Industry Survey of the 1997 eastern gemfish Season

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NON TECHNICAL SUMMARY

97/147 Industry survey of the 1997 eastern gemfish season.

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Objectives:

1. Collect timely, accurate catch rate and length frequency data from four vessels; Charissa, Marina Star, Illawara Star and Santa Rosa A during the 1997 gemfish season.
2. Supply EGAG with catch rate and length frequency data before 1 September 1997.
3. Analyse the relationship between oceanographic features and the timing and location of gemfish aggregations.
4. Analyse the feasibility of developing acoustic indices of gemfish abundance.
5. Provide the final report to EGAG by April 1998 documenting the data collected, targeting practices observed, and analyses of oceanographic influences and feasibility of acoustic surveying.

Non Technical Summary

Gemfish (*Rexea solandri*) are midwater fish (Paulin 1997) caught along the edge of the continental shelf of southern Australia and New Zealand. Mature fish apparently move north along the NSW shelf break during winter, spawning in large aggregations.

In 1988 a 3000t TAC for trawl catches was introduced for eastern gemfish to control and reduce catches. The TAC was progressively reduced to zero in 1993 and remained at zero for 1994, 1995 and 1996 due to concerns about low stock size resulting from an extended period of low recruitment. The reduced TAC has made it difficult to assess the status of the stock because there has been no valid targeted catch rate data to use as an index of stock abundance.

In 1996 the first industry survey of gemfish was conducted with the aim of estimating catch rates for targeted gemfish fishing that are directly comparable to estimated catch rates prior to the managed reduction of gemfish catches. In 1997 there was a TAC of 1000t but it was considered necessary to repeat the industry survey.

The daily landings documented by the 1997 industry survey of eastern gemfish were approximately 50% lower than in 1996. In 1996 approximately 27 shots were recorded with catch rates >500kg/h in 1997 the survey vessels recorded only 10 catch rates >500kg/h were recorded.

These lower catch rates reflect both changed fishing patterns and the effect of the oceanographic conditions of 1997 on catchability. The exact extent to which these data also reflect lower than expected stock abundance is not entirely clear. However when the stock assessment for eastern gemfish was revised to incorporate these data it produced a substantially more pessimistic outlook for the stock.

A total catch of less than 500t has been planned for 1998 to allow for incidental catches only.

The results of this study also show that the location and timing of gemfish aggregations is strongly influenced by the annual north-south oscillations of the East Australian Current. Aggregations apparently form around ephemeral interfaces between waters of Sub-Antarctic and South-west Tasman origin.

Designs for potential fishery independent surveys of this stock will need to account for this variability.

The results of this study also demonstrate that acoustic techniques will be extremely difficult to apply to this stock because of the:
- The multi-species composition of the acoustic marks, and
- The temporal and spatial variability of the gemfish aggregations.

All the project's objectives were successfully achieved.

Keywords: Eastern gemfish, catch rates, stock assessment, oceanography

List of Figures

showing a reefy bluff from 350– 450m and associated acoustic biomass running out into midwater between 400 – 450m. The 11-13°C thermocline seen around 350m in figure 32b coincided with these features.

Figure 35 The relationship between catch per day (kg) and number of shots per day on the gemfish line (360-480m) for the four survey vessels during 1997.

BACKGROUND

Gemfish (*Rexea solandri*) are midwater fish (Paulin 1997) caught along the edge of the continental shelf of southern Australia and New Zealand. The eastern gemfish is caught from eastern Tasmania to northern NSW. Eastern gemfish mature at 3-6 years of age and have been aged to 17 years. Mature fish apparently move north along the NSW shelf break during winter, spawning in large aggregations.

Eastern gemfish are mainly caught by Commonwealth licensed demersal board trawlers targeting mobile spawning aggregations along the edge of the continental shelf in depths of about 400m. This trawl fishery developed in the late 1960s and early 1970s, and recorded catches peaked at around 5,000t in 1980. To a lesser extent (<100t/annum) gemfish are also caught by droplining and gillnet methods although the catch by these sectors is growing.

In response to a decline in catch rates and mean fish size in the early 1980s the Demersal and Pelagic Fisheries Research Group (DPFRG) initiated a series of cohort analyses beginning in 1988 (see Allen 1989, 1992). In 1994, several other catch-at-age methods were applied by various researchers and these are described in the annual Stock Assessment Reports prepared by SEFAG (Chesson 1995, 1996, 1997). Although the results of these analyses differ in their details, they show a similar overall pattern, namely a decline in adult biomass in the early 1980s, and a marked decline in recruitment from cohorts spawned in the late 1980s.

In 1988 a 3000t TAC for trawl catches was introduced for eastern gemfish to control and reduce catches. Taking into account the results of the cohort analyses which indicated a continuing decline in stock size, the TAC was progressively reduced to zero in 1993. The TAC remained at zero for 1994, 1995 and 1996, with trip limits to allow for unavoidable bycatch.

