about the manner in which they thought that the data upon which the gemfish quotas were based, were biased.

As a result of these concerns, Dr Prince initially considered that the project should include a thorough anthropological study. Such a study would have fully documented the fishermen's perceptions and knowledge of the gemfish aggregations, and their capacities to catch the fish. However, in the negotiations leading to the award of the contract for the study, the anthropological component was not supported and so the formal study of the human side of the fishery was dropped. Nonetheless, there remained a need to have suitably experienced people to carry out the length frequency measurements on boats during the survey, and I was engaged for the purpose of assisting in the length-frequency surveys. I am an anthropologist who specializes in the study of commercial fisheries, and I have had some previous experience collecting length-frequency data.

My principal duty to the project was to provide practical assistance to the gemfish length-frequency study, but I also interviewed fishers in order to document what I could of their perceptions of the fishery and their feelings about its present predicament.

A good deal of mistrust had developed between many of the fishers and both State and Federal government agencies, and it was hoped that my participation in the project might help to break down some of the antagonistic relationships that had become apparent, by giving a larger number of fishers the chance to air their concerns directly with a project member.

I had lengthy interviews with seventeen fishers. Most of the interviews were at least two hours in duration and some were spread over two or more days. Most of these interviews were taped. Interview subjects were chosen by a combination of methods; some were simply opportunistic, such as the crew of a boat from a northern port which was on the slips in Ulladulla; some fishers came recommended by other fishers as people who would be worthwhile to interview; other fishers were interviewed after I had come to a realisation, after spending some time in a port, that these were key fishers in that port, in terms of fishing capabilities, or because they were politically important, or because I had reason to believe they would make an interesting contribution to the gemfishing story. There was no

attempt to contrive a sample that would be in some way quantifiably "representative", since the main aim of the exercise was simply to report the views of a range of fishers. In addition to the interviews I also had many more less formal encounters with fishers in the coops and on the various fishing wharfs of the New South Wales southern coast.

No claims are made for this report to be a rigorous treatment of the social aspects of the fishery, which would have taken a much more directed research effort. However, this less formal approach has the capacity to give voice to a range of points of view about the state of the fishery, and some of these are reported below. In terms of style of presentation, I have made extensive use of direct quotes from the tape-recorded interviews, or from my notes taken at the time. My purpose is to try to allow the fishers to have as much of their own "voice" as is possible. I usually quote verbatim, although I have made some alterations to make the quotations more readable. Where words are added I have included them in square brackets.

2.2 History of the Gemfish Fishery

Since demersal trawling began in 1915, gemfish (*Rexea solandri,* Gemphilidae) have been caught off south eastern Australia.[1] Present day fishers remember catching gemfish as a by-catch in the 1940s. However, it was not until Tony Musumeci of Wollongong, who together with his brother Vince, began exploring the slope of the continental shelf in 1967 that the modern gemfish fishery was established:

> We were told, by an old man who used to work with steam trawlers in the fifties, that along the shelf there's a lot of clear ground. We took his advice and went there. In about 100 fathoms we started off, working off Sydney. We caught mixed species fish, like sting ray, haddock, redfish and dog shark.
>
> We worked damned hard and got good money for our catches in the deep water. As you know, wherever the fishermen see money they stick with it. So we started exploring a little further out, and little bit further south, until we started hitting more flathead, more redfish and more dog shark. An now and again we went to 140-150 fathoms and we'd start catching gemfish. Not many, maybe two or three boxes, and they were big mongrels. That was in early June.
>
> Then I said to my father and my brother, "you know it's good to try off Wollongong".

---

1 K.R. Rowling, 1990. Changes in the Stock Composition and Abundance of Spawning Gemfish Rexea solandri (Cuvier), Gempylidae, in South-eastern Australian Waters, Aust. J. Mar. Freshwater Res. 41, pp 145-63.

The fishery began in earnest almost straight away, with eight boats fishing for gemfish in the first year after the trawlable resource was discovered. Through the late 1960s the fishery remained centred on grounds off Sydney and Wollongong. Fishermen report that in the 1970s they were able to trawl shot after shot in the same location and there were still plenty of fish. More southerly waters began to be fished when fishermen perceived that the gemfish were entering trawlable waters earlier in the south. In the 1970s Ulladulla became a prominent port in the gemfish fishery, and many boats worked from their further south and followed the gemfish up the coast.

A Sydney fisherman:

> We were among the first [Sydney] boats to go out over a hundred fathoms, mainly because the catches were diminishing. We marketed [the gemfish] as hake because we didn't know what they were.
>
> Actually in those years the gemfish used to find us. We didn't go looking for them. We were just out there and we were towing in depths of about 140-150 fathoms. And then they'd come in and one day you'd be catching flathead and red fish and the next day you'd be catching those buggers.

A Bermagui fisherman:

> We got our first boat in 1972 and in about 1977 we started catching gemfish. We were just seine trawling and tuna fishing before that. Then we converted our boats to board trawling.
>
> The first gemfish were caught at Woollongong and Sydney. We lived in Ulladulla at the time and sort of picked up from there. [Then we started working south and] we used to go right down to as far as Eden.

Until the middle 1970s, fishermen say there was little market for gemfish. In 1972, an Ulladulla fisherman remembers getting about nine cents per kilo headed and gutted. He also remembers that the labour involved in heading and gutting:

> We started catching gemfish in 1972. We used to catch them by the hundreds of boxes. And we used to gut every single one of them.
>
> I remember one day down off "the Howe" we got 600 boxes. Twenty ton. We gutted the fish from one o'clock in the afternoon until one o'clock in the morning. There was five of us. Then at one o'clock in the morning we went in and took it off. Unloaded.
>
> We got nine cents a kilo. It wasn't much but because the quantity was there you could make something for it.

> Then after year or two we complained to the processor that we could not supply as much as he wanted unless he would take the whole fish, because there was too much work involved for us to gut it. Finally we started to take the whole fish and he used to fillet it himself. And as time went on the price it comes up. The market opened up. The fish were going well on the local market and also overseas.

It is not a well kept secret that much of the fish destined for the domestic market in earlier years went "on the black", unreported and undetected. Fishers made a variety of comments on the so-called "black market" for gemfish. Some accounts put the total percentage of black market sales as high as 75%, although we have no way of verifying this. Some fishermen remarked to us that they remembered particular incidents where up to 70 tonnes of gemfish would be loaded into semi-trailers destined for the fish and chips trade in Sydney and elsewhere. These estimates seemed to be given credence by others who made comments such as:

> Ten or fifteen years ago you couldn't count the number of semi-trailers that went out of here to the black market.

It would be very difficult to estimate the amount of gemfish that has been caught but has not been shown in official ledgers. However, it is likely that the figure has been substantial in past years. Given the implications for attracting interest from the Taxation Office, it is unlikely that fishermen would be willing to cooperate in any detailed accounting of this practice.

2.3 Fishers' Models of Gemfish Behaviour

2.3.1 There are Three "Runs" of Gemfish

Although the fishermen hold a range of points of view about the behaviour of the spawning aggregations of gemfish, there is what amounts to a dominant paradigm of fishermen's perceptions of gemfish behaviour. Most fishermen believe that the gemfish "run" occurs in three phases. At the start of the season, aggregations of gemfish, which are dominated by large females, appear on the NSW shelf. Caught with the females are a significant number of small gemfish (ie 50-60 cm). Following this "first-run", there is a noticeable drop off in the catches, and then a smaller "second-run" occurs. During this second-run, the fish are more "mixed", in that a greater percentage are in the mid-range of about 60-80 cm, and there are smaller numbers of the big females and small fish in the catch.

The results of the Gemfish Research Program indicate that these observations by fishermen are accurate. Significant catches of the 60-80 cm gemfish were taken, at approximately the correct time of the season. Nevertheless, there are fishermen who believe that the size of the second-run has been significantly diminished in recent years.

A Sydney fisherman:

> In those days there were two distinct [runs]. We used to get the bigger fish, like we still do, in the earlier run. And they used to last possibly 8-10 weeks and then they would disappear and the smaller run of fish would come along. And they would probably last for anything up to a month in pretty good quantities. Roughly 5-6 ton, 7 ton a day.
>
> And that was the way the season progressed for a number of years until the boats from further down the coast also started participating in the fishery and as more and more boats participated, most of that smaller [second-run] fish wasn't making it up the coast until one year they just didn't come at all.
>
> [You would get] smaller, box-length[2] fish in the second-run. They just stopped coming up the coast and you were only just picking them up in very small numbers.
>
> That would have been probably the late 70s, early 80s to become noticeable. And virtually all the way through the 80s there was very little of these small fish that ever made it. That was only at the first, say 1974-1977-78, that we were catching those smaller fish. Since then they've stopped. And after that we were just mainly targeting the main bulk of the big fish coming up the coast. Nobody sort of worried about where the little fish stopped. In those years when they weren't arriving in Sydney, they were still catching them in significant numbers down along the south coast.
>
> Actually in the last four years, if it hadn't been for the main big fish coming through, then there's been very little fish bar one year, which I think was three years ago. There was a month worth of fishing down around the Everard canyon. They sort of hung there for four or five weeks and then disappeared. But those fish were still running ripe, which we thought was quite strange for them to be running ripe and heading in a southerly direction. We thought they must have been lost. It was just an unusual once off.

Following the second-run is a "return-run" in which the fish that have already spawned are caught heading south. There is no clear view of the size structure of the return run fish. Some fishermen say that the return-run fish appear to them to be in less healthy condition and that their taste is poor in comparison with fish that have not yet spawned.

2.3.2 Where Do the Gemfish Come From?

Most fishermen believe that the fish come from the south and move northwards along the coast throughout the season, in the three phase pattern described above. This is evidenced, fishermen say, by the fact that the patterns of movement are relatively predictable, and also

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2 The "box length" fish are fish that are between 60-80 cm. They fit within the standard plastic fish box without their nose and tail needing to bend. During the research, fishermen realised that we were very interested in locating "box-length" fish because these were the fish that were missing from the previous length-frequency studies.

that the fish are swimming in a northerly direction when caught. Fishermen say that they know the fish are swimming towards the north because they can only catch them by trawling towards the south[3], and the general movement of the fish is from south to north.

A Bermagui fisherman:

> We had the impression that the fish were coming from the south, and for the first couple of years, it seemed that we were catching them down there first. And we used to follow them, more or less, up the coast. But whether they do come from the south or from out wide[4], I wouldn't have a clue.
>
> And I'm still not sure where they come from. Going on past years, there have been times where we used to think in those lines, until one particular season it happened that they were caught here in Ulladulla and no fish caught at Eden! So once that happened everybody sort of lost track a bit, you know. It would have had to have been round about 1980, 1982.
>
> I do remember that one year we caught a lot of fish and then the next year it was pretty quiet, but then the year after it was good again. So I won't say the fishery still is as good as it was, but then we still don't know where the fish come from. If we knew for sure where the fish came from, then we could say, well that's that.

2.3.3 The New Zealand Theory

Many fishermen believe that the gemfish are part of a trans-Tasman stock, although they are not clear about how they think the New Zealand and Australian populations are linked. The evidence for this model is less based on fishermen's empirical observations than their theoretical notions that the gemfish are part of larger stock that includes the New Zealand gemfish. The fishermen also point out that gemfish are often caught at the sea mounts in approximately the same depths as they are caught on the shelf, and that the fish are quite obviously pelagic in their appearance as opposed to demersal. The fishermen consider that these features point to fish which are highly mobile and which spend much of their lives in the mid-depths of the Tasman Sea.

The notion that the NSW gemfish are part of a trans-Tasman stock which includes New Zealand, was the most popular and strongly held view about where the gemfish go when they are not in the spawning aggregation. Many fishermen appeared to be quite convinced that the New Zealand and the Australian gemfish were parts of the same unit stock. This

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3 The "return run" fish are best caught by trawling towards the north, since they are assumed to be travelling south.

4 The term "out wide" is vernacular and refers to the waters to the east of the continental shelf. Fishing "wide", means fishing to the seaward.

theory gave heart to many fishermen who argued that limiting the catch in Australia was pointless so long as the New Zealanders were catching larger amounts.

The strength with which the New Zealand theory was held by many fishermen was probably a reflection of the fact that it offered them a small hope in an otherwise depressing outlook for the immediate future of the gemfishery. Nonetheless, there is some evidence that the notion of the two populations being linked can not be written off and this gives some credence to the fishermen's theories.[5]

2.3.4 The Moons

The trawler fishers believe that the lunar cycle has a significant effect on their gemfish catch. Some consider that the best fishing is just on the full moon, while others say that their catches build with the waxing moon, peak just before the full moon, and drop away quite rapidly on the waning moon. Thus the timing of the gemfish spawning run is seen to be closely related to the lunar phase.

In late July, 1993, when fishermen were anticipating the second run of gemfish, and there were only sporadic reports of catches of fish which matched the size structure that was expected in this run, Dr Prince suggested that a possible explanation for the weak catches could be that 1993 was a year in which there were 13 moons, as the calendar adjusts to the lunar cycle. The fishers were generally quick to recognize this as a useful explanation, given their understanding, based on empirical evidence, that the lunar cycle has a direct effect upon their catches.

A Bermagui fisherman:

> I think the moon has got something to do with the gemfish. I think the moon has got something to do with all fisheries.
>
> One day we caught no gemfish at all. And that was the day before the full moon. There was another fisherman with me and he said, "I was there yesterday and didn't see a sign of the gemfish, just a few grenadier". I went down to the same place the day of the full moon which was the very next day. We said, "well we're down here now, we may as well try, we didn't come all this way for nothing". And the gemfish were there!

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5 See, Adam Langley, Bruce Hartill and Cameron Walsh 1993 Summary of the Northern Gemfish (SKI I) Trawl Fishery 1989-92. MAF Fisheries , Northern Region, Aukland, and John R. Paxton and Donald J. Colgan 1993, Biochemical Genetics and Stock Assessment of Common Gemfish and Ocean Perch - Final Report, FRDC Project 91/35, Australian Museum, Sydney.

2.3.5 Gemfish are Affected by Eddies, Currents and Changes in Water Temperature

Many fishermen believe that water temperature and current have significant effects upon the movement of gemfish. Where the southward flowing warm current eddies to create a barrier of warm water, fishermen say that the northward migrating fish will bank up against the warm water and wait for it to shift before continuing. This notion fits with the fishermen's observations that fishing is most productive where cold water meets warm water.

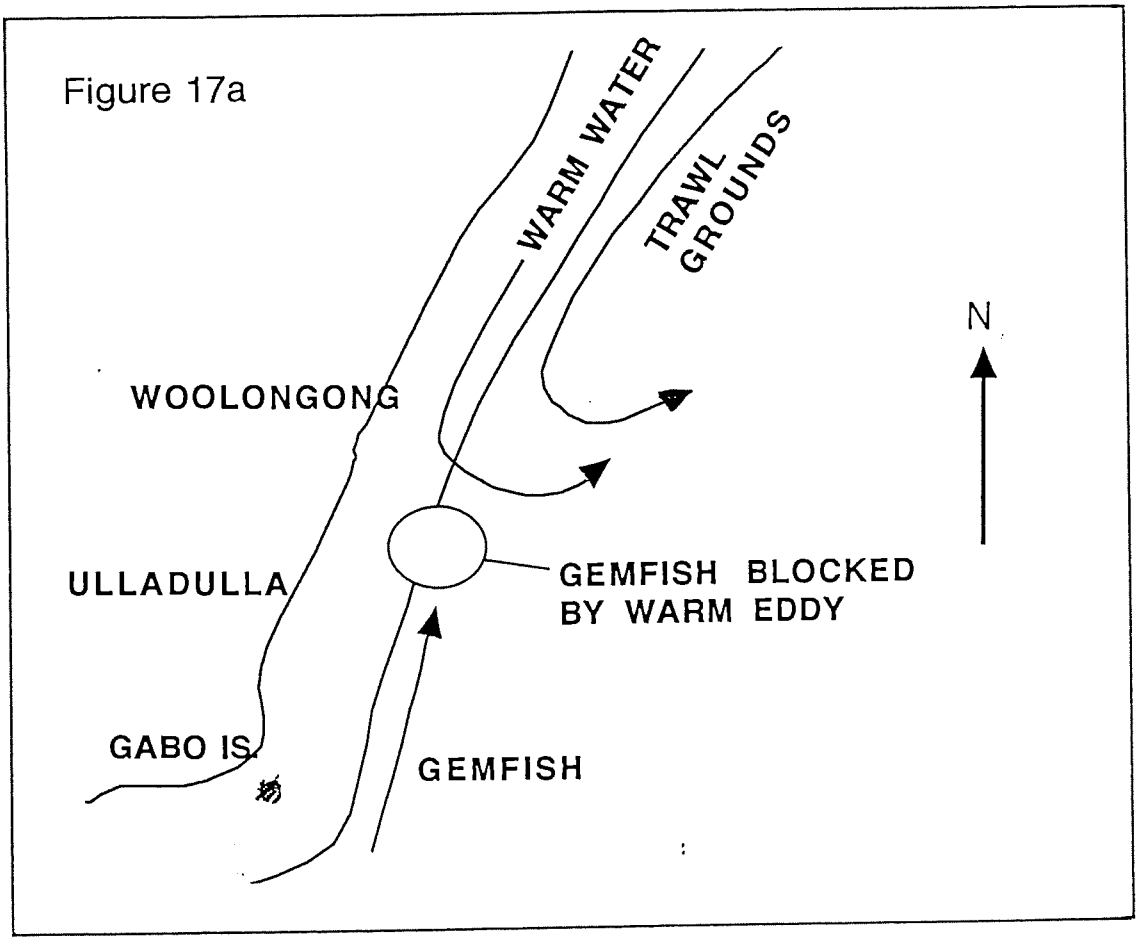
An Ulladulla fisher:

> See, on the shelf the winter months are the best because in the winter months the tide is slack and you get the dirty water, you know. You get the dirty water and you get the feed and the fish come around. During the summer months we get these hot water, currents running down from north to south, right. It clears the waters up.
>
> Every time we have a really strong, hard current running down, the water turns really blue. There's nothing in it. Because it's hot, there's no feed. The feed goes away or the current takes the food away from it. There's nothing, it is dead water. That's why during the summer time we [don't go to] the shelf, because we catch nothing.
>
> Down there at Eden in the south they've got better catching rates than the fishermen on the east coast. And I believe that's [because they are less affected by the warm current on the east coast].

A former Ulladulla fisher:

This fisher explained the large eddies encountered between Ulladulla and Wollongong. He drew a sketch map to help explain himself (Figure 17).

