

**Industry Survey
of the 1996 Eastern Gemfish
Spawning Season.**

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**F I S H E R I E S
R E S E A R C H &
D E V E L O P M E N T
C O R P O R A T I O N**

Project 96/157

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1. NON TECHNICAL SUMMARY

96/157 Industry survey of the 1996 eastern gemfish spawning season.

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Objectives:

1. To collect catch rate data from the 1996 spawning run of eastern gemfish in a manner as similar as possible to previous practices of targeted commercial fishing.
2. To collect length frequency data and digital acoustic data for the 1996 winter eastern gemfish aggregations.
3. To study industry claims that the timing and location of gemfish aggregations is influenced by cold water currents along the edge of the NSW continental shelf.

All the project's objectives were successfully achieved.

Non Technical Summary

Four commercial gemfish fishing vessels; the Charissa, Marina Star, Illawara Star and Santa Rosa II, were used between 34°S and 36°S to fish eastern gemfish aggregations 18 June and 12 August, 1996.

A total of 54 shots were conducted by the Ulladulla vessels Charissa and Marina Star between 36°S and 35°S, and 52 shots were completed by the Wollongong vessels Illawara Star and Santa Rosa II between 35°S and 34°S. The quota allowed for the research project was 200t. Approximately 40t of gemfish were caught from Ulladulla and 103t from Wollongong. Catch rates were generally lower off Ulladulla peaking at around 2,000 kg/h, compared to the highest catch rate of 4,674 kg/h off Wollongong.

Off Ulladulla peak catch rates were recorded 25-27 June at the southern margin of the of the research area (36°S). While off Wollongong catch rates the highest catch rate of the survey (4674 kg/h) was recorded 10-12 July at the northern end of the research area (34°S). High catch rates (>1,000 kg/h) were also recorded 24-26 July in this latter area. The timing and location of these peak catch rates coincided with conditions likely to have been causing upwelling of cold nutrient rich waters in the aggregation area. It seems likely that the eastern gemfish are aggregating around these seasonal upwelling events.

After several poorly recruited year classes the size structure of the gemfish aggregations is returning to normal with a single pronounced mode between 70-80 cm caudal fork length. On superficial inspection these catch rates appear similar to rates reported during the mid 1980s, prior to the recruitment driven decline in the stock at the end of the 1980s (Eastern Gemfish Assessment Group Oct. 1996).

2. LIST OF FIGURES

- Figure 1 Map of South-eastern Australia showing the location of Sydney, Wollongong, Ulladulla, Bermagui, Cape Howe, and latitudes 34°, 35°, 36°S which delineate the Wollongong and Ulladulla survey areas.
- Figure 2 The survey vessel Charissa of Ulladulla. Steel vessel purpose built for gemfishing in the 1980s.
- Figure 3 The survey vessel Marina Star of Ulladulla. Wooden vessel purpose built for gemfishing in the 1970s.
- Figure 4 Illawara Star of Wollongong. Wooden vessel purpose built for gemfishing in the 1970s.
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- Figure 19 The pooled length frequency histogram for all sampled survey shots. Individual samples have been weighted in proportion to the catch rate of the shot from which they were taken.
- Figure 20 The pooled length frequency histograms for 10 arbitrary periods of the surveys. Individual samples have been weighted in proportion to their sample size.

3. INTRODUCTION

Background:

On the basis of trends in size structure and catch rates the eastern Australian gemfish stock (*Rexea solandri*) is assessed to have experienced a period of poor recruitment from 1986 to 1989 and is now in a depressed state.

The stock is managed within the framework of a multi-species system of Individually Transferable Quotas (ITQ). The Total Allowable Catch (TAC) for eastern Australian gemfish has been set at zero since 1993 although a low by-catch is allowed under a system of trip limits. Stock assessment research on the stock is a high research priority for the South East Trawl Management Advisory Committee (SETMAC) and the Australian Fisheries Management Authority (AFMA).

Need:

Since 1990 the size structure of the eastern gemfish stock has been returning towards its appearance before the impact of the recruitment decline was observed. However quantification of the stock status relies principally on the interpretation catch and effort data collected from the commercial fishery.

Previous assessments (Allen 1989, 1992) have used a form of the Laurec-Shepherd algorithm for tuning the most-recent-year fishing mortalities (Pope and Shepherd 1985), this tuning requires the use of stock abundance indices derived from commercial catch and effort data. Since the zero TAC was set in 1993, there has been no targeted fishing of the stock and no valid catch and effort data for tuning the analysis. Consequently it has been impossible to update the stock assessment.

A more recent analyses based on the stock synthesis approach (Methot 1989, 1990) has been able to provide assessments of the status of the stock since 1992 (Bax 1996; Punt, 1996). These analyses confirm that a series of weak year-classes entered the stock during the late 1980's and suggest that there has been some recovery in recruitment from cohorts spawned in 1990 and 1991. However, the extent of that recovery is uncertain for the same reason; the lack of any index of spawning stock abundance since 1992.

This situation is compounded because the estimation of the absolute strengths of the recruitments in recent years relies heavily on the assumption that there has been no change in the power of fishing effort directed at the winter spawning run fishery in recent years. Given the changes in the management regime for the fishery that have been occurring since 1989; which have resulted in the gradual control of targeted fishery, then movement to a small trip-limit arrangement with no TAC, this assumption is unlikely to be strictly valid.

Prior to the winter spawning season of 1996 a pressing need was identified by the South East Fisheries Assessment Group (SEFAG), to obtain an index of relative abundance comparable with indices which have been, or can be, derived from commercial catch and effort data for years prior to 1992.

Objectives:

The primary aim of this project was to collect catch and effort data from the 1996 spawning run of eastern gemfish. These data were to be collected in manner as similar as possible to previous practices of commercial fishing. The survey had to be practical, cost-effective and potentially the starting point for an ongoing monitoring program. The survey was required to have wide-spread industry acceptance, and be capable of implementation with a lead time of less than 2 months in time for the June - August 1996 winter spawning season and be followed by prompt reporting.

The relative abundance index obtained from this survey, together with size and age composition data for 1995 and 1996, are being incorporated directly into updating the 'stock synthesis' analysis of stock status described above by the recently formed Eastern Gemfish Assessment Group. It is hoped the up-dated analysis will greatly reduce the uncertainty about the current status of the eastern gemfish stock. This should provide a much firmer basis for evaluation of future harvest strategies using, for example, the method described in Smith *et al.* (1996), and therefore a sounder basis for the possible re-opening of the fishery.

Subsidiary objectives were to collect length frequency data and digital acoustic data for the gemfish aggregations. The length data will be incorporated into the stock assessment and the acoustic data will be used in assessing the feasibility of developing acoustic surveys of the eastern gemfish stock.

A further personal objective of the project stemmed from the author's wider role in the South East Fishery as the Industry's Scientific Liaison Consultant. From this role comes an interest in seeing the knowledge of SEF fishers, accumulated through years of observation, more effectively incorporated into the research process. Our scientific knowledge of the SEF species such as gemfish is extremely limited hence it is essential that we utilise effectively all available sources of information.

Prince & Wright (1994) documented the claims of gemfish fishers that the timing and location of gemfish aggregations is influenced by cold water currents along the edge of the NSW continental shelf. A personal objective of the author's was to examine more quantitatively these claims.

All the project's objectives were successfully achieved.

4. MATERIALS & METHODS

The broad approach of the project was to conduct a small scale fishery on the 1996 winter run of the eastern gemfish under close research observation. This approach has been used successfully in Canada where it is called a 'Sentinel Fishery' because the small research fishery acts as a sentinel watching over a recovering fish stock.

The survey design was developed during April 1996 during a workshop and it was based upon some preliminary analyses of SEF1 logbook data, experience with a previous industry survey (Prince & Wright 1994) and the co-operative input to the workshop from the representatives of the fishing industry, SEF managers and members of South East Fishery Stock Assessment Group .

Analysis of SEF1 statistical returns for the fishery show that the gemfish run is most variable south of Bermagui, moreover, the 1993 industry survey experienced great difficulties in co-ordinating surveys in that region due to the large distances involved and exposed nature of the southern fishing grounds. These factors together with budget limitation were used by the workshop to justify focusing the 1996 survey on Ulladulla and Wollongong. Considering that over 40% of total historic gemfish catches (1970 - 1992) have been landed into this area the selection of the region was considered to be relatively unimportant to the stock assessment.

Consequently the 1996 survey (Figure 1) concentrated on the northern end of the historic fishery:

- Wollongong - North-east Canyon to Kiama Reef 34° - 35°S
- Ulladulla - Tuross to Wreck Bay Reef 35° - 36°S

Within these areas the two survey skippers from each port were allowed to select the positioning of their trawls.

The Australian Fisheries Management Authority authorised a total research catch of up to 200t of gemfish for the project.

Vessels Selection

Two vessels were selected in each of the ports of Wollongong and Ulladulla. Initial plans were to use only a single boat from each port. However the skippers of Ulladulla and Wollongong strongly criticised that proposal. They believed a single vessel would be bound to perform poorly because of the time required by a single vessel to find the fish.

The observation was repeatedly made that, at the height of the fishery all the likely locations would be searched in a single day and the aggregation would then be targeted. Through constant fishing the industry followed the aggregation, rarely needing to search for it. They argued that the catch rates of a single vessel would be extremely unrepresentative of previous fishing patterns. This was also argued when the use of two boats in each port was initially proposed. However finally under protest the skippers agreed to use two vessels from each port. But as will be discussed below in more detail, the issue of whether or not survey fishing patterns are representative of previous fishing patterns, was not entirely solved by using two vessels.

In selecting the four vessels to be used, a list of gemfish vessels was developed by the Eastern Gemfish Assessment Group. The list was developed on the basis of them having fished consistently through the time frame covered by the SEF1

data base 1986 - 1992 SEF1. Listed vessels from Wollongong and Ulladulla were invited to tender for the surveys.

In Wollongong the vessels selected were the Illawara Star and the Santa Rosa II, in Ulladulla the vessels selected were the Charissa and Marina Star (figures 2-5). The Illawara Star and Marina Star are wooden gemfish vessels purpose built during the 1970s and the Charissa and Santa Rosa II are larger steel gemfish vessels purpose built during the 1980s.

Period of Survey

Even though there is significant inter-annual variation in the gemfish run, analysis of SEF1 returns shows that the forward run of mature fish in both survey areas normally falls within the eight week period from the 12 June to the 6 August. During the seasons from 1986 to 1992, this period contained 96% of the forward run catches from Wollongong and Ulladulla areas.

Consequently the project concentrated on this time period. Within this time period participating skippers were allowed to determine which particular days they fish. With few exceptions the skippers chose to fish every day they considered the weather allowed them. The most notable exception to this rule was in Wollongong where the skippers of the port all take Saturdays off regardless of weather or fishing conditions.

Gear

To make surveyed catch rates as comparable to historic catch rates the selected vessels were asked to use gear that was as similar as possible to that used prior to the restriction of the fishery.

It should be noted that none of the boats used the large wooden spreader boards or trawl doors (Figure 6), which were normally used when gemfish targeting was at its peak. The wooden doors had a larger surface area and were relatively light weight (Figure 7). Formerly when targeting gemfish fishers tried to trawl slowly and the large light wooden doors spread widely even at low speeds. Since targeted gemfish fishing has ceased the fishers have adopted smaller, heavier, but more hydro-dynamically efficient metal trawl doors which are better for faster trawling and catching a wider range of species. Reconditioning, fitting and tuning trawl boards is a major undertaking for a vessel. One which can cause a vessel to fish inefficiently for weeks or months while the boards are tuned. No vessel was prepared to undertake this process for the survey.

At the height of the gemfish catches specifically built gemfish nets were also used. These were lightly built with a large mouth and wide long belly leading down to the cod-end. Fishers say they were built for trawling slowly and for holding large catches of gemfish without the mouth closing. All the participating skippers claimed to be using smaller versions of the original gemfish nets. Others in industry claim that the net used by the Marina Star did not have the width in its belly to fit this description and was simply a normal 'market fish' net.

Fishing Patterns

Within the defined time and constraints the four survey vessels were given as much flexibility as possible so that their fishing practice would be as consistent as possible with fishing practices prior to 1992. As a matter of principle the research staff did not influence the daily fishing patterns. The skippers in association with each other and the broader fleet determined their own fishing strategies.

However it must be noted that all skippers continually commented on how different their survey fishing pattern was to previous patterns of gemfish targeting. Without numerous other boats fishing for gemfish around them they felt that they were fishing blindly. They often remarked that they were using several days of good weather to find the gemfish aggregations and then being prevented from actually fishing by the intervention of bad weather. This common complaint will be discussed below in detail.

Scientific Observers

Scientific observers were stationed in Wollongong and Ulladulla for the duration of the surveys. Observers accompanied the survey vessels, recording positions, timing duration of all shots, weight of gemfish and approximate composition by weight of the by-catch. Length-frequency information was also collected for the gemfish catch from virtually every shot. In 2-3 cases, all small shots, conditions or events precluded measurement. From large catches a sub-sample of 100-200 gemfish were sexed and measured to the nearest cm, in smaller catches all the gemfish were sexed and measured. Qualitative notes were made on gonadal status and, where observed, gut contents.

Ownership of the Catch

The catch from the surveys was sold on behalf of the Fisheries Research and Development Corporation to Wollongong Fisheries Australia for \$3.00/kg net. Excess monies from this project were returned to the Fisheries Research and Development Corporation.

Collection of Acoustic Data

EchoListener devices developed through the FRRF "Industry Acoustics Program" (FRRF - 7-1992/93) were fitted to the Marina Star and Santa Rosa II part way through the project. Some acoustic data were collected from both vessels although not as successfully as hoped. The data have been screened and prepared for archiving and transfer to CSIRO. They will be used in assessing the feasibility of developing acoustic indices for the gemfish stock. Some acoustic images are presented in this report.

Data Analysis

The primary objective of this survey was to provide catch and effort data for 1996 gemfish run, comparable with the existing 1986 - 1992 SEF1 catch and effort data. A secondary aim was to describe the size structure of the 1996 spawning run. As such the survey had a focus on data collection focus rather than data analysis. The data collected have been entered into an Excel Spreadsheet, and supplied to EGAG members for further analysis. This report describes the data using the software packages Excel and MapInfo.

5. DETAILED RESULTS

Project Journal

Below is an edited version of the project's journal. It was largely written as the project occurred and was used as an interim reporting medium. It has been edited for this final report but an attempt has been made to avoid changing the temporal context of the writing. The aim of this section is to describe the process of conducting the surveys, and in doing so, describe the factors that influenced the project.

The participating characters and vessels are named. The personalities involved have had access to drafts of the report and were asked to correct details they believe to be incorrect. None have chosen to do so. In fairness this should not be taken to imply that all details of personal involvement or implied motive are strictly correct. The journal merely reflects the author's perception and recollection of events. Apologies are offered in advance for errors of detail.

Because the aim of this passage is to be readable for industry members and the industry is still working in fathoms as a unit of depth, the author has chosen to use fathoms (f) rather than the standard unit meters (m) when describing the day to day events of the survey. An approximate conversion is to convert fathoms to meters by doubling, their being slightly less than 2 meters in a fathom.

Sunday 16 June 1996

NEW MOON

Project staff assembled in Sydney.

Monday 17 June

Touched base with Kevin Rowling NSW Fisheries Research Institute, Cronulla. Kevin and his crew were leaving for Eden where gemfish were reported being dumped late last week. That morning Kevin had measured fish in the market from Eden, Bermagui and Ulladulla. Spawning run fish. Over the weekend the Charissa and Marina Star, had both landed under their trip limit of gemfish. There had been no catches from Wollongong.

We drove to Wollongong Co-operative and saw Mario Belatoni the Co-operative manager and Tony Lamacchia of the Santa Rosa. They had heard the news, that good amounts of gemfish had been encountered off Eden and Bermagui. Tony had not been out for 12 days and did not know what was off Wollongong. The local drop-liners were reporting that bottom currents were still running from the north. The next day Tony was going to trawl for royal red prawns, deeper than down the continental slope than the gemfish run. As the Wollongong season starts they normally first contact traces of gemfish while prawning and then start looking along the gemfish line.

Drove to Ulladulla. Met on the wharf with the Puglisis on the Charissa and the Battagliolos and Basiles on the Marina Star. Also in the meeting were representatives from a boat that had accidentally contacted gemfish off Bermagui. They had fished deep for ling (220-240f) and had unexpectedly caught 1.2-1.6 tonnes of gemfish. They had then fished shallow for their second shot (170-180f) and caught another 0.8-1.2 tonnes. The gemfish line in 190-210f was a blaze of red marks on the sounder and they avoided it. They claimed they would have been able to make a shot of 4-8 tonnes if they had fished the gemfish depth. Some fish were filleted and observed to be full of roe. Milt was running from the

males onto the deck. Pino Puglisi was anxious to start surveys in Ulladulla as soon as possible.

The fishers were noticing large amounts of southern frost fish (industry call it ribbon fish) in their by-catch over the last couple of weeks. The equivalent abundance had not been observed since the late 1980s. This was thought to bode well for the survey as good gemfish runs are thought to go with good ribbon fish catches. The ribbon fish normally run a little before the gemfish arrive and a little shallower.

The crews of the Charissa and Marina Star confirmed that they had started catching spawning run gemfish (Mature size classes 65-80 cm) as they fish for ling outside the gemfish line. They were catching less than the daily trip limit for the day's fishing. But the main run had not yet arrived off Ulladulla. I ask about the warm northerly current. It is apparently still running on the surface, but off Ulladulla a bottom current from the south is now pushing north against the warm current. This change had occurred over the previous few days and was expected to bring the gemfish to Ulladulla.

"The gemfish ride north on the colder bottom current" one of the fishers told us.

The crew of the Marina Star suggested waiting at least another day before beginning surveys, until there was a better indication that the fish were off Ulladulla and the others agreed. However I asked the skippers to start fishing immediately so that the project could document the low catch rates prior to the arrival of the fish. I assured them that the low catch rates prior to the run or after the run would not be added into a calculation of a simple mean catch rate for the entire period of the surveys. That only catch rates within the peak catch rate period would be taken to indicate peak catch rates. They agreed to my request and we arranged to fish the next day.

I spoke with John Symonds Manager of the Twofold Bay Fishermen's Co-operative at Eden. He told me that 4-6 tonne shots had been dumped off the Everards and the northern Howe ground. The gemfish had moved through the area in such densities that long liners fishing well outside gemfish depths for blue-eye trevalla had to stop fishing for a the preceding fortnight to avoid over-catching gemfish trip limits. From the reports I estimated some 20 tonnes might have been dumped. I spoke with Kevin Rowling and he had the impression it was more like 8-12 tonnes.

Climatological and Oceanographic Conditions

Prior to the surveys commencing sea surface temperatures throughout the study area were very warm, above 20°C. Satellite imagery (Figure 8a) showed a large tongue of the warm Eastern Australian Current (EAC) extending the full length of the NSW coastline, virtually to Cape Howe. However the 18 June satellite imagery shows a small wedge of cold water was beginning to protrude around Cape Howe northward along the shoreline.

The 19 June 250m isotherms chart (Figure 9a) showed the deeper structure of this characteristic cold water wedge as it began moving north from Cape Howe along the continental shelf. With the appearance of a zipper opening northwards along the shelf edge, the feature is formed by cold water pushing up the continental slope out of deepwater. This upwelling cold water forms the eastern edge of the Front of the Sub-Tropical convergence. This is called the Tasman Front and arbitrarily defined as the 15°C isotherm here shown as a broken line. The 19 June isotherm chart shows the Tasman Front intersecting the shelf south

of Jervis Bay. A current of 1.5-2.0 knots is shown flowing from the north-west off the continental shelf along the front.

These 250m isotherm charts are produced weekly by Royal Australian Navy METOC services and carry the warning that they are based on a few actual measurements by submarines and are largely interpolated from sea surface temperatures. While not accurate in close detail they do provide the best basis for describing oceanographic conditions likely to affect the 400m environment of the gemfish.

During preparation for the surveys the skippers of Wollongong and Ulladulla had consistently commented that the strong tide from the north suggested that the gemfish run would be late. Mario from Wollongong Co-op. predicted no earlier than 1-18 July for Wollongong (the full and new moon of July), and that the gemfish would arrive with the first serious snowfall in the Alps.

Prior to the surveys commencing the south-east coast of Australia had been unusually wet while the south-western corner of Australia had been particularly dry. In the south-east rain had been coming from the north-east in summer like tropical weather systems one, while across southern Australia there had not yet been any winter frontal systems which to bring winter rain and snow. The first winter fronts normally break the agricultural season in south-west Australia around 20 May each year. In 1996 the first major front of winter did not hit Western Australia until Saturday 15 June.

At the time of commencing the survey a low pressure system to the north-east of the research area was dominating local weather as it slowly moved south out of the Coral Sea. It was stronger and was persisting longer than expectations. The first frontal system of the winter had hit Western Australia on 15 June, but it was weakening and was expected to be absorbed into the low pressure system to the north-east of the study area. There had been no snow on the alps and the city of Canberra was very dry. The Meteorological Bureau was predicting a second frontal system crossing Western Australia could bring the first snow to the Alps by 20 June.

Tuesday 18 June

Marina Star - 186 kg
Charissa - 252 kg

The Ulladulla boats used the first day's fishing to fish at the southern margin of the main Ulladulla ground immediately to the south-east of the port. They tried a complete range of depth. Searching for the fish rather than concentrating on the depth most likely to produce gemfish.

Four approximately 3 hour shots were completed. Marina Star's morning shot was in 220-230f starting around 35°34' and hauled around 35°41', it took 163 kg of gemfish at around 50 kg/h. Charissa's morning shot was between 170 and 200f starting around 35°38' and ending around 35°37', the catch was 180 kg at around 60 kg/h.

Marina Star's afternoon shot was shallower 190f, starting around 35°43 and ending 35°48', it caught only 23 kg of gemfish in three hours. Charissa's three hour afternoon shot started in 180-190f and towed between 35°48' and 35°54' for only 72 kg.

All shots produced by-catches of ribbon fish.

I spoke by mobile phone to a skipper trawling south of Eden on the Howe ground, he had just taken about 500 kg of gemfish towing to the north; the opposite direction normally used to target gemfish. Someone else had taken about 400 kg in similar circumstances. These catches had been shared out amongst the fleet. From this I assumed that these were the only large catches that had occurred that day and that the run of gemfish had moved north from Eden.

Wednesday 19 June

Marina Star - 363 kg
Charissa - 216 kg

On the second day of surveys searching for gemfish continued on the main trawl grounds off Ulladulla.

Four approximately 3 hour shots were completed. Marina Star's morning shot was in 235-245f starting around 35°29' and ending around 35°35', 154 kg of gemfish were caught at around 50 kg/h. Charissa's morning shot was between 210-250f starting around 35°34' and ending around 35°40', it took 162 kg at around 50 kg/h.

Marina Star's afternoon shot was around 225-240f, starting around 35°35' and ending 35°40', it caught only 42 kg of gemfish in two hours. Charissa's two and a half hour afternoon shot in 250-260f between 35°42' and 35°47' caught only 54kg.

The Ulladulla vessels had now thoroughly searched the second and third most southern of the Ulladulla grounds. Within the survey area only the Tuross ground which actually straddles the latitude 36°S boundary is more southern. We have towed above, below and on the normal 200f gemfish line. Significant by-catches of ribbonfish were again taken in some of the shots (particularly in the afternoon shots), also caught were several hundred kilograms of mirror dory, ling and ocean perch and several young broadbill marlin.

The gemfish that had been caught were a good mix of sizes. There were still some very large fish. But what was noticeable in contrast to 1993 was the presence of 65-85cm sized fish. It was immediately apparent that the so called 'missing' size classes of fish were back to some significant extent. Kevin had told me that the fish he had measured in the by-catch from Eden were a similar mix of size classes.

The fish were fully mature but in a resting state, the ovaries did not look close to running ripe. The ovaries were the same milky colour as the testis and were only distinguishable by their small but visible ova. There had been no hydration of the ova at all. As spawning approaches the red veins become highly visible in the ovaries which swell and become engorged with blood and fluid. When running ripe the ovaries of the gemfish are pink and bloody, immediately before spawning they are so hydrated that the ovaries become like bags of jelly and burst even if handled gently.