A workshop in April 1996 proposed that the South East Trawl Advisory Committee (SETMAC) should form the Eastern Gemfish Assessment Group (EGAG) to update the assessment of this species. A problem confronting the newly formed EGAG was the reliance of the assessment on commercial catch rates as the primary index of abundance, and the lack of these data since the TAC had been reduced to zero.

EGAG developed the methodology for a trawl survey which was conducted in 1996 to produce catch rate data similar to the historic time series (Prince 1996). EGAG selected four survey vessels on the basis that they (or their skippers) had a substantial history in the fishery. From Ulladulla the selected vessels were Charissa and Marina Star, and from Wollongong, the Illawara Star and Santa Rosa A. Using the data produced by the 1996 survey EGAG also developed a new and more comprehensive assessment of the status of the resource, together with a preliminary evaluation of possible future harvest options (Smith *et al.* 1996).

The EGAG assessment, summarised in its March 1997 report, indicated a high probability that the stock had recovered to above the reference point of 40% of the 1979 biomass. The report also emphasised the variability in recruitment to the stock, and the possible benefits of a flexible approach to the setting of future TACs.

Need:

Initial assessments of the eastern gemfish stock (Allen 1989, 1992) 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. But 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. More recent analyses based on the stock synthesis approach (Methot 1989, 1990) were able to extrapolate previous trends into the future and provide some assessment of the status of the stock since 1992 (Bax 1996; Punt, 1996). These analyses confirmed that a series of weak year-classes entered the stock during the late 1980’s and suggested that there was been some recovery in recruitment from cohorts spawned in 1990 and 1991.

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, because quantification of stock status relies principally on the interpretation of catch and effort data collected from the commercial fishery, the extent of that recovery was uncertain due to the lack of any index of spawning stock abundance since 1992.

This situation was 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 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.

In 1997 SETMAC recommended the setting of bycatch trip limits for the fishery for the period 1 January to 30 April 1997, and delayed recommending a 1997 TAC until the 1996 assessment report was available. On the basis of that report, and of further evaluation of harvest options during the meeting of the TAC sub-committee, a recommendation was made for a 1200t total catch for 1997, of which 1000t would be an allocated TAC for the SEF trawl sector.

This recommendation also noted that there was a strong possibility that the catch would be reduced substantially in 1998 (back to previous by-catch levels) due to preliminary evidence of further weak year classes spawned since 1990. Plans were also developed for a further trawl survey for winter 1997 as it was thought that the 1000t TAC would be insufficient to allow targeted fishing of the stock comparable to historic fishing practices. These recommended management arrangements for 1997 were endorsed by SETMAC, the Non-trawl Consultative Committee and the AFMA Board, and after some further evaluation by Environment Australia, the Minister for Environment.

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All the project's objectives were successfully achieved.

METHODS

Negotiated Conditions for Survey Vessels

As in 1996 the basic aim of the 1997 industry survey of eastern gemfish was to provide estimates of catch rates for targeted gemfish fishing that are directly comparable to estimated catch rates prior to the managed reduction of gemfish catches.

However from the outset it should be noted that the management context for the 1997 survey was significantly different to that of 1996 and this changed the fishing pattern of the survey vessels. In 1996 no targeted fishing was allowed outside the industry survey's 200t research quota and consequently the four designated survey vessels were the only vessels to legally target gemfish. During the 1996 survey the participating vessels only fished under research permits and their catch belonged to the project. The vessels were paid a flat daily fee and only fished for gemfish during the period of the 1996 survey.

By contrast in 1997 a TAC of 1,000t was allocated to the trawl industry according to their unit holdings, with an additional 100t of research quota being set aside to maximise targeted fishing for gemfish by the four survey vessels selected by EGAG in 1996. In 1997 all four survey vessels had some of their own gemfish quota to fish in addition to the pool of research quota that was available to them. The Charissa had approximately 120t, the Marina Star approximately 17t, the Illawara Star approximately 25t and Santa Rosa A approximately 7t.

Negotiations with the owners and skippers of the survey vessels prior to the 1997 season commencing showed that they all expected returns from their own commercial fishing practice to greatly exceed the flat daily survey fee paid during 1996. Furthermore they were concerned that by interfering with their commercial activity co-operation with the survey team would prove costly for them. Moreover some of the participants expressed dissatisfaction with the flat fee of 1996.

These circumstances forced the conditions of the 1996 survey to be substantially renegotiated for the 1997 survey. The aim was to use the 100t research quota to supplement the private holdings of survey vessels and thus maximise the amount of targeted gemfish fishing observed by the project team. The participating skippers decided that they would catch most of their private quota holdings before requesting research permits and access to research quota. Each notionally reserved 1-2t of their private allocation for potential by-catch after the forward run. Prior to the season they thought it was likely that once taking out research permits they would then each fish for gemfish under research quota until the research quota was filled.

It was agreed that while fishing on research permits the survey vessels would receive a 50% share of their research catch.