> We've had big years off Ulladulla, Bonanza years. Let me draw you a crude map....
>
> We've had these big eddies, big currents, in here and screaming out to sea, really hard. It creates a fence, a barrier. And all this fish that is travelling north gets as far as the top of this canyon and stops. It stops there for two weeks.... And the Ulladulla boats have had big seasons. As soon as that current shifts -- the fish go through like a rocket.
>
> Now the same situation applies down here... at Gabo Island. You have trawl grounds here and here, [on either side of a substantial canyon] and you have the same effect coming through here. It seems to be [that the eddying is a consequence of] these headlands jutting out has some impact on the current moving around. It creates a barrier for the Gabo Is. ground. And that current will [also] trap the fish before they move north. But [the Gabo Island] current doesn't get as strong as the [Ulladulla] current. [The



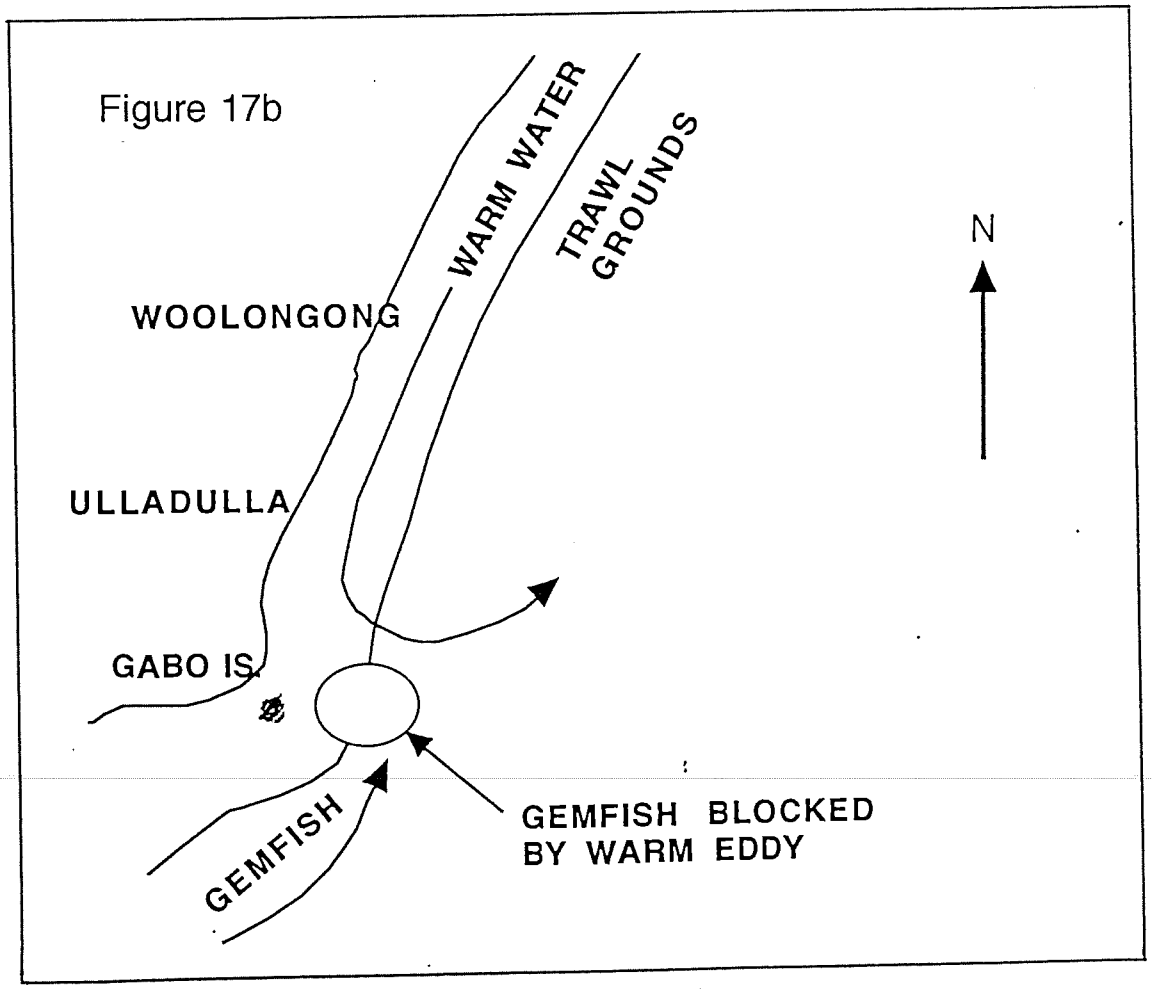


Figure 17.
Sketch maps of eddy structures drawn by an Ulladulla fishermen to explain the perceived influence of oceanographic features on winter gemfish aggregations off (**a**) Ulladulla and (**b**) Gabo Island.

current north of Ulladulla] gets very strong and I have seen the fish locked up there for up to two weeks. And [as a result of the current preventing the gemfish from moving northwards] Ulladulla has had a massive year on gemfish. Big years.

[And the size of those fish would be] mixed. But you would get the big ones, and some maybe a little bit bigger than the "box" size, but they would be in it as well, I would think.

2.3.6 Westerly Winds

A feature of the 1993 gemfish season was the relative lack of westerly, offshore, winds. These winds are, almost universally, associated with good gemfish catches. Indeed some of the large new trawlers have been purpose-built to handle gale-force winds. One of the more famous of the gemfish trawlers was the "Bonanza," a large boat which fished, out of Ulladulla, on days when all the other boats stayed in harbour. The Bonanza is said to have lived up to its name by catching huge amounts of gemfish during these westerly gales.

A former Ulladulla fisher:

In the westerly gales off Ulladulla, [the harbour's best fishers] would still work. The Bonanza would still work. All the little wooden boats would be home. The fish are still moving through though; they don't stop; the fish still come through. And this is how they caught all this fish. With the westerly gales off Ulladulla, some of them would still work. The Bonanza used to always work. Wouldn't matter 40 knots, 50 knots, he'd be out there.

I know that one year we had fourteen or fifteen days of absolute gales, right in the middle of the run, [between Eden and] Wollongong. And there was not a boat out there other than [our boat] and we were working 40 and 50 knots off Sydney, in westerly gales -- you don't get a big sea, but you get a lot of wind ... and we had some big shots of fish.

An Ulladulla fisher, on the 3 August 1993:

This season has been very strange. The Westerly winds have not come and the current has not arrived.

2.3.7 Concentrations of Gemfish are Found in the "Canyons"

The coastal shelf is made up of trawlable and non-trawlable "ground." Between the areas of trawlable ground are "canyons" and other features which make trawling more difficult. Although some boats are able to use "bobbin" gear[6], which allows trawling over more rugged terrain, there are particular areas that are inaccessible to trawlers and which are highly productive of gemfish caught by line fishermen. The gemfish are caught in depths

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6 The use of bobbin gear is strongly criticised by some fishers because it is thought to damage the bottom.

ranging from 120 - 300 fathoms.

According to the trawler fishers, the spawning gemfish tend to concentrate in these areas of high relief.

A retired Bermagui trawler fisherman:

> One year I was drop lining and I dropped line in the canyon. Now that canyon was full of fish! It was full of gemfish. I was catching blue eye, of course, because I was targeting them. But I was catching heaps of gemfish. [My brothers, who were working on trawlers, were] towing for eight miles [on the clear ground] from one canyon to the next, and for about a week there, they weren't catching nothing. I was saying to my brothers, "You'll kill them today" and they were towing right down next to me, within half a mile and they were catching none. And in the canyons it was full! And that went on for about a week and then all of a sudden [the gemfish] left the canyon and they went onto the clear a bit.

An Ulladulla fisherman:

> The main bulk [of gemfish is nearly always found] near the bad bottom. Near canyons and stuff like that, where not everybody can get in. Where you not disturb them. Why is the fish there? Because they are trying to get away from the activity of the fishermen.
>
> They not disturbed. I mean they can lie there, they can spawn eggs. You go in the ground where 5-6 board trawlers fishing all up and down, the amount of fish, the catch rates are going down almost zero. You go someplace where not many trawlers go, working that ground, right, and you probably get a catch. Many species. Same as the gemfish.
>
> Any animal or fish, they got understanding in their own language. They're not stupid! Because, you see, in the canyon, we can't get in the canyon. And the boat that shoots the nearest to the canyon, it always catch more fish than anybody if they shoot them in the good bottom, always.

2.3.8 Line Fishers Work the Canyons

The line fishermen complain that they are unable to fish in favourite places near these canyons during the gemfish spawning season without catching large quantities of gemfish, of which they may presently take a by-catch of only 50kg. They complain that the gemfish are so numerous that it is impossible to catch the species they are targeting because of the gemfish take hooks so readily.

As a group of "concerned fishermen" from Kiama wrote in August 1993:

> As schools [of gemfish] move north the abundance of Gemfish on these grounds is so

great they prevent the catching of Blue-eye Cod and Shark and as a consiquence(sic) of their varaciousness (sic) Gemfish have frightened other species off the grounds. The present by-catch limit makes it impossible for drop-line fishermen from this area to earn a decent wage in the months May to August.

The line fishers also note that they are able to catch gemfish year round, in an area they refer to as "the Hill", a large rise in the seabed off Kiama. They also report a pattern of catching size classes that differs significantly from that reported by the trawlers. The line fishermen apparently find that during the spawning runs the small to medium fish appear first, followed by the very large fish. There is a lull of about one week between the main run and the return run, but in the return run, no small fish are reported.

The fishers describe gemfish movement at the Hill as coming "in bunches". At certain times there are bunches of gemfish which they recognise as being part of the larger "runs." They report August as being a "pretty dead" month for gemfish, meaning that the gemfish runs seem to taper off, before the return run begins in September.

2.3.9 Staying in Touch

Another important feature of fishing strategy is remaining in touch with the day-to-day knowledge of the location of gemfish. The fish are not evenly distributed and knowledge of where the fish are is vital information. Each fisherman guards his information as closely as possible, but it is easy for a colleague, who is able to use his own local knowledge and experience, to decipher the various codified behaviours that indicate the location of a good catch.

The fishermen consider that knowledge of where the fish are is a critical factor in their capacity to catch. In normal seasons this knowledge is maintained by active fishing and information gleaned from observations made of other boats. According to the fishermen, the information gained from observations of other boats is nearly as important as the information gained directly from fishing experience. In the seasons since the introduction of the quota system, the information on the location of fish throughout the season has been missed altogether, or skewed because the boats are not in constant touch with the fish migrations.

2.3.10 Gemfish Follow the "Feed Line" Vertically

Fishermen believe the gemfish follow the layer of feed, composed of jack mackerel and other marine organisms, from mid-water to the bottom. The gemfish are thought to be principally a pelagic species and are not catchable in mid-water with the bottom-trawling gear that is used. Therefore, the position of the feed layer has a significant effect on whether the gemfish are catchable.

An Eden fisher:

You'll sit out there and you'll watch the feed line. And here is your [feed line] up here,

twenty-five fathoms off the bottom. And just on seven o'clock, daylight, you'll see it starting to descend. We know that gemfish are semi-pelagic. They're only on the bottom when they're feeding and [they get] full, and then they come on back up to the top. [And here's proof].

We're catching fish off here... fourteen miles south of Gabo for three days, and there's hardly a fish seen off Eden, none off Bermagui, and then on the fourth day they show up off Bermagui. They've travelled all that way, they've travelled all night and all day, in this column here [thirty-five fathoms off the bottom]. They don't always come down. We have seen them come down so far [in the water column] and then stop.

2.3.11 Gemfish Have Become Smarter

A variation on the theme of gemfish moving into uncatchable portions of the water column, is a persistent belief among some fishermen, that the poor gemfish catches of recent years can be partly attributed to an increase in the gemfish's capacity to avoid capture. The gemfish are found on the bottom at dawn and this is when they are most vulnerable to the trawl. Soon after, the fish rise in the water column and remain off the bottom, out of reach of the trawl. Some of the fishermen say that they can see this movement on their sounders, and consider that the fish have learned to avoid the net.

A Wollongong fisher:

I don't care what people say. Other people think the fish is stupid. But we believe they have brains, because we build the nets and we know if we don't build the right nets, we can't catch the right fish. So they must be smart enough to get away from the net.

They learn. They start getting bashed by us down at Eden, and [by the time they get up here] they've got to have learned not to go in the same pattern.

When they start telling us that we were killing the gemfish, we probably was catching a little less [than before], but not because the gemfish were less. I'm nearly 100% sure, as a fisherman, it is because fish are getting wiser. And one day this will come out. One day. One day when the mid-water comes in, this will be known. There will be fish, plenty gemfish then from the mid-waters.

2.3.12 Nets and Skill

In several of the interviews, it became clear that knowledgeable fishers considered that fishing skill counted for a great deal in terms of the amount of fish that was caught. Indeed, some felt that a very small number of the total fishermen on the coast, caught a very significant proportion of the total catch. Some fishers felt that the loss of some of the important fishing personalities was sufficient to make a significant contribution to skewing the gemfish research results because fishing skills, especially the capacity to work a large gemfish net in inclement conditions, contributed greatly to the overall catch.

The fishing skills that appeared to be most valued were those of getting the right combination of net and boat, and being able to effectively fish a very large net for gemfish, especially in strong westerly winds, as evidenced by the success of the "Bonanza" mentioned above.

An Eden fisher:

> [We fishermen are very cynical of the "scientific" surveys carried out by fisheries research vessels, because] we know that certain nets will catch certain species better than other nets. We know that certain change of technology will be quite destructive of certain species.
>
> In each port, gemfish was not an easy fish to catch in big abundance. It took a special net; it took precise setting of the doors; it took greater skill than a lot of people give it credit for. I can name you the three or four people that took 60-70% of the total landings in Ulladulla.... [These people] caught more than the rest of the fleet put together.

Gemfish nets are considerably larger than more standard trawl nets, and good fishers continually experimented with differing shapes and sizes. The nets have a much wider mouth, the wings are much longer, and in general they are made as big as the boat that will tow them can manage.

A former Sydney fisher:

> It's specifically one design of net, for the gemfish. It's a different style of net. It's a longer, flatter, bigger opening. But it is capable of holding big lots of fish and being towed along for long periods of time. Whereas the shorter, higher nets tend to distort and they lose their efficiency as soon as you start putting a few ton of weight into the net. What happens is, the more weight you put on the cod end, the more weight is transmitted down the seam to the net, which tends to make the net collapse.

An Italian fisher from Wollongong commented to me that his father had brought valuable skills in net making from Italy, and stressed the importance of continually developing more efficient nets. These skills appear to be held by individuals or within families.

A Bermagui fisher:

> You know the old blokes .... that used to catch a thousand boxes of fish [in a shot]; these blokes have been doing it for 30 years. They were making their own nets for 30 years, they learned how to make them, how to make things work. I've only been making myself for ten years. I can make good nets. But when I started making, I often made a net that would hold 200-300 [boxes] but not 1,000. I haven't made a net yet that would hold a 1,000 [boxes].

[The nets we were towing for gemfish] they are a speciality net, twice as long as what we are towing at the moment, and we are towing big nets. Now they are talking 60 fathoms, 70 fathoms nets. Now to put it on, I'd have to take both nets off the drum to fit one net on, where I've got two nets on the drum. They are just enormous! The whole net would be, from one end of it to the other, would be longer than the wharf and that's 50 fathoms.

An Ulladulla fisher, who is recognised as particularly skilful:

[A gemfish net is different from other nets, it is] much deeper, bigger, long wings. I have found that the deeper you go the bigger nets you got to have. Because the water is very dense at that depth and it would bounce up all the time. [The net weighs less down there.]

We always fished deeper [than others], so we had a much bigger net. Bigger in the mouth and long wings. Twice the size of the normal net we use.

You have to tow at the right speed, because I have been in that depth, you towing too hard and too fast, you might lift him off the bottom or you might close him up. Because you make the boards come together and you get less spread.

I have found that my best speed, with a tide behind, for gemfish was 2.2 knots; that was the best speed. Because we saw by experience if you were towing at 3 knots you come more around but you use more fuel. Because if you tow at 3 knots for 3 hours that's 9 miles. If I towed at 2 knots, 3 hours is 6 miles but I still catch even more fish.

Fifteen hundred boxes [is the biggest single shot I've made].

2.4 Fishers Think the Sampling Strategies Have Skewed the Research Results

Fishers have been very distrustful of the length-frequency data, collected by the New South Wales Department of Fisheries, upon which the gloomy recruitment prognosis has been based. It would be easy to write this distrust off as the fishers merely trying to protect their short term interests. However, they point to a number of potentially salient features which appear, to them at least, to make a common-sense case that the much of the data is skewed.

2.4.1 Early Catches were Graded

Some fishers make that case that the early catches were "graded," that is, that the fish were sorted by size at sea and that different sizes went to different markets, depending on perceived advantage in pricing arrangements. The result, claim the fishers, is that the fish sampled at the Sydney markets, was not representative of the fish that was caught.

An Eden fisherman:

> When [New South Wales Fisheries] originally did their data ... the very initial basis of it was taken from sampling at the Sydney Fish Markets. And yet, in those days, and this was years ago, the majority of the fish was going to processors such as "Poulos"[7]. Now Poulos would not take juvenile or small gemfish. And we used to "grade" the fish in those days. The small stuff went to the market, or Melbourne, and only selected sizes went to Poulos Processing.
>
> So the initial data gathered was flawed seriously. [They] then started to take samples from other areas, but they rarely, if ever did, go to Poulos Brothers... who was a major purchaser of gemfish.
>
> And it was things like that, that got fishermen offside from the very onset. And they haven't forgotten. And because they see them getting the information from the wrong area, they take everything with a great degree of scepticism. Worse, they just don't believe [it].
>
> The fishermen know that the fish [behave, and interact with the environment, in certain ways -- such as being held up on the coast by the warm currents, or by swimming lengthy distances during times when the fishermen are unable to catch because of weather].
>
> So what we are saying to you people is that the mechanism that they used to get the stock assessment is flawed because they weren't able to get a mixed cross-examination [ie an adequately unbiased sample]. And the whole sequence of events has just compounded the problem and made it worse. But as I say... we're only fishermen [and we're not taken very seriously].

2.4.2 Quota System Promoted Grading

Many fishermen believe that the manner in which quotas on gemfish have been implemented has been partly responsible for the results obtained from the gemfish research. These fishermen point out that the initial introduction of quota management in gemfish was a global "first in best dressed" system in 1988. In that year, one fisherman alone took approximately 1,000 tonnes of the 3,500 tonne total catch.[8] He was able to do this, say the other fishermen, because he was based at Lakes Entrance, a southerly port, and was able to catch big numbers of the "first run" fish which first appear in southern waters. Fishermen believe that the data based on these large catches of first run fish skewed the results of the data collected by the New South Wales Department of Fisheries, because the data were obtained from the point-of-sale at the Sydney Fish Markets, and were assumed to be representative of a typical cross-section of the fishery. According to the fishermen, virtually

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7 Poulos Brothers, Pty. Ltd.

8 The TAC of gemfish was 3,000 tonnes but there was an estimated overcatch of about 500 tonnes.

all of the 1988 quota was taken from the first run thereby skewing the length-frequency sample in favour of large female fish.

In 1989, the gemfish were managed by individual transferable quotas (ITQs) with a total allowable catch (TAC) reduced to 1,750 tonnes. The total catch did not reach the TAC. The management authorities point to this fact as an indication that the gemfish stocks were in such poor condition that it was not possible to catch up to the TAC. Many fishermen claim that the apparently poor catches were the result of fishermen not reporting their catch, due partly to their cynicism about the effectiveness of the management system.

The TACs for gemfish were further reduced in the ensuing years, reaching zero in 1993. The fishermen claim that throughout this period, they were targeting the large first run fish, and that they "graded" the fish by discarding all but the biggest fish, for which they received the premium price.

A great deal of cynicism and distrust of the management system developed throughout the five years of quota control in the gemfish fishery. A significant portion of this distrust stemmed from the fishermen's belief that the management structure was generating a "self-fulfilling prophesy." The fishermen's experience told them there were plenty of gemfish, but they thought that the strictures on their capacity to catch, combined with the particular methodology used by the scientists for sampling, resulted in population estimates which verified the dismal forecast that the scientists were promulgating.

The distrust of management's prognosis for the gemfish fishery was most strongly held by those who were most critical of the whole quota management system. These fishermen claimed to have been dispossessed of their rights to catch appropriate amounts of other species by the ITQ management regime, resulting in over-dependence upon gemfish in their quota species mix.

2.5 Fishers' Critiques of the Quota System

The severe restriction of the gemfish fishery since 1988 has coincided roughly with the implementation of the ITQ management system. Those fishermen who have been most affected by the reduction in available gemfish quota have, generally speaking, also been those who are most adversely affected by the introduction of ITQs on other shelf species.

In the late 1980s a system in which "boat units" were allocated, based on the size and power of the vessel, was implemented. These units were transferable and it was hoped that reduction in capitalisation and effort in the fishery could be achieved by forfeiting units when boats and engines were upgraded or sold. This plan did not work. There were about 23,900 units in the fishery in 1987, which was reduced only to 22,439 units by the end of

1991.[9] Many of the fishermen suggest that the reason for the failure of units-based management was the widespread rorting of the unit system that was thought to have taken place. They point to at least one incident where an administrator was convicted of having falsely created units for personal benefit.

In April 1990, the Minister for Primary Industry and Energy, Mr Kerin, announced that ITQs would be introduced. A Quota Implementation Team (QIT) began researching the best arrangements for implementing the new ITQ arrangements.

It is not my intention to offer a detailed critique of the implementation of the ITQ system. This has been done by the AFMA Review Committee, which was charged with examining the bases upon which the management arrangements by ITQ and TAC were implemented. However, it became clear during the course of the research that many fishermen were thoroughly dissatisfied with the manner in which the management arrangements had been established. The following is an account of some of the fishers' concerns.

2.5.1 The 80/20 Split

When the fishery for orange roughy developed in earnest in the mid 1980s a significant market for boat units in the SET Fishery was created, and the capital values for units rose accordingly. During this time, the gemfish fishery was flourishing and there was little incentive for NSW boats to venture into fisheries taking place more widely afield. This was especially so for boats operating between Sydney and Bermagui and many of these fishermen sold units into the orange roughy sector thinking they had made a legitimate windfall.

In 1990 it was clear that the Government intended to introduce the ITQ based management scheme and set up the QIT. The QIT endeavoured to speak to virtually every fisher who would be affected by the new ITQ management scheme. The impression that many fishers were apparently left with, following these discussions, was that quota would be allocated on a basis that gave a significant weighting to the number of units that a boat had apportioned to it, but that a boat's historical catch record would also be an important factor.

From the fishermen's point of view, these impressions were reinforced by the various statements by politicians and administrators which attempted to reassure fishermen that their interests, especially in relation to their investments in boat units, would be looked after. For example John Kerrin, in a Media Release issued on 31 July 1990, stated that "catch history and investment are two important elements to be taken into account when determining the amount of quota each participant will receive".

Many of the fishermen interviewed were of the impression that the ratio of history to boat unit that would be granted in the final outcome of the QIT's work would be about 50/50. It

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9 AFMA, Review of the South East Fisheries Management Plan April 1992.

came as a shock that the eventual determination was ITQ based on only 20% unit value and 80% history. The units that had been sold into the orange roughy and other fisheries carried with them much of the catch history because the history was attached to the units. The fishermen had not seen that selling their units would have such an effect.