The quantity of ribbonfish continued to arouse great interest because of their reputed association with previous good gemfish runs. Ribbonfish look like elongated version of gemfish, have the same highly and dangerously toothed mouths. The fishers say that ribbonfish run in front and 'inside' or 'above' the gemfish. Bits of ribbonfish are commonly found in the stomachs of the gemfish. The relative abundance of the ribbonfish after several years of low abundance was being taken as a good omen for the gemfish run and for the performance of the surveys.

After two days surveying it was concluded by all the participating skippers that we should stop searching for gemfish as they had not arrived off Ulladulla yet. Any lingering fears that a first run of gemfish might have slipped past to the north without being noticed were allayed. Most now seemed prepared to go back to the opinion that it was going to be late year. Someone pointed out that it may actually be reverting to a 'normal' year. The favourite predictions for when the gemfish would start running was after the next change in the weather, or in the week approaching the full moon. The fishers of Ulladulla were agreed that we should wait for the approaching change of weather, and the approach of the 1 July full moon before conducting more surveys.

The Wollongong fishers had been out fishing for the first time in almost a fortnight. They had fished on their prawn grounds (240-260f) and also inside a bit shallower (150-170f). They had caught very few gemfish (ones and twos). The northerly current was still strong at all depths. But they also were hopeful for the approaching change in the weather and the next full moon. They were beginning to fret that the 1996 gemfish run was going to be a southerly run and that Wollongong might miss out. Mario from the Co-op. kept asking me what was happening to the south, off Eden and Bermagui.

With every bulletin the Meteorological Bureau were delaying the predicted arrival of the next westerly change. It had originally been predicted to hit the area on Thursday 20 June but was now predicted to arrive 22-23 June. The actual weather was warm, balmy and sunny. What clouds there were, were offshore; tall tropical looking thunder heads. The Ulladulla fishers were reporting that bottom running current from the south was still not established over the trawl grounds but remained variable. Sometimes it seemed to run from the south and held their nets firmly against the bottom, but at other times a northerly current was pushing down off the shelf, making it hard to hold their nets on the sea-bed.

With the following week being seen as the earliest that the skippers would be interested in doing some serious searching for gemfish. I made arrangements to have Ian Higginbottom fit at least one EchoListener to one of the Wollongong boats by early in the following week.

Friday 21 June

Charissa - 900 kg

I allowed the Ulladulla vessels to go about their normal fishing (non-surveys) observed by survey staff. Unexpectedly, the Charissa contacted gemfish at the southern end of the Ulladulla grounds. About 300 kg in the first 3 h shot in about 230f, then 450 kg in a second 2h shot in 180f, and finally 150 kg in a 2.5h shot going north (the wrong way) in 280f. None of the Charissa's shots could be termed a targeted shot, just general searching. The Marina Star working to the north took little gemfish, but two of its shots were inside in 80f and the other was deep in 255f.

We also heard that two boats off Bermagui took 300-400 kg each towing for ling and grenadier in 225-300f. Apparently a Bateman's Bay boat in between also took some gemfish. At that stage I was unable to talk to any of the boats directly. Nothing had been heard from the south around Eden for a couple of days.

Reports of these catches excited the Ulladulla skippers. They were thought to be the beginning of the first run. On the Saturday a funeral which most of the fishers were attending in Sydney would keep most boats, including ours, tied up. We arranged to resume surveys on Sunday - targeted gemfish shots. They

seemed confident that, weather permitting, we would be fishing pretty consistently over the next few days.

Wollongong had still not seen any signs of fish and said the northerly current remained strong. They believed the week beginning 1 July would still be the most likely time for the run to start up there.

Sunday 23 June

Marina Star - 137 kg

Charissa - 577 kg

On the Saturday an Ulladulla vessel had dumped around 3 tonnes on the grounds south-east of Ulladulla. So the survey vessels went to that area with high expectations of making catches. A single shot was made by each survey vessel before the first Westerly change of the winter season moved through the research area and drove them home.

Marina Star trawled in about 200f starting at 35°29' and winching up around 35°35' for 137 kg. Charissa trawled in 195-200f between 35°33 and 35°36' for 577 kg. Ribbon fish again dominated the by-catch. The Charissa also landed a large thresher and mako shark.

The sea surface temperature had fallen to below 19°C over the Ulladulla trawl grounds, but the tide from the south east which had apparently been prevalent over the previous two days was no longer in evidence. There were feed marks 50f thick over the trawl grounds. The top of the shelf was aflame with soundings, probably of redfish. Inside our trawl shots, in 160f another boat took 5-6 tonnes of redfish. Young hapuka were salted through the masses of small redfish apparently caught feeding in the redfish shoals.

There had been friction within the Ulladulla fleet at the beginning of the day. The Salvatore V had occupied the shot that Charissa had wanted to conduct. There was a heated exchange between the two skippers. The Salvatore V insisted that he had a living to make, implying that the survey skippers were on 'easy street'. He was prepared to risk a major catch of gemfish to catch the 600-700 kg of market fish he had caught the day before. Augustine Puglisi from the Charissa tried to explain over the radio that it was for the industry's good that they get a clear shot at where (on the basis of yesterday's dumping) the gemfish were thought to be. He then argued the morality of dumping all the gemfish the Salvatore V would probably catch just for the sake of a few market fish. The Charissa was forced to bow to convention and let the first vessel on a shot shoot away its gear first. The Charissa started her shot 2-3 miles further south than she wanted and 10-15 fathoms deeper than she wanted in order to stay clear of the Salvatore V's shot.

The gemfish were similar sizes to the previous days. But the gonads of the females seemed to be developing rapidly appearing bloodier than before, although still not swollen to any appreciable extent. The skippers felt that the fish were still to the south and placed us on 24h alert. The Wollongong vessels also informed us that they wish to begin surveying in the coming week.

Monday 24 June

The Ulladulla and Wollongong vessels all stayed in port because of the bad weather. Strong sou westerly winds finally reached the study area bringing the first snow of the season to the alps. An easing was expected for Tuesday followed by another series of fronts on Wednesday and Thursday.

Tuesday 25 June

Marina Star - 770 kg
Charissa - 5,897 kg

I met with Ian Higginbottom in Wollongong and made arrangements to fit EchoListener equipment to the Santa Rosa. Wollongong thought westerly weather would keep them ashore until the end of the week.

The Charissa and Marina Star fished to the south. The first shot of the Charissa was in 180-205f for 3h between 35° 47' and 35°53' and it produced 3,312 kg of gemfish. On the strength of this Charissa steamed further south to the Tuross Grounds for a midday shot in 200-215f shooting between 35°57' and 36°03' and catching 2,148 kg in 3.5h. The Charissa also put in a twilight shot, 1h in 190-200f between 36°02' and 36°04' for 437 kg. With the exception of the last shot ribbonfish catches were low.

Inter-boat jealousies again played a part in the days proceedings. Torina M occupied the gemfish line (205 fathoms) 46 miles south of Wreck Bay despite Joe from the Marina Star telling the fleet that he wanted to shoot at 45 miles south of Wreck Bay. The Torina M would not yield and Joe was forced to start at 47 miles and 215 fathom. Trying to bring the shot back onto a better line the Marina Star ripped the belly out of its net. Despite the invalid shot Marina Star ended up with about 500 kg for the first shot.

After replacing nets the Marina Star completed a 3h afternoon shot in 200f between 35°46' and 35°53' but only took 280 kg. The Marina Star crew were frustrated and had to spend most of the night mending their gemfish net.

Off Bermagui the Camela T had apparently again taken its trip limit. Another Ulladulla boat had also taken about 300 kg towing north. Torina M had also dropped another 800-900 kg.

Wednesday 26 June

Marina Star - 1,115 kg
Charissa - 7,735 kg

Both boats only completed a morning shot as the weather deteriorated. Charissa shot away in 200f between 35°40' and 35°48 for 4.5h and caught 7,735 kg. The catch also includes a large thresher shark. Marina Star shot for 4.5h in 200-210f between 35°33' and 35° 42' and caught 1,115 kg. The catch includes a large thresher shark. The ribbon fish by-catch remains low.

Thursday 27 June

Marina Star - No fishing - fitting the EchoListener.
Charissa -9,606 kg

Charissa successfully completed morning and afternoon shots but expecting further good catches we kept the Marina Star ashore to fit it with EchoListener equipment. Charissa shot first in 200f between 35°39' and 35°46 for 4.0h and caught 6,695 kg. Her second shot was around 195f between 35°44' and 35°50 for a little under 3.0h and caught 2,910 kg. Ribbonfish catches were again low.

Earlier catches had been mainly 5 & 6 year old fish (75-80 cm fish). The larger catches of the previous days had significant numbers of smaller (65-70cm) 4 years olds in them as well.

Ian Higginbottom had now fitted an EchoListener to both Santa Rosa and Marina Star but unfortunately further adaptations were needed to accommodate the Marina Star's 38 KHZ echo-sounder. Adaptations that would not be ready for a further week. Our decision not to let Marina Star fish when Charissa was catching fish so that we could fit an EchoListener had been understandably controversial. It was taken to minimise the time Ian had to spend in the field and in the expectation that good catches would continue for some time.

Despite the various controversies the port was very pleased with the weeks proceedings. They were supremely confident that catch rates would continue to increase towards the 1 July full moon and then remain good for the next week as the gemfish aggregations moved north along the shelf edge off Ulladulla. The prediction was that Ulladulla's 100t research quota would be filled before the end of the approaching week.

However Marina Star was worried their net was not fishing properly because their catch rates were so much lower than those of the Charissa. Like the other boats they were not using the original large wooden gemfish doors but the gemfish net they were using was larger than their normal 'market fish' net. They thought the smaller steel doors might not be holding the mouth of the net open wide enough. Their ribbon fish catches which were larger than the Charissa's suggested to them that their headline might be looping up too high from the bottom indicative of the mouth being too narrow. They adjusted the boards to open up the angle of attack and make them tow more obliquely. Santo the original skipper responsible for the Marina Star's good gemfish catch history decided to spend the next couple of days on the boat to help work out the problems.

Friday 28 June

Bad weather kept the boats in port for Friday. Instead several crews gathered at 4.00 AM on the Charissa to talk and drink coffee until 7.30 AM. Then they all headed home for breakfast before coming back to unload Charissa's of 11,500 kg of gemfish. The port was happy.

Mario Puglisi seemed to have addressed the issue of other boats interfering with the survey vessels. The main motive seemed to have been jealousy that only two boats were being allowed to do the surveys. After discussions with Katrina Maguire of AFMA I had spoken with Mario and Pino about what was going on. Mario had told me to leave it all with him for a couple of days while he got around the owners of the vessels involved. We left it that and I heard no more. But I noticed a change in the attitude of the other boats. The previous main offender actually became helpful in relaying information to the survey vessels.

The Wollongong boats had been fishing on the shelf before the westerly change, they still reported a strong northerly tide and no gemfish. They wanted to reconsider the situation next week, but were not interested in starting their surveys immediately.

Climatological and Oceanographic Conditions

There had been strong westerly winds during the preceding week with periodic fronts moving through the area. The Alps had received their first snow falls, but not in large amounts. More was expected over the approaching weekend.

Sea surface temperature charts showed that the body of warm water in the study area was now breaking up quite rapidly (Figure 8b). The cold water wedge had inserted itself along the shoreline as far as Bermagui, and virtually all the 18-20°C water had been pushed north of a line extending south-east from Jervis Bay.

However the 26 June 250 m isotherms showed less change at depth along the shelf (Figure 9b). The Tasman Front which had been advancing north was stalled below Jervis Bay. It was still delineated by 1.5-2.0 knot current flowing off the shelf to the south-east. But a cold current was now shown running north counter to the warm current of the Tasman Front. Consistent with this the Ulladulla fishers had observed that to the south of Ulladulla the southerly current was now established and interestingly we noticed that this was where the gemfish were being caught.

A new offshore feature was also evident in the 26 June isotherm chart. A ridge of cold water had begun to form between 34° and 35° apparently constricting the flow of warm surface water down the coast from the north. It appeared as if a warm core eddy may develop from the constriction.

Saturday 29 June

Marina Star - 49 kg

Charissa - 140 kg

On Saturday both Marina Star and Charissa fished out of Ulladulla. Marina Star trawled the shot southeast of Ulladulla where Charissa had been successful on the previous days and Charissa went north-east initially and then moved south to the ground due east of Ulladulla for the afternoon shot. The rationale behind this strategy was to try Marina's Star's gear on the area which was thought to be holding fish and to have Charissa search to the north to determine whether the fish had moved north, and if so how far and how fast?.

But the plan did not work out. Something had changed! Something had gone wrong!

There were strong wind (20-30 knot westerlies). The feed layers showing on the echo sounders was fairly dispersed and little of it was in contact with the bottom. The bottom currents were wrong, either absent or weakly from the north-west. The skippers were not hopeful even before they brought their shots to the surface. Charissa's first shot was 200f for 3.0h between 35°24' and 35°30' and it caught only 120 kg. The Marina Star's first shot was around 200f between 35°39' and 35° 47' hearing about the Charissa's catch they towed longer 3.5h before winching up for a catch of only 13 kg. Meanwhile Charissa had shot again in 210f and towed towards 190f between 35°24' and 35°30 testing for feed-layers on the shallow side of the line. Strategically Marina Star was sent out wide for their second shot, a short 1.6h tow in 245f between 35°45' and 35° 48' in case the fish have moved deeper and colder in response to the strengthened warmer current from the north. But Marina Star saw little on the sounder to suggest activity in deeper water. Both boats winched up together at around 14.00h, Marina Star caught 36 kg and Charissa 20 kg.

The total gemfish catch for the two boats on the day was only 200-300 kg. Little other commercial fish was taken. Charissa caught a 2-3 m mako shark and about 5-6 tonne of ribbon fish.

No-one was quite sure what to make of these unexpected results. None of the other boats had taken any quantity of gemfish. Charissa had fished around 190-210f on adjacent grounds while Marina Star had fished on the next ground south and trying 200-240f. They were confident that they had not missed the fish. The explanations offered were that the currents had changed and the fish were either off the bottom or had been pushed back to the south by a strengthening of the northern current. There is much talk of the rare years when the run of gemfish

does not make it all the way to the north, or fails to cross the main Ulladulla ground.

The few fish caught were typical of non-aggregation catches, with a high proportion of very small fish and just a scatter of mature fish. The gonads of the mature females examined were now ripening rapidly. The veins through the ovaries were engorged with blood and the ovaries were gaining bulk and darkening in colour. Inside the ovaries the ova were beginning to move freely and fluidly in strands and layers of strands. It appeared that some level of spawning activity was approaching.

Sunday 30 June

The Ulladulla vessels set out from port but turned back because of the strength of the westerly winds.

Monday 1 July

FULL MOON

Marina Star - 402 kg

Charissa - 962 kg

Charissa went south her first shot was in 220-200f for 3.5h between 35°39' and 35°45' and caught 584 kg. Her second shot was for 2.5h in 225-185f between 35°46' and 35°52' and caught 378 kg. The Marina Star completed a single 6 hours shot between 35°34' and 35°45' between 200 and 240f for a catch of 400 kg. All catches included large by-catches of ribbon fish which was taken to be indicative of the gemfish being further south. The gemfish taken in these small catches were unlike those in the previous bigger catches, containing a larger proportion of males and broader spread of size classes.

Wednesday 3 July

Marina Star - 725 kg

Charissa - 1,330 kg

Desperate to try something different the boats split up. Charissa went to the northern end of the Ulladulla grounds in case the fish have slipped past, while the Marina Star went back the area where the fish were last found.

The Charissa shot first in 220-240f for 3.0h between 35°16' and 35°22' for a catch of 1,050 kg. To everyone's surprise there was only a few ribbon fish, but 9-10t of redfish! Surprising because the 150-160f region is generally considered the depth for catching redfish. The Charissa's second shot was for 2.5h in 245-185f between 35°24 and 35°27' for a gemfish catch of about 280 kg.

The Marina Star's first shot was for 3h around 200-210f between 35°37' and 35°43' for a gemfish catch of 700 kg and a very large by-catch of ribbonfish (9-10t). The ribbonfish were running ripe. The Marina Star's second shot was for 2.5h in 185-200f between 35°43' and 35°47' the gemfish catch was just 25 kg, but the catch of ribbon fish was about 2 tonnes.

As measured by the Marina Star surface water temperature was down to 16.8°C.

Thursday 4 July

Marina Star - 867 kg

Charissa - 2,657 kg

The Charissa took 2,800 kg of gemfish in three shots totalling 6.5h. The first shot 3h in 195-210f between 35°16' and 35°22' took only 143 kg of gemfish and similar amounts of ling, redfish and ribbon fish. The second shot was for only 1.5h between 11.00 and 12:30 hours. The shot angled up from 245f and was hauled in 190f. The catch was 1,580 kg of gemfish with ribbon fish, redfish and ling in similar quantities to the morning shot. Charissa's third shot was for 2h in 230f between 35°28' and 35°32'. It produced a similar by-catch to the other shots together with 1,077 kg of gemfish.

The Marina Star shot away first in 225f and trawled between 35°29' and 35°36' for 3h, winching up out of 220f. The catch was about 600 kg of gemfish mixed in with about 1.8t of ribbon fish. Their second shot was for 1.5h between 35°37' and 35°40' in 215 - 230f. The catch was mainly gemfish (267 kg) and ribbon fish (900 kg).

The size of the gemfish seemed to have changed to some extent. The main mode for females was now around 78cm, down from 82cm, and that for males around 68cm down from 72cm.

Oceanographic Conditions

Sea Surface temperatures off Ulladulla and Wollongong had continued to fall during the previous week (Figure 8c) although the 3 July 250m isotherm chart show the Tasman Front still crossing the shelf around Jervis Bay (Figure 9c). Most noticeably the ridge of cold water forming between 34° and 35° had intensified, ridging from the south-east towards the coastline around Sydney. So that the Tasman Front which was running around these features with a 1.0-1.5 knot current approached the shelf again between Wollongong and Sydney.

The isotherm chart concurred with reports from Ulladulla and Wollongong that a strong northerly bottom currents had prevailed during the week.

During the week the Ulladulla skippers had begun considering conserving the number of survey days they had left in case they ran out of survey days before what they considered would be the main run of fish occurred off Ulladulla. They were disappointed by the results of the first half of the week when the full moon occurred. On the Wednesday night Pino had told me that they would try on Thursday but would take a break from surveys if the results remained disappointing. The results from Thursday were good enough to create an interest in continuing. But the passage of cold fronts through the study area and several low pressure systems to the south created westerly and south-easterly winds that were strong enough to keep the boats ashore on Friday, Saturday and Sunday.

During the week on-going discussions had also continued with the Wollongong skippers about commencing surveys from that port. Tony Lamaccia of the Santa Rosa had wanted to start at the beginning of the week but Rocco Musumeci of the Illawara Star wanted to wait until it became certain that there were gemfish on their grounds. On Friday I had been informed that the Wollongong boats had almost filled their trip limits. The decision was made to begin surveying as soon as weather permitted.

Monday 8 July

Bad weather - strong southerlies kept all boats ashore.

Tuesday 9 July

Santa Rosa - 1,421 kg
Illawara Star - 686 kg

Marina Star - 478 kg
Charissa - 1,087 kg

Boats fished of Ulladulla & for the first time off Wollongong.

Off Ulladulla the Marina Star's morning shot was in 225-230f between 35°30' and 35°36' for 3.5h and caught only 376 kg of gemfish together with some mirror dory, ling and ribbon fish. Her second shot was for 3h in 220-245f between 35°37' and 35°42' for about 100 kg of gemfish, with equal amounts of ling and mirror dory, but about 4.5t of ribbonfish.

The Charissa completed only one shot between 210 and 220f for 4h towing from 35°28' to 35°35' and catching 1,087 kg of gemfish, about 500 kg of mirror dory, 250 kg of redfish and 2.4 tonnes of ribbon fish.

The two Wollongong Boats completed a single shot and took mainly mirror dory. The Illawara Star shot away in 225f and towed for just under 5h between 34°33' and 34°45' taking 686 kg of gemfish and 2,366 kg of mirror dory along with about 90 kg of ribbon fish. The Santa Rosa also towed for about 5 hours in 230-235f between 34°34' and 34°47' catching 1,400 kg of gemfish, 2,116 kg of mirror dory and little ribbon fish.

Hearing of the survey catch of mirror dory the Guiseppa from Wollongong repeated the shot also hoping for a good shot of mirror dory. The result was 4-6t of gemfish. Considerable drama resulted with the survey vessels requesting that Guiseppa be allowed to land the fish under the research quota. Under the terms of the research permit the request could not be allowed.

Wednesday 10 July

Santa Rosa - 9,119 kg
Illawara Star - 8,316 kg

Marina Star - 62 kg
Charissa - 1,023 kg

There was mutiny in Wollongong. The Illawara had dropped her ropes and pulled away from the wharf without any observer. They wanted to drop out of surveys until they started getting gemfish and instead wanted to go commercial fishing for mirror dory. Obviously some behind scenes lobbying had been going on. I told them they could fish as they wanted but that for their fishing permit to be valid, they had to have one of the observers aboard. They left the wharf with an observer aboard. Lengthy mobile phone calls between 3.00 AM and 4.00 AM followed.

In the end all four boats participated in surveys out of Ulladulla & Wollongong.

The Wollongong boats shot inside the previous day's shots and came up with 17.5t of gemfish for the day. The bottom currents were pushing in strongly from the east onto the shelf slope and the fish were apparently very shallow compared

to normal. The Illawara Star first shot in 215-225f for 3h between 34°31' and 34°38' catching 1,505 kg of gemfish, 490 kg of mirror dory and about 30 kg of ribbonfish. While the Santa Rosa first shot in 205-215f for 3.25h between 34°29' and 34°36' catching 5,156 kg of gemfish and 384 kg of mirror dory. About 20 of the 90 females measured were running ripe with fully hydrated gonads. From these shots the skippers deduced that good gemfish concentrations were to the north and shallower than the original shots.

The Illawara Star's second shot was for 3h in 195-205f towing back to the north between 34°34' and 34°26'. The feed marks on the sounder were particularly thick for the last half hour of the shot causing Rocco on the Illawara Star to pull out because he was worried it was ribbon fish. Instead the catch was 6,811 kg of gemfish, many of which were very lively suggesting they had entered the net only a little before it was winched up. About 240 kg of mirror dory was also taken. Only a few ribbon fish were caught. The Santa Rosa's second shot was in 205-215f for 2.5h between 34°28' and 34°22', 3,963 kg of gemfish were caught with 355 kg of mirror dory.

From Ulladulla the Charissa initially shot off Wreck Bay, attempting to determine if the gemfish had somehow bypassed Ulladulla, but they aborted the shot because the northerly tide was so strong the net could not be held against the bottom. Further south the Marina Star reported a weak southerly current. The Charissa eventually set its trawl in 220-240f towing for 2.5h between 35°24' and 35°27' for 985 kg of gemfish, 127 kg of ling, 144 kg of mirror dory and about 4t of ribbon fish. Its second shot was also for 2.5h and slightly deeper in about 230f between 35°28' and 35°33'. Again there was trouble keeping the net against the bottom and the catch of 38 kg of gemfish, 127 kg of ling and 200 kg of mirror dory was disappointing.

The Marina Star had one 5.75h shot in 220-240f between 35°29 and 35°41' catching mainly ribbon fish (approximately 6t) and ling (360 kg) with only 64 kg of gemfish.

Oceanographic Conditions

The 10 July 250m isotherm chart (Figure 9d) showed the ridge of cold water stretching south-east off the coast between Wollongong and Newcastle was continuing to develop and that associated with this the currents along the Tasman Front around the ridge were also intensifying (up to 2.5 knots). Below 250m the currents around southern side of the ridge would have been directed onto the shelf edge between Wollongong and Sydney as reported by the skippers.