In return the guarantee was sought that the four vessels would allow scientific observers aboard their vessel throughout the season and not just when research quota was being caught. This guarantee was given by three of the vessels (Marina Star, Illawara Star and Santa Rosa A). The skipper of the fourth vessel pleaded that they were temporarily carrying a double crew and because of their large private quota allocation they wished to undertake extended trips to the south, and that this would make it extremely difficult to carry an observer. However they undertook to liaise closely with the survey staff and make available their own detailed records of their fishing. They also undertook to carry observers if they filled research quota.

During 1996 the vessels had remained continuously operating under research permits throughout the period of the gemfish survey and had been unable to fill their own quota holdings during the survey. But in 1997 the vessels anticipated that they might want to fish for their other quota species between periods of gemfish aggregation. Consequently they requested greater flexibility in the way research permits were granted. This flexibility was granted and the guarantee was given that if necessary the system of applying for research permits could made flexible enough that, more or less, on a shot by shot basis survey vessels could choose to fish for research quota or private quota.

Thus in contrast to 1996 during 1997 the participating fishers had the dual aims of finding gemfish and maximising the income they earned from catching other winter quota species.

Under the terms of the research permits the vessels were restricted to fishing to the north of Montague Island off Bermagui. But in contrast to 1996 the vessels were permitted to move between Wollongong and Ulladulla.

Nominal allocations of research quota were made to each of the survey vessels prior to the season:

Charissa	0t
Marina Star	15t
Illawara Star	25t
Santa Rosa	45t

The aim of the initial nominal allocation was to give each skipper a share of research quota sufficient to ensure that they targeted gemfish from the outset of the season. The initial nominal allocation of no research quota to the Charissa acknowledged their own large private holding which was expected to be large enough to maintain them targeted gemfish without resort to research quota. However it was agreed that these allocations would remain flexible and that the research quota would be moved between vessels as needed to ensure it was filled if possible.

Scientific Observation

Scientific observers accompanied the Marina Star, Illawara Star and Santa Rosa A throughout the gemfish season. Details of each shot were recorded including:

1. Place and time at which each shot was commenced (brakes on) and finished (winching up commenced)
2. Sea conditions together with approximate wind speed and direction through shot.
3. Catch composition of each shot.
4. Size composition of the gemfish catch. Up to 200 fish measured from each shot. Caudal fork length measured to the nearest centimeter.

For reasons outlined above the scientific observers did not accompany the Charissa during the 1997 season. Daily contact was maintained with this vessel via mobile phone and its skipper was interviewed face to face by project staff every 2-3 days. The skipper of the Charissa fastidiously maintains a detailed personal logbook and these were made available to the project staff who transcribed from them details of the Charissa's fishing pattern.

The scientific observers also recorded the fishing strategies of the survey vessels together with that of the other SEF trawlers operating out of Ulladulla and Wollongong during the survey.

Acoustics

The results of the 1996 Industry Survey showed that gemfish form ephemeral aggregations within larger multi-species aggregations. Consequently the inability of single frequency acoustics to distinguish between species will limit its usefulness for surveying gemfish abundance. However because fish species vary in their acoustic reflectivity multi-frequency acoustics might be useful in the situation.

Consequently in 1997 the two EchoListener units purchased in 1996 were placed upon the Santa Rosa A to monitor both the acoustic frequencies used by that vessel.

The decision to use Santa Rosa A was based upon a range of factors:

1. Santa Rosa A routinely uses two echo-sounders with frequencies thought to be amenable to visualising gemfish.
2. In 1996 Santa Rosa A was found to have the cleanest electronic environment making it conducive to collecting good acoustic data.
3. In 1996 the gemfish aggregations were most stable and long lasting off Wollongong where the Santa Rosa A operates similar conditions in 1997 would have been conducive to collecting a good body of acoustic data.

Oceanographic Observations

Three Vemco TDRs (Temperature Depth Registers) were purchased and deployed during each monitored shot by the Marina Star, Illawara Star and Santa Rosa A. The TDRs are cylindrical and about 15 x 2cm in dimension. They were clipped to the headline of the nets prior to each shot and recorded temperature and depth at 2 minute intervals. Down loading the stored data and transferring it into Excel allowed temperature and depth profiles of each shot to be reconstructed.

The Remote Sensing Unit of CSIRO, Hobart provided daily colour Sea Surface Temperature (SST) imagery throughout the survey period, together with historical composite SST imagery of the study area.

Data Analysis

The primary objective of this survey was to provide catch and effort data for 1997 gemfish run, comparable with the existing 1986 - 1992 SEF1 catch and effort data . As such the survey had a focus on data collection rather than data analysis. The data collected have been entered into an Excel Spreadsheet, and supplied to EGAG members for further analysis. This report simply describes the catch and effort data.

RESULTS

Chronology of the 1997 Season

The first members of the project team took up residence in Ulladulla during the first week of June, 1997 and established contact with the fleet between Eden and Wollongong.