A Bateman's Bay fisherman:

> We weren't happy really with any form of control but we said, "Okay, it's necessary, we're going to go along with it." And units were the way that the fishing industry adjusted. When orange roughy came on, a lot of boats sold their right to fish the units and New South Wales had some huge reduction in units and I think it is something like 60 percent. Now with those units went our history and this is why we [fishermen in the northern ports] have all our table fish sold further south.
>
> There was no talk in those days that when someone bought units to go into an orange roughie industry, that they were automatically getting the history. Because history was [a] person's superannuation.

A Wollongong fisherman:

> If people from New South Wales knew that by selling the units they [were also] selling the history, they wouldn't have sold it. They sold units [and they didn't understand that they were also] selling the history. If they had known that they wouldn't have done it.
>
> From units went the history. They took half of the industry. Because half of the New South Wales units [went] there, to build the boats for the roughy.

2.5.2 The Criteria Period

The qualifying period for the determination of historical catch levels used in determining the ITQs was the years 1984 through 1989, with the provision that the worst year of the six, for any species, was not counted. Many fishers complained that these years were not typical and did not accurately reflect their historical fishing patterns. In particular, fishers in the northern ports considered that during these years there was a heavy reliance upon gemfish, which did not reflect their more longstanding interests in exploiting the full range of species available.

Some fishers argued that because of the emphasis on gemfish during the criteria period, the northerly ported boats now tend to have significant quotas for species that are caught in close association with gemfish, such as mirror dory. This results, they say, in a situation where boats are forced to fish for species (especially mirror dory) which necessarily result in high incidental catches of spawning gemfish. They consider that this works against the efforts to conserve what remains of the gemfish spawning stock, and creates a situation which exacerbates the need to dump gemfish that are caught beyond the allowable by-catch limits.

A Batemans Bay fisherman:

> The criteria period was worked during a period of time where fishermen were allowed to catch gemfish for most of that period, so their historical catches of things like mirror dory, or ling or royal red prawns or ocean perch or whatever, was developed during a period when they were fishing for gemfish. So the quota allocations that they have been granted now under the quota management scheme in fact gives them large [quotas] of fish that normally swim with gemfish - because that was the historical pattern of catch!

The quota allocations appear to have caused a significant amount of financial hardship, especially to those who had sold many of their units. A number of particularly sorry cases have become quite famous among fishers. For example, one boat owner in a northern port invested very heavily in a large new boat for which he was able to acquire sufficient units. He claimed to have asked the relevant fisheries authorities whether he was doing the right thing. He claimed that they told him they saw no difficulty in pursuing his particular strategy. However, when the ITQs were distributed, he was left insufficient quota for his new boat to operate effectively. When the gemfish quota continued to diminish, it became clear that he would not be able to operate his boat on a paying basis. He pleaded with us:

> How can we live? My "history" goes back to 1965. But they turned that around. Now "history" only means quota history, and the quota history has been unfair.

In the view of nearly all the fishers that were interviewed, the eventual allocation of ITQ was unfair to those who had established lengthy careers in the general fishing industry, especially as it created an unsuspected windfall to a few people who were "in the right place at the right time."

A Batemans Bay fisherman:

> The units were bought off the boats from this east coast, which took the pressure away from the stock here. [They] went to boats which were being built only for a single purpose fishery, which was the deep water orange roughy fishing.
>
> Then they found that the roughy were going to run out and they used that to their advantage to get quota which they had never even attempted to catch when they initially bought the boats. And it's created the problem where the [right to catch] the resource [was taken] away from here and spread all over the fishery.
>
> [The orange roughy boats did not consider that they were buying] history because history wasn't a consideration! They bought the effort. It was just handed to them because if they bought the effort, the history went with it.
>
> The fish and the fishery should be confined to an area where it is being caught by the

blokes that are based nearby. See, there's no point if you are from Tassie, you get 20-30 ton of redfish a year to catch, but you haven't even got a red fish in your waters!

2.6 Observations on the Political Organisation of the Fishermen

2.6.1 North/South Divide

Fishermen throughout the NSW sector of the trawl fishery are dissatisfied with the distribution of the ITQs. However, the dissatisfaction is most intense in the northern portion of the sector, between Sydney and Bateman's Bay. It is this portion of the fishery that most actively sold units into the orange roughy fishery. This portion of the fishery was also most dependent upon gemfish as an important economic species.

There is a distinctive change in the attitudes of fishers towards management, and of their perception of the equitability of the management system, between fishermen based at Eden and the other, more northerly, ports. The principal cause of the distinction between the northerly and southerly ports is the availability of good quantities of a wider range of species available in the southern waters, which resulted in more diversified catch histories and consequently more diversified quota allocations. In the southern ports there has been less reliance upon gemfish as a major cash earner. The southern ports also contain fishing entrepreneurs who appear to have significantly greater skill for making the management system work to their advantage, than do many of the northern ported fishermen. Ironically, some of the more active entrepreneurs presently located in Eden were originally non-Italian fishermen from northern ports who have recently moved to the south.

Historically, there has long been antagonism between the predominantly Italian fishermen of the northern ports and the non-Italian fishermen who tend to predominate in Eden. In the 1950s and 60s the fishermen based at Eden actively persecuted northern-based Italian fishermen by cutting boats from their moorings, by throwing rolls of barbed wire in front of their seine shots and similar aggressive acts. The motives for such unfriendly behaviour were a combination of ethnically based xenophobia and jealousy, which derived from the willingness of the Italians to work hard and diligently at fishing, which resulted in higher catches.[10] Today Eden remains a distinctly non-Italian fishing port, although in recent years some Italian fishers have moved there from northern ports. However, the difference between Eden and the more northerly ports is no longer based in ethnic antagonism.

An Italian fisher from Ulladulla:

In the early in 50s we used to put a line just south of Bermagui and [the Eden fishermen]

10 Part of the antagonism may have resulted from the fact that Italians had displaced some non-Italian fishermen on the northern portions of the coast, and the non-Italian fishermen had moved south to Eden.

say you no come south of this line but we used to go just the same. They had no right to stop us but there was always arguments and they were out after us. They used to get our ropes; they used to throw rocks out at us. We would drop a flag when we used to shoot the net away to make a seine. By the time you dropped the flag and do the circle, take about 20 minutes, they used to cut the flag!

In 1970 when we built [a new boat] we had a lot of commitment at the bank and we had to go down [south] to pay that off. One day we came in with over 300 box of fish for the day; the weather was bad. We dropped the anchor at the wharf, then tied up at the wharf, unload the fish, have tea, had a shower and went to bed. And during the night the boat was started rocking, and we thought "what's going on here?" We woke up and we are about 10 metres away from the wharf! The anchor was holding us. If we didn't have the anchor we would have finished up on the rocks. The next day police took over.

A small number of the southern fishermen now based in Eden seem to be particularly astute in the business side of fishing and have begun to create vertically integrated fishing enterprises which include several boats, which are worked by hired skippers, and processing plants ashore. They have been able to tie into the wider fisheries business world effectively and to use the features of the various SET management programmes to good advantage. In comparison, the fishermen based in more northerly locations have not been as fortunate in their use of the management programs to enhance their fishing businesses. As discussed above, the more northerly based fishermen sold many of their boat units to southerly based operators, with the result that when the ITQs were distributed the northerly boats finished up with lower ITQs than they otherwise might have, on key shelf species. By contrast, many of the southerly based fishermen hold or control excess quota which they are able to offer for lease to other fishermen.

These anomalies in the results of the quota allocations continue to annoy and anger fishers who have been left without adequate quota, or who have ended up with quota on species that is of little use to them. Because of the capacity for the larger companies to buy and hold quota, many fishers perceive that the prices for purchasing extra quota on the market are artificially high and act as a disincentive to catch.

Following is the situation of a fisher who came out of the ITQ allocation process with a windfall of blue grenadier quota that he would prefer to unload in exchange for something more useful to him:

I've tried, you know we've been dealing with this quota deal now for three seasons and it doesn't work. AFMA keeps telling us that the market force will work itself out and we'll be able to swap our grenadier for the flatheads that we've caught in Tasmania. But it won't work because we can't deal with big company boats from New Zealand, they just won't talk to us because they are financial enough that they don't have to.

They just buy whatever quota they want. And the quota that they have got, the flathead,

the ling, the redfish -- the bloody fish that we can catch -- they just sit on it or they want that much money for it [that] it's not viable for us to go and catch it.

See we're not going to catch fish for the sake of catching them. I'm not going to pay $1 kilo to lease red fish and sell them for $1.20, because we'd go broke. So it doesn't work.

And the flathead that they catch down [in Victoria], aren't even the same bloody species as we catch here! But they still have to use their quota that they got off this coast to catch flathead down there. So they need that, plus they want our grenadier [quota] which they want to pay us for. But [the price] they are [willing] to pay for [the grenadier] is not enough; 50-60 cents a kilo for 50 ton of fish. It's not a lot of money. It's not worth mucking around with it.

2.7 Suggestions for Management

Where there is a group of people who identify themselves principally as fishermen, and who have developed their community culture around the fact of them being fishers, then I believe they can be expected to contribute responsibly to the management of their fishery, given two conditions. These conditions are:

1. That the fishery is relatively self-contained and fishermen are genuinely cognizant of the various interests competing for the resources.

2. That the administrative structures are readily understood by all fishermen and considered by them to be fairly managed and without any "hidden agendas".

These are the basic ideas which seem to underlie the management of the SET fishery. Nonetheless, many fishermen are greatly dissatisfied with the fishery's management and have been known to behave in a less-than-responsible manner towards it. Where is the problem then?

My view is that too great a gap has been allowed to develop between the fishers and those charged with managing the fishery. There is insufficient liaison between management and industry about the day-to-day operation of the fishery. A consequence is that management is seen to be handed down by people who have little detailed understanding of the various concerns that are deeply felt by the fishers. Although the South East Trawl Management Advisory Committee (SETMAC) process is designed to give fishers a genuine voice in the management of their fishery, a persistent criticism that I heard was that ordinary fishers with single boats were not satisfied that their interests were adequately represented in the various deliberations.

I believe that the New South Wales south coast should have at least one dedicated manager who would spend a very substantial portion of his/her time doing the sort of work that I was

able to do for only a few weeks. Mostly, that entailed listening to fishers, and reporting on their perceptions of the working of the fishery. With this dedicated link between industry and management, I would expect that management could become more responsive and felxible, with the result that many of the more heated debates could be cooled. The result is likely to be a more rational debate about the truly important issues in the fishery.

Section 3: The Biological and Environmental Context of the 1993 Gemfish Run

3.1 Introduction

Stock assessments can use a wide variety of indices, catches, catch rates, surveyed abundance or size composition data to estimate the status of a stock at any time. The interpretation of any measured trend, in terms of how accurately the measured trend reflects real population abundances, depends on a broad understanding of the biology of the species being measured.

Depending entirely on the behaviour of the species, the abundance of any fish species and the size of the fish being monitored at any location will vary enormously through seasonal cycles. Commercial fishermen exploit this fact, taking advantage of some specific behaviour pattern that renders the fish vulnerable to human technology. Fishermen learn to exploit some form of aggregation; when and where the species occur in peak abundance and become most vulnerable to capture. In the case of mature gemfish they are most catchable during the spawning season when they aggregate.

These cyclical abundances impact the indices that are used to monitor fisheries by introducing time specific variability into monitored abundances and size compositions. Thus to understand the basis of any stock assessment, a broad appreciation of what is being monitored is essential. Measures of abundance can only be understood if the biological context from which they are derived is understood. It is the behaviour of the fish in the context of its environment that largely determines the accuracy of any stock indicator.

The following section contains observations and comment on the biological nature and environmental context of 1993 gemfish season. These observations were gathered during the 1993 gemfish programme and are provided in the hope of stimulating further detailed discussion. They are more qualitative than quantitative in nature, having been gathered as an incidental part of this program.

3.2 Defining the NSW Gemfish Run

The bulk of the gemfish caught during the winter months off the shelf of NSW congregate along the shelf to feed and participate in spawning aggregations. This much can be agreed by all sides of the NSW gemfish debate. Fisherman and scientists also agree that the location of aggregations of mature gemfish moves generally northward each season.

During this study catches made away from aggregations were small and had a greater proportion of immature fish. The proportion of mature fish occurring in non-aggregation catches was higher in the north than in the south.

In contrast, the aggregations that produced high catch rates were principally comprised of mature gemfish. The relative lack of immature fish in these catches is often explained by fishermen as evidence that the large fish scare away the smaller fish. But this phenomena can also be interpreted as the movement of large, dense aggregations of adults into the area of aggregation - thereby outnumbering the existing small, sparse aggregations of juveniles.

The occurrence of these aggregations on or above the trawl grounds is extremely variable, occurring on some mornings and not others, and at some times of the day and not others.

The obvious questions to ask are:

What is the behaviour that gives rise to the aggregations being fished?

What mechanisms determine or influence the timing and location of these aggregations?

Johannes (1981) describes the behaviour of pre-spawning fish, which has previously been termed "spawning stupor". The ancient Greeks first gave it this name when they described the behaviour of spawning mullet. Fish that spawn by broadcasting their ova and sperm into the water to mix *en masse*, and do not practice internal fertilization or copulation, must nevertheless participate in coordinated and synchronized behaviour. If maximal rates of fertilization are to be achieved, optimal concentrations of sperm must be provided for the females to release their eggs .

Prior to spawning, most fish that do spawn *en masse* apparently form ordered (often sex segregated) ranks. These ranks, or linearly moving schools, form up some distance from spawning sites and gradually move towards them, growing in size and increasing in density as they approach the breeding grounds. These fish become progressively less sensitive to outside stimuli as they approach the area and the time of spawning. The behaviour known as spawning stupor is exhibited immediately prior to actual spawning. At this time schooling fish will pack more densely than at any other time of their life and may be completely oblivious to all outside stimulation, slavishly keeping in position within dense slow moving schools. At this time predators may often be seen killing fish at will because the fish do not exhibit any flight response. During the final approach to spawning, size segregated schools exhibiting spawning stupor often meet near the substrate and individual fish from separate schools may pair vent to vent as they swim vertically up into the water column strewing sperm and ova into the water together.

It seems likely that the fished gemfish aggregations are tightly packed, de-sensitized, pre-spawning aggregations forming up and moving across trawl grounds towards spawning sites.

From observation it is apparent that gemfish generally do not release all their eggs in a single spawning. Females that were partially spent but still relatively full of ripe eggs were

common in aggregation catches until 1 September, 1993. The overall body of fish into which the mature females apparently arrive before mature males, can be assumed to remain in the general aggregation area for days, perhaps weeks, and even months. The aggregations presumably arise from the background body of fish, with mature individuals participating in several aggregations until their individual spawning is complete. The overall body of gemfish presumably moves gradually north during the season, periodically forming dense pre-spawning and spawning aggregations.

The more difficult question is: What mechanisms determine or influence the timing and location of the aggregations?

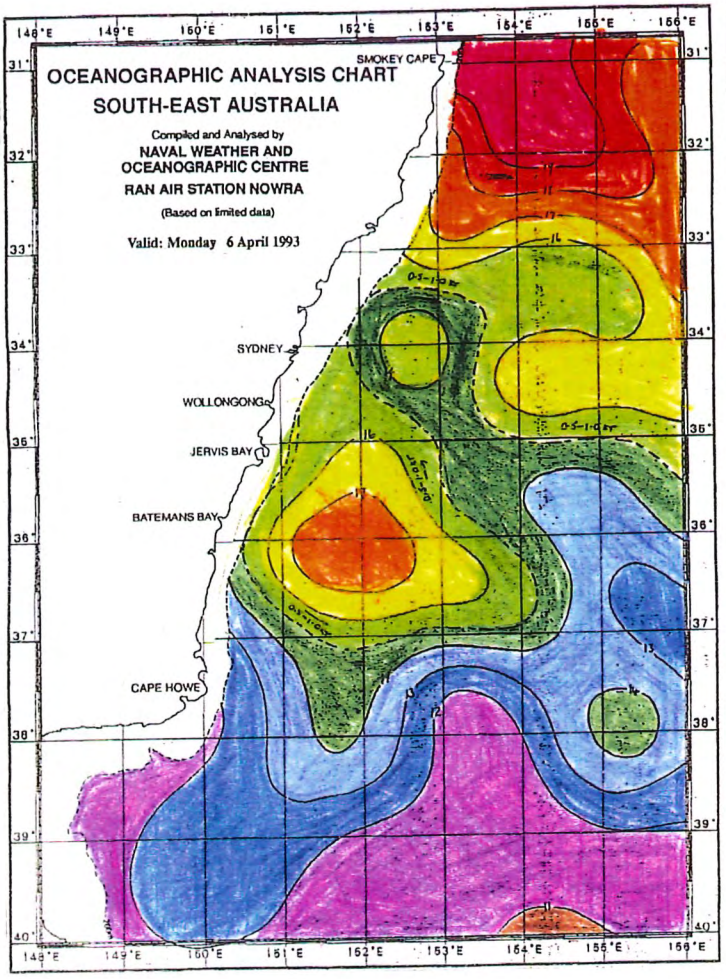
3.3 Industry Opinions on the Timing and Environmental Influences on the Gemfish Season

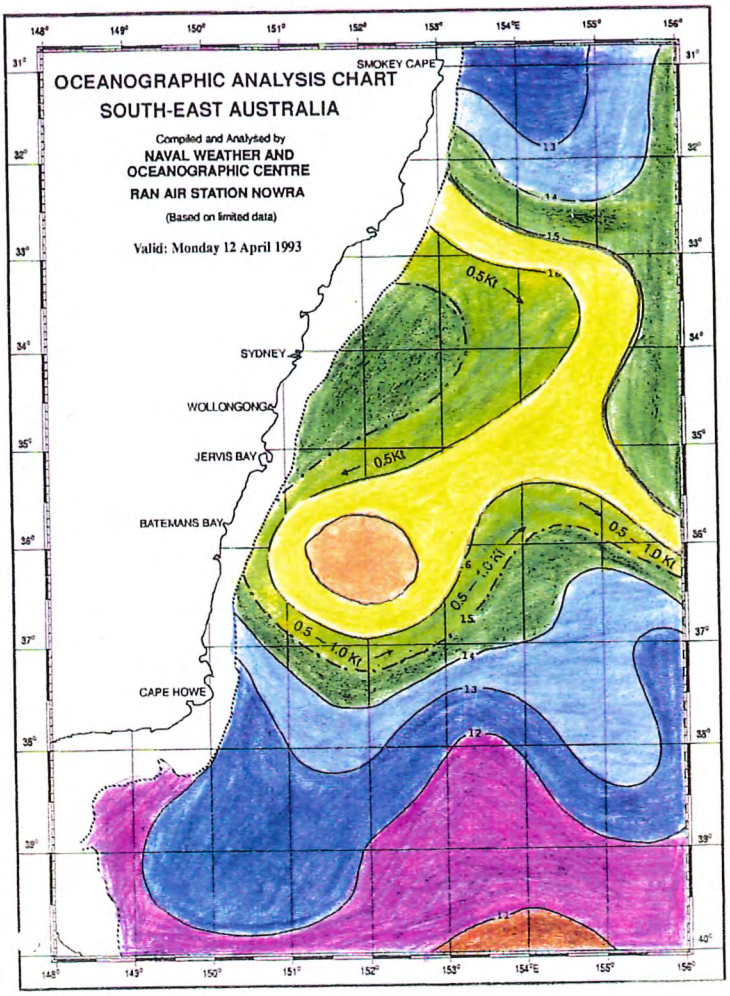
Conversations with fishermen reveal that they believe various environmental parameters affect the annual gemfish run (Wright - Section 2, this report). Many fishermen associate gemfish aggregations with cool waters, derived from a southerly current working in opposition to the predominant warm northerly current. It was often suggested that strong westerly winds are associated with good gemfish catches. Fishermen also believe in the importance of moon phase in catching gemfish. Some associate the beginning of the gemfish season with the sixth and seventh full moons of each year. Many others limit the impact of the moon to changing the catchability of gemfish by changing light conditions. Fishermen note the importance of understanding the gemfish's daily cycle. Most large catches are taken at dawn, when acoustically prominent traces can be seen moving towards the bottom along the shelf edge. Although dawn usually sees the best catches, it is not unknown for the day's best catch to be taken at midday or even during the afternoon.