South of Ulladulla the Tasman Front appeared to have locked onto Jervis Bay.

Thursday 11 July

Santa Rosa - 12,568 kg
Illawara Star - 9,213 kg

The boats did not fish out of Ulladulla. A strong northerly current was prevailing on all the main Ulladulla grounds. Pino wanted fish to the extreme south or north, any where as long as it was outside the Ulladulla area. We had lengthy discussions about the survey conditions and about whether he was allowed to fish north off Wollongong, or south off Bermagui. He wanted to hear from people fishing off Bateman's Bay to the south or Shoalhaven to the north to find out if they had gemfish on their grounds or southerly currents. But until he heard some positive news he did not think it was worth surveying. He noted that the weather was perfect - especially inside the harbour. But the boats stayed home because it

was not worth fishing for gemfish in their survey area between latitudes 35° and 36°.

Santa Rosa and Illawara Star initially fish inside the normal gemfish line where they had found the fish on the previous day. The Illawara Star initially towed for 3h in 195-200f between 34°23' and 34°30'. The feed marks looked good on the echo sounder and there was a tide from the south east pushing onto the shelf, but the shot only produced 280 kg of gemfish with 300 kg of mirror dory and about 4t of bait fish. The Santa Rosa shot in much the same area, 3.5h in 195-200f between 34°21' and 34°28' for 493 kg of gemfish and a similar amount of mirror dory. Something like 20% of the female gemfish were running ripe.

The San Diego and Guiseppa from Wollongong both fish near us but outside the gemfish line (in 230-240f) for mirror dory. Both made substantial gemfish catches. The San Diego begged us to take their 4-5t gemfish from them and land it under the research quota so they did not have to throw it away. The diagnosis of the skippers was that the first shot of the day had been too shallow and that the gemfish were back on a more normal line.

The second shot of the Illawara Star was around 220f for 3h between 34°32' and 34°39' it caught 9,833 kg of gemfish. The Santa Rosa's second shot was also for 3h between 34°29' and 34°37' and caught 12,075 kg of gemfish.

The four shots of the seemed to provide an interesting picture of the depth structure of the gemfish aggregation. The Illawara Stars first shot was the shallowest of the day and came up with non-spawning run fish or background type fish - with lengths 30-100 cm. Santa Rosa's first tow was a bit deeper 195-200f and about 20% of the females were running ripe. The highest proportion seen so far in the surveys. The afternoon shots were deeper still and apparently hit the main body of fish which were uniformly 55-90 cm.

Rocco kept emphasising how the gemfish come and go and how difficult it is to find them. His father Vince, one of the pioneers of gemfish fishing told him that's how it has always been. 'sometimes you get them sometimes you don't', 'some boats get 200-400 boxes while others get 30-40 boxes.'

Friday 12 July

Santa Rosa - 9,417 kg
Illawara Star - 6,493 kg

Marina Star - 62 kg
Charissa - 299 kg

All four boats fish out of Ulladulla and Wollongong. Wollongong boats 15.9 tonnes, Ulladulla boats almost nothing.

The Ulladulla boats went as far south as they could go. They were hoping to find cold water, southerly or south-easterly tide pushing their nets and boats onto the shelf slope. Marina Star fished Tuross (almost off Bateman's Bay) and Charissa fished on the ground to the north of Tuross.

The Marina Star shot away in 210f and towed for 2.5h between 35°57' and 36°02' catching only 33 kg of gemfish, similar amounts of mirror dory and redfish, 180 kg of ling and a large thresher shark. Her second shot was for 2.3h and ranged desperately between 210 and 260f between 36°01' and 35°56' it resulted in another mixed catch with only 29 kg of gemfish.

Fishing a little to the north Charissa towed in 210-230f for 2.5h between 35°39' and 35°44' catching just 67 kg of gemfish in amongst 600 kg of ribbon fish. The Charissa's second shot was put out wide for 3h in 245-250f trying to avoid the ribbon fish, and towed between 35°40' and 35° 34' it caught 232 kg of gemfish, 378 kg of ling and 198 kg of mirror dory and only a little ribbonfish (60 kg).

Back on the dock the Ulladulla boats decide to surrender their research permits as they can see no point continuing fishing for gemfish in the Ulladulla area. They warned that they may want the permits back around the next full moon if gemfish started showing up again.

The Wollongong boats fished directly in front of Wollongong but at the southern end of the grounds. As had become usual the Santa Rosa fished immediately behind the Illawara Star as they trawled south. Along the shelf edge the survey vessels had a southerly tide but further inshore in 70f the Guiseppa has a northerly tide pushing to the south-east.

The first shot of the Illawara Star was in 210-220f for 3h between 34°27' and 34°34'. It caught 3,534 kg of gemfish and about 1t of spider crabs. The Santa Rosa's first shot was also for 3h in 215-220f between 34°24' and 34°30' it caught 4,473 kg of gemfish, the males were oozing milt into the boxes and running ripe females were prominent in the catch.

The second shot of the Illawara Star was around 215f for 3h between 34°30' and 34°37' for 2,959 kg of gemfish and about 6t of the same spider crabs which are normally taken as a small by-catch. The Santa Rosa's second shot is similar, 3.3h around 210f for 4,944 kg of gemfish and a large catch of spider crabs. Unlike fish, crabs have no natural flotation and the Santa Rosa had to cut its net open and spill some of the contents to manage the dead weight of the crabs.

During the day John Symonds from Twofold Bay Co-operative rang to tell that the boats have been forced to dump again off the Everards south of Eden. I wa told one boat had dropped 2.5-3.0t of gemfish.

Saturday 13 July

As usual the Wollongong boats took Saturday off even though the weather and fishing was good.

Fishers from Nelson Bay, north of Sydney tell me that about two weeks before gemfish had began showing up on their prawning grounds along with ribbon fish. Since then their by-catches had gradually increased. These by-catches of gemfish and ribbon fish were being made between 150 and 240f between Sydney and the canyons to the north of Sydney, just to the south of Nelson Bay.

Sunday 14 July

No fishing due to bad weather. The bad weather settles in. They should have fished on Saturday!

Oceanographic Conditions

The 17 July 250m isotherm chart (Figure 9e) showed that the ridge of cold water off Wollongong had intensified to the extent that it included an upward dome of cold 12° water, situated just off the shelf in front of Sydney at the north-western end of the ridge. Flowing around these structures the Tasman Front formed a complete figure 's' flowing south-east off the shelf below Jervis Bay and then looping back to flow north along the shelf edge off Sydney and the back out to

sea. The currents around the cold dome of water were directing currents onto the shelf in front of Wollongong.

South of the cold water dome the 16° and 17° isotherms no longer intersected with the shelf but had broken from the shelf and closed in on themselves to begin forming a warm core eddy. But at this stage the Tasman Front still linked the budding eddy to the main body of Eastern Australian Current water to the north.

Thursday 18 July

Illawara Star - 1,722 kg
Santa Rosa - 2,121 kg

The first day fishing after five days of bad weather. Four semi-successful 3h shots were completed.

The first shot of the Illawara Star was around 210f between 34° 21' and 34° 28' and the first shot of Santa Rosa was around 210-230f between 34° 17' and 34° 24'. The result was very disappointing with catch rates around 60 kg/h.

The second shot of the Illawara Star was around 190-215f between 34° 27' and 34° 35' and produced a heavy net of spiny crabs. The net was so heavy that the Illawara had trouble lifting the weight of the cod-end inboard. The situation became dangerous. Two lifts, about half the catch, were taken aboard and then the net was cut open and the weight spilled. The crew sorted gemfish from the crabs, a not inconsiderable 1,533 kg. Some of the gemfish were lively indicating capture towards the end of the shot.

The second shot of Santa Rosa was around 205-225f starting at 34° 25' and winching up around 34° 32'. The shot produced 1,919 kg of gemfish and about the same amount of ribbon fish. A catch rate of around 640 kg/h.

The Illawara Star was talking about having some days off (4 or 5) and not bothering until the moon build a bit towards full. But the Santa Rosa felt the prospects were good for next day if they went south.

Friday 19 July

Illawara Star - 40 kg
Santa Rosa - 115 kg

Bad weather day. Only a 3h morning shot was completed. Illawara Star in 220-230f between 34° 31' and 34° 39'. Santa Rosa in 230 -210f between 34° 30' and 34° 39'.

Tuesday 23 July

The Wollongong boats did not fishing because of bad weather.

I drove to Ulladulla to bring the Ulladulla skippers up to date. Charissa had landed its trip limit over the weekend. Pino told me it was a catch of about 300 kg made on the gemfish line over a couple of hours, but it had to be gaffed out of a bag of ribbon fish. Not much is happening in their area according to them. Northerly tide prevails but they are hopeful things might change over the coming full moon.

Anthony Jubb had the Kendon B on the slip again. He told me nothing had been happening off Bermagui. The only decent fish they had seen had been around the time the project had started and he had already told me about them.

Wednesday 24 July

Illawara Star - 1,144 kg

Santa Rosa - 2,118 kg

First day of fishing since the previous Friday.

The boats each completed two approximately 3h shots. The morning shot of the Santa Rosa was between 200 and 210f while the Illawara Star's morning shot was between 220-230f. The morning shots began around 34°30' and ended around 34°40'. Santa Rosa took about 450 kg/h while Illawara Star took about 260 kg/h.

The afternoon shots were in 190 - 200f beginning around 34°35' and ending around 34°40'. Both boats took about 120 kg/h. The catch was mainly female. No fully hydrated - running ripe animals were observed. But most had moved out of the resting phase and showed evidence of hydration. Few gonads were creamy coloured any more almost all were showing bloody veins running into the gonadal tissue.

Immediately to the north of our afternoon shot the Guiseppa shot away in 160f for redfish and towed north for 2.5 hours. For the last 25 minutes he towed in 180-190f and took around 2.5t of gemfish. Many were still alive when the net was brought aboard.

I spoke with various people from Eden. They say that about 10 days ago (when the Wollongong boats were catching) they had been catching fish out the front of Eden several boats dropped 6-9t each. The fish were 'all big and small - none of the run fish'. 'Now there was not much fish around - 60 kg from 2-3h on the line and all very small fish - summer run fish.'

Oceanographic Conditions

The 24 July 250m isotherms (Figure 9f) showed that a warm core eddy had now formed off Jervis Bay. For the first time the eddy was fully encircled by the Tasman Front, and detached from the main body of warm EAC water to the north of Sydney. Separate sections of the Tasman Front were now running counter current to each other separated by the remains of the cold water ridge.

The separation of the eddy is clearly shown in the Sea Surface Temperatures of 22 July (Figure 8d). A thin cold sheer line is evident running north-east to south-west across the Wollongong trawl grounds separating the two warm water masses

Thursday 25 July

Illawara Star - 6,575 kg

Santa Rosa - 8,452 kg

The vessels each completed two approximately three hour shots. The morning shot of the Santa Rosa was 190-210f while the Illawara Star's morning shot was in about 180f. The morning shots began around 34°20' and ended around 34°30'. Both shots took about 1,000 - 1,100 kg/h.

The afternoon shots were in 170-180f beginning around 34°25' and ending around 34°35'. The Santa Rosa took about 1,700 kg/h while the Illawara Star took about 1,200 kg/h.

Noticeably for the first time there were more males than females in the catch. The females were generally ripening very few were in the resting state, but only one fully hydrated female in a running ripe state was seen. Males were expressing milt freely in the boxes and across the deck.

Friday 26 July

Illawara Star - 1,187 kg
Santa Rosa - 6,209 kg

The vessels completed one extended morning shot of around 5h duration. The shots were made towing north in 165-170f beginning around 34°15' and ending around 34°08'. Santa Rosa took 1,164 kg/h while nearby the Illawara Star only took 246 kg/h.

The catch was again dominated by males.

Tuesday 30 July

FULL MOON
Illawara Star - 299 kg
Santa Rosa - 1,560 kg

The vessels each completed two approximately three hour shots. The morning shots were around 160f and the afternoon shots around 150f. The morning shots were towed north beginning around 34°15' and ended around 34°08'. Santa Rosa took about 500 kg/h while nearby the Illawara Star only took about 50 kg/h.

The afternoon shot was in about 150f and was towed to the south beginning around 34°15' and ended around 34°20'. The Santa Rosa only took about 15 kg/h while the Illawara Star took about 50 kg/h.

The catch was dominated by males. The females caught were generally looking very ripe and running ripe individuals were prominent in the catch.

Wednesday 31 July

FULL MOON - Blue Moon or second Full Moon of July.
Illawara Star - 5,070 kg
Santa Rosa - 2,789 kg

The vessels each completed two approximately three hour shots. The morning shots were around 180f and the afternoon shots 160-170f. The shots began around 34°20' and ended around 34°30'. In the morning Illawara Star took approximately 1,100 kg/h while nearby the Santa Rosa took only about 260 kg/h. In the afternoon shot both vessels took approximately 660 kg/h.

The catch was dominated by males, approximately 80% of the fish measured.

Oceanographic Conditions

The 31 July 250m isotherm chart (Figure 9g) showed little change to that of the previous week. The fully formed warm core eddy was moving slowly off shore but would have continued directing currents onto the shelf around Wollongong. Inshore and to the south of the eddy, cold water was again wedging north along the shelf.

Thursday 1 August

Illawara Star - 1,925 kg
Santa Rosa - 1,846 kg

There was anxiety in the air when this long anticipated day finally arrived. This was to be the day that Wollongong caught its 100t of research quota. Negotiations about what would happen after 100t were fierce? In the end it was decided that the Wollongong boats should continue fishing past 8 August as long as the overall 200t limit and the spawning run allowed.

The boats put to sea hoping to finish off the first phase of the Wollongong surveys by reaching the 100t for Wollongong. Each boat completed two approximately three hour shots in depths between 150-160f, the shots began around 34°15' and ended around 34°30'. Catch rates were around 500 kg/h in the morning and 120 kg/h in the afternoon shot.

The catch was dominated by males - few fish over 80 cm were measured.

Because of the nature of the Co-operatives infrastructure there was considerable uncertainty as to how close the 100t mark really was. Late on the day as the second shot was sorted the Lamaccias enquired whether they would be held to the exact kilo. No free fish was on offer at the weigh-in that night. Vince Musumeci stood guard over the fish making sure every last gemfish was weighed. But the skippers had been quietly confident since their decks had been cleared.

The final prognosis on the night - 53 kg over 100 tonne. The beer flowed and the WIN TV cameras rolled. Even Vince Musumeci had a smile on his face.

Tuesday 6 August

Illawara Star - 400 kg
Santa Rosa - 651 kg

The first day fishing since Thursday 1 August due to bad weather.

Re-negotiations had finished late Monday night. All parties had again agreed to keep fishing while the restrictions research catch allowed or until they determined that the run has finished off Wollongong.

But the boats were an hour late putting to sea because a fierce debate had broken out on the dock between the skippers. The Illawara Star did not want to participate in further surveys because they feared low catch rates might drag down their overall catch rates. The vessels eventually put to sea. But day-break found them in 150f and to the south, over shallow redfish grounds rather than the gemfish grounds where the previous catches had been made.

At 7.00AM the Illawara Star rang to inform me of developments since the agreement of the previous evening. I spoke to all four survey skippers and whoever else I could think of. The Illawara Star was again assured that low catch rates before and after the main run would not affect estimation of peak catch rates. I explained that the length of the season could contribute to an optimistic biomass estimates.

By this time the boats had shot away on the redfish grounds and had boxed themselves inside the other boats fishing for redfish. Never-the-less they worked their way deeper on the grounds. Illawara Star shot away in 154f and towed for 3.5h between 34°34' and 34°44' winching out of 170f for a catch of 400 kg of

gemfish. The Santa Rosa also shot away in 150f and towed for about 4h between 34°35' and 34°47' winching out of 190f. The Santa Rosa caught 651 kg of gemfish, mainly males bodies full of milt. Most of the females were out of the resting state about 20% of the females were running ripe, a few were spent. The first observation of spent fish during the 1996 program. Both vessels caught little by-catch besides 200-300 kg of redfish.

Bad weather then forced all the boats ashore.

The other Wollongong boats working around the area had all filled their gemfish trip limits. Drop-liners around Kiama reported lines filling up and the existence of two distinct schools of gemfish; large fish on the outside, smaller fish on the inside. Perhaps female and male schooling separately. One of the drop-liners also reported a large catch of gemfish floating north on the southerly breeze towards Kiama.

The Santa Rosa was furious and the Illawara Star chastened. It was felt that a great opportunity to record further good catch rates had been missed. The widespread catches, the smooth uniform size distribution of the gemfish (65-80 cm) together with their gonadal status, suggested to everyone involved that active spawning had been going on during the day somewhere in the Wollongong area.

Thursday 8 August

Illawara Star - 374 kg
Santa Rosa - 1,260 kg

Despite strong winds the survey vessels fish tried to re-establish contact with the gemfish run. But the vessels only completed one shot each before being blown back to port. The Illawara Star shot away in 175f for 3.5h between 34°24' and 34°32' and caught only 374 kg of gemfish and a similar amount of redfish. The Santa Rosa shot in 175-180f for 4h between 34°21' and 34°29' and caught 1,260 kg of gemfish and 225 kg of redfish.

The crew of the Santa Rosa were happy with this result saying it was enough to indicate the runs was still there and active. They thought the fish were slowly moving north and that as long as the weather cleared a little over the weekend the run up to the new moon at the end of the following week would probably produce some more good catches.

Sunday 11 August

Illawara Star - 70 kg
Santa Rosa - 253 kg

Each vessel completed two approximately 3 hour shots. Santa Rosa's first shot was in 175f between 34°25' and 34°15' for about 133 kg, Illawarra Star's first shot was also in 175f between 34°28' and 34°19' but took only 35 kg. Santa Rosa then tried deeper between 230f and 220f between 34°17' and 34°22' for 120 kg, while the Illawara shot in 210f between 34°20' and 34°26' for 35 kg.

Monday 12 August

Illawara Star - 16 kg
Santa Rosa - 10 kg

The vessels only completed one shot each before deciding that the surveys should be terminated. Santa Rosa's shot was in 240-235f between 34°24' and 34°29'

for 10 kg, and Illawarra Star's was in 210f between 34°24' and 34°29' for only 16 kg.

The Research permits were surrendered on the same day and the vessels reverted to commercial fishing. It was understood by all concerned that surveys could recommence if gemfish aggregations re-occurred.

There was no call for this because the aggregations did not re-occur off Wollongong or Ulladulla in the 1996 season.

Catches and Catch Rates

A total of 54 survey shots were conducted from Ulladulla and 52 from Wollongong. Approximately 40t of gemfish were caught from Ulladulla and 103t from Wollongong.

In Figure 10 catch rates (kg/h) for each shot are shown for Ulladulla and Wollongong. Catch rates were generally lower off Ulladulla than off Wollongong peaking around 2,000 kg/h compared to 5,000 kg/h. The other notable feature was the co-incidence between the decline in catch rates off Ulladulla and the increase of catch rates off Wollongong.

Figure 11 shows the catch rates for each survey vessel. Note that in this figure the catch rate scales on the left hand side of the graphs are different for each vessels. Peak catch rates ranged from 244 kg/h for the Marina Star off Ulladulla up to 4,674 kg/h for the Santa Rosa off Wollongong.

Ulladulla

Off Ulladulla surveys began 18 June after reports from Bermagui suggesting that gemfish aggregations were moving north towards Ulladulla. Catch rates remained low (<500 kg/h) until 25 June when in both their morning and afternoon shots Charissa recorded high catch rates at the extreme southern end of the Ulladulla survey area (1,104 & 661 kg/h). During the period 25-27 June Charissa took more than 1,000 kg/h in each morning shot (1,104, 1,757, 2,026 kg/h respectively) and on 27 June the catch rate of Charissa's afternoon shot also exceeded 1,000 kg/h (1,225 kg/h).

On 28 June bad weather stopped fishing for a few days.

After this initial episode of fishing catch rates off Ulladulla declined and catch rates >500 kg/h were only recorded in 3 subsequent shots. These were short shots (<2h) made by Charissa during the mid-morning and early afternoon. On 4 July Charissa completed 3 short shots for catch rates of 46, 1,019 & 552 kg/h respectively, and on 10 July she took 568 kg/h in a 1.75h shot started around 08.30 AM.

Surveys off Ulladulla ceased on 12 July, 1996.

The highest catch rate taken by the Marina Star was only around 244 kg/h but her catch rates show the same trends as Charissa's, peaking and falling co-incidentally. In comparing the different performance of the two Ulladulla vessels two specific events should be noted:

- On 25 June during the first shot of the morning, when Charissa recorded its first catch rate >1,000 kg/h, the Marina Star was interfered with by other vessels and ripped the belly out of its net trying to regain the correct line for the trawl. This resulted in a catch rate of 140 kg/h

which was still the Marina's Star fifth highest catch rate. For the second shot of that day Charissa caught >500 kg/h while the Marina Star was forced to fish with its 'market fish net' as a replacement for their 'gemfish net'.

- On 27 June when Charissa recorded two of its three highest catch rates the Marina Star was not permitted to fish. Acoustic equipment was being fitted to the vessel on that day because it was thought that a period of high catch rates was just commencing.

The events of those days undoubtedly deprived the Marina Star from recording several shots with relatively high catch rates. Crudely comparing peak catch rates; 2,000:250 kg/h, suggests an 8:1 difference between the boats. But this difference partly reflects the Marina Star's lost opportunities. A closer comparison of the data shows that when the vessels fished simultaneously the Marina Star's catch rates were generally only 4-6 times lower than those of the Charissa's.

The crew of the Marina Star were clearly concerned about their poor performance and talked about it constantly. They felt keenly their responsibility towards the rest of industry in terms of their performance and constantly discussed what could be done to remedy the situation. On 27 June they altered the angle of their trawl boards to increase their angle of attack. In doing this they hoped to open and flatten the mouth of their net. They felt that their gemfish net might have been too big for their normal 'market-fishing' boards and that this may have been causing the mouth of the net to close and the head-line to float up high. This they deduced from their higher by-catch of ribbon fish which is believed to swim higher in the water column than gemfish.

Others in industry criticised the net the Marina Star used claiming its cod-end was too narrow and short to be classed as a 'gemfish net' but it should also be noted that the Marina Star was the smallest of the vessels used in the project.

Wollongong

As already noted catch rates off Wollongong were generally higher than off Ulladulla, the peak catch rate was 4,674 kg/h and there were 13 shots with catch rates >1,000 kg/h compared with only five for Ulladulla. Three shots above 2,000 kg/h were recorded off Wollongong while only one was recorded off Ulladulla.

Both the Illawara Star and Santa Rosa recorded ten shots with catch rates >500 kg/h although the Santa Rosa generally recorded catch rates greater than the Illawara Star. The peak catch rate of Santa Rosa was 4,674 kg/h compared to 2,897 kg/h for the Illawara Star. This was probably due to the fishing practice and the greater power of the Santa Rosa.

Off Wollongong the surveys began 9 July as catching declined off Ulladulla. While no surveys were undertaken off Wollongong prior to 9 July, the survey vessels and other Wollongong vessels fished commercially over the shelf break during the month prior to surveys commencing. From their reports it is known that significant amounts of gemfish did not move onto the Wollongong grounds until 8 July.

On 10 July the four shots completed off Wollongong recorded catch rates of 2,208, 525, 1,586 and 1,639 kg/h. On 11 July the morning shots only recorded 144 and 90 kg/h, but the afternoon shots were made 30-40f deeper and recorded 1,639 and 4,674 kg/h. This latter the highest recorded during the project. On 12

July both morning shots and the Santa Rosa's afternoon shot recorded catch rates over 1,000 kg/h.

Bad weather then prevented fishing again until 18 and 19 July when catch rates were low. The best two of six shots gave catch rates around 500 kg/h. Then bad weather again prevented fishing; this time until 24 July.

On 24, 25 and 26 July a total of ten shots were completed. On the first day low catch rates (<500 kg/h) were recorded. But on 25 July both Santa Rosa's shots recorded catch rates <1,000 kg/h and the Illawara Star's shots recorded 990 and 1,175 kg/h respectively. The vessels only completed a single shot each on 26 July the Santa Rosa recorded 1,164 kg/h and the Illawara Star 246 kg/h.