June 1997

The 1997 Eastern Gemfish season began optimistically. The allocation of 1,000 tonne of Eastern Gemfish quota to the trawl sector had injected a level of enthusiasm not seen in the previous few years which had been managed with zero TACs and trip limits of either 100 or 200 kg/boat. Tangible signs of this enthusiasm included the purchase or renovation of purpose built gemfish nets by most vessels and all the survey vessels. Some trawlers (including the Charissa) re-fitted their original wooden otter boards which give greater control of the net at the slow trawl speeds thought to favour catching gemfish. While the Illawara Star completed a partial re-fit prior to the season increasing its power.

This enthusiasm is called “gemfish fever” by the fishers and it was manifested by an intense interest in the environmental conditions of the season and close monitoring (if not exaggeration) of reports of gemfish catches to the south of the fishery. For example, on the 16th June it was reported in Wollongong that the Charissa had caught “a couple of hundred boxes” (approximately 8 tonne) south of Eden. At the time an observer was travelling south touring the ports and assessing the situation. The afternoon was spent in Ulladulla where it was reported that Charissa had caught 400 boxes off Eden (approximately 16 tonne). Knowing the level of secrecy and guardedness which surrounds fishing activities during winter, the decision was made to travel to Eden immediately to meet with the Charissa and determine the true catch level. Upon arriving in Eden on the morning of 17th June it was discovered that the true catch was actually about 4 boxes (less than 200 kg).

The project team began monitoring the catch of the survey vessels on 19 June, 1997.

At this time the Ulladulla vessels were fishing around 36°S anticipating that gemfish catches would commence at the extreme southern end of their trawl grounds. With the largest quota of gemfish the Charissa fished the furthest south, working as far south as Eden, and trawling almost continually in gemfish depths (360-460m). In contrast the other survey vessels, like most of the rest of the fleet, while looking for gemfish by trawling on or across the gemfish line during the morning shot, monitoring water temperatures and the catches of other vessels, remained fishing for other species. The Marina Star remained north of 36°S on the Ulladulla grounds fishing mainly for ling in 480-540m deeper than the gemfish line. While the Illawara Star and Santa Rosa A remained fishing on the trawl grounds adjacent to

Wollongong (34.5 – 34.9°S) fishing either for royal red prawns in 480-540m or redfish in 280-320m.

During late June skippers across the fleet, from Sydney to south of Eden, began reporting increased catches of juvenile gemfish (15-60 cm). The fishers interpret this increase in the background density of gemfish as indicating the approach of the main "run" of gemfish. On 23 and 24 June Charissa reported the first survey catch rates in excess of 100kg/h and other vessels working out of Eden began to report similar catches. Fishing over trips of 3-4 days duration boats working out of Eden began routinely unloading catches of several tonnes which fueled the gemfish fever rumour mill.

Severe bad weather in the form of strong south to southeast winds prevented fishing 25-28 June and again 1-4 July.

This bad weather resulted in severe local flooding and widespread property damage through the study area. Coming from the southeast this bad weather differed to that observed by the project team during the winters of 1993 and 1996 when bad weather was associated with cold fronts moving across the study area from the west bringing strong northwest and southwest winds. In contrast to this more normal frontal weather the winter of 1997 was characterised by a succession of large slow moving high pressure systems which moved southeast across the Australian continent often centering themselves for a time over Adelaide. While centered over Adelaide the lead edge of these high pressure systems generated strong south to southeast winds over the study area. The succession of high pressure systems and the lack of powerful cold fronts provoked considerable discussion and frustration amongst the fishers as they associate good gemfish catches with strong westerly winds and frontal weather patterns.

Between bouts of bad weather on 29 and 30 June Charissa managed to fish at the southern end of the Ulladulla grounds recording peak catch rates on the two days of 192kg/h and 450kg/h respectively and catching 1,908kg on 30 June. However when she returned to the same area on 5 July after the second bout of bad weather catch rates had declined back to 40-75kg/h so she steamed back south to around Eden (38°S) searching for better catch rates.

July 1997

Frustration with the persisting high pressure systems and the lack of a westerly break in the weather grew during early July. Port discussions focused on the variability of past seasons with talk of past "late seasons" when the gemfish did not aggregate until late July. Most boats, including the other three survey vessels, limited their travel to the trawl grounds adjacent to their own port. They continued their one shot on the gemfish line and one shot off the line fishing pattern which combined keeping an eye out for gemfish aggregations with filling their quotas of other winter species.