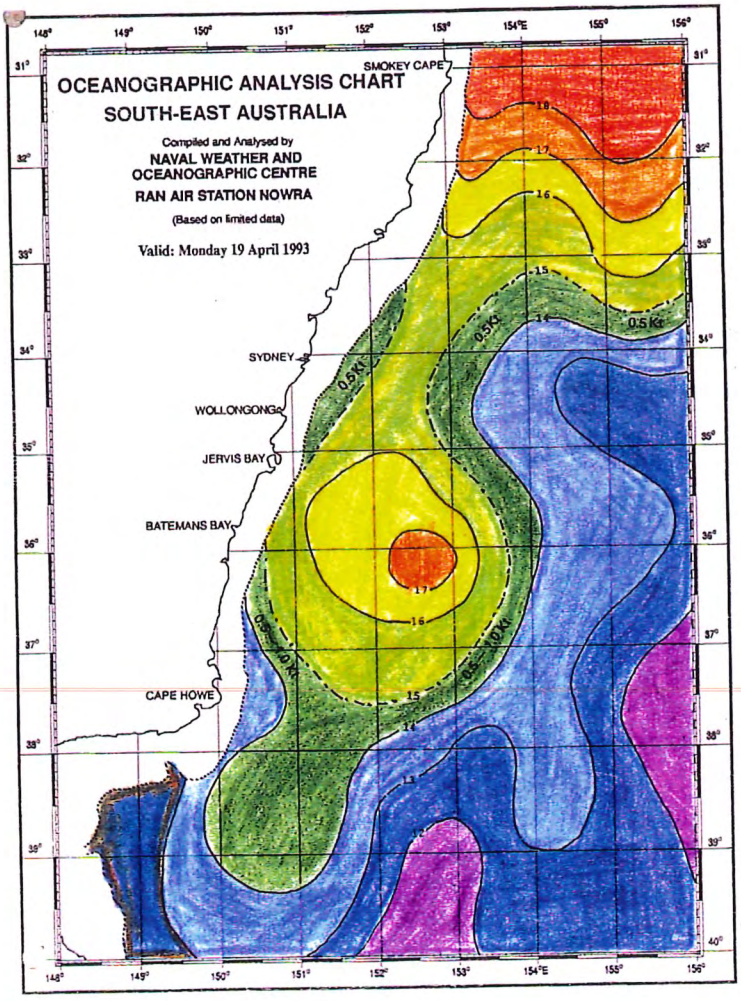
3.4 Oceanographic Conditions

The prime source of information about the oceanographic conditions of the winter gemfish run is the Royal Australian Navy's weekly charts, which show estimated surface and 250 m (approx. 125 fthm) isotherms. Although these isotherm charts (Figure 18) are created from individual measurements made by RAN surface vessels and submarines, these data are gathered opportunistically and can be very sparse, with broad extrapolations often being necessary to complete the charts - which, therefore, while providing some indication of broad patterns, should not be trusted in closer detail.

The 250 m isotherms have been used here because they indicate oceanographic conditions closer to the depths used by gemfish (350 - 450 m) than the surface isotherms.







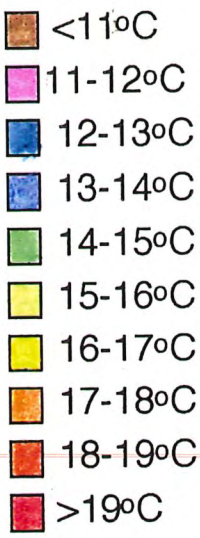
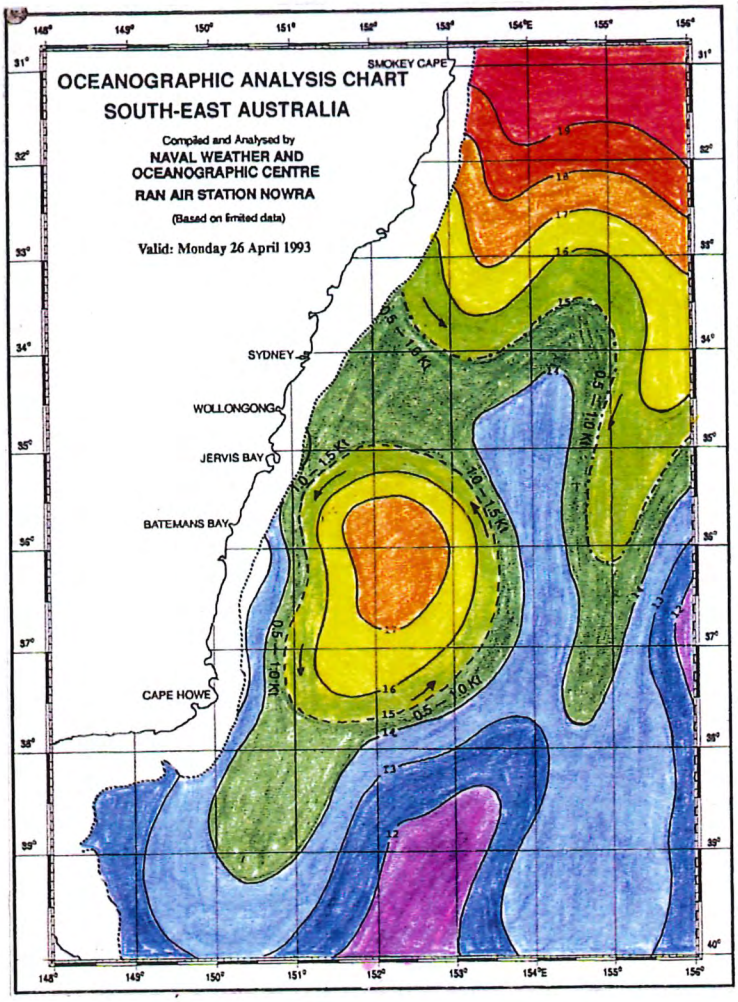
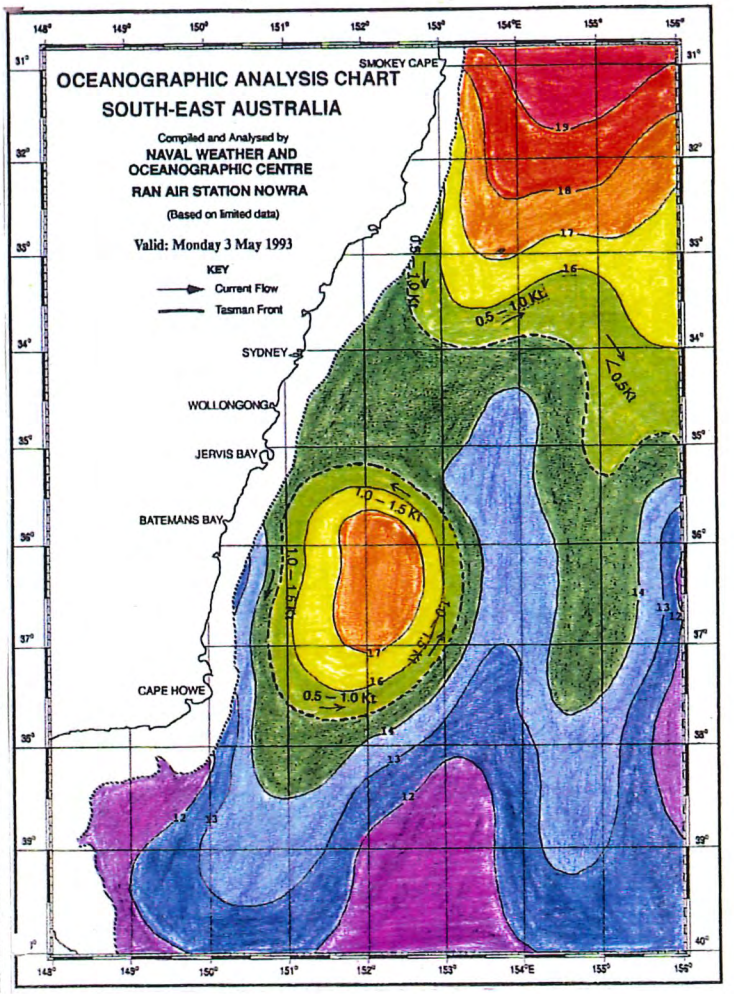


Figure 18.
Weekly 250 m isotherms off south-east Australia for the period 5 April -15 December 1993.


OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Monday 26 April 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE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SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Monday 3 May 1993
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Tasman Front
SMOKEY CAPE
SYDNEY
WOLLONGONG
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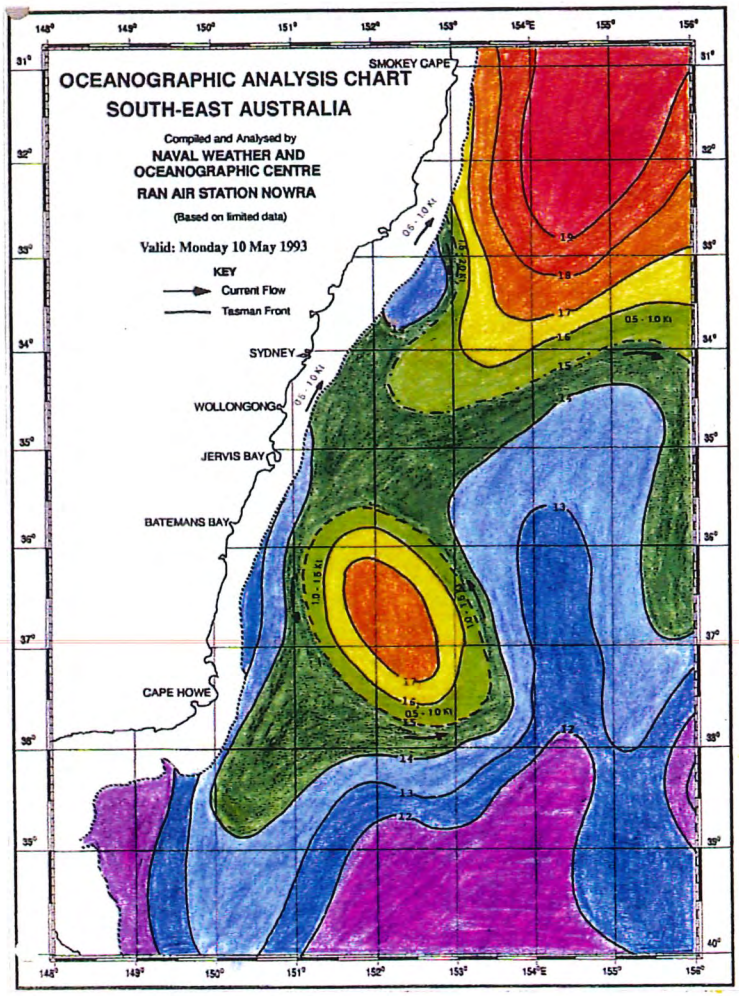
CAPE HOWE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(Based on limited data)
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SYDNEY
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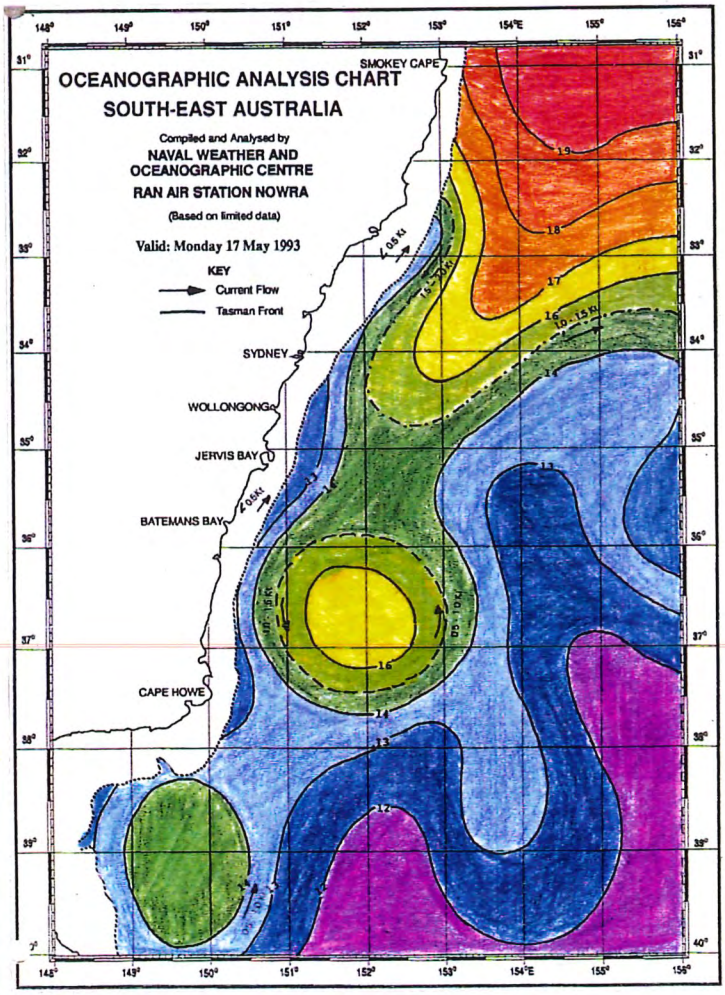
BATEMANS BAY
CAPE HOWE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OCEANOGRAPHIC CENTRE
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(Based on limited data)
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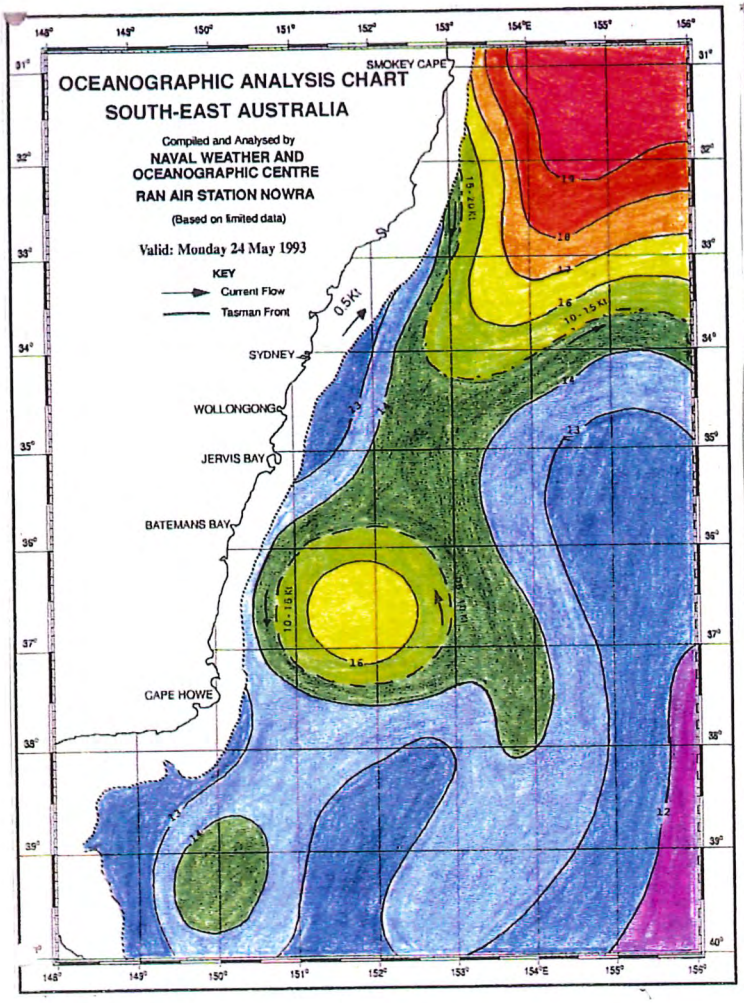
Current Flow
Tasman Front
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE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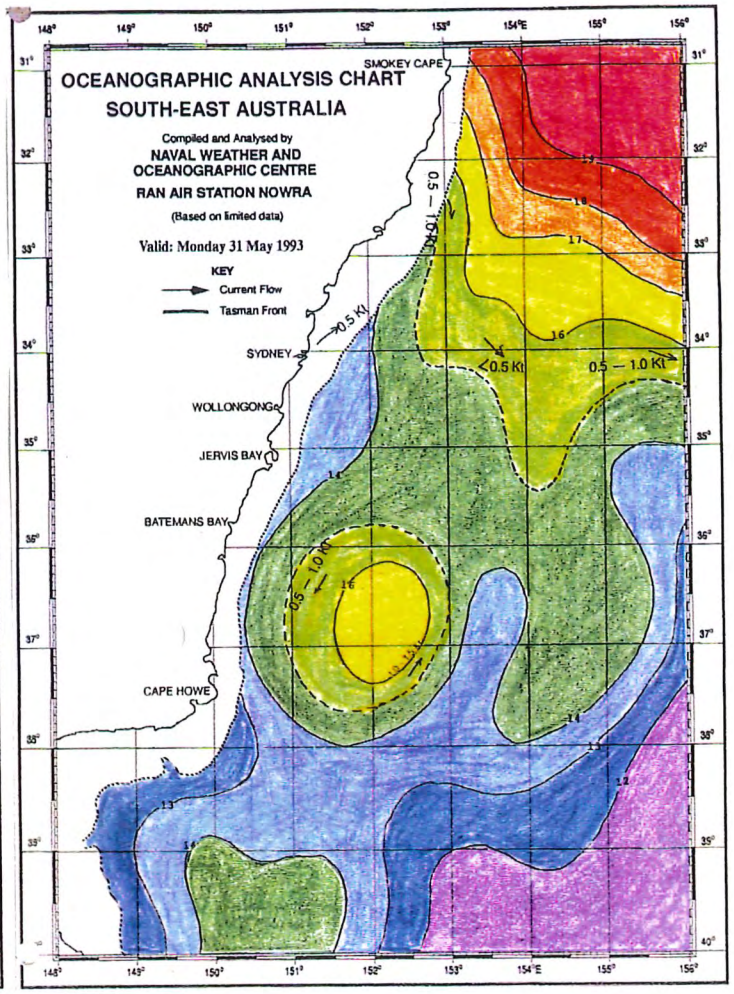
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Monday 24 May 1993
KEY
Current Flow
Tasman Front
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
0.5Kt
10 - 15 Kt
15 - 20 Kt
200 m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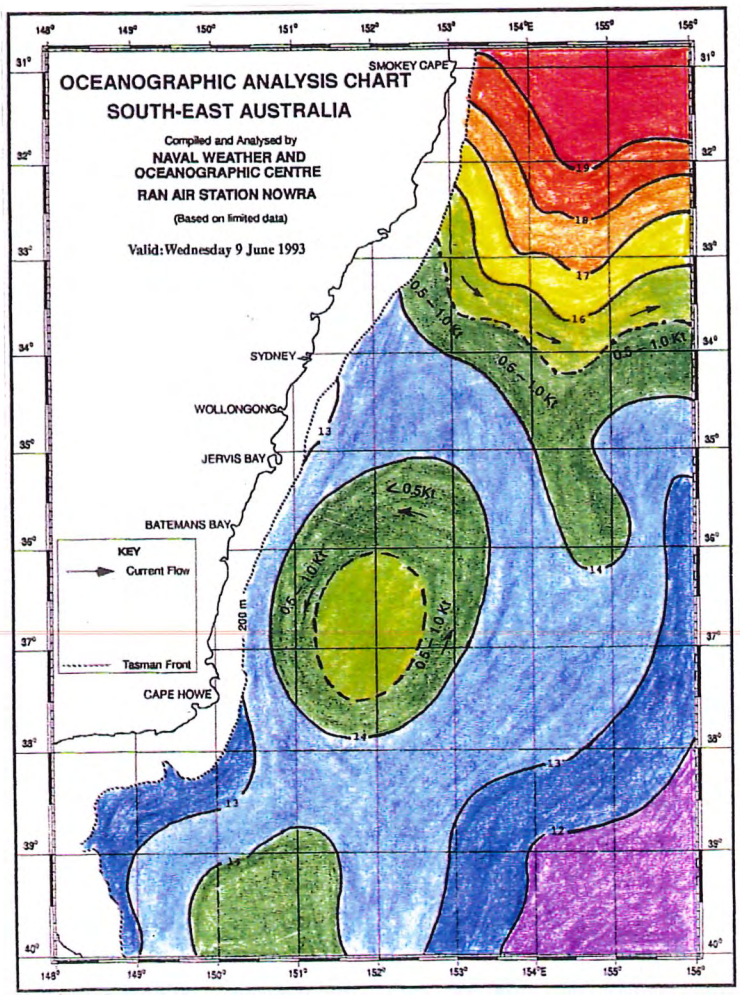
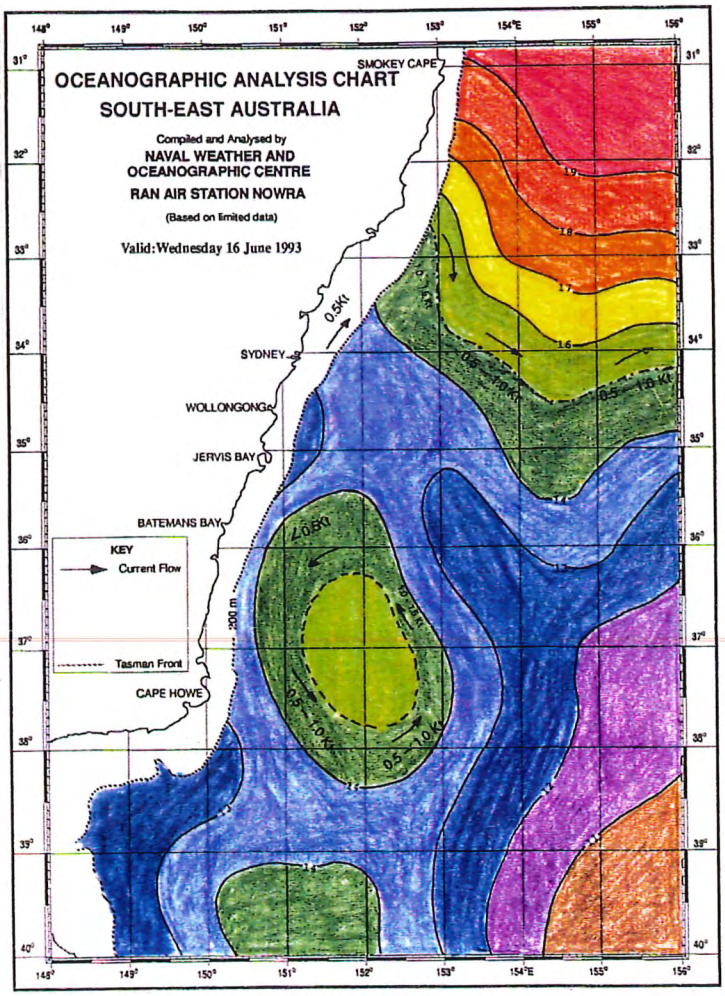
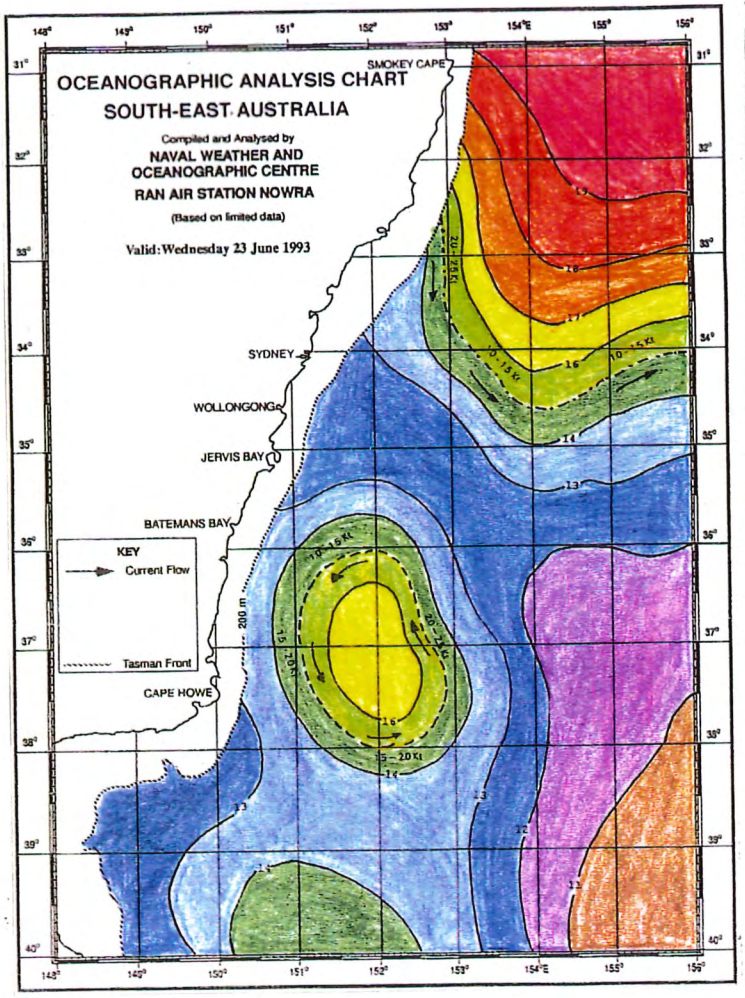
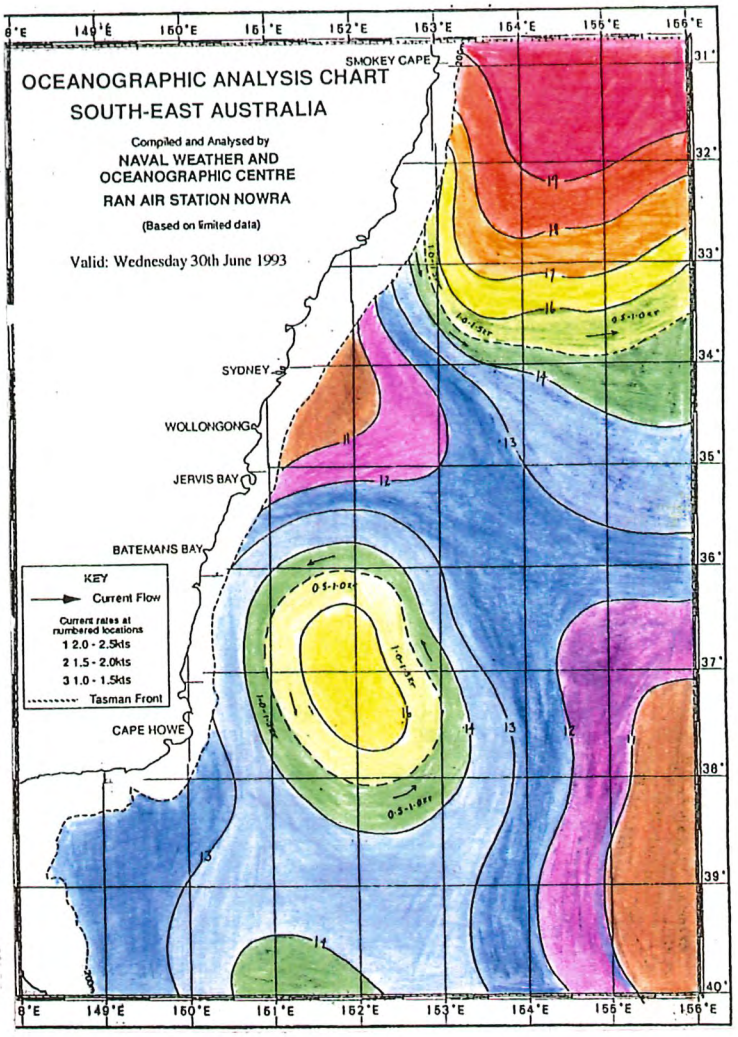
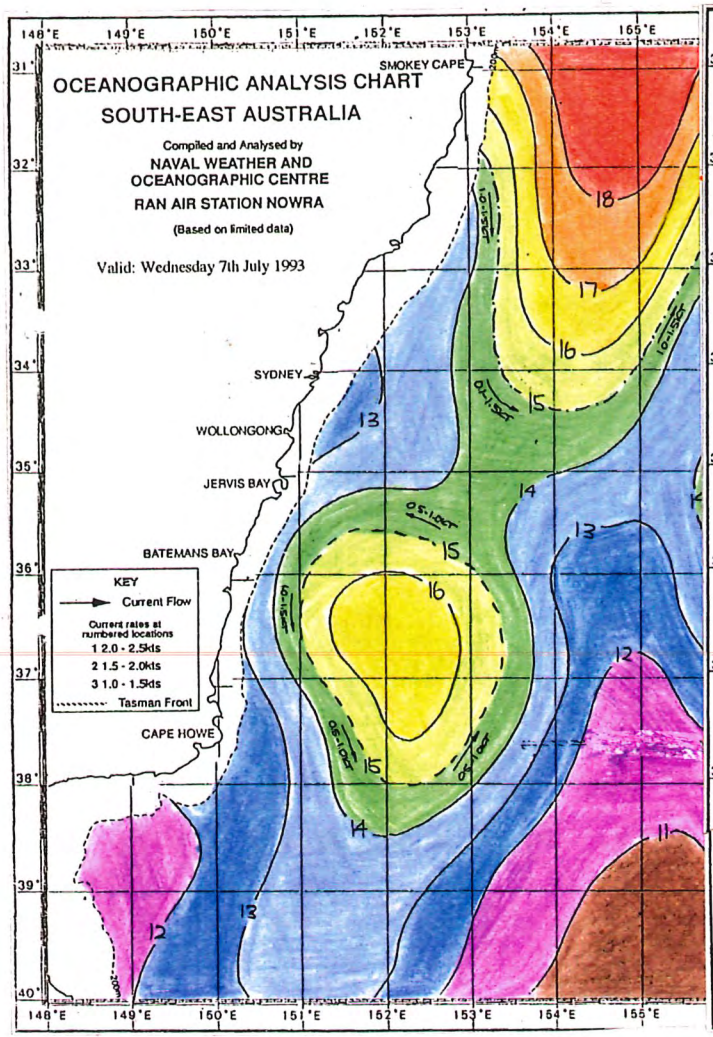
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Monday 31 May 1993
KEY
Current Flow
Tasman Front
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
0.5Kt
0.5 — 1.0 Kt
0.5 — 1.0Kt
10 - 15 Kt