Catch rates were lower 30 July to 1 August when weather next permitted the boats to fish. Only 4 of the 12 shots recorded catch rates >500 kg/h. During the next period of fishing, 6-12 August, the highest catch was only 311 kg/h. On 12 August the catch rate of the two boats were only 15 kg/h and 4 kg/h and the surveys ended.

Missing Data

Catch rates are not available over the same time period for both ports. This was because the participating skippers were reluctant to fish unless they believed they could catch gemfish.

This was particularly evident with Wollongong at the start of the time series and Ulladulla at the end of the time series. The Ulladulla boats were initially coaxed to begin fishing on 18 June and went fishing knowing they would experience low catch rates. On 17 July they requested to cease fishing when they considered further surveys pointless because of the low catch rates. When the surveys stopped in Ulladulla it was made clear that they could recommence at any time if they wanted. Likewise the Wollongong vessels refused to start surveying until they believed they were assured of catching gemfish. Gemfish were first found on their trawl grounds 8 July the day before surveys commenced, and surveys ended when catches declined.

Because of this it can be assumed that the catch rates recorded by the surveys (with a tolerance of a few days either side) are at least a good indicator of the presence or absence of the spawning aggregations of gemfish through the research area. Where there are no survey points before and after surveying it can be assumed that the aggregations were absent from the areas and that the missing values are missing zero values.

This of course does not apply to gaps within the data series, with the exception of Saturdays in Wollongong the gaps within the survey data are due to bad weather.

Oceanographic Context of the Study Area

The Tasman Sea adjacent to the study area is dominated by two water bodies; the warm East Australia Current (EAC) flowing southwards from the tropics and the cold, deep Sub Antarctic water mass moving northwards at depth from the Antarctic Convergence. Where these water bodies converge is called the Tasman Front, which is often arbitrarily defined as the 15° isotherm. Along the Tasman Front the water column is enriched by the mixing of the two water bodies and the convergence zone is characterised by comparatively high levels of phytoplankton production (McClatchie *et al.* 1995).

Adjacent to the Australian continental shelf the convergence zone frequently contains large eddies formed where the main body of EAC water breaks away from the continental margin and flows south-east into the Tasman Sea. The eddies also move generally south-east, often interacting with the shelf edge for a while, before finally dissipating in the Tasman Sea or being re-absorbed into the EAC.

The location of the convergence zone is not stationary but moves seasonally north and south, from north of Sydney in spring to the south-east of Tasmania in Autumn. The driving forces behind this oscillation are not fully understood (Ridgway & Godfrey in press).

Small upwellings, or intrusions of cold water, are commonly observed along the NSW shelf between Eden and Newcastle during September to January, as the Tasman Front moves north along the shelf edge. Seasonal blooms of phytoplankton are commonly associated with these intrusions of cold water and these have some of the highest phytoplankton densities measured in Australian waters (Jeffrey & Hallegraeff 1990). These intrusions of nutrient rich cold deep water and associated plankton blooms have been extensively discussed in Australia's scientific literature (see Rochford 1958, 1975, 1984; Humphrey 1960; Newell 1966; Grant 1971; Boland 1979; Godfrey *et al.* 1980; Pearce & Boland 1982; Huyer *et al.* 1988; Cresswell 1994; Hallegraeff & Jeffrey 1993)

A number of factors have been observed to influence this upwelling of cold nutrient rich Sub Antarctic water and to cause deep mixing of the water column (Cresswell 1994). The two principal factors are thought to be:

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

Northerly winds blowing along and across the shelf area probably provide additional forcing for these two features.

This authors of this body of oceanographic work have discussed in general terms the likely importance of these upwellings to the commercial fisheries of NSW. Hallegraeff & Jeffrey (1993) cite a body of international work showing the importance of plankton blooms in ensuring the survival of larval fish and the eventual recruitment of young fish into fished stocks. However specific observations of the interaction between these seasonal upwellings and the south eastern Australian fish assemblage remain few.

The NSW gemfish fishers believe that the timing and location of spawning gemfish aggregations is linked to the movement of cold deep water along and onto the shelf slope. Warm clear blue plankton poor water is brought by the strong summer current from the north (Prince & Wright 1994). The fishers expect the cold weak winter current from the south to bring water made 'dirty' by plankton and they associate the winter runs of fish with the cold currents from the south and southeast. Fishing is reputed to be best where the cold and warm waters mix. Fishers believe that the gemfish ride deep northward moving currents onto and along the shelf, and that the northward migrating gemfish will sometimes bank up in an area if they run into warm currents from the north associated with large warm core eddies.

The design of the 1993 industry gemfish survey (Prince & Wright 1994) precluded quantitative assessment of a possible relationship between the timing

and location of gemfish aggregations and intrusions of cold water. However based on their surveys results, industry reports and the 250m isotherm charts produced by the Royal Australian Navy METOC services they qualitatively noted an apparent link between oceanographic features and the gemfish aggregations.

Oceanographic Context of the 1996 Surveys

During 1996 the aggregations of gemfish were clearly associated with oceanographic conditions likely to have been causing upwellings.

During the survey catch rates reached their first maxima 25, 26 and 27 June south of 35°40' when Charissa recorded four shots with catch rates >1,000 kg/h. The highest being the record for the surveys out of Ulladulla 2,026 kg/h. The 250m isotherm for 26 June (Figure 12) showed that a cold bottom current had been pushing north along the shelf underneath the southward flowing EAC. The surface flowing EAC would have inflecting the bottom current inshore and up the continental slope in the vicinity of the catches.

Catch rates next peaked off Wollongong (Figure 13) on 10 July between 34°28' and 34°39' in 200-220 fathoms when four completed shots took 2,208, 525, 1586 & 1,639 kg/h. The record catch rate for the survey, 4,674 kg/h, was taken on the afternoon of 11 July between 34°29' and 34°37' in 215-225f. On 12 July in the same area and depth catch rates for four completed shots were around 1,000 - 1,600 kg/h.

High catch rates were again recorded in the Wollongong area (Figure 14) on the 24, 25 and 26 July when fishing occurred between 34°18' and 34°47' in 165-215f. Ten shots were completed and the best five shots recorded catch rates around 1,000 kg/h.

The isotherm charts (Figure 13 & 14) show that these Wollongong catches occurred on the northern edge of a developing warm core eddy. The intensified anti-cyclonic currents around the eddy as it formed would have directed a flow of deep water onto and up the shelf break around the site of these catches.

From this co-incidence between gemfish aggregations and conditions likely to cause upwelling along the NSW shelf it is tenable to suppose that the gemfish are aggregating around the seasonal winter upwellings that occur along the NSW shelf. A full quantitative analysis of historic gemfish catch rate data and the 250m isotherm data Royal Australian Navy METOC is beyond the scope of this study, but such an analysis could feasibly be used to fully test these hypotheses.

These ephemeral upwelling events could attract the aggregation of gemfish for two reasons; food for adults, and conditions for enhancing the survival of eggs and larvae.

Commercial echo-soundings and the contents of commercial catches show that these seasonal upwelling events support or attract a rich and diverse fauna. The stomach content of gemfish show them to be preying upon some of these species, principally ribbon fish and jack mackerel. The gemfish fishers believe the aggregation of species lower in the food chain than gemfish feed the gemfish during their annual migration.

The upwellings along the NSW coast seasonally enrich the marine environment along the shelf edge during late winter and early spring causing the plankton community to bloom through until summer. These condition can be expected to enhance the survival of larval and juvenile gemfish which prey on the planktonic

communities . By aggregating against the edge of the shelf spawning gemfish could place their fertilised eggs into the stream of upwelling bottom water which will enrich the food chain of the shelf during the first six months of the gemfish life cycle.

Fishing Patterns and Feed Layers

Within the defined time and area constraints the four survey vessels were given as much flexibility as possible so that their fishing practice could be as consistent as possible with fishing practices prior to 1992. This was so that the catch and effort information gathered through the surveys can be compared with historic data, and for the Eastern Gemfish Assessment Group it seemed a reasonable condition to set, and a reasonable objective to achieve.

But reality is often more complex than a committee can easily accommodate.

The fishers who conducted these surveys repeatedly asked the author to explain in this report why the fishing patterns used during the surveys could not be directly compared to historic fishing patterns, to explain the reason the industry would have boycotted this project if it had proceeded using only one vessel from each port.

Put simply it is because hour by hour gemfish aggregations can vary greatly in density, location and depth and fishers cannot reliably detect them with commercial echo-sounders or any other means. Searching for gemfish is essentially a process of trial and error and like anything takes a certain number tries. When the fishery was unconstrained there were enough vessels available to try every trawl ground in the fishery every day. Normally the gemfish would be found on the first day of searching and then the aggregation would be targeted by all vessels while weather conditions allowed.

In comparison to earlier seasons the survey vessels spent most of their shots searching for the right depth and location rather than in targeted fishing. Consequently the fishers participating in these surveys argue strongly that in comparison to normal fishing practises these data significantly under-estimate stock abundance. In comparison to normal there will be a much greater proportion of low "searching" catch rates, and few higher "targeted" catch rates.

To fully understand the perspective of the fishers it is necessary to understand a little about the nature of the fishery. To this end in the following sections I describe the practice of fishing for gemfish.

Feed Layers

Gemfish aggregate sporadically and relatively invisibly over established trawl grounds along the shelf break. Hour by hour, day by day gemfish aggregations vary greatly in density, location and depth, and gemfish fishers cannot reliably detect them with echo-sounders. This means that gemfish aggregations cannot be targeted with bottom trawl nets in the same way as orange roughy which form identifiable schools and aggregate regularly around fixed locations.

Instead gemfish fishers search for gemfish by trawling along established trawl grounds, trying different depths, locations and times of day. Each trawl shot takes a minimum of 2-4 hours to set, fish and retrieve and consequently a single trawler can only search 1-3 different combinations of depth and position each day. But the fishers do not trawl randomly when searching for gemfish. Instead they search with their echo sounders for acoustically reflecting layers in the water column which they call 'feed layers' (figures 15-18).

Fishers call the acoustically reflective bands 'feed layers' because they are thought to contain the food of commercial finfish and at the certain times the target species as well. The fishers discuss the nature and dynamics of the feed layer constantly in the way farmers discuss weather.

The feed layers extend horizontally out of the ocean across the shelf break and outer shelf (Figure 15). The fishers believe that the feed-layers contain whole food chains of species. This they believe because their catches contain many species of pelagic and demersal fish, pelagic and benthic crustaceans and large amounts of pelagic jellyfish. The finfish in the catch include predators of plankton and jellyfish as well as large predatory sharks and fish (including gemfish and ribbon fish), whose stomach contents regularly show they have been feeding on other species in the same catch.

Off southern NSW the feed layers are more common and thicker during winter than summer, their prevalence is linked to the northward movement of the Tasman Front each year and its associated upwellings. Knowing that the species in their catches associate with distinct depth bands the fishers search for thick feed layers in the right depth. Gemfish are normally caught between approximately 380m and 480m.

Specifically the fishers search for where the feed layers extend out of the ocean in midwater and 'touch down' on the sea bed floor along the shelf edge and shelf break. They associate good catches with the feed layers being 'hard down' on the seabed floor (Figure 17), reasoning that the mouths of their bottom trawls are only 4m high and they can only catch fish in the bottom 4m of the water column.

The principal behind targeting gemfish are well illustrated by figures 15-17 even though the principal component of the feed layers shown are probably redfish and ribbonfish and are unlikely to have contained gemfish. (As noted above trawl fishers of southern NSW fish for many SEF species using the principals being described here).

Figure 15 was made as the vessel steamed (left to right/east to west) back onto the shelf. Depth (m) is shown on the side of the figures. At the bottom of the figure the continental slope can be seen as a solid layer rising out of 300m towards 200m. Below the intense surface scattering layer, a feed layer can be seen stretching horizontally between 200 and 250m towards the shelf. The two dimensional extent of the same feed layer on the same day is shown by Figure 16. This echogram was made as the vessel steamed parallel to the edge of the shelf and the feed layer is seen stretching along the shelf edge from north to south. The same strong horizontal banding between 200 and 250m is observed.

To the right of Figure 15 the feed layer can be seen in contact with the shelf slope between 200-250m depth strata. Several large acoustic marks can be seen 'touching down' on the bottom between about 220-250m but only the shallowest could be considered hard against the bottom. Figure 17 shows a different mark (probably containing ribbon fish) on a different day 'hard down' on the bottom as the vessel steamed from north to south parallel to the shelf edge.

The fishers of the SEF target their trawls at these types of midwater acoustic marks in the depth band appropriate for the species being fished, their trawls are targeted at the acoustic marks when and where the marks are against the sea-bed. They assume that their nets are ineffective at capturing fish more than 3-5m above the substrate.

The Ocean's Midwaters

The ocean's midwaters are the most expansive habitat on the earth yet because it is so foreign to the human world we still know extraordinarily little about its fauna (Robison 1995). Scientific sampling techniques such as nets and grabs have been too primitive to sample most of the species found in the midwater. Recent research by Robison (1995) based on direct observations using submersibles and remotely operated vehicles in the canyons off Monterey, California support many of the beliefs and suppositions of the SEF fishers.

Early work on the midwater environment described a rather sparse array of species, shrimps, lantern fish, squids and pelagic worms, in an apparently almost empty space. But the modern work is describing a far greater array of species occupying the midwater environment many of them simply too fragile to extract from their supportive watery environment. These fragile organisms are now thought of as 'forming' the midwater environment. The bodies and feeding parts of large (up to 40m in length) gelatinous animals actually form a biological substratum through which other midwater species hunt and hide. Robison (1995) says that the midwater environment can be best visualised as "a dim, weightless world filled with ragged, three-dimensional spider webs."

Perhaps the most surprising result of this new work has been the description of how important surface lighting is in this low light habitat. For decades marine biologists have believed that sunlight could only support vision down to 300 to 400 meters below the surface. But the recent studies have found light to be a key influence on animals down to at least 1,000m. Predatory midwater fish, like gemfish, and squid orientate vertically rather than horizontally. They feed by hanging stationary, searching the surface gloom for the silhouette of prey species passing above them. Silhouetted prey are stalked stealthily from below and taken in a final upwards lunge. Conversely the flight response of most midwater species is to dive down into the sheltering darkness. Rapid movements are minimised because they trigger spectacular bioluminescence displays from the surrounding biological substratum. These displays have the appearance of underwater lightning storms and are thought to protect the gelatinous species from predation by putting the spot light on small jellyfish predators and turning the hunter into the hunted.

Many of the midwater species appear to regulate their depth in response to light intensity, rising towards the surface at night and retreating through the water column as daylight strengthens.

Fishing Practices

The fishers of the SEF are familiar with the daily rise and fall of the feed layers. Where the feed layers extend out of the open ocean over the shelf break, the early morning dive of the feed layer often results in the feed layer crowding down hard against the sea bed along the shelf break.

Along the established trawl grounds the fishers target their trawl shots where the feed layers touch the sea floor. The fishers associate their highest catch rates with the feed layer being crowded against the bottom by the light. The first shot of the day is generally begun at day break when the feed layers diving rapidly away from the growing daylight. The middle of the day when the sun is strongest and the feed layer is pushed deepest by the light is also thought to be good for catching gemfish. Little fishing is done in the late afternoon or the dark of night.

This pattern is illustrated by Figure 18(a-i) which are a series of echograms recorded 26 July, aboard the Santa Rosa II during a 5 hour 20 minute shot which took 6,209 kg of gemfish and 750 kg of redfish.

This was an unusually long shot for this survey. It was made because the skippers were confident about the location of the gemfish after several days of good catches, and because they expected bad weather to prevent a second shot being completed. This series of echograms shows all the major acoustic marks observed during the shot, the time (EST) at which each echogram was recorded is shown for each echogram. Depth (m) is marked on the right hand side of each echogram. As the shot began around day break (Figure 18a) there were diffuse marks scattered 50-100m above the bottom in 200-300m. By 07:33 (Figure 18b) the marks had concentrated below 250m and by 07:45 (Figure 18c) strong targets were occurring within 10-15m of the bottom in 315m. The size and frequency of these marks then declined and little was seen on the echo sounder between 08:00 and 10:30 after which a few marks were again seen in the bottom 50m of the water column.

At the height of the eastern gemfish fishery the fishers tended to use 5-6h shots routinely. Beginning around day break and hauling after midday as light intensities began declining. These long shots could be made because with so many vessels searching for gemfish the skippers were generally confident about the location of the gemfish aggregations.

With only two boats in each area during this study the survey boats were forced on most days to combine searching with fishing. This basically meant breaking the single long shot into two shorter 3 hours shots so that the skippers could check their catch and try a different depth or another ground for a second shot. Throughout the project this was a constant source of frustration. Fishers were constantly pointing out that survey fishing was not as effective as real fishing because the trawls were being hauled mid-morning and the winching, sorting and resetting process kept the net out of the water during the middle of the day, wasting the hours between 10:00 and 13:00.

Before they began surveying themselves the Wollongong boats were especially critical of the Ulladulla boats on this point. However after a single unsuccessful 5-6h shot the Wollongong boats adopted shorter 3h shots and then almost exclusively used shorter shots throughout the rest of the project.

Length Frequency Data

A total of 11,593 gemfish were measured from 210 sampled catches. A total of 6,087 males were measured and their caudal fork length found to be mainly 60-80 cm with modes around 70-74 cm. A total of 5,506 females were measured, mainly 68-90 cm in length with modes around 75-82 cm (Figure 19). Overall sex ratios were relatively even, males comprised 52.5% of the fish measured.

These results contrast with those of the 1993 industry surveys (Prince & Wright 1994) which observed that overall females (66%) outnumbered males and that there were two distinct size classes of males (45-55 cm and 70-85 cm).

These length frequency data have been arbitrarily grouped into 10 short phases with the subjective intention of visually examining the data for patterns and heterogeneity (Figure 20). For this purpose the following phases were defined:

Phase #	Period	Description
1	18-23 June	Initial low catch rates at Ulladulla
2	25-27 June	Catch rates peak of Ulladulla
3	29 June - 1 July	Lull in catch rates at Ulladulla
4	3-4 July	Second peak in catch rates at Ulladulla
5	9-12 July	Catch Rates fall away at Ulladulla and surveys stop. Catching starts and peaks at Wollongong
6	18-19 July	Lull in catch rates at Wollongong
7	24-26 July	Secondary peak in Wollongong catch rates broken by bad weather
8	30 July - 1 August	Tertiary peak in Wollongong catch rates broken by bad weather
9	6-8 August	Catch rates decline in Wollongong
10	11-12 August	Low catch rates in Wollongong surveys stop

From Figure 20 it can be seen that there was some variability in the length frequencies collected:

- Higher proportions of small gemfish were found during periods of low catch rates (phases 3,9,10).
- In contrast to the overall even sex ratio the gemfish catches taken off Ulladulla during phase 4 were dominated by females (67%).
- Males (73%) outnumbered females in phase 8, 9 and 10. This increasing proportion of males late in the season was also observed in 1993. It may indicate that most females finish spawning before the males and move away from the aggregations.
- A small but interesting feature is the small mode of females recorded at 54 cm in phase 5. Most females <60 cm were immature and were taken during periods of low catch rates, however the 50-58 cm females measured during phase 5 were taken running ripe at a time of high catch rates.

Data Base

Electronic copies of these data accompanied by the interim report for this project were forwarded to CSIRO, BRS and NSW FRI in September, 1996. The data is contained in an Excel spreadsheet and further copies are available on request from the author. A hard copy version of the catch and effort data is contained in Appendix 1.

6.0 BENEFITS

As identified in the original proposal the benefit flowing from this project is the timely provision of data for 1996 to the Eastern Gemfish Assessment Group (EGAG). This will enable EGAG to update the assessment of the Eastern Gemfish stock by March/April 1997 so that the South East Trawl Management Advisory Committee can make an informed decision as to whether or not there should be a Total Allowable Catch for winter 1997.

Less tangible benefits will also flow from this projects descriptions of the midwater ecosystems, SEF fishing patterns and the coincidence between upwelling conditions and gemfish aggregations. Fishers of the SEF have repeatedly expressed their frustration with the standard of scientific understanding of their fishery. Introducing this material into the Australian fishery science community via this report will help to inform future debate, stock assessment, research and management.

7.0 INTELLECTUAL PROPERTY AND VALUABLE INFORMATION

No intellectual property has been created by the research project as all the valuable information generated belongs in the public domain.

The valuable information arising from the project are of two types:

1. Quantitative data for immediate incorporation into the 1997 assessment of the eastern gemfish stock by EGAG. The catch rate and length frequency data collected by the project are essential components of the stock assessment being conducted by EGAG.
2. Qualitative information which will stimulate and edify continuing discussions about the assessment, research and management of the SEF.

The description of the link between upwellings and gemfish aggregation is an important new piece of information to arise from this study. While fishers of the SEF have discussed this linkage for many years the scientific community has lacked the evidence necessary for them to embrace the phenomenon. The linkage has important consequences for the assessment of SEF fish stocks as most assessments rely on the assumption of a direct relationship between catch rates and stock abundance. The implication of a linkage between upwellings and gemfish aggregation is that the catchability of gemfish and thus catch rates will be heavily influenced by the nature, timing and location of upwelling events.

For example if upwelling conditions were extremely poor in a year, aggregations may not occur and catch rates may be extremely poor, despite the gemfish stock being abundant in that year. Alternatively if upwelling was particularly intense in a small stable area extremely high catch rates may occur which may not reflect true stock abundances. This seems to have occurred in 1992 when the stock was apparently at low levels but a long season of extremely high catch rates occurred off Wollongong. The 250m isotherms for 1992 show that at that time a small area of upwelling occurred stably off Wollongong for 6-8 weeks.

The description of fishing patterns and the midwater ecosystem illustrated with the echograms collected using the EchoListeners will also add substantially to ongoing debates about the assessment, research and management of the SEF. There has already been a great deal of discussion in this fishery about the impact

of fishing pressure on the exploited species and on the habitat of the SEF. These discussions have focussed on the seabed and the importance of the seabed to SEF species. Until recently the scientific assumption has been that because this fishery uses bottom trawls the species being fished are principally bottom living, or demersal, species. For example early stock assessments were based on swept area methods which assumed a relationship between the area of the continental shelf and shelf slope, and the biomass of the SEF species.

The discussion and images contained in this report highlight the importance of the midwater environment to this fishery. The fishers of the SEF have consistently stressed this focus for many years but there has been too little practical knowledge within the scientific community for this industry knowledge to be recognised.

8.0 FURTHER DEVELOPMENT

The catch, effort and size structure data collected by this study have already been provided to the Eastern Gemfish Assessment Group which is using them to update the assessment for this fish stock. On the basis of these newest data and their stock assessment EGAG will discuss and propose research priorities to SETMAC's Research Sub-committee.

This study noted a strong correlation between gemfish aggregations and conditions likely to cause upwelling along the NSW shelf. This correlation appears to be supported by a qualitative examination of historic data, however full quantitative analysis of historic gemfish catch rate data and the 250m isotherm data Royal Australian Navy METOC was beyond the scope of this study. Such an analysis could feasibly be used to fully test this hypothesis.

This study is the first attempt to scientifically describe the importance of the midwater environment to the South East Fishery. These aspects of this study are sure to be controversial but will stimulate much needed debate. Whether the SEF is assumed to be principal a fishery for demersal or midwater species changes the assumptions one makes about a range of issues fundamental to stock assessment, research and management in the SEF. These issues include but are not limited to:

- the power of fishing effort. If the fishery is assumed to be mainly for demersal species then bottom trawling can potentially fish the species throughout their range and life cycle meaning that fishing effort is extremely powerful in its catching ability. In contrast if most of the fish are midwater species which only come into contact with the seabed under particular environmental conditions or during limited phases of their life cycle the potential fishing power of bottom trawling is greatly diminished.
- the impact of bottom trawling on the environment of the fishery and the sustainability of the fishery. If the species are principally demersal species it is reasonable to assume that the nature of the seabed is of fundamental importance to the exploited species. Thus bottom trawling may potentially make the fishery unsustainable if it changes the nature of the seabed. In contrast if the species are principally midwater species which are driven against the bottom by light and water currents the nature of the seabed may be irrelevant in terms of the long term sustainability of the fishery and fishing practices.
- the overall productivity of the fishery. If the fishery is principally for demersal species the productivity of the fishery will be largely determined by the productivity of the shelf area around south east Australia. However

if the species are principally midwater species they may forage over a much wider area of the Tasman Sea and the productivity of the fishery could potentially be considerably greater than that found in continental waters.