By 7 July the Charissa had satisfied itself that catch rates around Eden were no better than further north and so returned towards Ulladulla. On 8 July in

440-460m on the Tuross ground, which stretches across the 36°S line, she caught 2,025kg recording a catch rate of 523kg/h in the morning shot and 152kg/h in the afternoon shot. Several other Ulladulla boats also recorded reasonable catches on the same day and the Bermagui boats just to the south recorded their peak catch rates for the 1997 season. Anticipating bad weather the Charissa remained at sea that night in order to make an early morning shot. She was the only Ulladulla boat to fish 9 July taking only 392kg in her morning shot before the strong south easterly winds forced her to return to port. Bad weather kept the Ulladulla boats in port 10 July but the fishers were encouraged because the midwater feed layers were thickening and had descended to within 40m of the bottom over the gemfish line. They felt this indicated that the main gemfish run was about to hit their trawl grounds.

No fishing occurred on the Wollongong grounds between 25 June and 6 July or 9 and 12 July because of severe southeasterly weather. However observing less build up in the midwater feed layer over the trawl grounds and lower background densities of gemfish they remained confident that the gemfish would hit the Ulladulla grounds before the Wollongong grounds and that filling their relatively small quotas would not require travelling south to Ulladulla. Consequently the Wollongong boats remained fishing for either redfish or royal red prawns when they able to fish.

On 11 July the Charissa and Marina Star both conducted two shots towards the south in 420-480m towing between 35.6°S and 35.9°S. They took 2,026kg (426kg/h) and 2,214kg (409kg/h) respectively in their morning shots but only 523kg (131kg/h) and 39kg (13kg/h) respectively in their afternoon shot. On 12 July the boats fished the same area again and Charissa made similar catches; 2,352kg (392kg/h) in the morning shot and 588kg (261kg/h) in the afternoon shot. The Marina Star only completed a morning shot for 1,181kg at 248kg/h.

13 July 1997

On 13 July the Charissa once again returned to the same area 35.6°S to 35.8°S and trawled south in 400– 440m taking 2,222kg in their morning shot (555kg/h) and 2,745kg in their afternoon shot (915kg/h). Fishing alone the Charissa concealed its catch on that day from the rest of the fleet only reporting it to this project's observers.

On the same day the Marina Star traveled north to Wreck Bay near the entrance to Jervis Bay (35.2°S to 35.4°S) and shot away in about 450m, she towed for about 1 hour before snagging on the bottom, "going fast". The shot was winched up and only had about one box (40kg) of gemfish in the net. The Marina Star shot away again on roughly the same line and towed for about 3 hours. This shot yielded 11,700kg of gemfish (3,800kg/h) the largest shot recorded by the survey. Like the Charissa the Marina Star was anxious to conceal its catch and retain the advantage of knowing the most recent location of the gemfish aggregations.
However sorting and stowing a catch of that size takes a couple of hours and during the process another Ulladulla vessel nudged up to the Marina Star and saw

about 4 tonnes of gemfish on the deck. From there word that the gemfish were aggregating off Wreck Bay spread rapidly amongst most of the Ulladulla fishers.

Off Wollongong the boats also fished on 13 July having been weather bound since 7 and 8 July. The Santa Rosa A fished for redfish in 280-290m with its morning shot. However the Illawara Star shot away in 430m and towing between 34.6°S and 34.70°S took 700kg of gemfish (140kg/h). She also noted that for the first time in the 1997 season there was a current pushing onto the shelf edge from the south. These were good enough signs of gemfish for her to remain on gemfish line for her afternoon shot. Thinking she had contacted the outside of a small gemfish aggregation she shot back to the north over the same ground (34.6°S and 34.7°S) but in a little shallower (410m). This shot produced 750kg at 250kg/h.

The reports of the Illawara Star and their own echosoundings were good enough for the Santa Rosa A to terminate its redfish fishing early and steam out to the gemfish line for an afternoon shot. She fished in 370-380m towing between 34.6°S and 34.8°S and took 3,805kg at 1,202kg/h.

For the first time in some years the full impact of gemfish fever was observed that night in Ulladulla with each vessel trying to conceal the information they had as to the probable location of gemfish aggregations. Most of the vessels had made reasonable catches of gemfish or knew the location where another vessel had made reasonable catches. But the vessels only unloaded token amounts and the skippers acted nonchalantly trying to preserve the illusion of business as usual. In public arrangements were made between skippers and crew to meet the next morning at the normal time of 4.00AM. But in private each boat arranged to return to sea that night at 8.30PM so that they could be first in line for the morning shot on their preferred trawl ground.

Both the Charissa and Marina Star assumed that the location at which they had found gemfish was the exclusive or main location for the gemfish aggregation. Only the scientific observers knew that in fact on that day reasonable aggregations of gemfish had extended between Bermagui and Wollongong. But like all the crew members the observers had been sworn to secrecy by the skippers involved.

The following day, because the Marina Star’s catch had been bigger than the Charissa’s, this swearing to secrecy rebounded on the project team. The skipper of the Charissa when eventually appraised of the situation was upset that the project team had not seen fit to appraise him of the situation. Even though he had sworn them to secrecy about his own catch. A considerable amount of money was spent on mobile phone calls before the feathers ruffled by this incident were smoothed approximately back into place. But that was still to come.