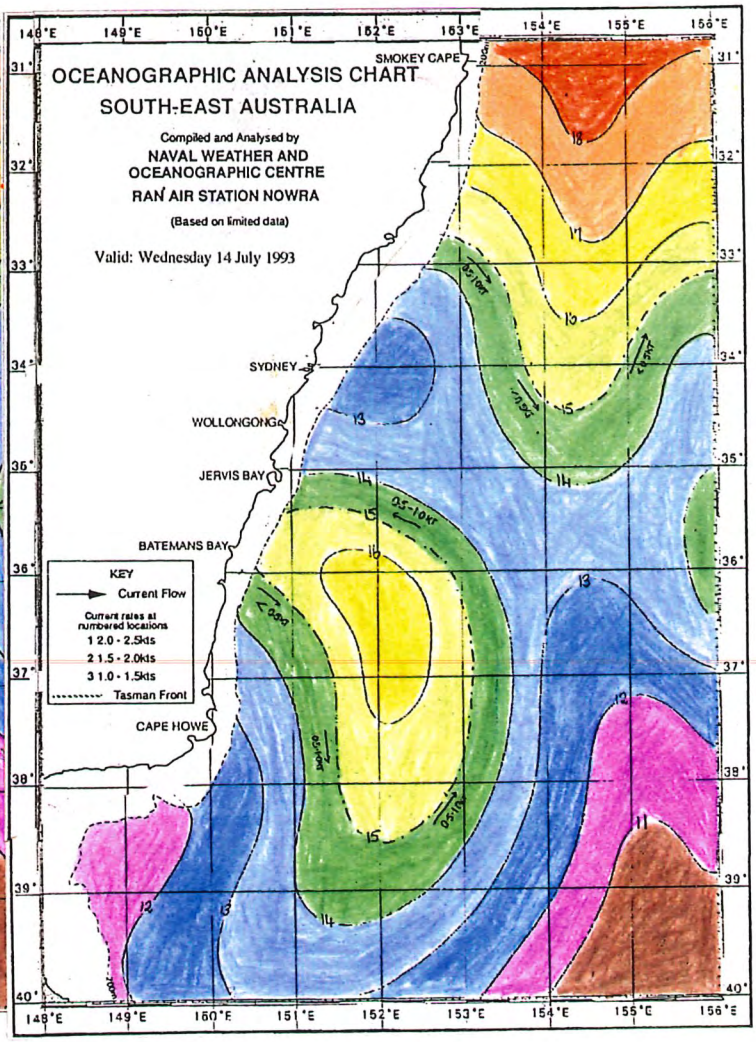

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 9 June 1993
KEY
Current Flow
Tasman Front
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
0.5Kt
0.5 — 1.0Kt
200 m

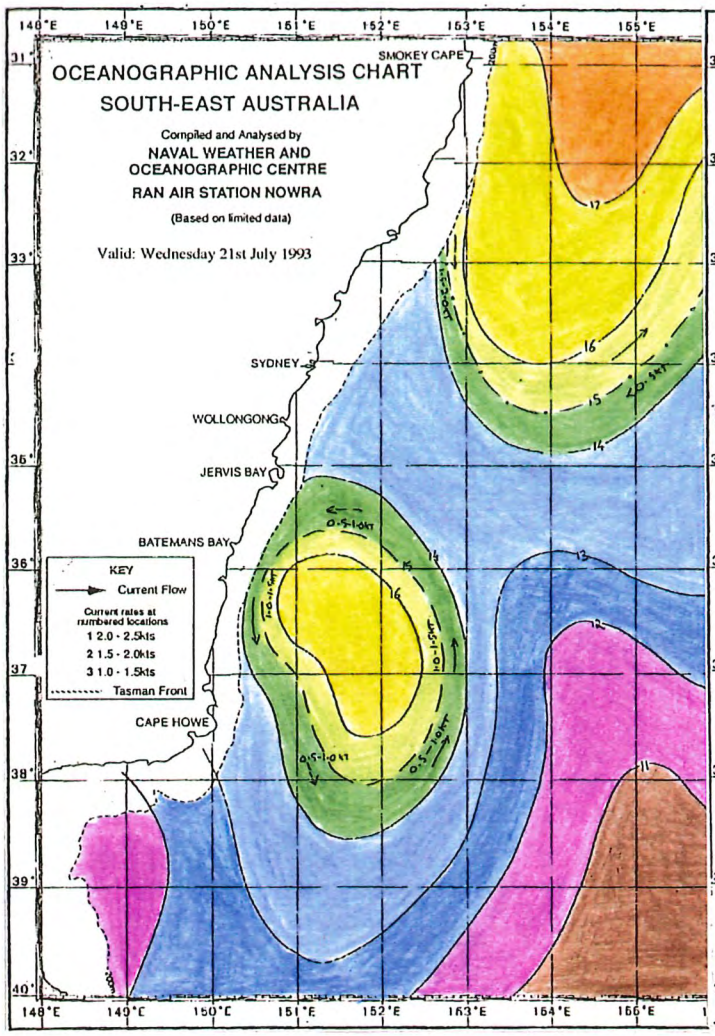

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 16 June 1993
KEY
Current Flow
Tasman Front
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
0.5Kt
1.0Kt
0.5 — 1.0Kt
200 m

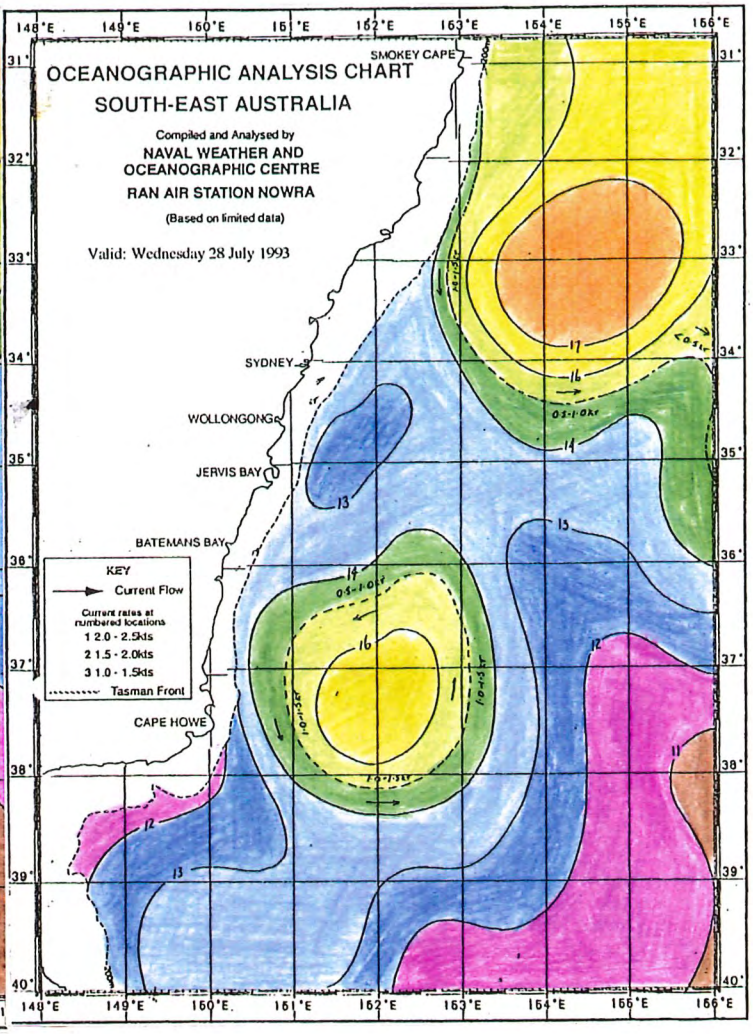

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 23 June 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Tasman Front
200 m

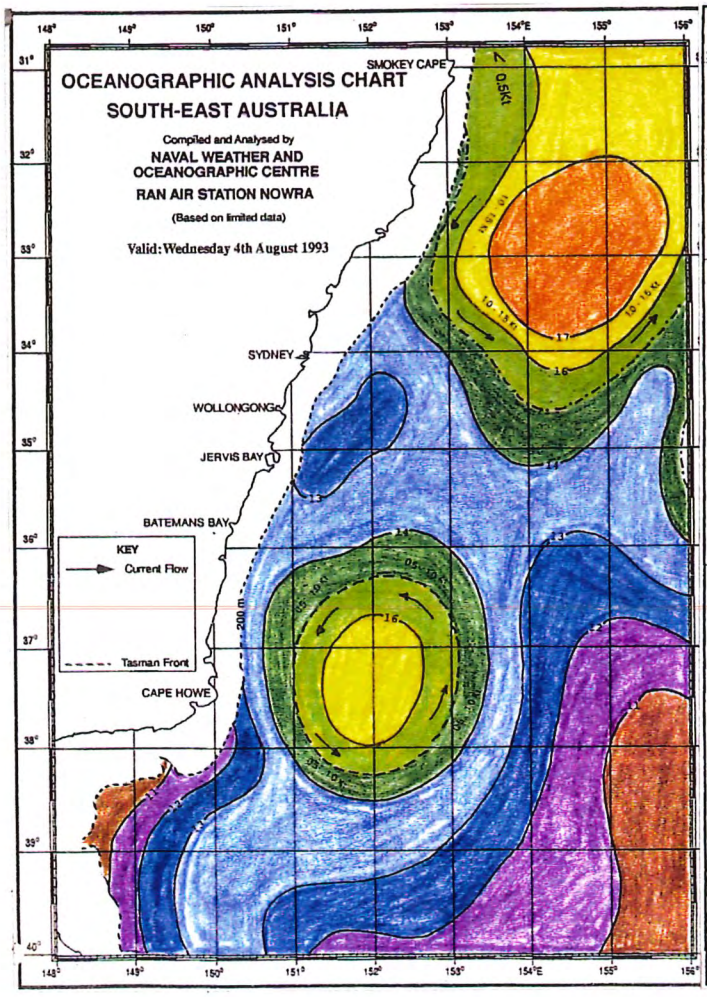

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 30th June 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front

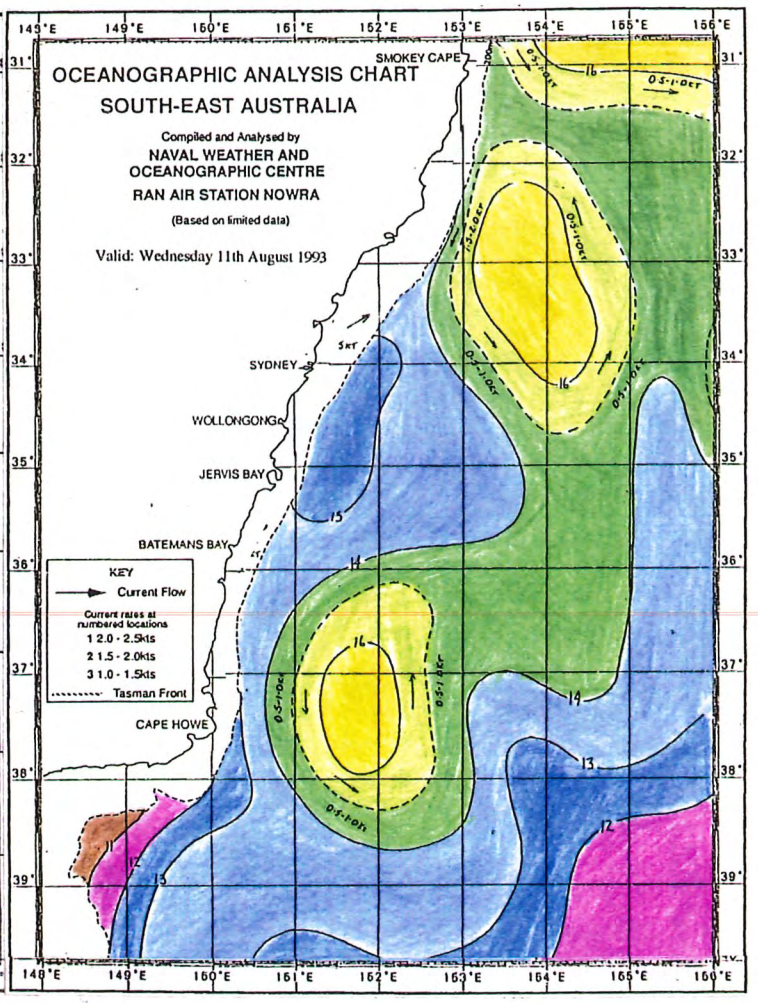

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 7th July 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front