- the role of catchability in determining catch rates. If SEF species are principally midwater species which are only brought within the range of bottom trawls by specific environmental conditions it must be assumed that catch rates are heavily influenced by these specific conditions. A priority of SEF stock assessment which relies heavily on catch rates as indicators of abundance should be to describe in detail the factors affecting catchability so that when catch rates vary changes in catchability can be distinguished from changes in actual stock abundance.

Stock assessment, research and management in the SEF will benefit from having these concepts formalised within this report. Further development will occur as these issues are debated and analysed through the South East Fishery Assessment Group and Research Sub-committee.

9.0 STAFF

Supervision & Reporting

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Full-Time Scientific Observers

Steve Rush
Geoff Diver

Part-Time Scientific Observers

Nokome Bentley
David Payne
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10.0 FINAL COST

The total cost of the project was \$427,151.87.

The project earned \$463,374.10 through the sales of gemfish (\$430,492.70) and mixed fish (32,881.40).

The profit from the project \$36,222.23 was returned to FRDC for future gemfish research.

11.0 ACKNOWLEDGMENTS

The support and flexibility of the staff of the Australian Fisheries Management Authority and the Fisheries Research and Development Corporation in making this project possible at extremely short notice needs to be acknowledged and praised. The members of the Eastern Gemfish Assessment Group and in particular Kevin Rowling of the NSW Fisheries Research Institute who had the role of co-investigator for the project are also thanked for their input, advice and support. Thanks also go to Dennis and Con Poulos of Wollongong Fisheries Australia.

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I would particularly like to thank all the NSW fishers whose co-operation, support, acute powers of observation and pattern recognition skills have made this study possible.

12.0 APPENDICES

Appendix 1 Catch and effort data collected during the project.

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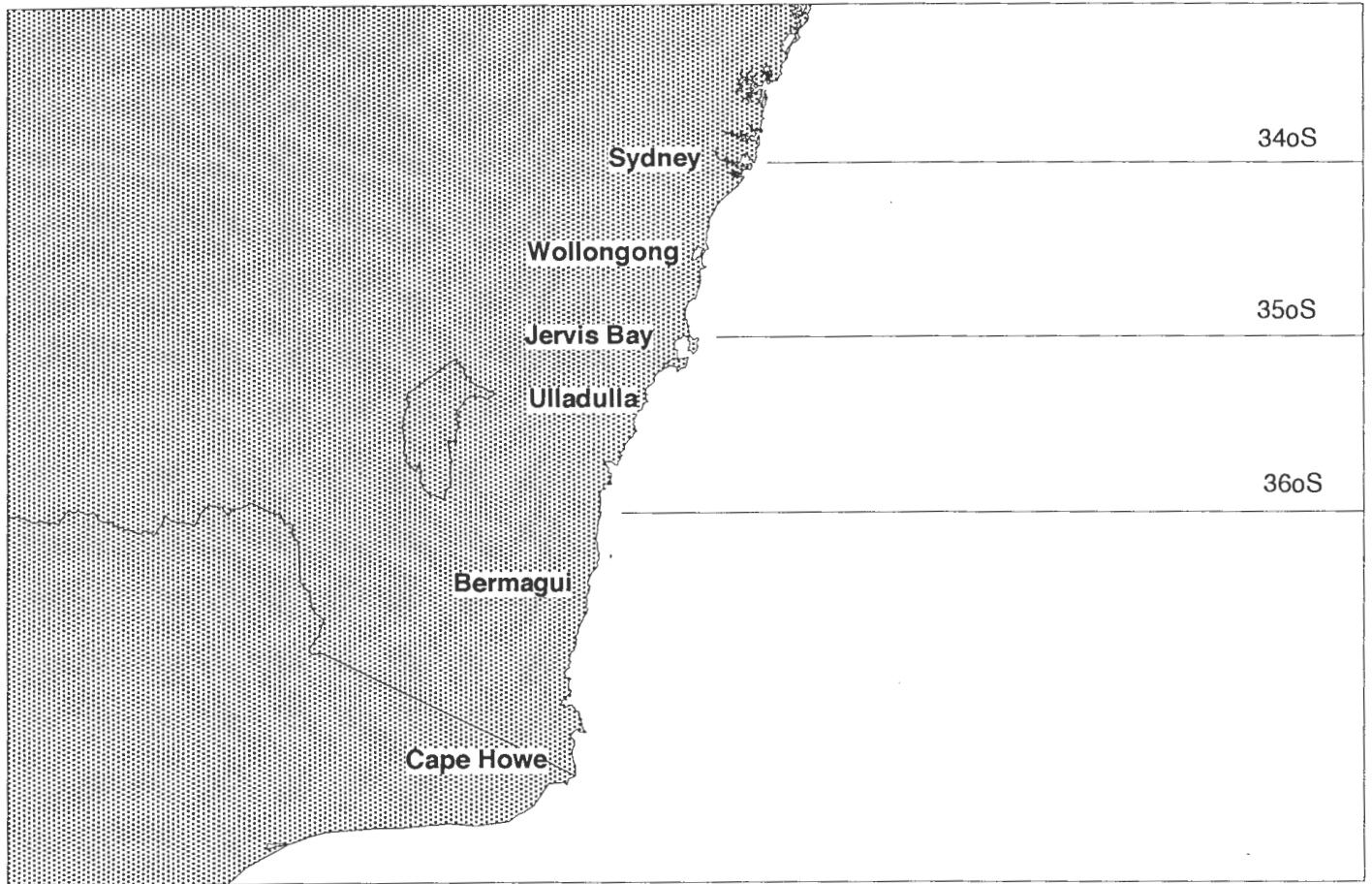


Figure 1 Map of South-eastern Australia showing the location of Sydney, Wollongong, Ulladulla, Bermagui, Cape Howe, and latitudes 34°, 35°, 36°S which delineate the Wollongong and Ulladulla survey areas.



Figure 2 The survey vessel Charissa of Ulladulla. Steel vessel purpose built for gemfishing in the 1980s.



Figure 3 The survey vessel Marina Star of Ulladulla. Wooden vessel purpose built for gemfishing in the 1970s.



Figure 4 Illawara Star of Wollongong. Wooden vessel purpose built for gemfishing in the 1970s.



Figure 5 The survey vessel Santa Rosa II of Wollongong. Steel vessel purpose built for gemfishing in the 1980s.



Figure 6 Old wooden trawl doors lying disused at Wollongong. These large but light wooden spreader boards were used during the peak of the eastern gemfish fishery. The light construction and large surface area caused the board to spread the mouth of the net well at low trawl speeds.



Figure 7 A pair of modern steel trawl door lying next to a pair of old wooden trawl door showing the comparison between the two types. The wooden doors were used for targeting gemfish but they have now fallen into disuse and disrepair and were not used during the current survey.

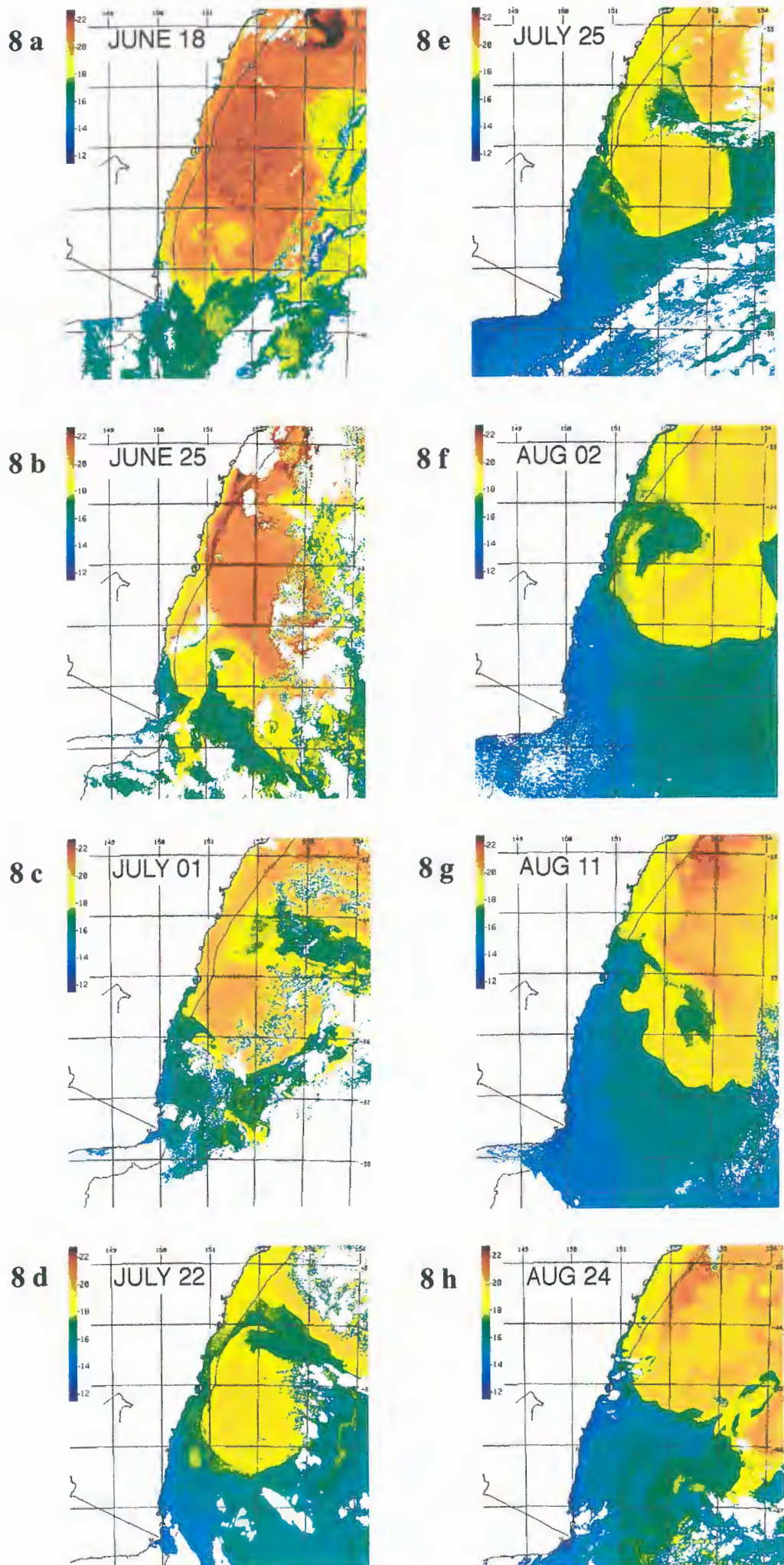


Figure 8 Satellite imagery of sea surface temperature through the research area 18 June to 24 August, 1996. Courtesy Remote Sensing, CSIRO, Hobart.

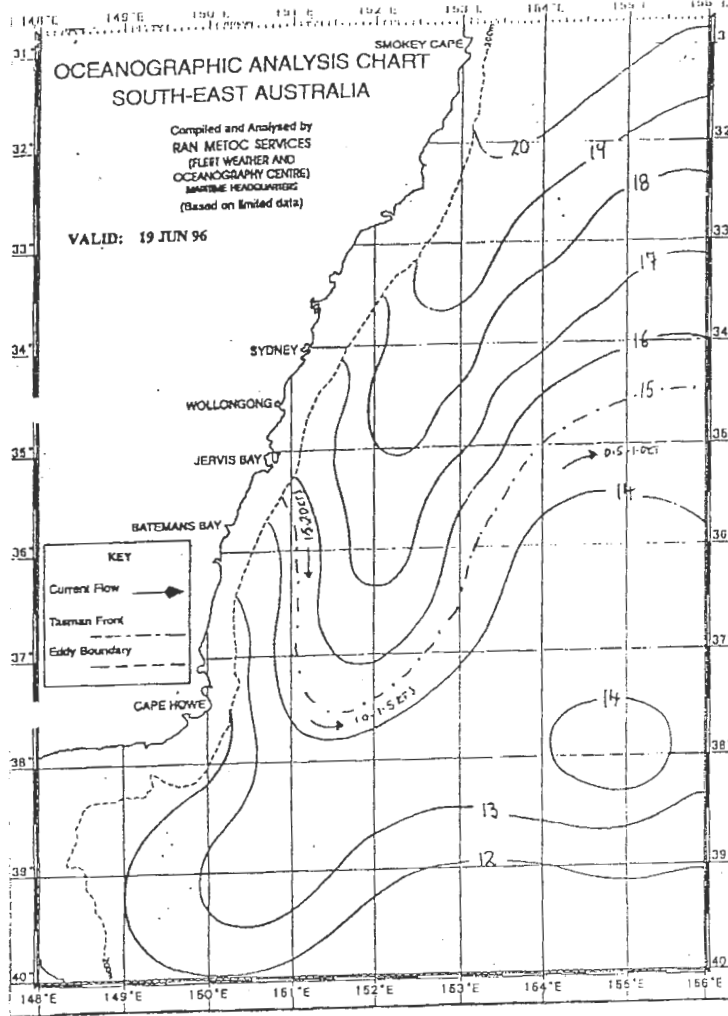
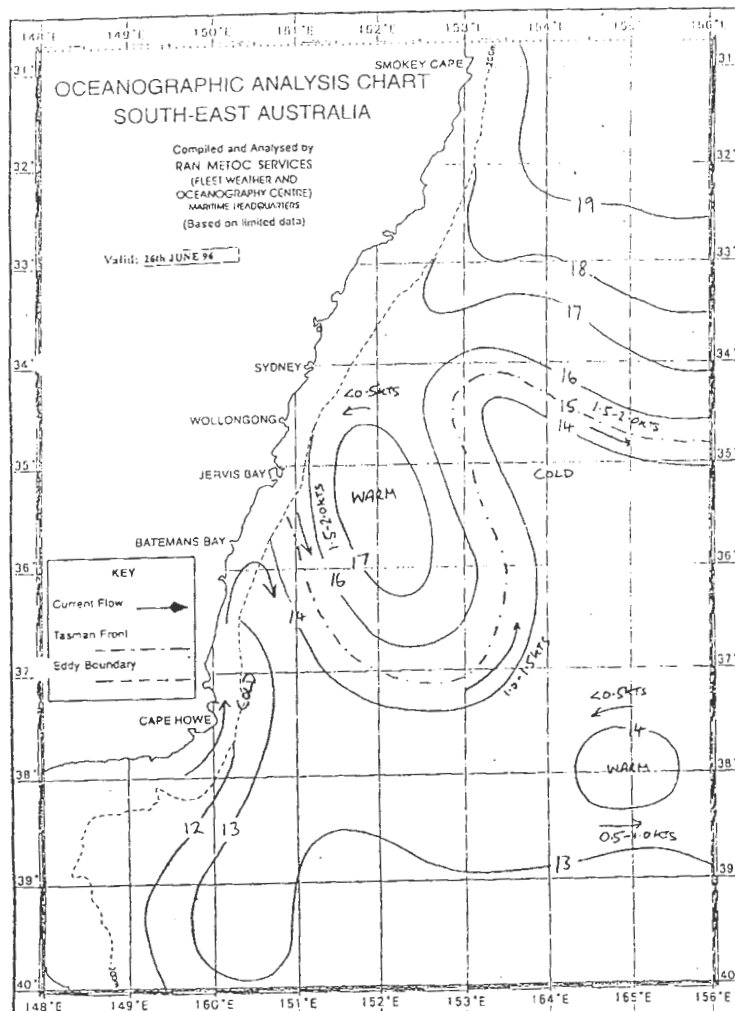
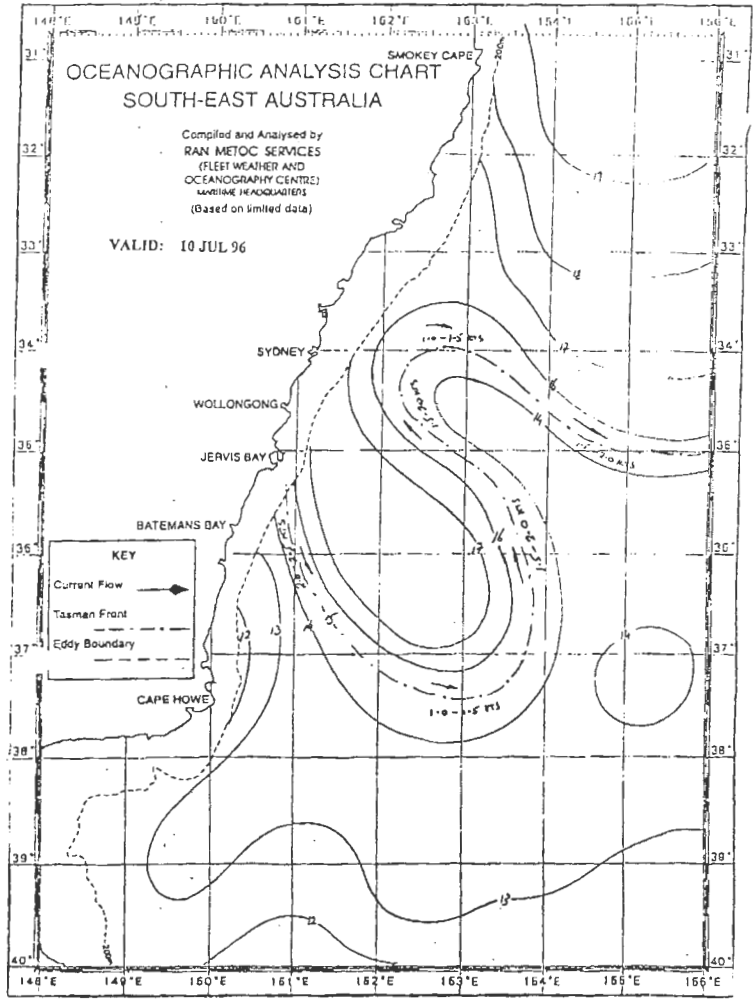
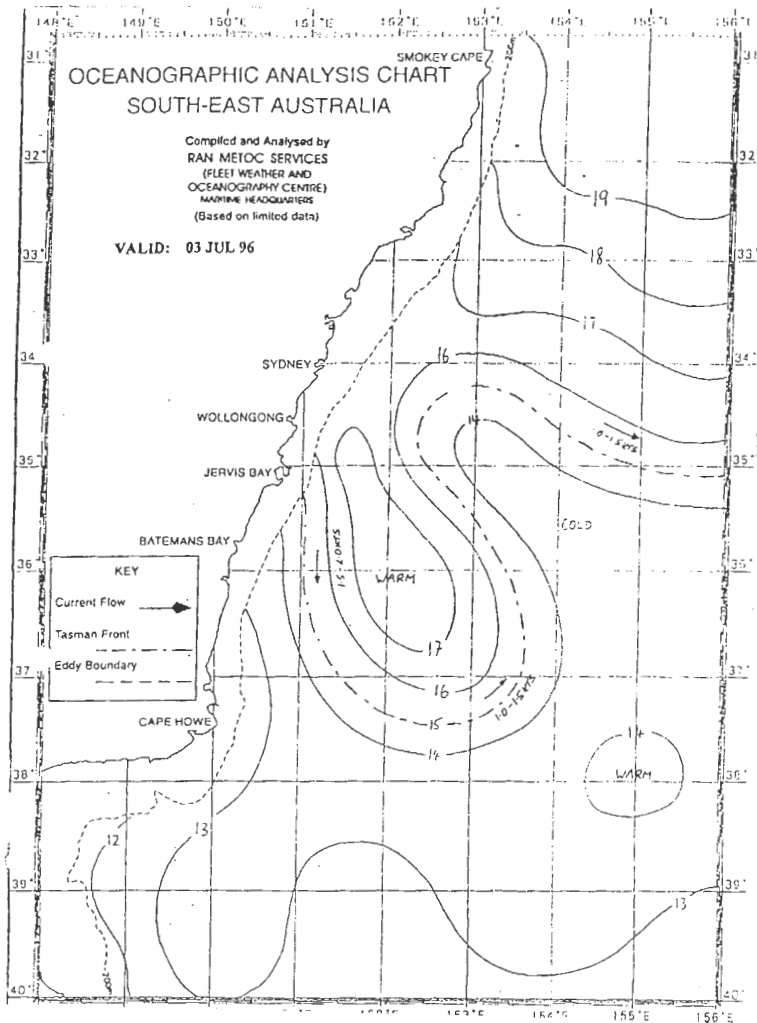
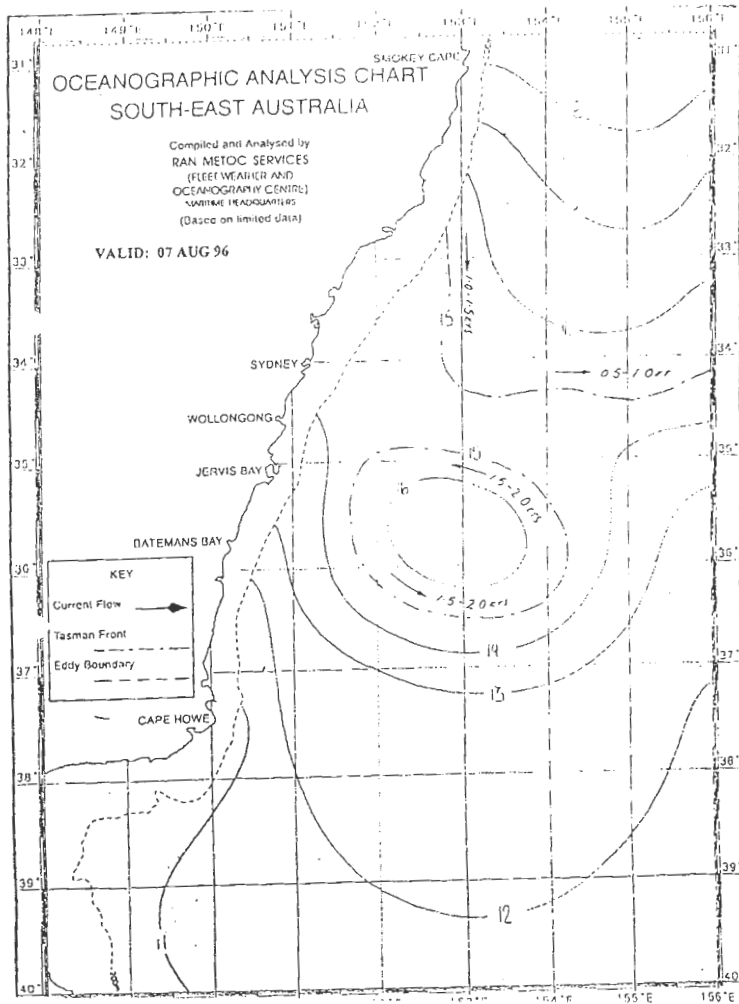
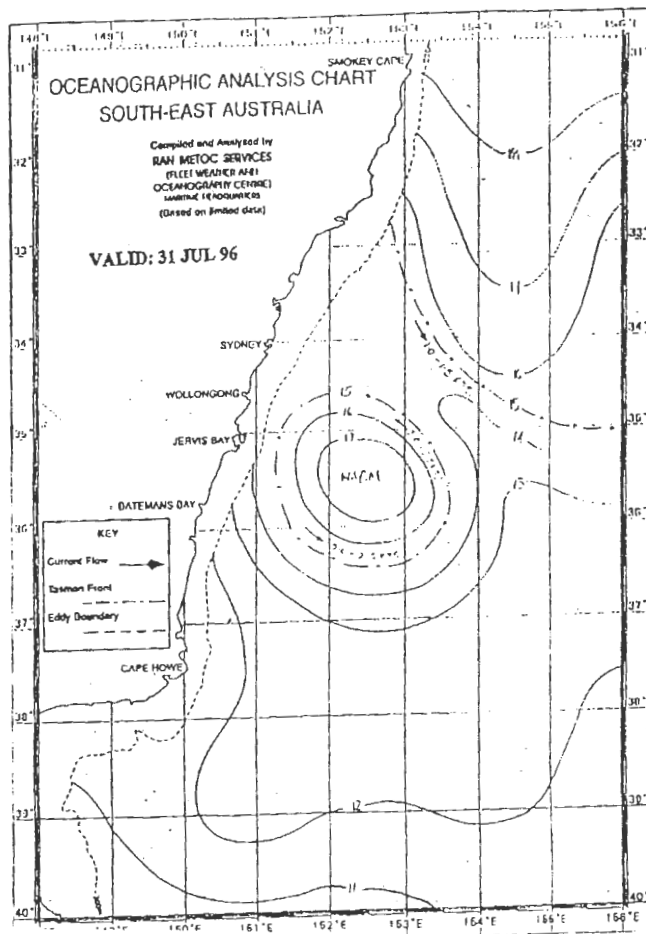


Figure 9 Weekly water temperature profiles at 250m through the survey area 19 June to 7 August, 1996. Courtesy Royal Australian Navy METOC Services.