By 10.00PM 13 July the port of Ulladulla was unnaturally empty and the fleet was out at sea, laid over on the trawl grounds “waiting in line” to shoot away the next morning. The weather was particularly bad and would have prevented fishing had there not been such a catch immediately preceding it. Tending to keep to themselves anyway, and secure in their belief that they knew the location of the main gemfish aggregation, the Charissa was one of the few boats that had not heard the port talk about the Marina Star's catch. Consequently they lay out over the southern part of the Ulladulla grounds by themselves while almost the entire rest of the Ulladulla fleet queued off Wreck Bay where Marina Star had fished that day.

The unfortunate Marina Star paid the price of having been spotted with a load of gemfish on its deck earlier in the day and was beaten back to its trawl shot by all the other boats. Being the last in line they could have saved themselves the discomfort of a rough night at sea and still shot away at the same time the next morning.

The boats shot away on 14 July into increasingly rough weather. But the gemfish catches were poor. Off Wreck Bay (35.2°S to 35.4°S) the Marina Star took only 16kg (12kg/h) in its short morning shot and 415kg (213kg/h) in its afternoon shot. To the south (35.6°S to 35.8°S) Charissa took 196kg (56kg/h) in its morning shot and 78kg (16kg/h) in its afternoon shot. While off Wollongong the Illawara Star and Santa Rosa A only completed shots in the morning taking 273kg (55kg/h) and 165kg (35kg/h) respectively between 34.4°S and 34.8°S. The Illawara Star reported that along the shelf break the current from the north had resumed. The fleet was extremely disappointed with these results, but maintained their high hopes with talk about how the trawl gear had not been able to operate properly due to the rough conditions.

The prospect of finding aggregations drove the boats out again on 15 July in conditions that they would not ordinarily have fished. But at long last a cold front was expected to cross the area so it was expected to be the last chance to fish for some days. The Charissa steamed up to Wreck Bay angry at having been left out of the party on the previous day and fished in 400-440m towing between 35.2°S and 35.4°S. She took 539kg (359kg/h) in a short first shot and 572kg (143kg/h) in her second shot. Dispirited the Marina Star fished on the main trawl ground in front of Ulladulla (35.5°S to 35.7°S) completing only one shot for 130kg (24kg/h). Sizeable by-catches of ribbonfish (southern frostfish) were in evidence, which was interesting because knowledgeable fishers say that ribbonfish run shallower, or to the north, of the main gemfish run. Despite these telltale signs the majority of the fleet concluded that the main gemfish run had now moved to the north of the Ulladulla grounds. Consequently boats from as far south as Eden began travelling north to Wollongong expecting to be ahead of the gemfish aggregation when the weather next allowed.

Meanwhile off Wollongong on 15 July the boats unsuccessfully searched the southern end of their grounds. The Illawara Star completed one long shot to the south in 400m between 34.6°S and 34.8°S for 595kg at 85kg/h. With her morning shot the Santa Rosa A towed to the south between 34.8°S and 34.9°S in 510m to 460m for 300kg (86kg/h), and back to the north in the afternoon shot between 34.9°S and 34.8°S in 460m to 320m for 133kg (36kg/h).

There was no fishing from any of the NSW ports on 16 July and in Wollongong the weather kept all the gathering boats tied up until Saturday 19th July amid growing pessimism that they were “missing the fish”. During this time the Charissa and Marina Star managed to keep fishing out of Ulladulla.

On 17 July towing south between 35.3°S and 35.6°S the Charissa took 1,568kg (448kg/h) in her morning shot in 440m and 3,185kg (708kg) in her afternoon shot in 460m. On the same day the Marina Star towing south and then north between 35.4°S and 35.6°S took only 200kg (50kg/h) from her first shot in 435m and 40kg (20kg/h) from her second shot between 340m and 380m. At this point the Marina Star decided that the weather and catches were bad enough to stop them fishing and only the Charissa kept working. On 18 July she again completed two shots towing south between 35.3°S and 35.6°S in 440m to 460m taking 2,009kg (574kg/h) in her morning shot and 4,899kg (1,153kg/h) in her afternoon shot. Her fishing pattern was similar on 19 July, although she made three shots on that day, towing south between 35.4°S and 35.6°S in 440m to 460m for 392kg (261kg/h), 2,450kg (700kg/h) and 735kg (420kg/h) respectively.

On 19 July the boats tied up in Wollongong tried to put to sea but with the exception of the Miss Francesca from Eden the weather forced them back to port without fishing. Changing her previous plans to fish out of Wollongong the Miss Francesca headed back south to Eden, fishing her way down the coast, and relaying pessimistic news about her catch rates, further deflating the mood of the fishers waiting in Wollongong. About this time the warm current running out of the north and off the shelf increased markedly in strength. The boats began to have extreme difficulty holding their trawl nets against the bottom along the shelf edge. During some tows it became necessary for vessels to hold their rudders at a 25° angle to the direction of their tow in an attempt to hold the net in against the shelf edge. The Wollongong boats were fishing conditions they said they had never fished before in an attempt to salvage the gemfish season.