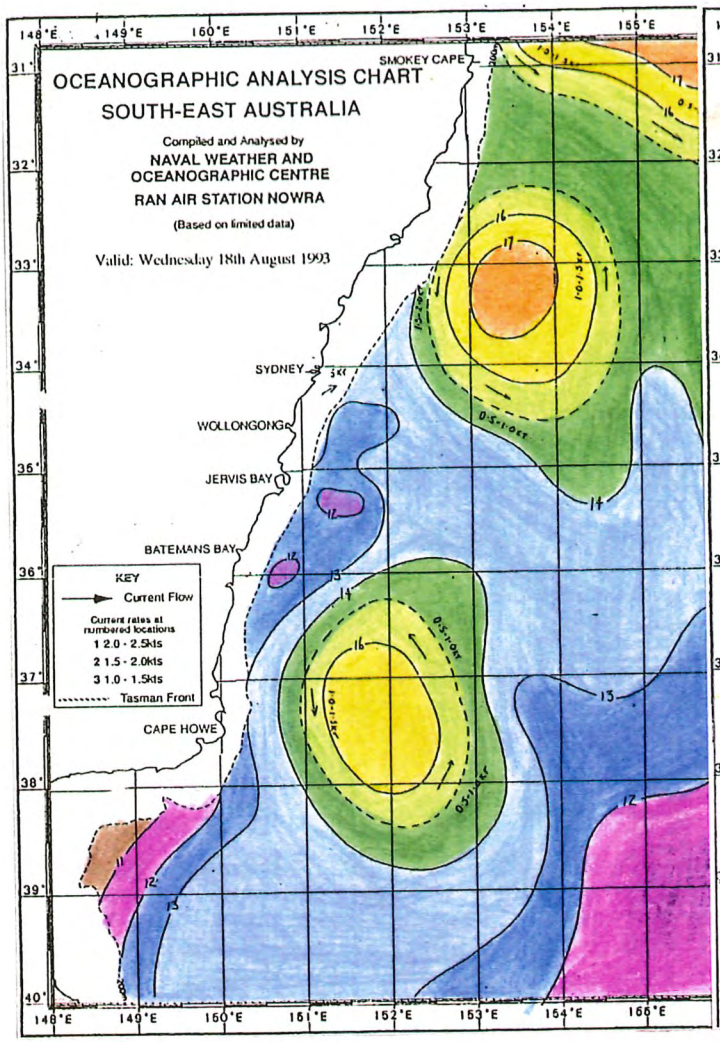

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 14 July 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front

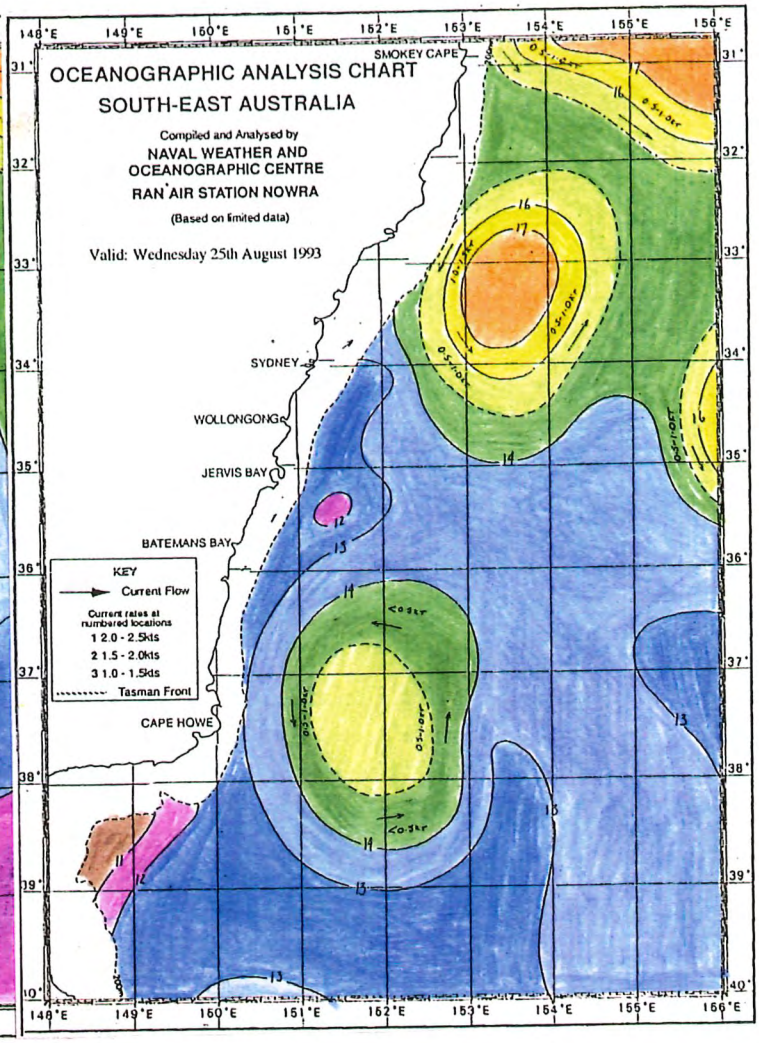

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 21st July 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front

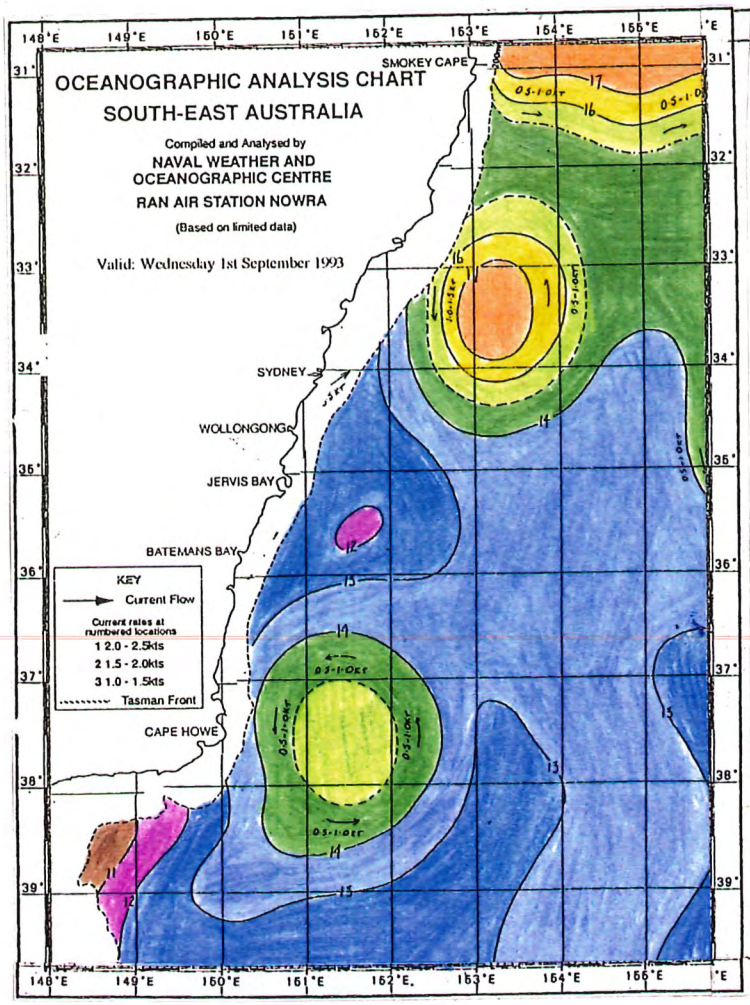

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 28 July 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front

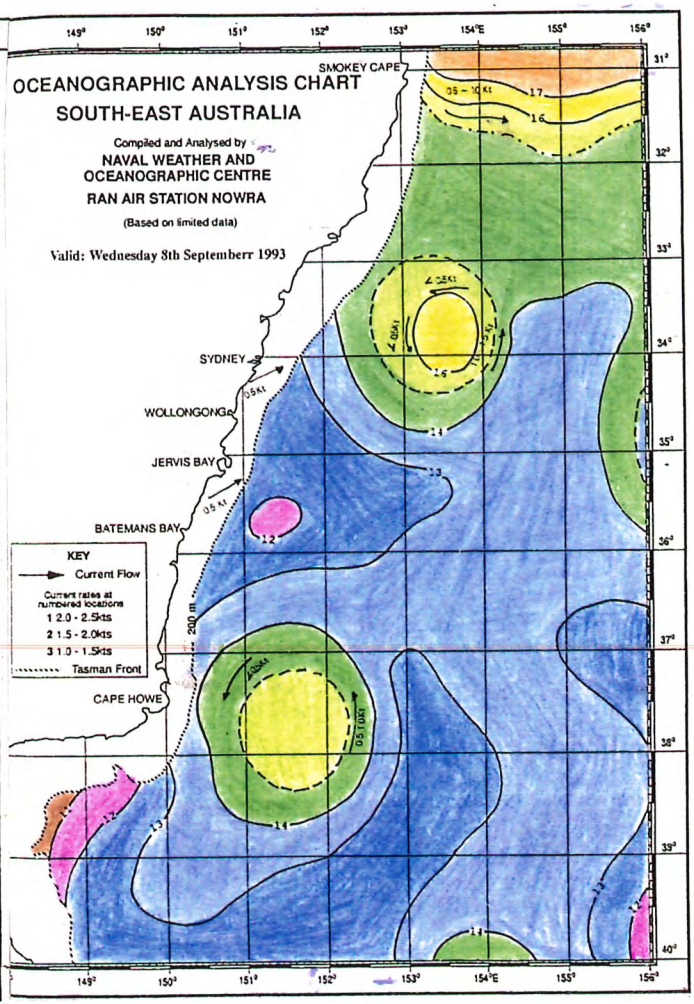

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 4th August 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Tasman Front

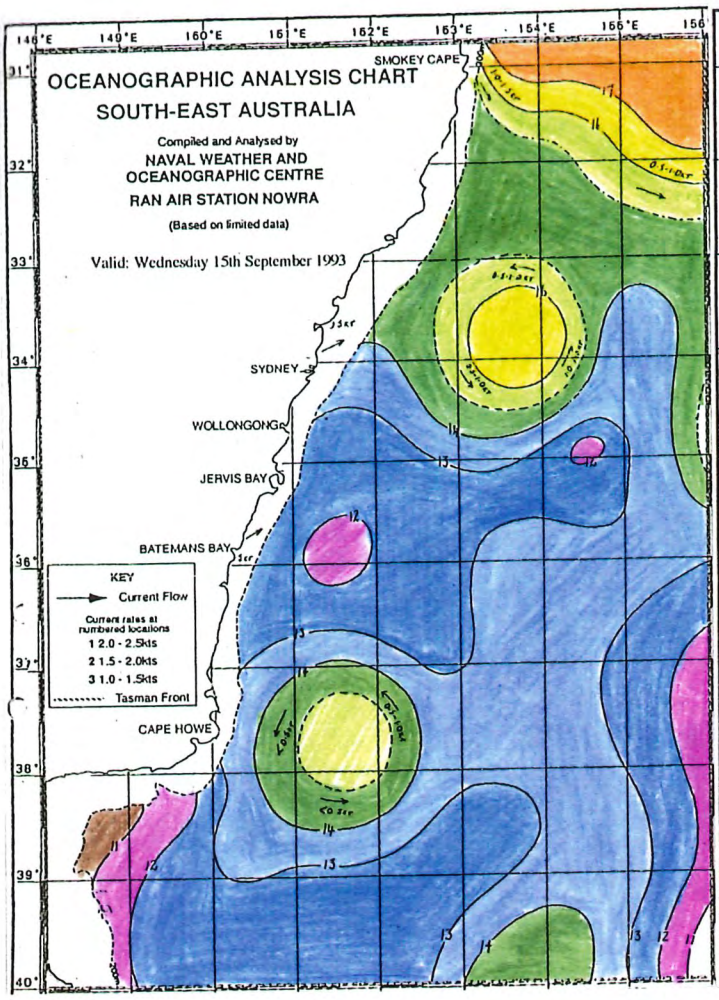

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 11th August 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front

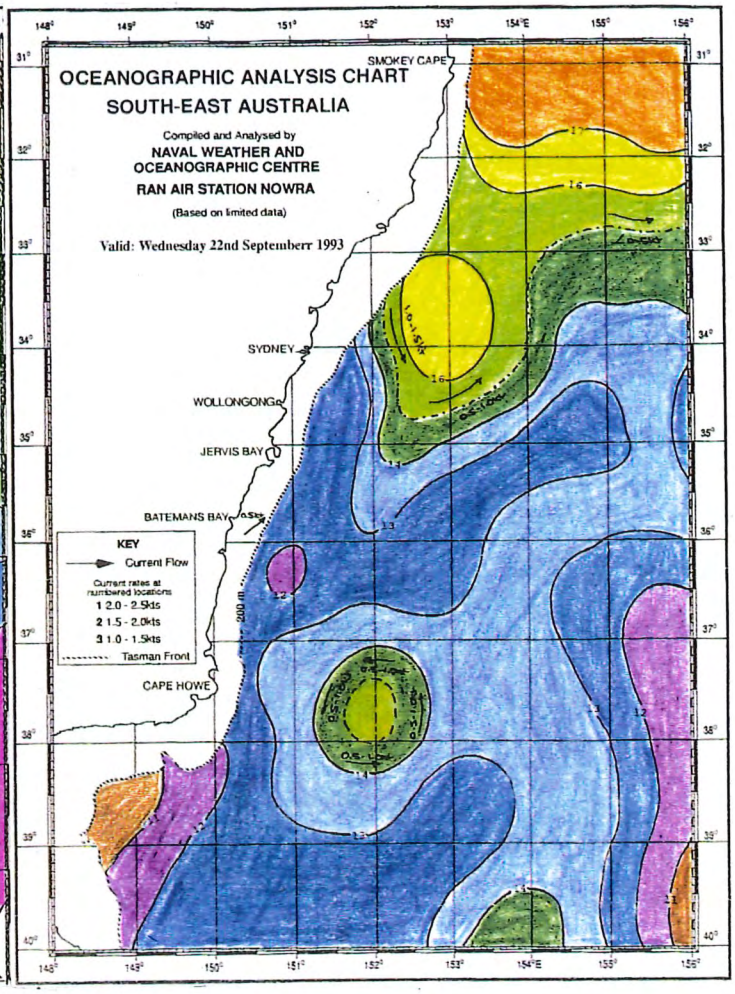

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 18th August 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front

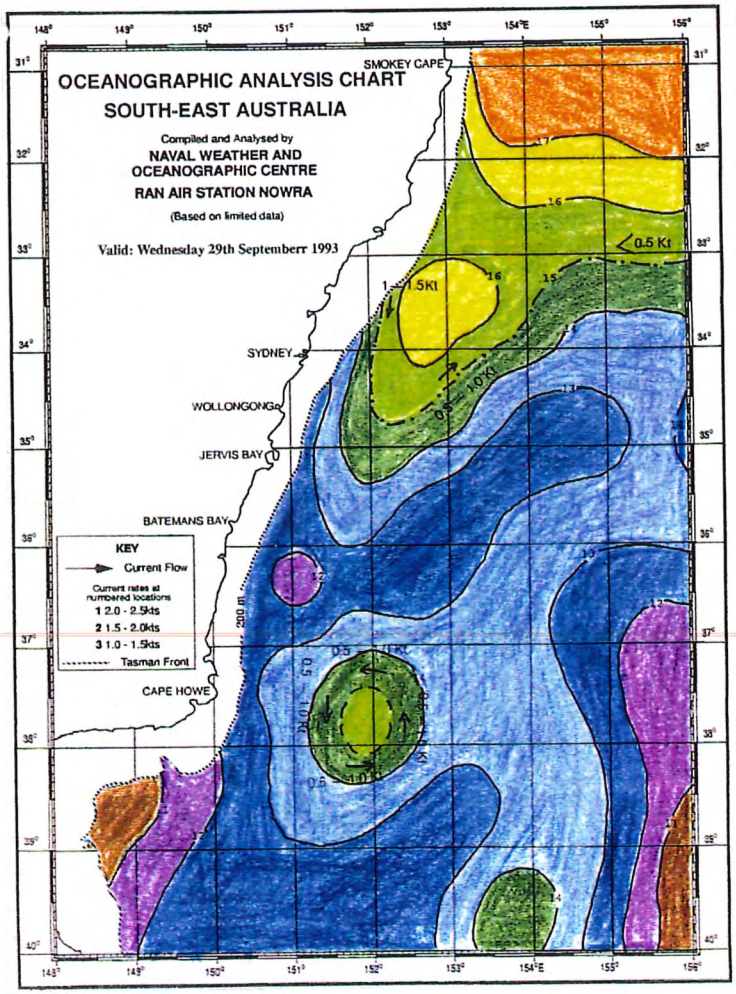

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 25th August 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front

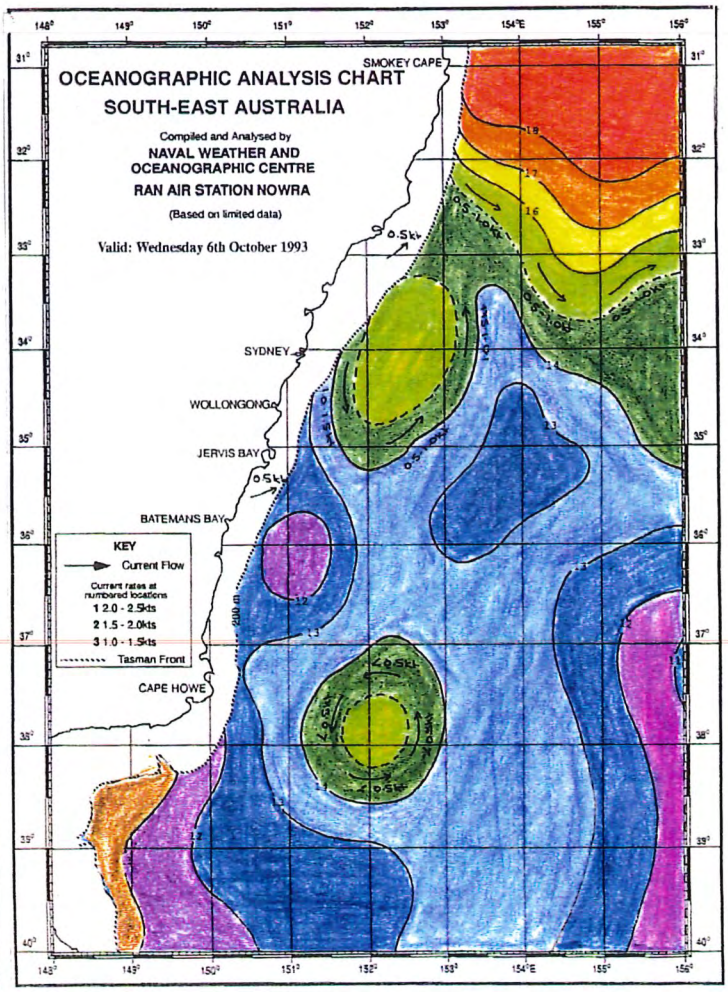

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 1st September 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front

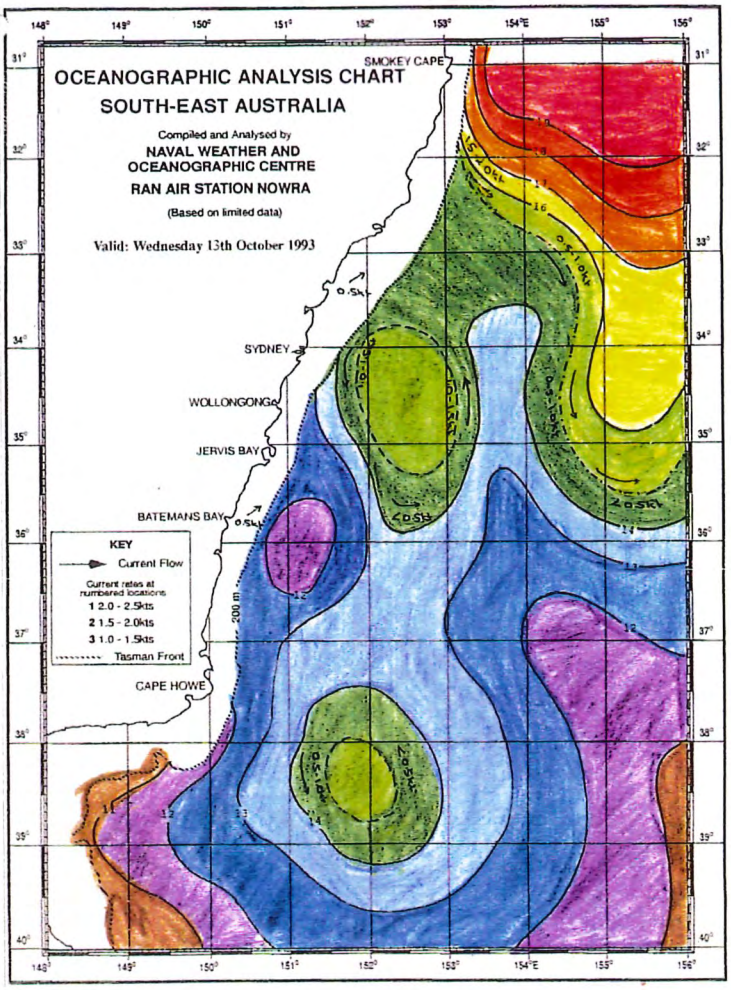

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 8th Septemberr 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front