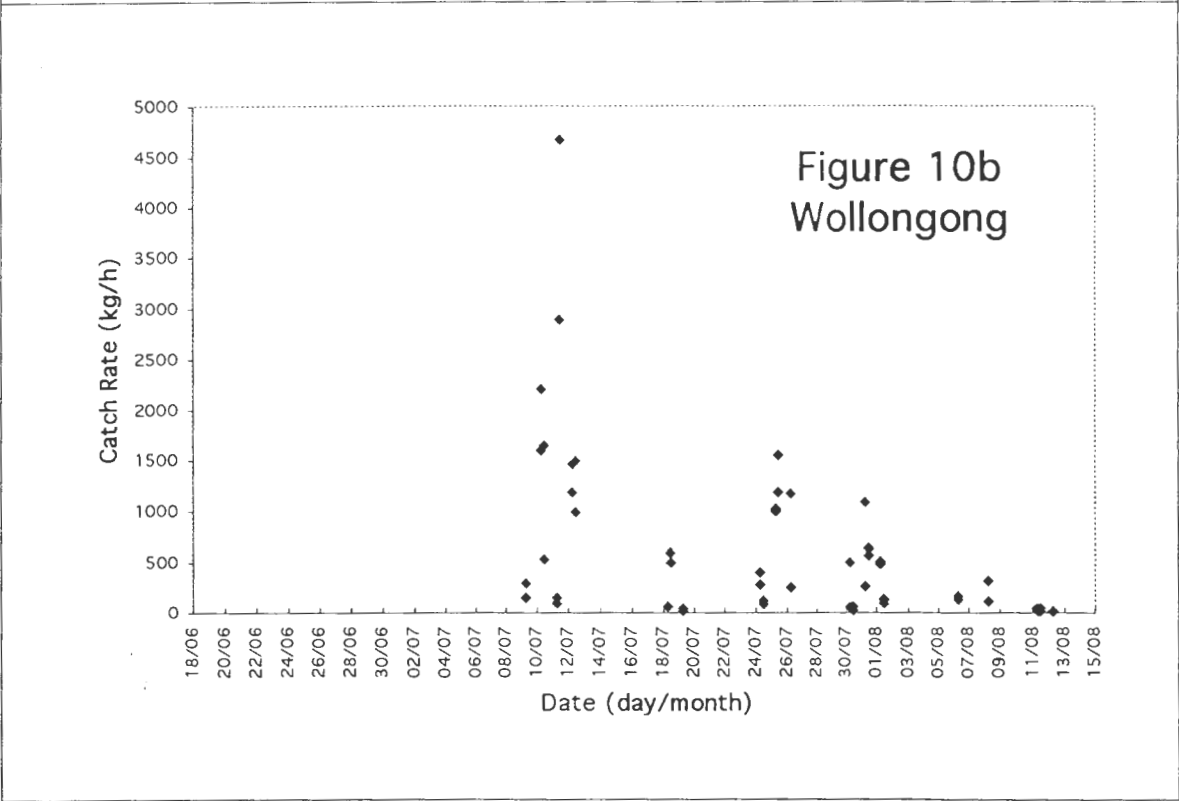
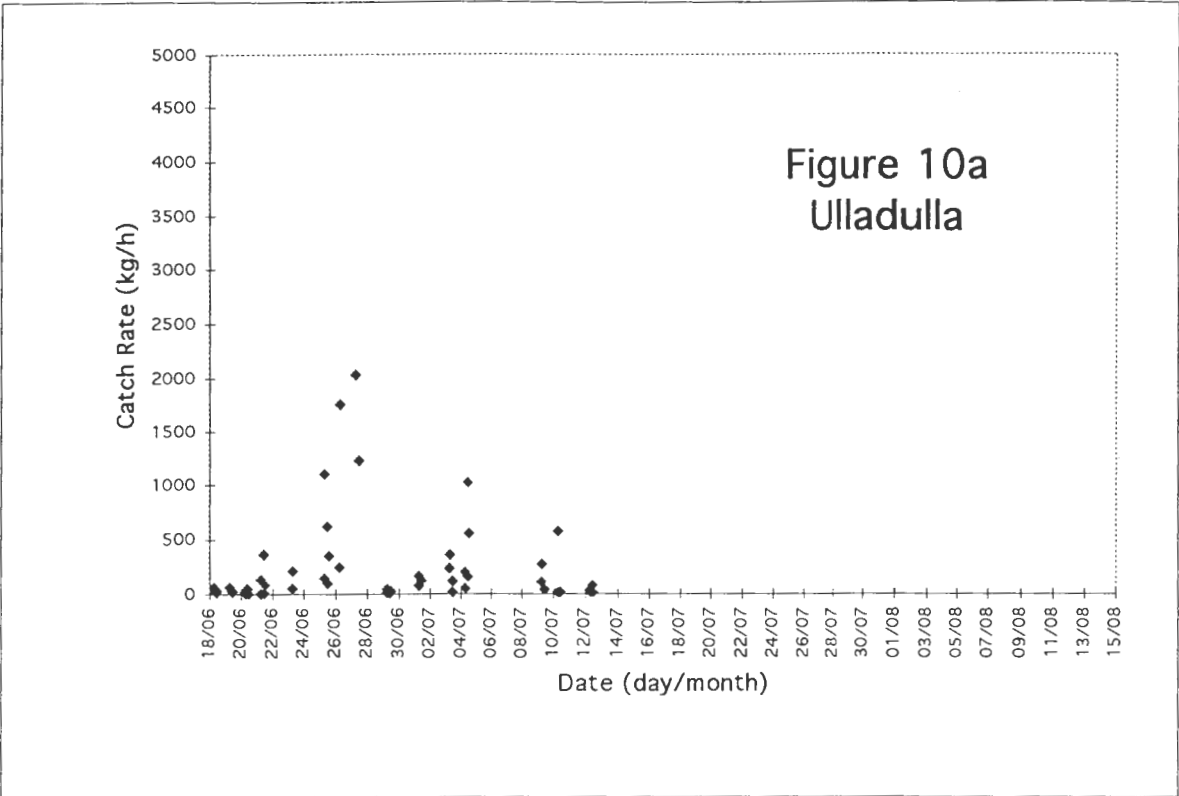


Figure 10 Catch rates (kg/h) of each survey shot for Wollongong and Ulladulla.

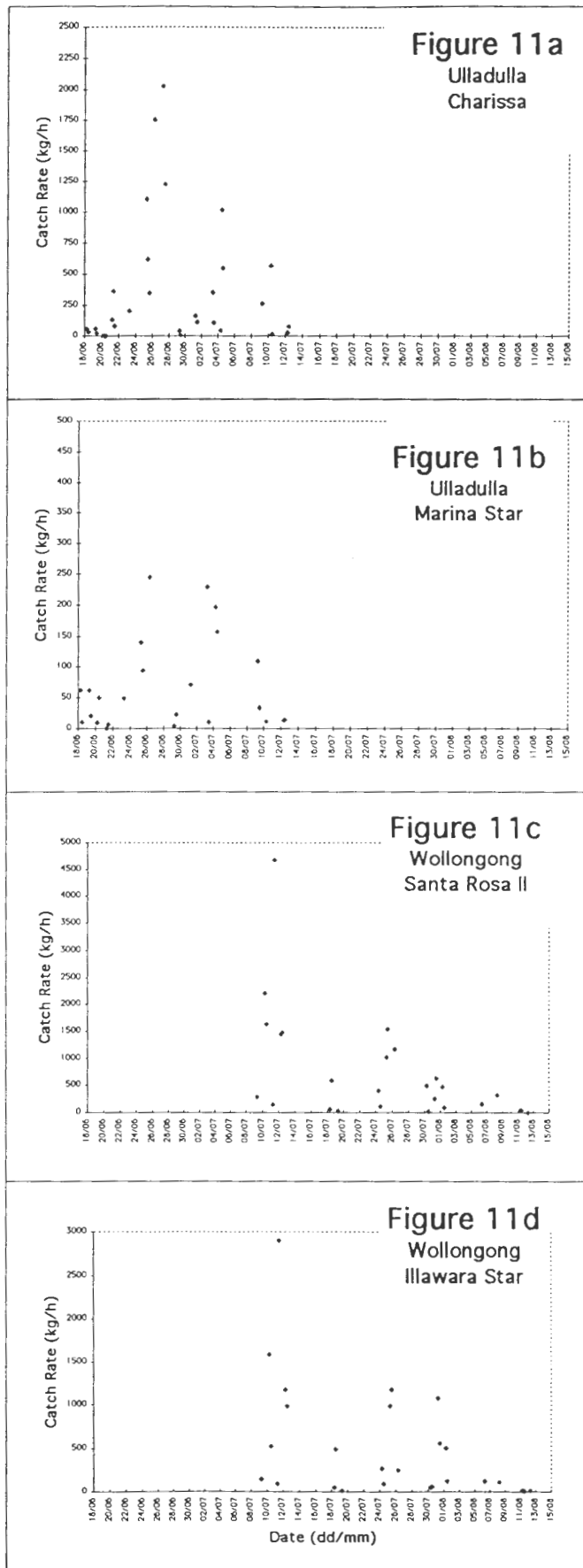


Figure 11 Catch rates (kg/h) of each survey shot by vessel. NB. Catch rates scales vary between vessels.

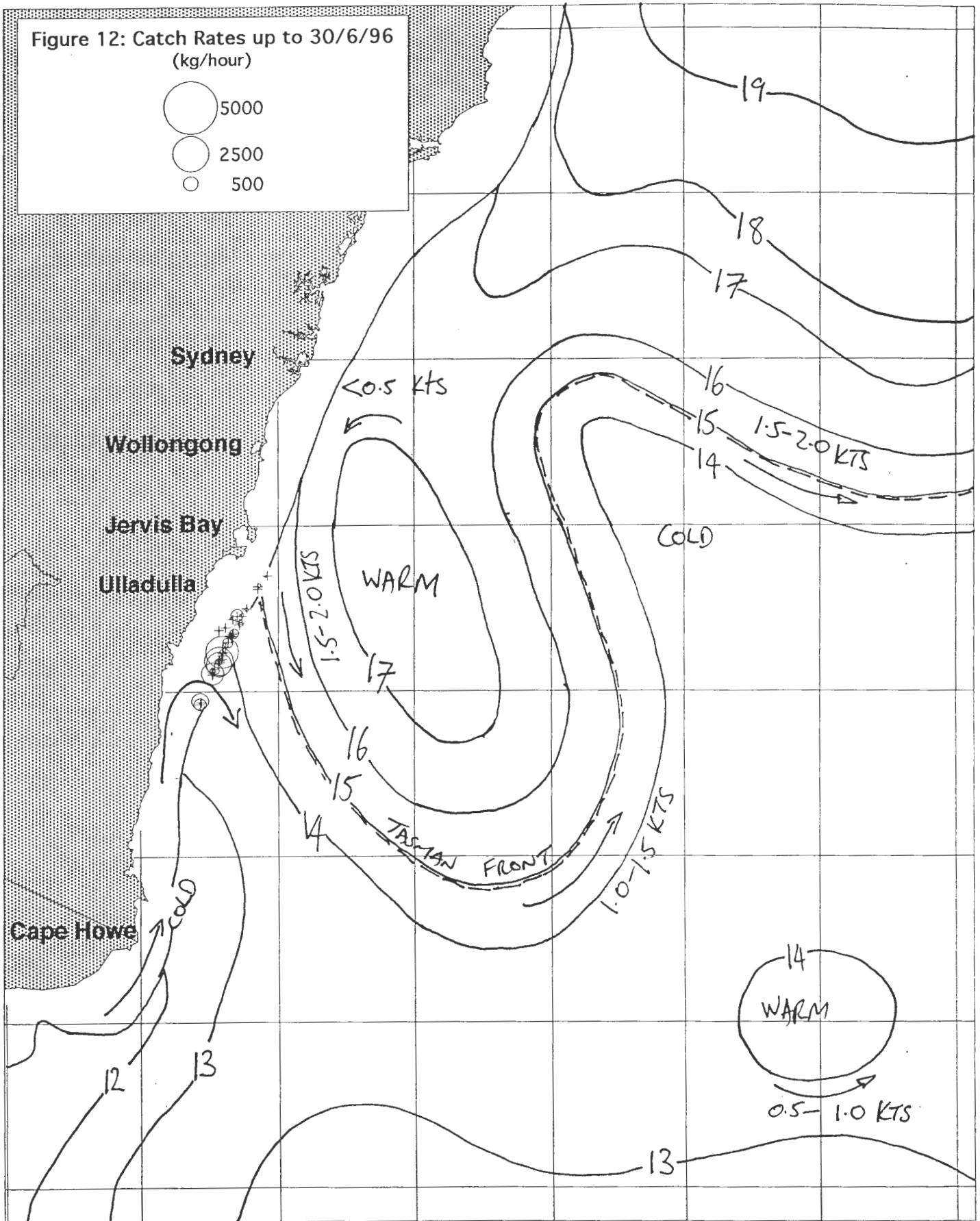


Figure 12 The 250m isotherms for 26 June overlaid with the position and catch rate of survey shots up to 30 June.

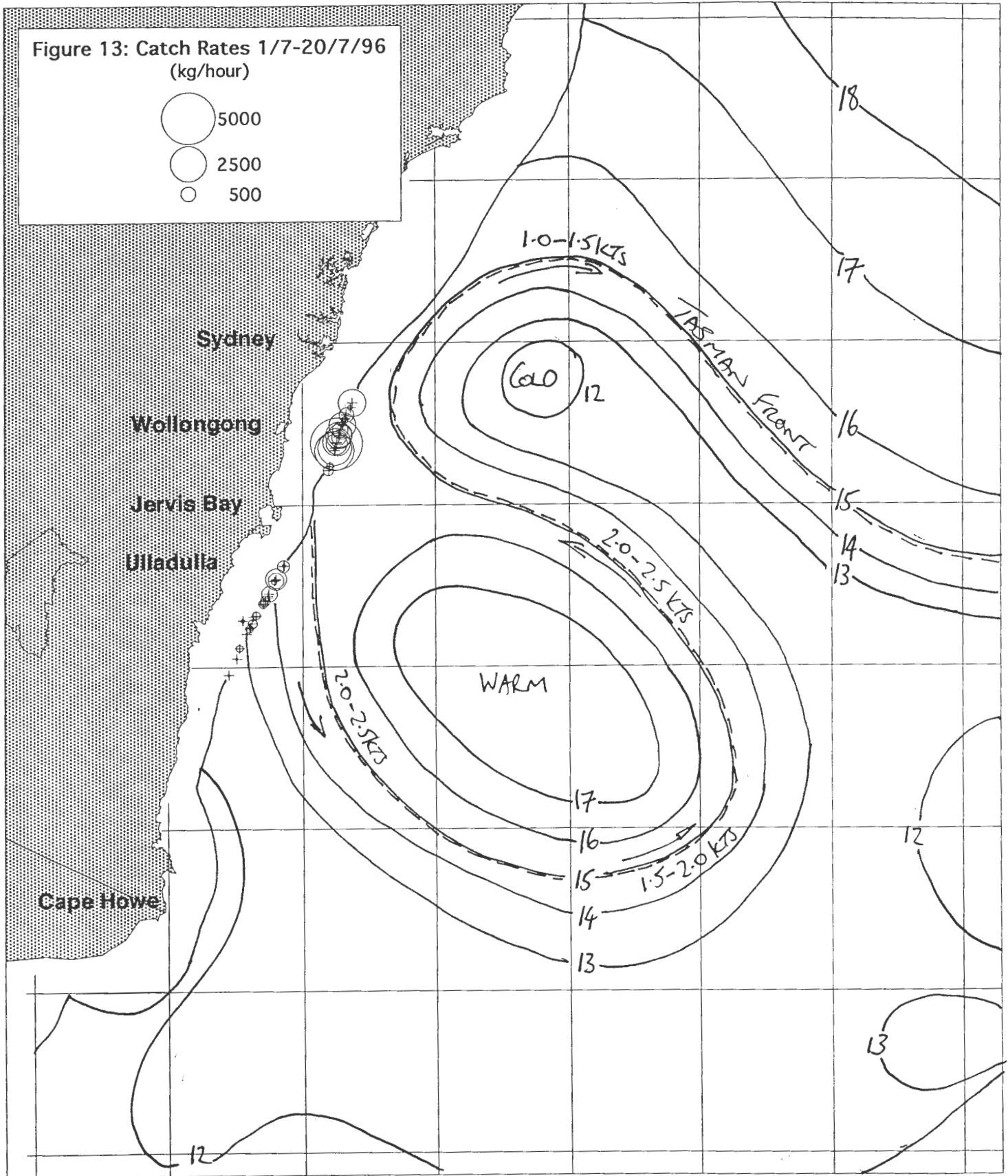


Figure 13 The 250m isotherms for 17 July, overlaid with the position and catch rate of survey shots 1-20 July.

Figure 14: Catch Rates after 20/7/96
(kg/hour)

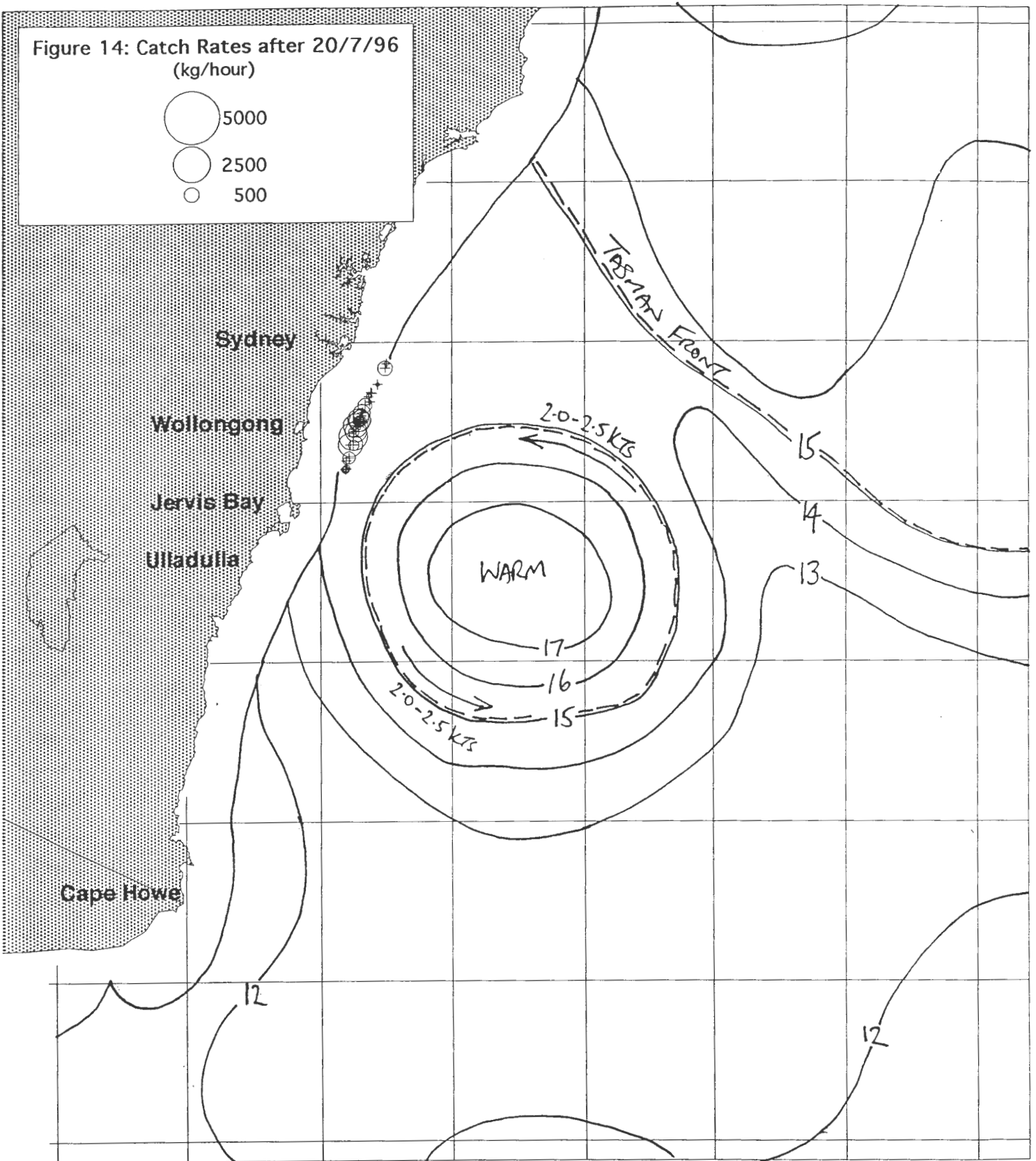
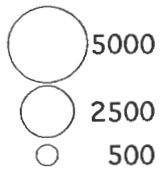


Figure 14 The 250m isotherms for 31 July overlaid with the position and catch rate of survey shots 21 July - 12 August.

Figure 15 An echogram collected using EchoListener equipment as the survey vessel cruised from east to west over the shelf break. Depth is shown in meter to the right of the echogram. The echogram shows the continental slope rising from 250m to 200m, and intense surface scattering layer above 100m and a midwater feed layer between 200-250m. Note the midwater feeding layer 'touching down' on the sea-bed to the right of the echogram in 200-250m.

Figure 16 An echogram of the same midwater feed layer depicted in figure 15. In contrast to the previous figure this echogram was made as the survey vessel cruised from north to south along the shelf break. Together figures 15 and 16 show the two dimensional extension of the midwater feed layer.

Figure 17 An echogram collected using EchoListener equipment as the survey vessel cruised from north to south along the shelf break. This echogram shows a midwater feed layer 'hard down' against the sea bed.

Figure 18 A series (a-i) of 9 echograms collected during Santa Rosa II's morning shot on 26 July, 1996. The 5h 20min shot caught 6,209kg of gemfish and 750kg of redfish. The series show all the major acoustic marks observed during the shot together with the time each echogram was recorded. Depth (m) is shown on the right hand side of the echograms. Most acoustic marks were seen in the first and last hours of the shot.