About this time the high hopes that the fishers had had for the 1997 gemfish season dissipated.

All the survey boats fished 20 July. Charissa again fished for gemfish in 420m to 440m towing south between 35.2°S and 35.6°S for 2,188kg (1,094kg/h) in the morning shot and 1,911kg (382kg/h) in the afternoon shot. Marina Star fished for ling in 500-520m during the morning shot but took 3,200kg (753kg/h) of gemfish with her afternoon with a shot in 405m between 35.5°S and 35.6°S close to where Charissa had made her catches over the previous few days. The Illawara Star fished for gemfish with her morning shot in 380m-430m towing between 34.6°S and 34.8°S for only 117kg (29kg/h) and then fished for redfish in the afternoon in 290m-360m.

The Santa Rosa A covered virtually the same shots as the Illawara Star and similarly caught only 295kg (45kg/h) of gemfish in its morning shot.

On 21 July the Charissa took its first day off for some time while the Marina Star returned to the area in which it had been comparatively successful the previous day, between 35.5°S to 35.7°S. She conducted one long shot in 380-430m for 665kg (108kg/h) of gemfish. The Wollongong vessels were by this time convinced that if anything the gemfish aggregations were to their south and steamed south towards Shoalhaven. Both vessels looked for gemfish with their morning shots towing between 34.9°S and 35.1°S. The Illawara Star towed in 440-390m for only 105kg (33kg/h) while the Santa Rosa A searched depths between 480 and 330m for only 247kg (64kg/h). On the basis of these poor results the boats moved into shallower water for their afternoon shots and fished for redfish towing back to the north in only 300-330m. Consequently gemfish catches were negligible.

On 22 July the Charissa was back at sea fishing the area she had been concentrating on since 11 July, 35.5°S to 35.7°S. Towing in 460m she took 784kg (196kg/h). The Marina Star also fished the same area again, towing in 405-450m she took 563kg (142kg/h). Off Wollongong only the Illawara Star fished. She fished in shallow for flathead in 130-140m and did not take any gemfish. All vessels returned to port after their morning shots as only the second frontal system for the season moved across the area. Bad weather kept all boats in port the following day.

On 24 July the two Ulladulla vessels managed to fish. Charissa towed between 35.3°S and 35.4°S for her morning shot in 420m catching 490kg (163kg/h) of gemfish. With their afternoon shot they continued towing south to 35.6°S but in 460m taking 735kg (163kg/h). The Marina Star conducted three shots towing parallel to the Charissa. Their first shot was in 430-440m between 35.2°S and 35.4°S for only 30kg (10kg/h). Their second shot was for ling, back towards the north between 35.4°S and 35.3°S in 460-520m, and no gemfish were caught. Their third shot was in 400m back between 35.3°S and 35.4°S only 67kg (20kg/h) of gemfish were caught.

All the survey vessels were out fishing on the 25 July but most of them had finished actively fishing for gemfish. Off Wollongong the Illawara Star used its first shot to check the gemfish line, starting the shot in 340m above the gemfish line where they could expect to catch large redfish but ending it in gemfish depths around 410m line. They towed between 34.6°S and 34.8°S and caught only 97kg of gemfish (23kg/h). For their afternoon shot they fished in 300m for redfish. Santa Rosa A did not bother checking the gemfish line, fishing for redfish in 300-350m with both shots. Likewise off Ulladulla the Marina Star used both shots to fish for ling in 500-570m. Only the Charissa stayed in touch with the gemfish line with both shots fishing on the lower side of the gemfish line in 460m and towing between 35.3°S and 35.7°S with a morning and afternoon shot taking around 390kg with each shot (157kg/h and 83kg/h respectively).

None of the boats fished on 26 July due to bad weather but on 27 July the Wollongong boats were back at sea. Both vessels conducted morning shots on the gemfish line. The Santa Rosa A shot between 34.6°S and 34.8°S in

390-400m catching only 115kg of gemfish (36kg/h) and moved back into redfish depths for her afternoon shot. In contrast the Illawara Star shot to the north between 34.4°S and 34.6°S in 410-430m and caught 1,101kg of gemfish (306kg/h), consequently she shot for gemfish in the afternoon between 34.6°S and 34.8°S in 400-450m taking another 1,720kg (467kg/h) of gemfish.

On the strength of its relatively good catches on the previous day on 28 July the Illawara Star conducted her morning shot on the gemfish line in 410-420m between 34.5°S and 34.7°S but caught only 221kg (56kg/h) of gemfish. She moved into shallow water (140-150m) to fish for flathead and shark with her afternoon shot. The Santa Rosa A also took her morning shot on the gemfish line in 420m between 34.4°S and 34.6°S only catching 148kg (49kg/h) of gemfish. She then moved shallower for her second shot fishing for redfish in 340m between 34.5°S and 34.6°S and taking 443kg (177kg/h) of gemfish as a bycatch of the redfish catch.