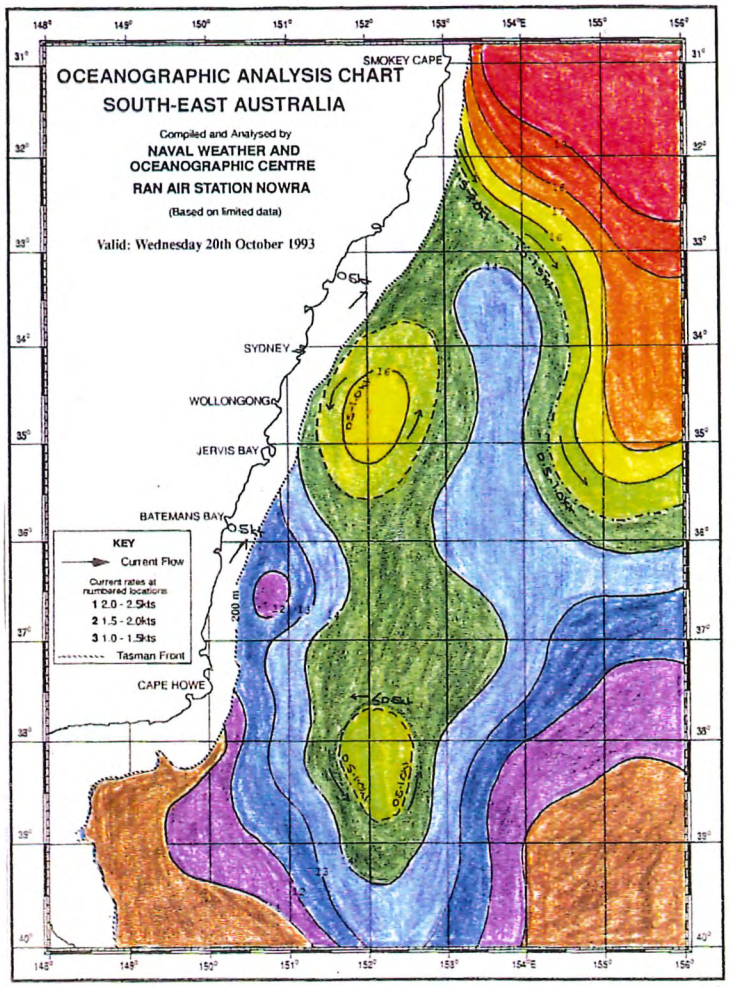

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 15th September 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front

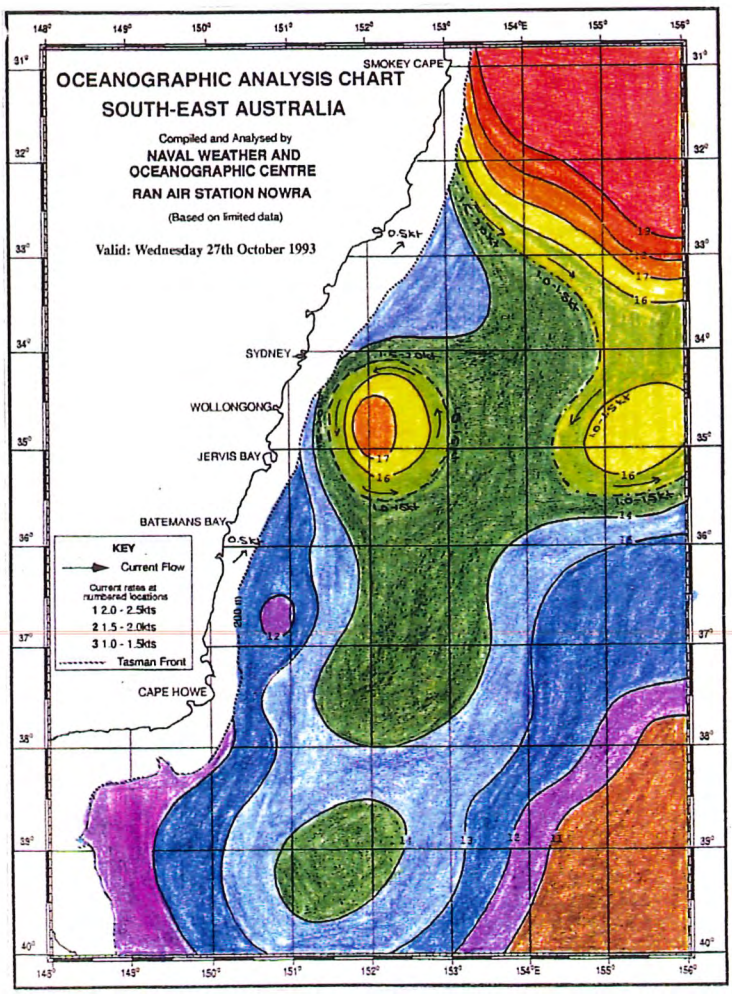

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 22nd Septemberr 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front

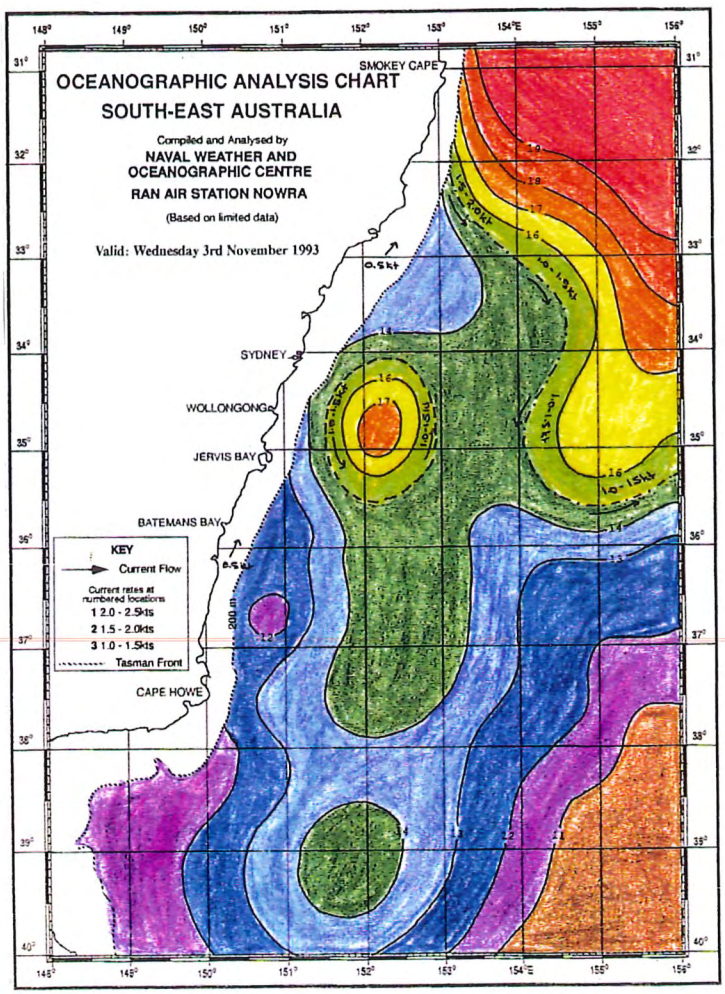

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 29th Septemberr 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front

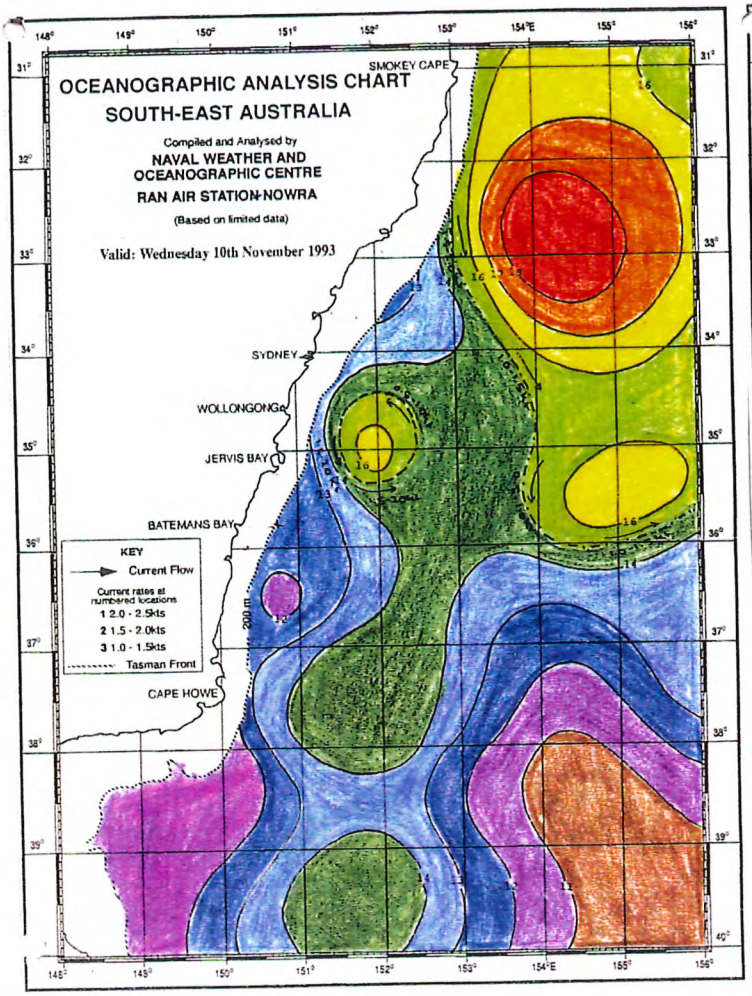

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 6th October 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front

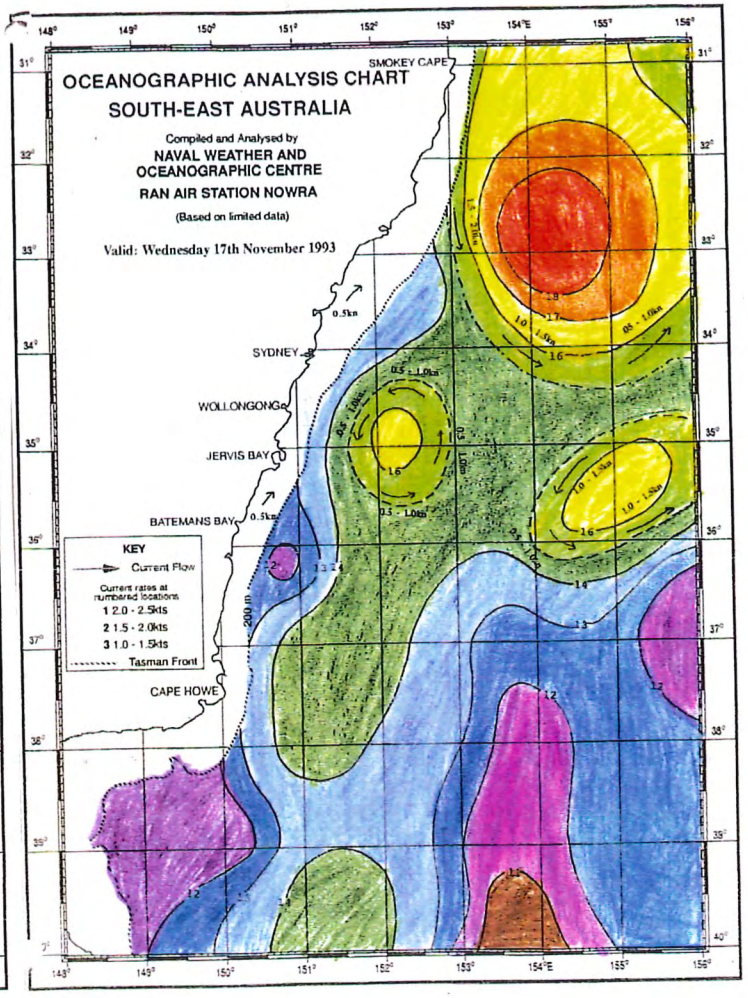

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 13th October 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front
200 m

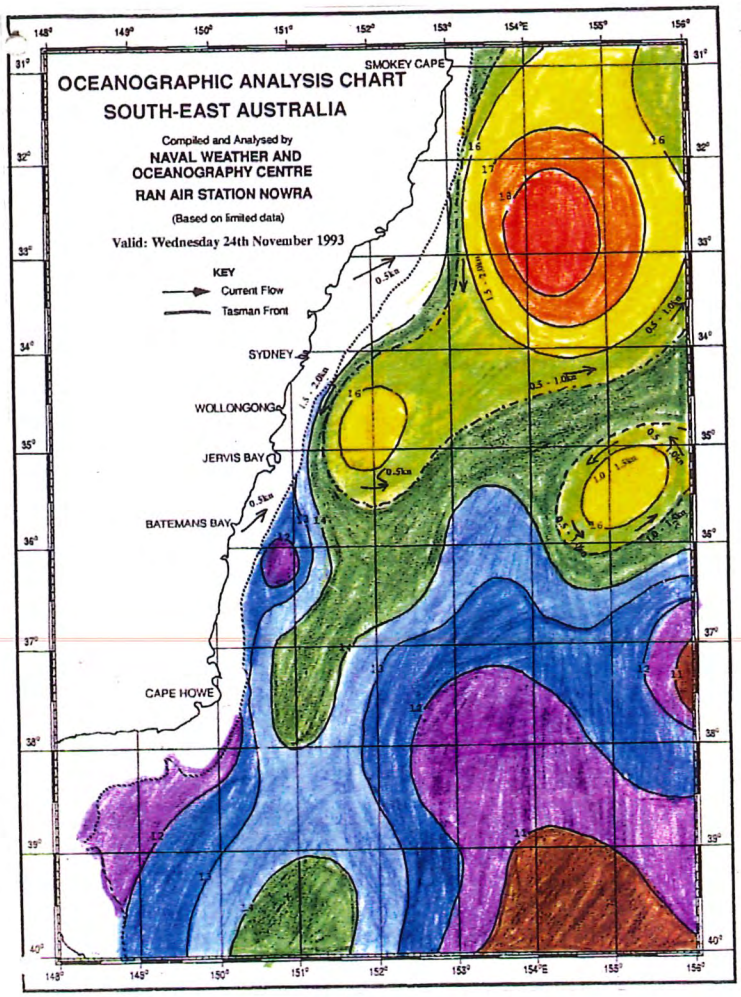

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 20th October 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front
200 m

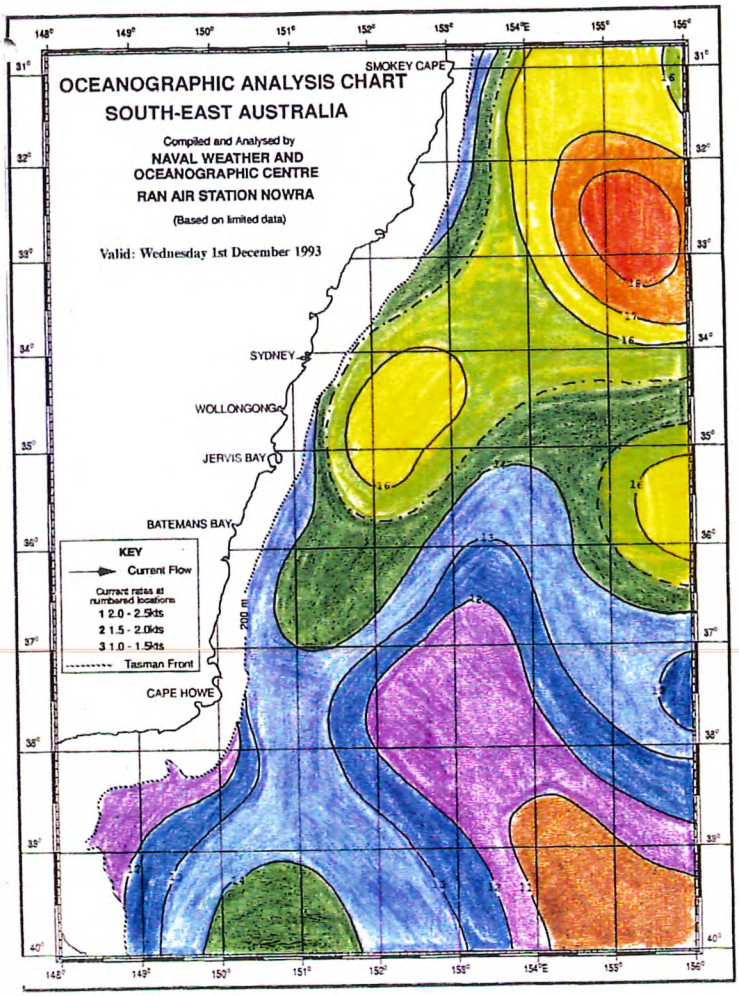

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 27th October 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front
200 m

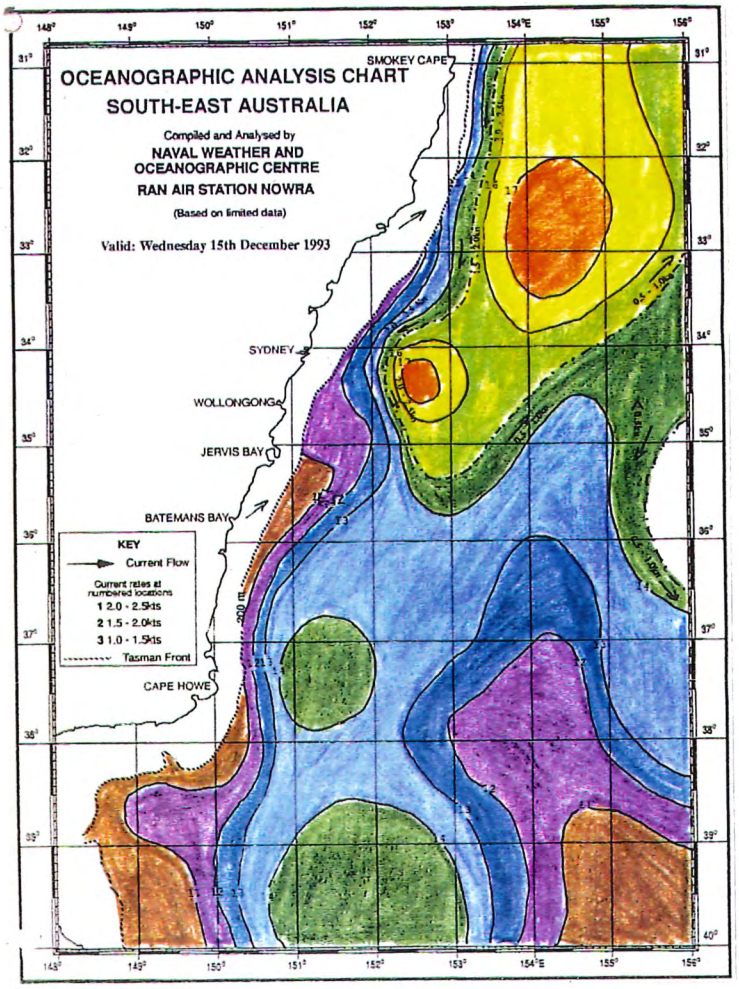

OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 3rd November 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front
200 m


OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 10th November 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front
200 m


OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 17th November 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front
200 m


OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHY CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 24th November 1993
KEY
Current Flow
Tasman Front
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE


OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 1st December 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front
200 m


OCEANOGRAPHIC ANALYSIS CHART
SOUTH-EAST AUSTRALIA
Compiled and Analysed by
NAVAL WEATHER AND
OCEANOGRAPHIC CENTRE
RAN AIR STATION NOWRA
(Based on limited data)
Valid: Wednesday 15th December 1993
SMOKEY CAPE
SYDNEY
WOLLONGONG
JERVIS BAY
BATEMANS BAY
CAPE HOWE
KEY
Current Flow
Current rates at numbered locations
1 2.0 - 2.5kts
2 1.5 - 2.0kts
3 1.0 - 1.5kts
Tasman Front
200 m
148°
149°
150°
151°
152°
153°
154°E
155°
156°
31°
32°
33°
34°
35°
36°
37°
38°
39°
40°

The 250 m isotherms for the period April-December are dominated by two principal features. The first is the warm Eastern Australian Current (EAC), which consistently protrudes from the north. The other feature is the wedges of deeper, cooler water protruding seaward from the continental shelf into the EAC.