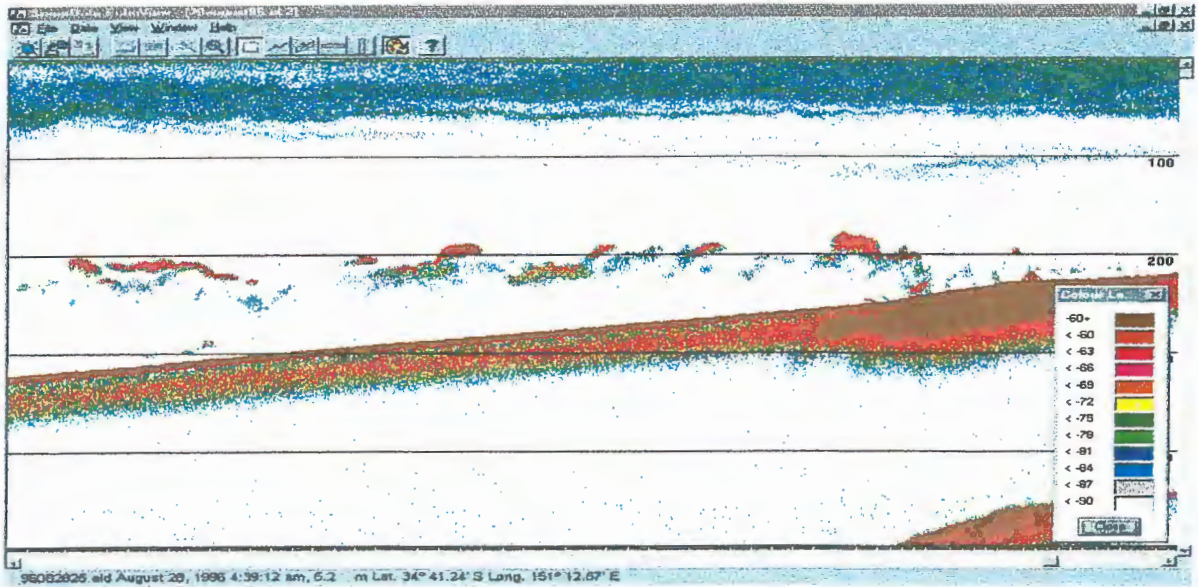


Figure 15

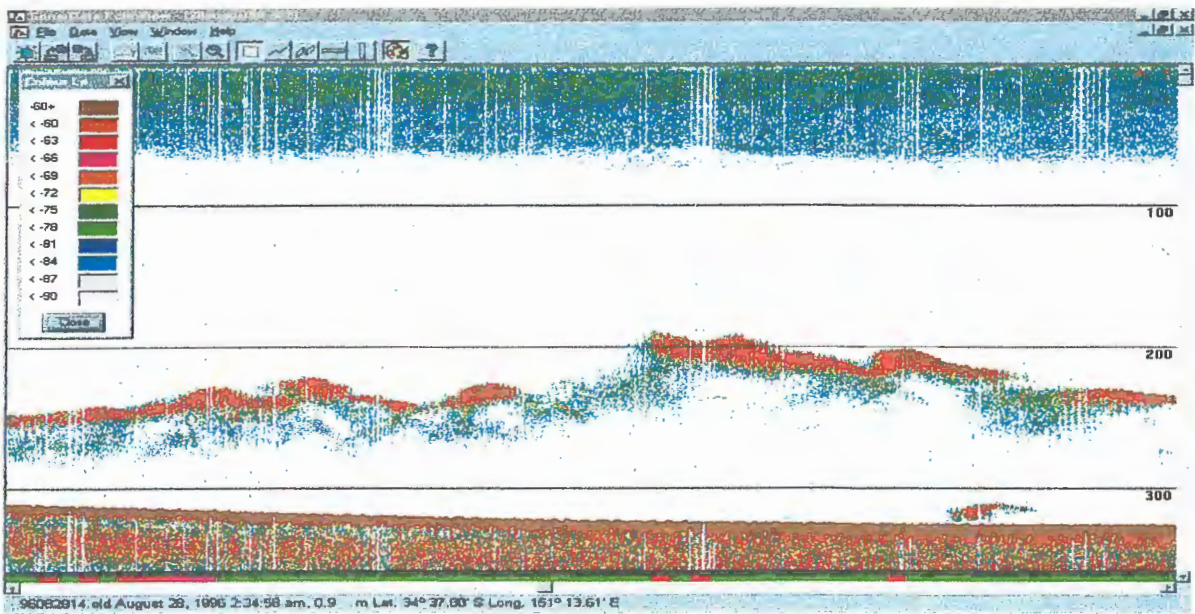


Figure 16

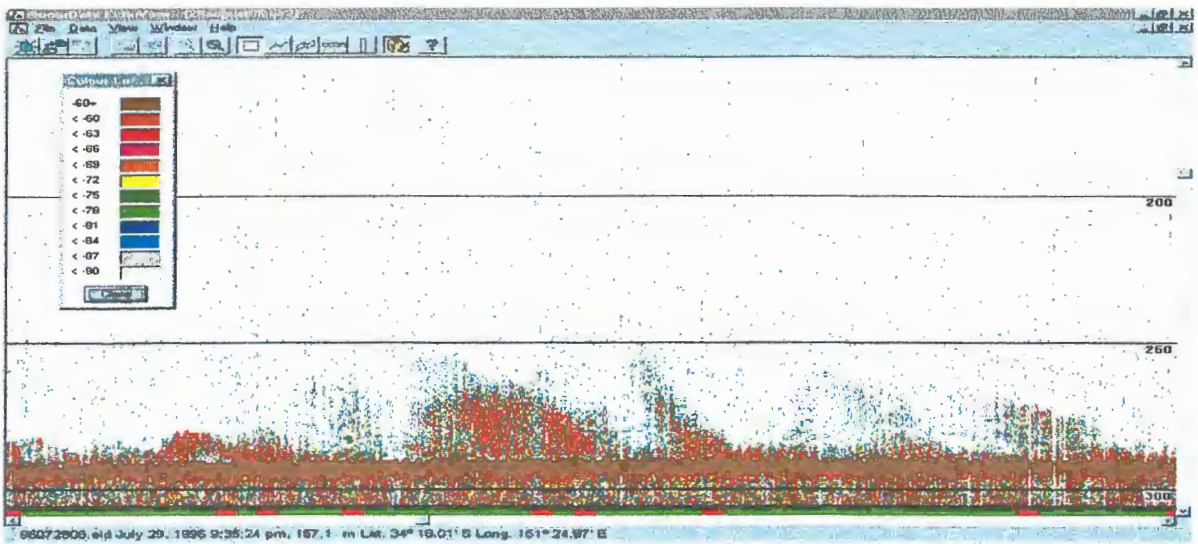


Figure 17

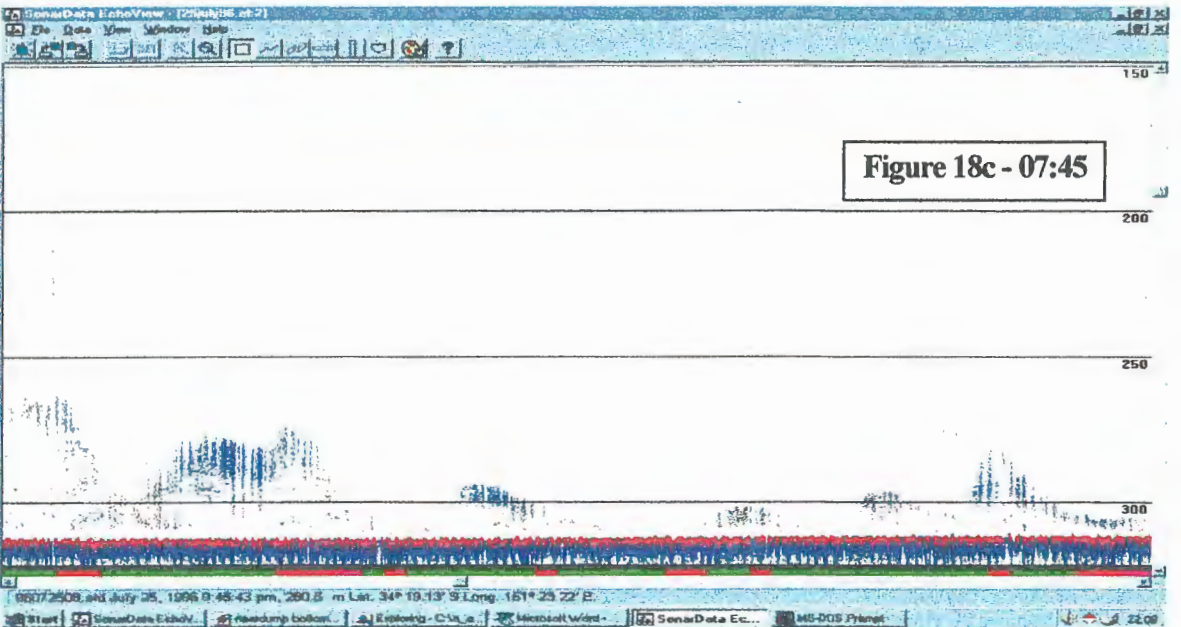
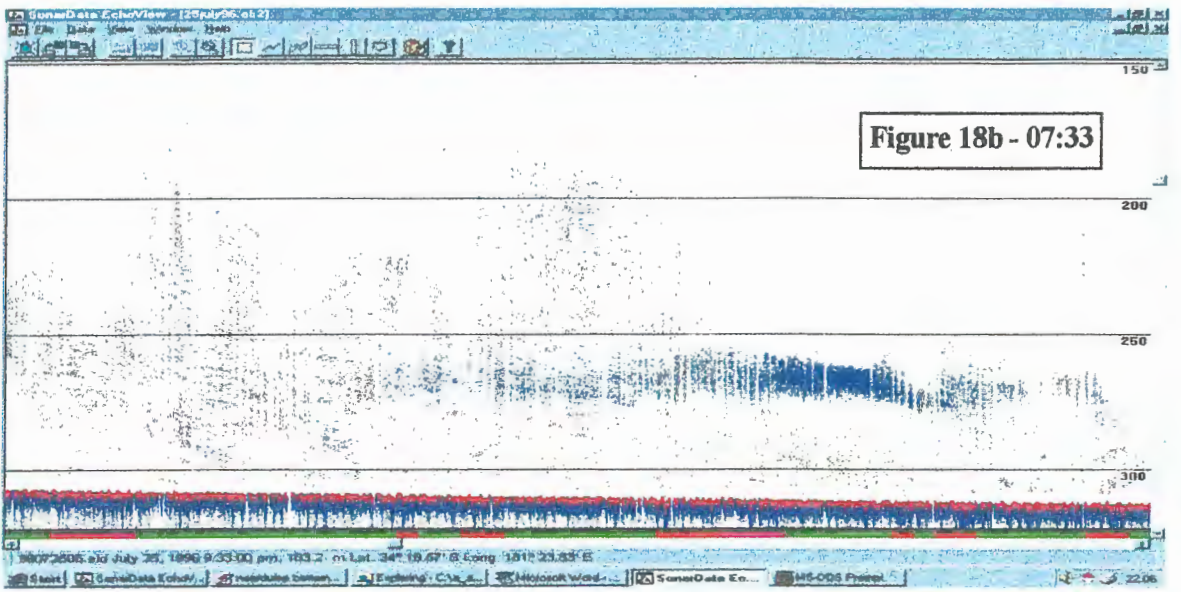
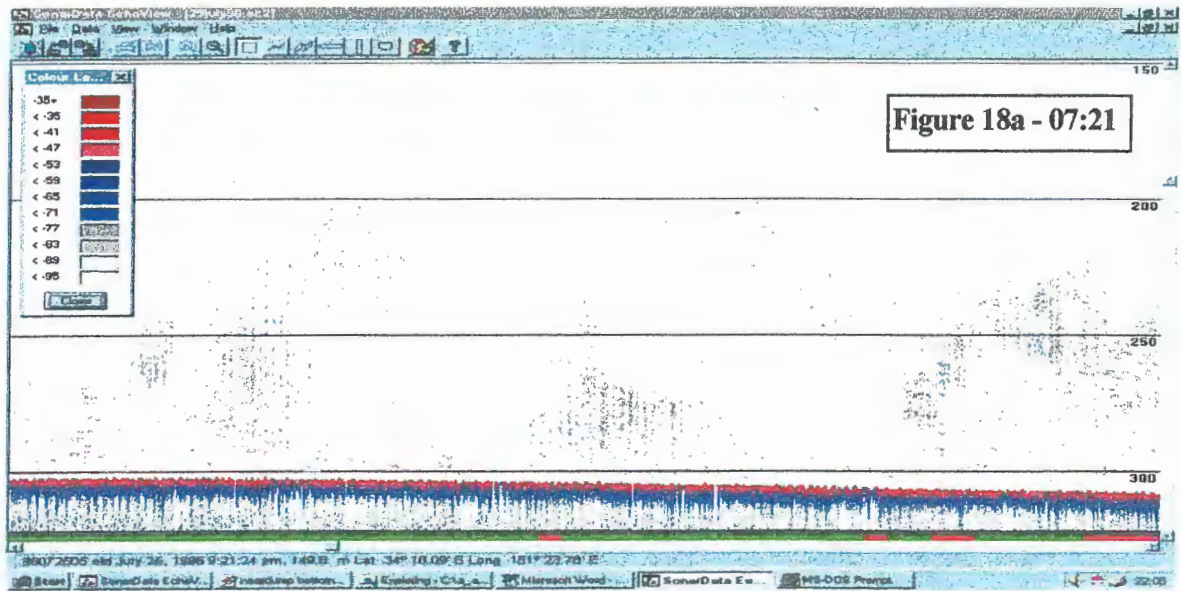


Figure 18a-c.

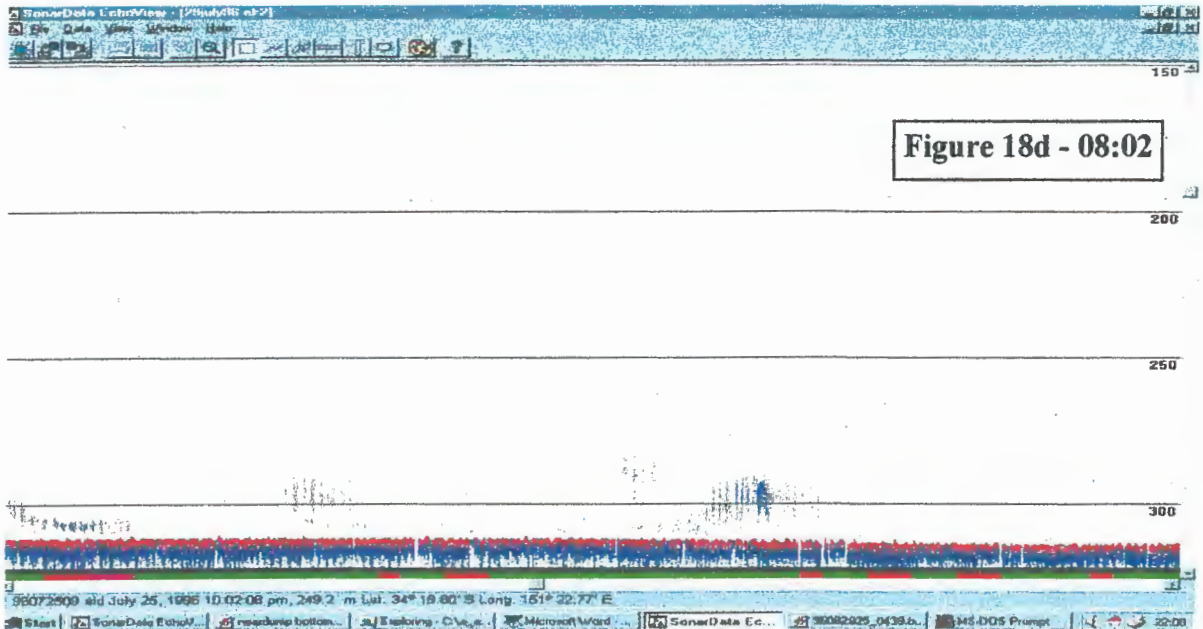


Figure 18d - 08:02

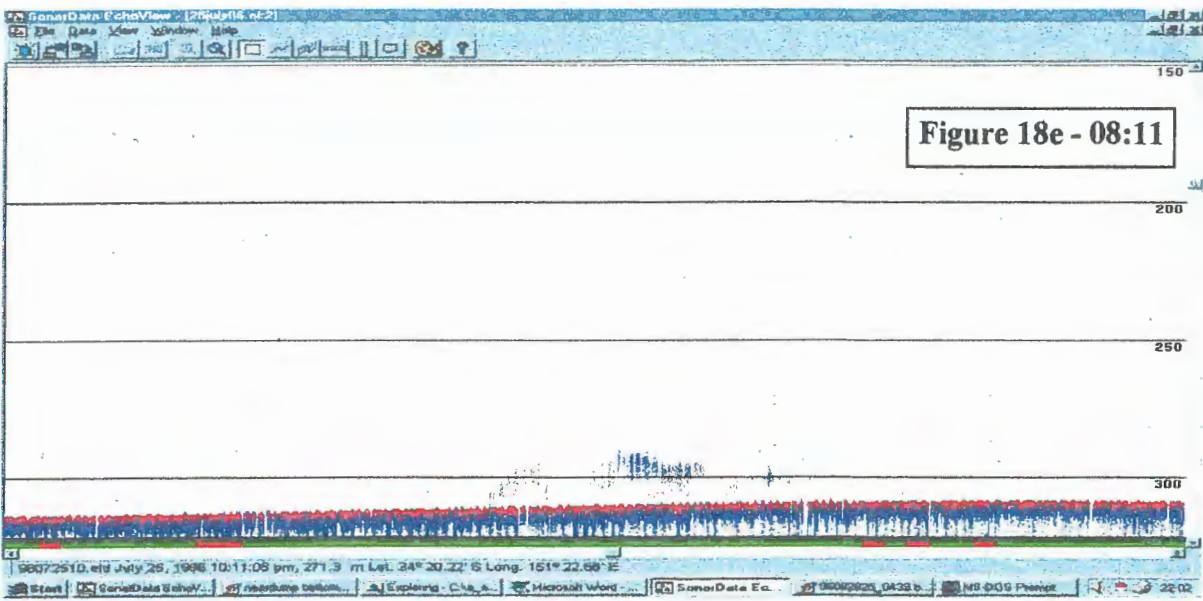


Figure 18e - 08:11

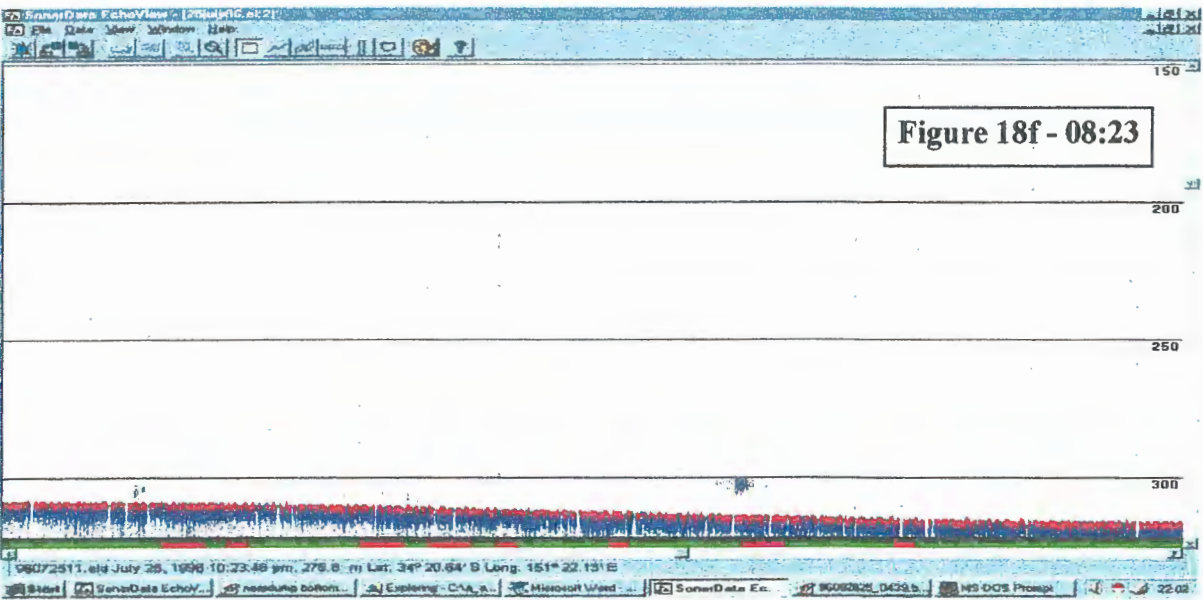


Figure 18f - 08:23

Figure 18d-f

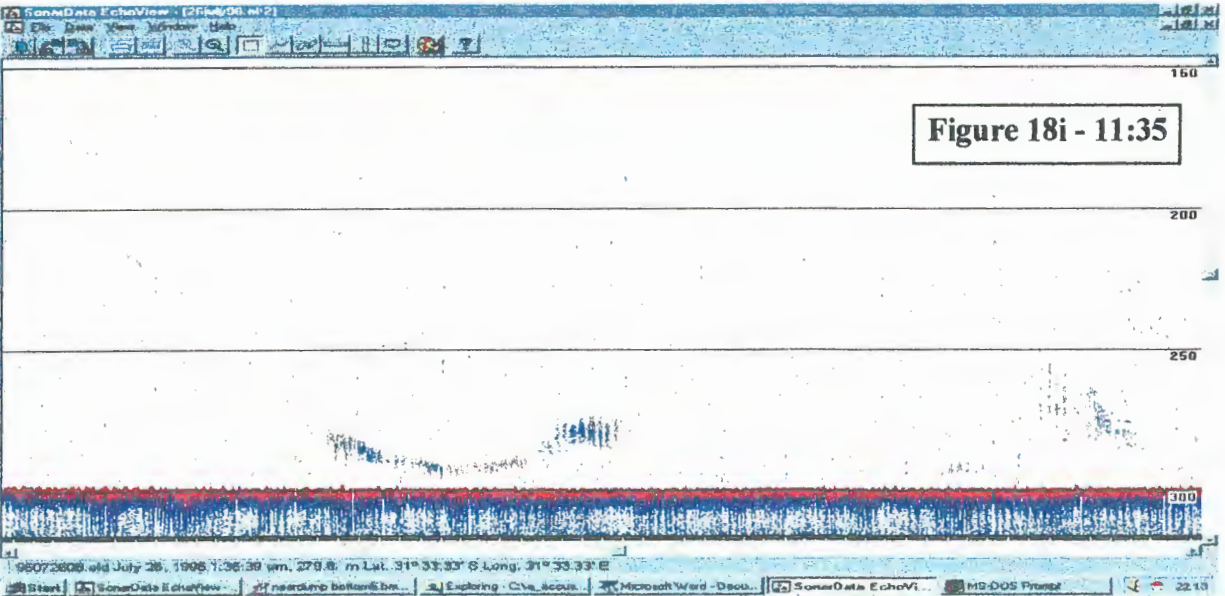
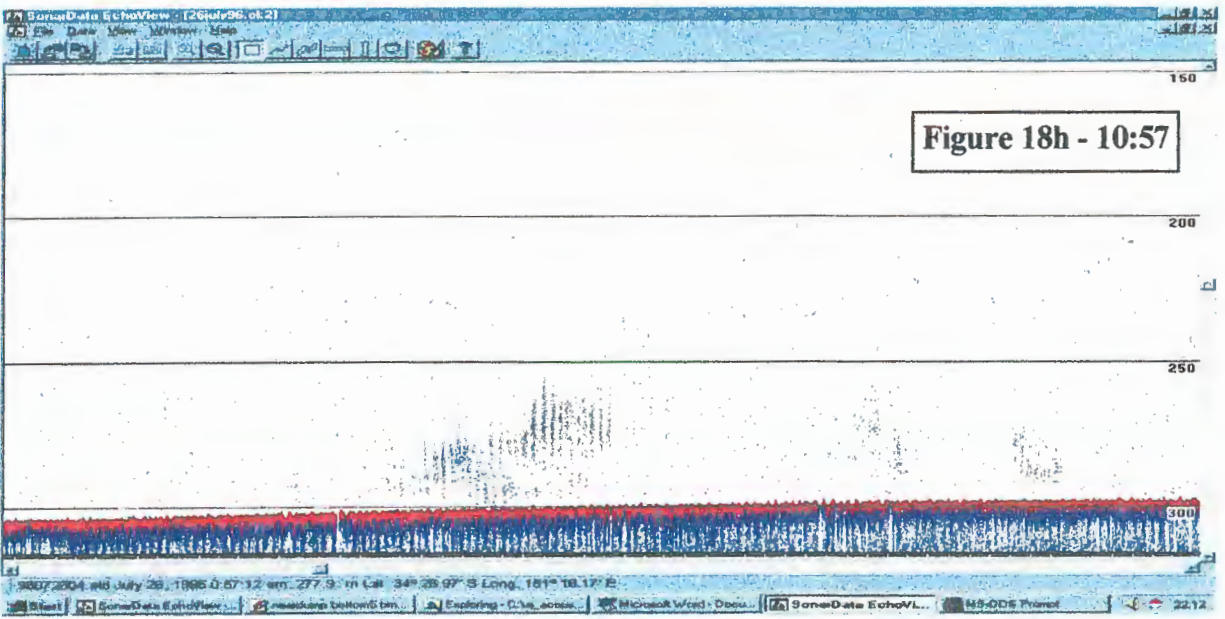
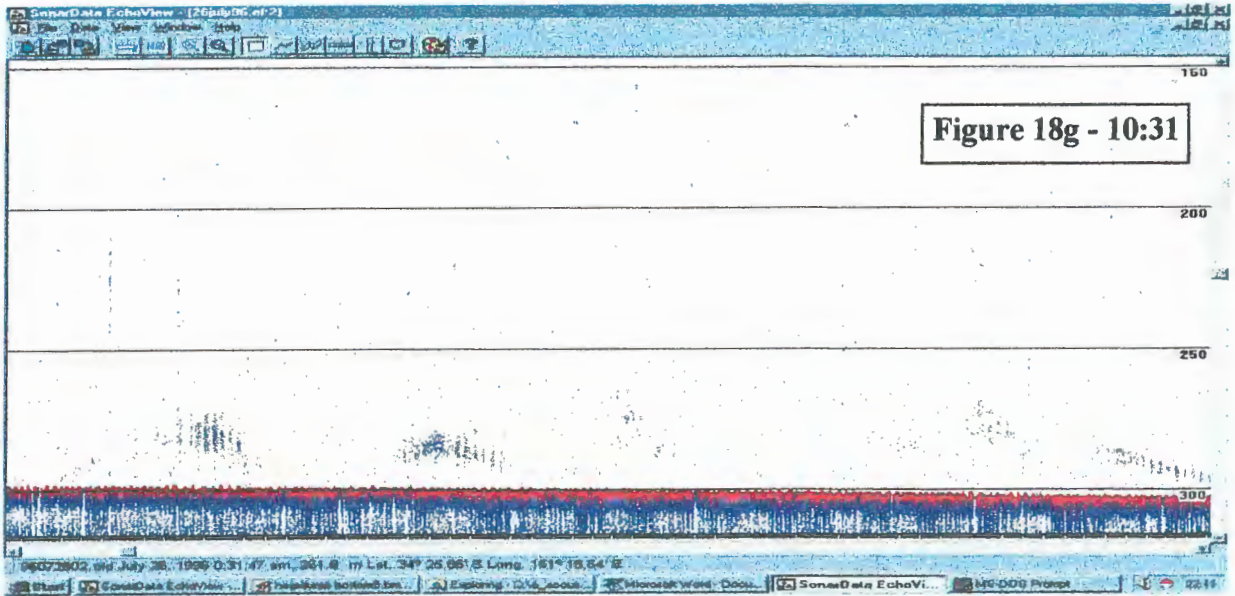