The Eastern Australian Current is a surface current of tropical origin which moves westward along the equator before being deflected southwards by the continental land mass of eastern Australia. At 250 m these waters are consistently 14-16°C. From the isotherms it can be learned that the current protrudes down the east coast and, between 35°S and 38°S, warm core eddies periodically bud off and separate from the main northern water mass to move southwards, as observed between 20 October - 3 November; or they can rejoin the main water mass, as observed between 8 - 18 August. To the north of these warm core eddies the EAC also gives rise to an eastward flowing stream of water which, during this period, streams off shore into the Tasman Sea between 32°S and 33°S of latitude.

These warm core eddies are similar to features observed along continental shelves elsewhere in the world, for example the Gulf Stream and the north-eastern seaboard of North America (Wiebe 1982).

The southward flow of EAC was strongest at the beginning and end of the 1993 time series presented here (in April/May and November/December) and weakest during winter, as evidenced by the cooler winter temperatures of the warm core eddies at 250 m and more frequent budding off of eddies.

The second feature shown by the 250 m isotherms are wedges of deeper, cooler (11-13°C) water which protrude seaward from the continental shelf into the warmer temperatures of the EAC. When the project began at the end of June, the isotherms show that a strong wedge of 11-12°C water protruded out to sea from the area of shelf between Jervis Bay and Newcastle. The strength of this feature (in terms of area occupied and coldness of temperatures) subsequently declined and by 21 July it was no longer evident in the isotherms. It was not until 11 August that it was observed reforming in the isotherms.

However, a second protrusion of cool water (around the Horseshoe) was observed strengthening on the isotherm chart for 28 July. This feature had been evident as early as 7 July, but around 28 July it strengthened, growing colder, and remained a feature of the charts for the rest of the period examined.

Around 11 August the more northerly protrusion of cooler water began strengthening off Jervis Bay and Wollongong. By early September this feature had grown to occupy the shelf between Bermagui and Newcastle. By the middle of September, at 250m, it had completely separated a warm core eddy off Cape Howe from the parent water mass north of

Wollongong, a feature that apparently continued to strengthen until early October. During late October the strength of this cold water feature began to wane and a second warm core eddy began forming and threatening to re-join the first, more southerly, warm core eddy.

3.5 Upwellings and Gemfish Aggregations

It is important to visualize what the cold water protrusions evident in the isotherms represent in reality, because two dimensional isotherms convey little information about the physical processes at work.

The warm surface waters of the EAC flow over the top of deeper, cooler water of the Tasman Sea. The pockets and wedges of colder water in the 250 m isotherms are evidence of deeper water welling towards the surface. During these cold water events deeper water is welling up towards the surface, thereby displacing and constricting the flow of the warmer surface water from the north. In the 250 m isotherms it appears that the colder water has displaced the warmer temperatures laterally - out to sea. But this is misleading. Surface temperatures in this area vary between 13-20°C. A temperature probe lowered through the water column would show that at each sampled point across the area water temperatures fall relatively evenly with increasing depth. However, if a temperature probe were lowered into one of the cold water features it would be evident that cold temperatures were much closer to the surface than in other areas.

The areas of cold water evident in the 250 m isotherms should be seen as areas in which deeper water is welling up towards the surface. The warmer surface water is actually being displaced towards the surface and the southward flow of the EAC is being constricted, rather than displaced laterally. In this time series it appears that the constriction of the EAC current, buds off and isolates warm core eddies, and that the subsidence of these events allows the eddies to rejoin the main water mass of the EAC.

The features evident in these isotherms should be recognized for what they are; cold, nutrient rich water upwelling along the edge of the continental shelf. Upwellings transport water towards the surface. In contrast to shallower waters, deep water is generally nutrient rich. Areas in which upwellings occur are normally characterized by elevated levels of biological productivity due to the combination of light, nutrients and warmer temperatures.

Upwellings are associated with most of the major fisheries of the world, but until recently it has been generally accepted by Australian fisheries biologists that no upwellings occur in Australian waters. No suggestion is being made here that the cold water features shown by these isotherms are major or even large upwellings on a global scale, but it should be recognised that the features described here are upwellings during which cold, nutrient rich water is periodically advected up the continental slope towards the surface.

The coincidence between significant gemfish catches during the 1993 seasons and protrusions of cold water should be noted. The first cold water wedge occurred around Wollongong - Newcastle during the latter half of June and catches dominated by large female gemfish were associated with it.

The second and third events partly coincided. At the end of July a cold water wedge around the Horseshoe intensified and, although later weakening, it remained a feature of the isotherms until the end of the time series. By mid-August another prominent cold water feature had developed immediately to the north of the Horseshoe event and was extending almost as far north as Sydney. This latter feature strengthened and extended northward through September into October. During August, September and October the flow of the EAC at 250 m, as delimited by the 14°C isotherm, was disrupted by an advection of cold water that extended out into the Tasman sea from the NSW shelf, isolating a warm core eddy directly off Cape Howe.

As with the June event of Wollongong, significant catches of gemfish were associated with both the second and third cold water events; around the Horseshoe in late July and the beginning of August, and off Wollongong and Sydney in late August and the beginning of September.

3.6 The Influence of Moonphase and Water Movement

Moonphase affects both light levels and water movement. Prince (1991) has previously suggested the possibility that the movement of water on and off the shelf can cause a pumping action along the edge of the shelf, drawing deeper water up the shelf edge as tides rise and dispelling them along the surface as tides fall.

Figure 19a shows the daily tidal amplitude along the NSW coast during 1993, calculated as a lagged, running 7 day mean, and also the timing of new and full moons. The tidal amplitude can be used as an index of tidal water movement onto and off the shelf. It can be seen that full and new moons correspond with periods of greatest tidal amplitude. The tidal amplitude associated with each full moon peaked in February 1993 and declined relatively smoothly until the first full moon of December. The tidal amplitude associated with new moons was relatively low until June, lower than that of the full moons, with minima in April, but then increased to be greater than the tidal amplitude of full moons in July. The tidal amplitude of the new moons peaked in September.

Figure 19a.

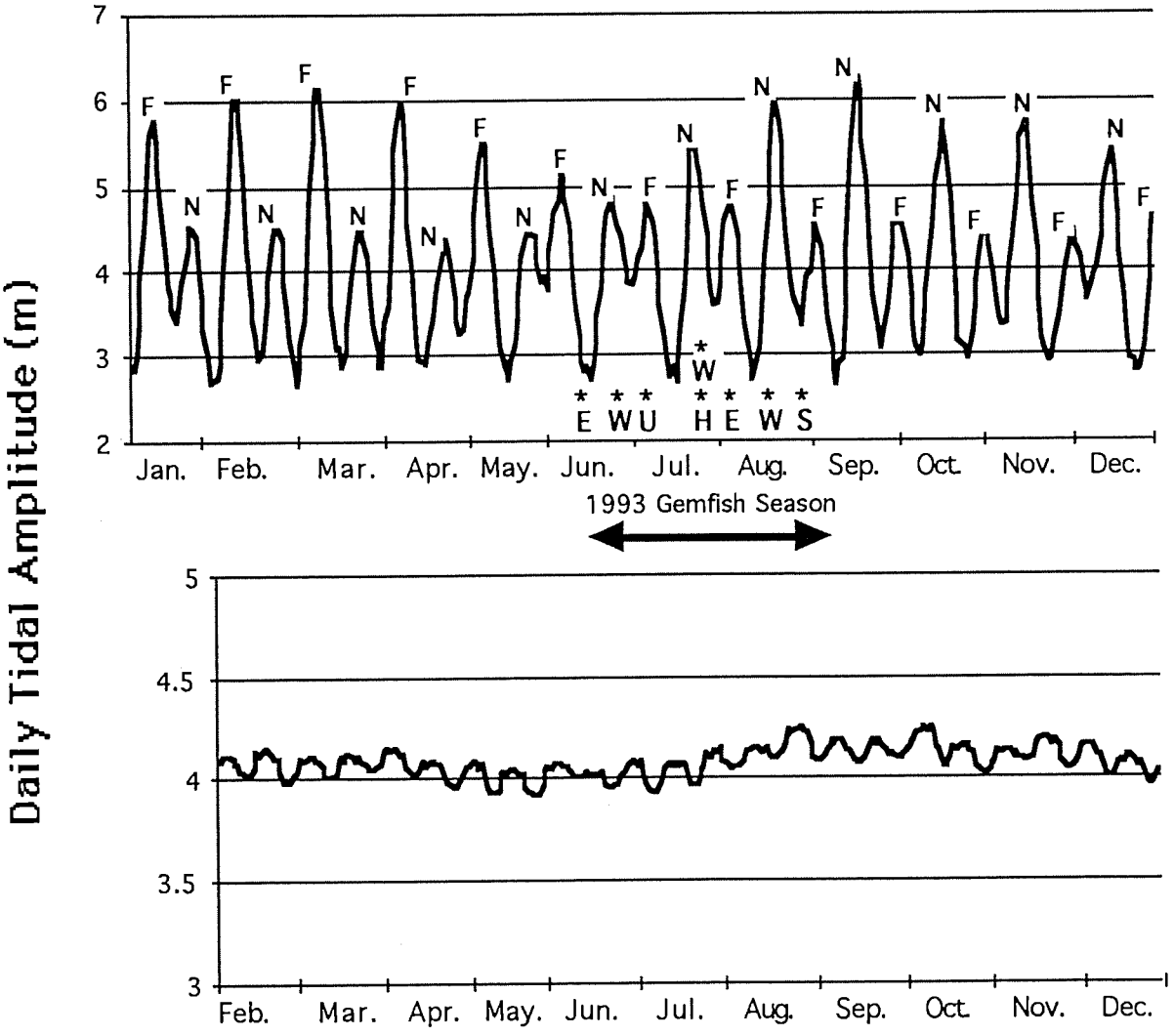


Figure 19b.

Figure 19.
(**a**) The daily tidal amplitude along the NSW coast during 1993 smoothed using a 7 day lagged, running mean. N & F indicate the timing of new and full moons respectively. Timing of major aggregations indicated with asterisks, letters identify location: H - Horseshoe, E - Eden, U - Ulladulla, W - Wollongong, S - Sydney; (**b**) daily tidal amplitudes along the NSW coast during 1993 smoothed using 28 day running mean.

Smoothing the tidal amplitude trends further by calculating a 28 day running mean (Figure 19b) shows that the gemfish season began in June when tidal amplitudes reached their annual minimum and most stable levels. The season ran through July and August when tidal amplitudes were increasing, and ended in September when tidal movement reached peak annual levels. Relatively high, but declining, levels of tidal amplitude continued into October and November after the gemfish season.

It should be noted that the greatest tidal amplitudes, in October-November, coincide with the strongest cold water event observed during the year. At this time 250m isotherms showed that the cold water event of the central NSW coast had completely separated the warm core eddy forming on the southern edge of the Eastern Australian Current from its originating water mass. The final spawning event of the 1993 gemfish season coincided with the establishment of this cold water feature.

3.7 Westerly Winds

The importance of offshore winds in driving upwellings events is widely recognized. Offshore winds drive shallow inshore waters offshore, thereby drawing cold water up from depth along continental slopes. Gemfish fishermen all believe that the strong offshore (westerly) winds, which are a normal feature of NSW winter weather, heavily influences the gemfish season. Many gemfish trawlers were purpose built to allow trawling to continue in gale force westerly winds because this is when the fishermen believe trawling for gemfish is best (Wright - Section 2, this report).

Dr Ron Thresher of CSIRO has been analysing wind data together with catch data from a number of eastern seaboard fisheries and is apparently finding indications that productivity in a range of fisheries may be statistically linked to the seasonal strength of westerly winds.

No quantitative data on westerly winds was examined by this study. However anecdotal accounts suggest that the 1993 gemfish season was marked by uncharacteristically weak westerly winds. This was the most often cited reason for the 1993 gemfish season being so apparently anomalous.

3.8 The Importance of the NSW Shelf Break to the Eastern Gemfish

Fishermen operating in this area are familiar with what they call "feed layers". These acoustically active layers, apparently comprised largely of jack mackerel (but undoubtedly including a wide range of organisms) are typical of the gemfish season and migrate vertically through the water column on a daily basis (Wright - Section 2, this report). Fishermen associate the gemfish season with a build up of the feed layers over the shelf edge and many believe that a form of biological succession takes place within the feed layers.

They claim that early in the cycle, nets passing through the feed layer will be landed relatively clean of by-catch while large amounts of pelagic tunicates and salps are taken later. During the final stage of succession before the gemfish move through, large amounts of small fish (mainly lantern fish) will be caught. According to fishermen, jack mackerel appear later in the succession. Many fishermen believe the gemfish run coincides with the final stage of succession and that the gemfish feed in this late stage food chain as the run moves north along the shelf edge.

Although it is extremely difficult to corroborate, it is entirely possible that much of what the fishermen believe is correct. The stomach contents of the gemfish casually observed during this project almost invariably contained segments of ribbonfish or jack mackerel, suggesting that the gemfish diet is relatively conservative at these times. These species (the ribbonfish is a top order piscivore and jack mackerel are plankton grazers) could be expected to concentrate around localized areas of enrichment for their own feeding and this could in turn attract the top-order carnivore, gemfish, to these areas.

But enriched feeding could be of secondary or co-incidental importance in determining the location and timing of the winter gemfish run. It is possible that it is actually the upward advection of deeper, cooler water that is being targeted by the spawning gemfish. Johannes (1981) has previously noted the importance of geological features to spawning aggregations of fish. He synthesized information about the spawning behaviour of shallow water coral reef fish and found that spawning commonly took place around geological features like pinnacles rising from deep water outside a lagoon or the leading point of an atoll. Johannes postulated that this behaviour was an adaptation to enhance the retention of eggs and larvae around the coral reefs occupied by the adults and to optimize the environment of the larvae. He noted that many of the geological features used could be expected to produce relatively stable gyres and eddy features.

The larvae of gemfish are planktivorous, feeding in the productive and warmer surface photic layers of the ocean above the adults. Placing the eggs and larvae into this zone can be no trivial matter for adult gemfish. The temperature layering of water over the oceanic basins is relatively stable, only the surface layers are thoroughly mixed by the action of wind. Moreover, most adult oceanic fish do not readily or willing move between these sort of depths and temperatures. Upwellings along the continental shelf may enhance the transport of eggs and larvae, which are otherwise limited to using their own natural buoyancy, into their appropriate habitat.

The topography of the shelf break probably creates relatively stable upwelling conditions, given prevailing oceanographic and meteorological conditions. These winter upwellings could enrich the gemfish habitat, creating a food chain of sufficient biomass to support large concentrations of gemfish within small areas, as spawning aggregations build up before specific spawning events. The physical properties of these upwellings could also be important to the gemfish life cycle, assisting the placement of eggs and larvae into water bodies optimal to gemfish survival.

Section 4: General Comments and Conclusions

4.1 The Existing Stock Assessment

While the results of this program apparently support many of industry's observations about the distribution of size classes through the eastern gemfish fishery, it is also immediately apparent from these results that these affects do not obscure the broader population trends within the gemfish stock.

It is clear that levels of recruitment have changed considerably through the history of the fishery. This is evident both in the relative lack of 60 - 80 cm gemfish, in comparison to previous years (1970s-1980s), and the large numbers of 50 - 60 cm gemfish now occurring in catches. This size structure is consistent with the view that recruitment of eastern gemfish into the stock was poor between 1986 and 1989 but may now have returned to more normal levels.

Having concluded that the FRI assessment has succeeded in describing the main trends in the gemfish population over recent years there remain three areas in which the assessment may still be prone to some lower level of bias and these deserve to be outlined.

The first concerns the geographic variability of size. The winter fishery for gemfish began on the northern grounds and slowly developed onto grounds further south. In the first year of quota management (1988) a significant proportion of the total catch was landed into Lakes Entrance in the extreme south. From the results of this study it should be expected that this change in the fishery over time may have lead to the average size of fish in the early stock being overestimated and then underestimated around the time of the introduction of quota. The contraction of the catch into the early part of the season should also be expected to have lead to an increase in the estimate of average size in the stock as catches were reduced by quota.

The second factor is the level of under-reporting that has occurred throughout the history of this fishery. Biomass estimates are derived from the current assessment using recorded catch histories. Interviews with fishermen suggest that under-reporting of catch levels has occurred consistently throughout the fishery (Wright - Section 2, this report.). This would lead biomass estimates to be underestimated by a factor equivalent to the under-reporting, without affecting estimates of overall population trends.

The third possible cause for concern with regard to the FRI analysis is the possibility that changes in net design, which have occurred since quotas were reduced, may have decreased gemfish catchability in recent years, thereby biasing estimates of the strength of recent year classes. As demonstrated by N. Hall (Cronulla, February 1994) estimates of biomass produced by the cohort analysis are extremely sensitive to assumptions about the stability of catchability in recent years. If the change from using purpose built gemfish nets to catching

by-catches of gemfish with normal market-fish nets has reduced gemfish catchability in recent years, then current biomass estimates can be expected to be overly-pessimistic.

As specialized trawling for gemfish developed, trawl nets were modified to increase their effectiveness (Wright - Section 2, this report.). Gemfish have a prominent lateral line which divides and runs the entire length of the body, high and low on the flank of the fish. This split lateral line undoubtedly helps the gemfish locate moving objects under the low light conditions normal to their environment. Fishermen believe that gemfish are extremely sensitive to pressure waves generated by trawl nets and can avoid nets. They claim that catches are maximized by slowing trawl speeds as much as possible (approx. 2.5 knots), and floating or flying the net forward into a southerly current, minimizing pressure waves, and almost "trapping" the schools of gemfish swimming towards the net. During the 1970s specialized gemfish nets were developed with extra large wings and large cod-ends. Heavy bottom chains and large trawl doors were used to stabilize these essentially unstable nets. The doors kept the large mouths open, almost "over-spreading" the net, even at low speed with large catches. Gemfishermen of renown were particularly skilled at "flying" these nets slowly across the trawl grounds. Since the introduction of quotas and the reduction of catches fishermen have reverted to fishing for gemfish with normal market-fish nets.

This being said, any more optimistic assessment of the stock must continue to recognise that the medium size classes of gemfish, which until recently dominated catches, now occur in low abundances relative to the other size classes.

Consequently, I conclude that while the FRI stock assessment estimates of actual stock size are likely to be conservative, the stock is now at historically low levels, having experienced several successive years of low recruitment.

4.2 Implications for Monitoring

The results of this study indicate that the composition of the winter gemfish aggregation varies through the season.

A study by Langley et al. (1993) of the northern New Zealand gemfish trawl fishery came to the same conclusion for that fishery. That report consequently concluded that:

"Future market sampling of the commercial catch requires a more rigorous, structured approach. The most appropriate methods would be to divide the fishing season into weekly strata and apportion sampling effort to each period in relation to the seasonal distribution of the commercial catch. Subsequent analysis of market sampling data would reflect the stratified structure of the sampling design."

The same recommendation is equally valid in the Australian context.

4.3 Implications for Management

There can be no doubt that the eastern gemfish fishery has experienced a period of extremely low recruitment and this justified its cautious management. If management has erred in this situation it is in allowing the debate between industry and scientists about gemfish stock assessment to become too polarized.

Both sides clearly have a valid perspective: industry observes variability in size and distrusts the size based assessment; government scientists observe clear changes in the size of fish caught over time and produce pessimistic stock assessments. In today's consensus society debates about the status of fisheries must be managed so that industry is as convinced about the need for strong conservation measures as are the scientists. Scientists must learn to appreciate that moving faster than industry on a topic will always lead to counter-productive controversy and will generate opposition to the implementation and enforcement of tight conservation measures.

If there had been more recognition of, and response to, industry's legitimate concerns and perspective, much of the acrimonious confrontation that has accompanied the eastern gemfish assessment and management may have been avoided. The polarization of any debate only leads to the re-enforcement of minority opinions at both extremes of the argument. This can never be good for the effective management of modern fisheries.

The abundance of small gemfish in the catch of 1993 suggests the welcome possibility that recruitment rates are now increasing. For a predatory fish like gemfish it might be expected that low numbers of larger fish may enhance the survival rate of smaller size classes. Considering the biology of gemfish and the evidence of these histograms it is a possibility that, with favourable environmental conditions, the eastern gemfish stocks could recover to the levels characteristic of the 1970s and early 1980s within 3 to 5 years.

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