Figure 18g-i

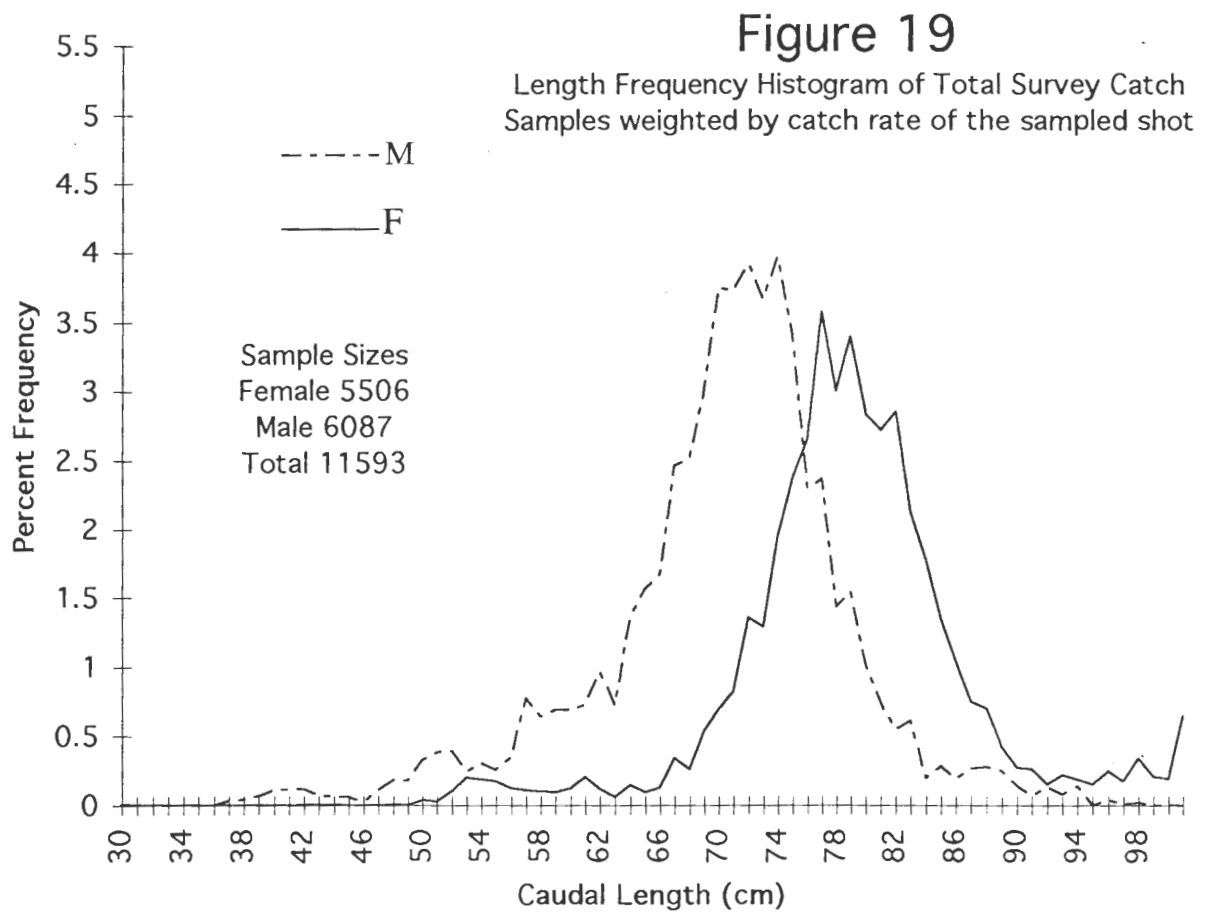


Figure 19 The pooled length frequency histogram for all sampled survey shots. Individual samples have been weighted in proportion to the catch rate of the shot from which they were taken.

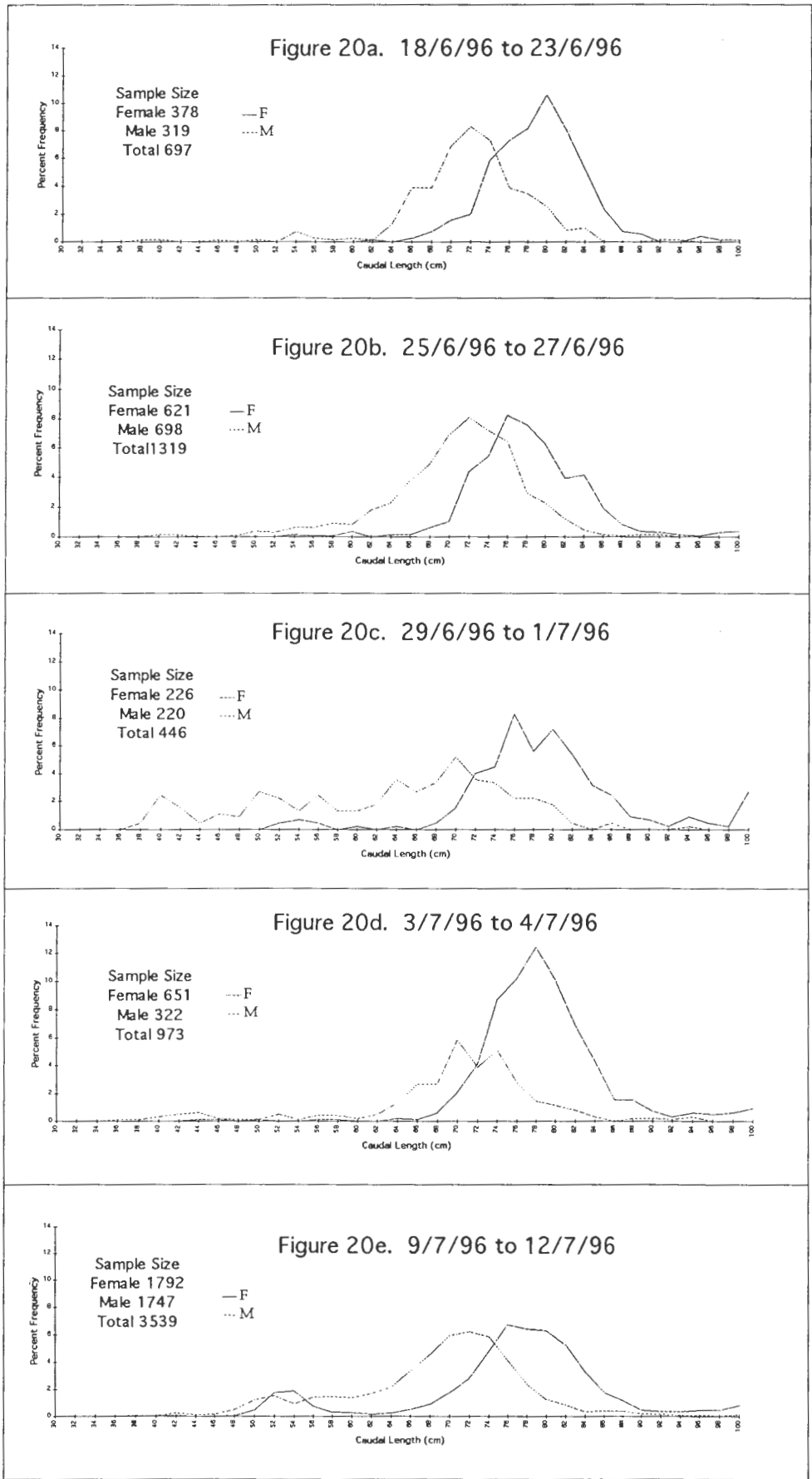
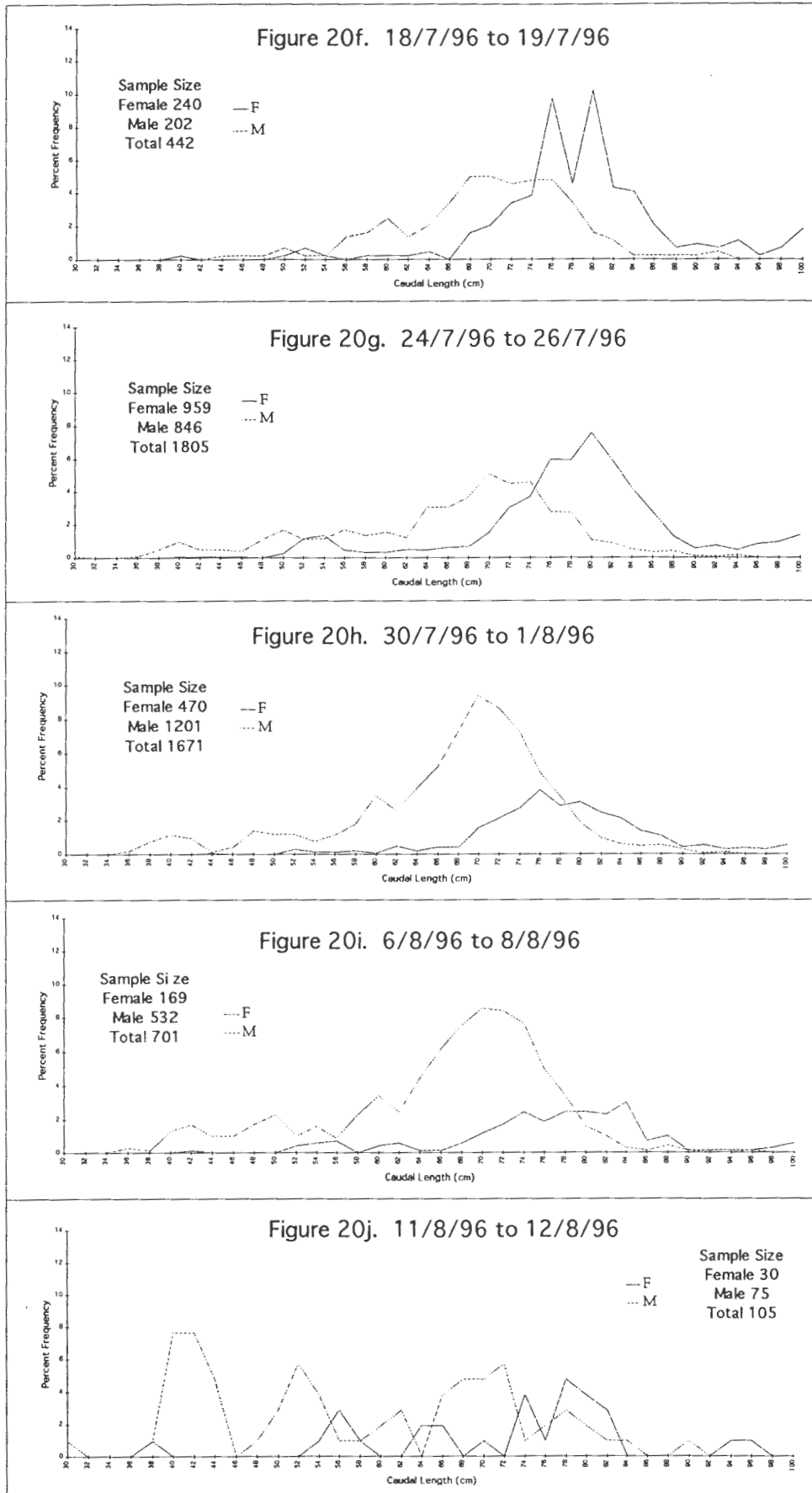


Figure 20 The pooled length frequency histograms for 10 arbitrary periods of the surveys. Individual samples have been weighted in proportion to their sample size.



Appendix 1

Date	Boat	Shot #	Brakes On	Finish Shot	Shot duration	CPUE	Gems	BShot	BShot L	BShot Depth	FShot	FShot L	FShot Depth	GEM	LING	MD	OP	RED	RIBBON	MIXE	OTHE	COMMENTS
18/06/96	C	1	06:57	09:59	03:02	59.34	35-3	150-39	200	35-4	150-35	196	180	15	215	7	0	750	0	0		
18/06/96	C	2	11:00	13:21	02:21	30.64	35-4	150-34	191	35-5	150-31	185	72	15	58	164	0	6000	15	0		
18/06/96	M	1	07:00	09:40	02:40	61.13	35-3	150-43	220	35-4	150-39	230	163	120	113	31	0	3600	34	0		
18/06/96	M	2	11:00	13:15	02:15	10.22	35-4	150-37	190	35-3	150-34	190	23	7	12	0	0	5400	3	0		
19/06/96	C	1	06:50	09:35	02:45	58.91	35-3	150-43	211	35-4	150-39	247	162	138	129	68	0	450	29	0		
19/06/96	C	2	10:20	12:50	02:30	21.60	35-4	150-37	254	35-4	150-34	258	54	154	172	164	0	2100	50	0		
19/06/96	M	1	07:00	09:30	02:30	61.60	35-3	150-46	243	35-3	150-42	238	154	67	61	28	0	0	30	0		
19/06/96	M	2	10:55	13:00	02:05	20.16	35-3	150-42	226	35-4	150-39	241	42	64	212	14	0	0	1	0		
20/06/96	C	1	07:00	10:35	03:35	0.00	35-4	150-39	280	35-3	150-04	280	0	250	0	80	0	0	0	0		
20/06/96	C	2	11:30	14:30	03:00	0.00	35-3	150-47	300	35-2	150-51	300	0	75	0	80	0	0	0	0		
20/06/96	M	1	05:30	08:10	02:40	9.38	35-2	150-51	215	35-1	150-55	215	25	5	35	30	100	150	35	0		
20/06/96	M	2	09:15	11:15	02:00	50.00	35-1	150-55	245	35-2	150-51	245	100	15	60	120	0	3000	10	0		
21/06/96	C	1	06:10	09:00	02:50	130.24	35-4	150-37	230	35-4	150-34	230	369	75	60	40	0	600	0	0		
21/06/96	C	2	09:45	11:15	01:30	364.67	35-3	150-33	180	35-3	150-30	180	547	30	100	100	0	2100	40	0		
21/06/96	C	3	12:30	15:00	02:30	84.00	35-4	150-34	280	35-4	150-37	280	210	90	100	30	0	600	70	0		
21/06/96	M	1	06:00	08:30	02:30	0.00	35-3	150-41	80	35-3	150-37		0	0	5	0	10	0	320	0		
21/06/96	M	2	11:30	14:30	03:00	6.67	35-3	150-40	255	35-3	150-44	255	20	150	250	180	0	0	0	0		
23/06/96	C	1	07:00	09:50	02:50	205.76	35-3	150-43	197	35-3	150-40	204	583	43	61	0	107	30	20	0		
23/06/96	M	1	06:52	09:40	02:48	48.93	35-2	150-46	197	35-3	150-42	204	137	95	84	0	0	2400	23	0		
25/06/96	C	1	06:56	09:56	03:00	1104.00	35-4	150-35	203	35-5	150-31	180	3312	90	300	75	0	0	30	0		
25/06/96	C	2	11:10	14:38	03:28	619.62	35-5	150-29	214	36-0	150-26	204	2148	60	90	45	30	0	30	0		BLUE-EYE & HAPUKA
25/06/96	C	3	15:40	16:55	01:15	349.60	36-0	150-27	191	36-0	150-25	209	437	45	15	60	45	450	45	0		Rudder fish, endeavour dogs
25/06/96	M	1	07:00	10:30	03:30	140.00	35-4	150-36	235	35-5	150-32	235	490	151	240	90	0	1200	15	0		RIPPED NET INVALID SHOT
25/06/96	M	2	12:00	15:00	03:00	93.33	35-4	150-35	200	35-5	150-31	200	280	50	60	30	20	1500	0	10		
26/06/96	C	1	06:47	11:11	04:24	1757.95	35-4	150-39	199	35-4	150-34	202	7735	25	85	10	76	120	0	10		2m Thresher
26/06/96	M	1	06:38	11:12	04:34	244.16	35-3	150-44	206	35-4	150-38	203	1115	154	210	30	15	950	0	0		BIG THRESHER
27/06/96	C	1	07:00	10:58	03:58	2026.13	35-3	150-39	200	35-4	150-35	196	8037	21	165	0	637	120	30	0		2m Thresher
27/06/96	C	2	12:21	15:12	02:51	1225.96	35-4	150-36	193	35-5	150-33	192	3494	11	55	0	127	300	30	0		2m Thresher
29/06/96	C	1	06:48	09:53	03:05	38.92	35-2	150-50	205	35-3	150-46	202	120	120	45	0	150	240	30	0		2.5M MAKO
29/06/96	C	2	10:54	13:54	03:00	6.67	35-3	150-43	202	35-3	150-39	186	20	25	25	0	40	6000	0	0		
29/06/96	M	1	06:50	10:20	03:30	3.71	35-3	150-39	198	35-4	150-35	204	13	15	20	15	70	0	0	10		Other=shark
29/06/96	M	2	12:10	13:50	01:40	21.60	35-4	150-36	246	35-4	150-35	245	36	40	10	10	0	0	0	0		
01/07/96	C	1	06:54	10:30	03:36	162.22	35-3	150-40	203	35-4	150-36	201	584	98	68	30	42	1200	29	36		Other=1.6 m oil fish
01/07/96	C	2	11:18	14:34	03:16	115.71	35-4	150-35	224	35-5	150-31	185	378	131	54	30	15	600	0	0		
01/07/96	M	1	06:48	12:28	05:40	70.94	35-3	150-43	200	35-4	150-36	238	402	225	94	27	91	4500	11	100		Other=2m thresher
03/07/96	C	1	07:56	10:54	02:58	353.93	35-1	150-56	238	35-2	150-51	217	1050	512	20	22	384	0	3	55		Other=shark
03/07/96	C	2	11:34	14:07	02:33	109.80	35-2	150-50	246	35-2	150-47	188	280	108	68	40	224	0	8	14		Other =one shark
03/07/96	M	1	06:58	10:02	03:04	228.59	35-3	150-40	208	35-4	150-37	202	701	79	98	17	21	9000	5	0		
03/07/96	M	2	12:00	14:30	02:30	10.00	35-4	150-37	185	35-4	150-35	201	25	63	22	12	23	2100	6	0		
04/07/96	C	1	07:06	10:12	03:06	46.13	35-1	150-56	209	35-2	150-51	210	143	268	97	46	160	220	25	15		OTHER=SHARKS
04/07/96	C	2	11:01	12:34	01:33	1019.35	35-2	150-50	244	35-2	150-47	192	1580	167	73	30	64	220	0	0		
04/07/96	C	3	13:17	15:14	01:57	552.31	35-2	150-47	234	35-3	150-44	234	1077	167	24	61	0	100	1	0		
04/07/96	M	1	06:58	10:01	03:03	197.05	35-2	150-46	224	35-3	150-42	219	601	158	86	17	0	1800	2	0		
04/07/96	M	2	11:24	13:06	01:42	157.06	35-3	150-41	231	35-4	150-39	215	267	127	74	8	0	900	0	0		
09/07/96	S	1	07:10	12:05	04:55	284.75	34-3	151-16	230	34-4	151-11	235	1400	0	2166	0	0	0	0	0		
09/07/96	C	1	07:05	11:10	04:05	266.20	35-2	150-47	219	35-3	150-43	210	1087	108	517	0	250	2400	22	0		
09/07/96	M	1	06:32	09:58	03:26	109.51	35-3	150-46	225	35-3	150-42	230	376	181	703	0	40	1200	39	0		
09/07/96	M	2	11:25	14:30	03:05	33.08	35-3	150-41	247	35-4	150-33	220	102	120	244	17	27	4500	0	0		
09/07/96	O	1	07:12	11:58	04:46	143.92	34-3	151-17	226	34-4	151-12	224	686	0	2366	0	0	90	13	26		
10/07/96	C	1	08:22	10:06	01:44	568.27	35-2	150-50	242	35-2	150-47	229	985	127	144	68	42	3000	8	0		
10/07/96	C	2	11:18	13:52	02:34	14.81	35-2	150-47	234	35-3	150-44	MISSING	38	127	202	135	18	0	7	0		
10/07/96	M	1	06:45	12:30	05:45	10.78	35-2	150-46	220	35-4	150-38	240	62	360	54	24	56	150	43	0		
10/07/96	O	1	07:15	10:20	03:05	2208.97	34-3	151-17	222	34-3	151-14	215	6811	0	241	10	0	0	11	0		
10/07/96	O	2	12:08	15:00	02:52	525.00	34-3	151-15	204	34-2	151-19	196	1505	0	490	8	0	30	12	0		
10/07/96	S	1	07:15	10:30	03:15	1586.46	34-2	151-18	217	34-3	151-15	205	5156	0	384	0	0	0	0	0		
10/07/96	S	2	12:35	15:00	02:25	1639.86	34-2	151-18	206	34-2	151-22	205	3963	0	355	0	0	0	0	0		
11/07/96	S	1	07:05	10:30	03:25	144.29	34-2	151-22	196	34-2	151-18	200	493	0	500	24	0	0	60	0		