Off Ulladulla the Marina Star fished the gemfish line with her first shot, towing between 35.4°S and 35.5°S in 380-420m but caught only 51kg (19kg/h) of gemfish. She then fished for redfish in 280-290m with her second shot.

August 1997

At the end of July bad weather forced all boats to tie up for several days. The mood of the fleet was that if there were no gemfish aggregations when the weather cleared the season had ended. Each of the boats checked the gemfish line during the first week of August when the weather cleared but negligible catches of gemfish were taken.

Consequently the decision was taken to cease comprehensive monitoring of the survey vessels. A single observer was left in place until the end of August to liaise with the survey vessels in case the unexpected happened and further gemfish aggregations were found. There was however no further reports of significant spawning run catches.

For the sake of completing the record for the 1997 gemfish season it is worth noting that during September the Illawara Star made significant catches from return run aggregations, although these catches were not monitored by this project. Return run catches are distinguishable from spawning run catches in that the fish are smaller and in very poor condition. The Illawara Star ended up catching more fish from the September return run than she had during the main season.

Catch, Effort and Catch Rate Data

Figure 1a shows the catch rate of each shot (in kg/hour) for the survey vessels during the 1997 season. The combination of a bad season, in-shore fishing and other factors can be seen in the large proportion of catch rates <100 kg/hour and relatively few shots recording high catch rate compared to the previous season. In 1996 approximately 27 shots were recorded with catch rates >500kg/h in 1997 the survey vessels recorded only 10 catch rates >500kg/h were recorded. As can be seen, the 3,800kg/h shot by the Marina Star on the 13th July was atypical of the 1997 season. Figure 1b is essentially the same graph with this single large shot excluded to give greater resolution in the data.

Figures 2a,b,c & d show the shot by shot catch rates of the individual survey vessels. These graphs show clearly the impact of the weather on the fishery with the Ulladulla boats having many more days fishing days and recording many more shots than the Wollongong trawlers. The Charissa reported 27 days fishing during the survey, the Marina Star 23, the Wollongong vessels Illawara Star and the Santa Rosa A each recorded only 10 days fishing during the survey.

Figures 3a,b,c & d are the same graphs with the scale normalised by again excluding the Marina Star's peak catch rate and setting a uniform maxima of 1,400kg/h x-axis. This makes direct comparison between vessels easier and emphasises the dominance of the Charissa's gemfish catches. Charissa recorded most of the shots with catch rates of gemfish over >500 kg/hour. She reported 48 shots on the gemfish line (defined here as 360-480m) and 9 catch rates >500 kg/h, 2 of these were >1,000kg/h. Between them, the other three survey vessels only recorded 5 shots of around 500kg/h or greater.

The Charissa also recorded more shots per day on the gemfish line than the other survey vessels; 1.78 gemfish shots per fishing day; compared with 0.87 for the Marina Star 0.6 by the Illawara Star and 0.5 for the Santa Rosa A.

Compared to 1996 the overall number of gemfish shots per day across the survey fleet fell from 1.6 in 1996 to 1.1 in 1997. But in 1996 the fleet shared the 91 gemfish shots and 57 fishing days evenly and the only vessel without a significant share of high catch rates was the Marina Star. In contrast during 1997 the Charissa recorded a disproportionate share of the 70 days fishing and 79 gemfish shots recorded.

Figure 4a-d are the catch rates for each boat excluding shots that were not on the gemfish line, again defined as 360-480m. In figure 5a-d the presentation is again normalised by excluding the Marina Stars 13 July shot and setting a uniform maxima of 1,400kg/h for each graph. Excluding shots outside of gemfish depths removes a number of >100kg/h shots from the Marina Star which tended to fished deeper than the gemfish line for ling, and the Wollongong vessels which tended to fish for redfish. The filter has little impact on Charissa's data because she fished almost exclusively on the gemfish line during the 1997 season.

Figures 6a-c and figure 7a-c give another perspective of catch data aggregating the data by latitude of the shots north to south. Again the second set uses the normalised view of the data. But both graphs show the typical south to north movement of high
catch rates through time. Catch rates peaked on the 13th July off Jervis Bay, with another minor event late in July off Wollongong. Interestingly the return run which was observed during August/September 1997 occurred on this same Wollongong ground. Only two shots around 500kg/h or greater were observed outside the latitudinal band 35°S to 36°S while 9 shots >500kg/h were observed

in that latitude. Peak catch rates were clustered north and south of Ulladulla with the highest being Marina Star's 3,800kg/h on 13 July off Jervis Bay north of Ulladulla.

The almost total absence of good catches off Wollongong in 1997 is notable by comparison with the Industry Surveys of 1993 and 1996. In 1996 there were 13 shots observed off Wollongong with catch rates >1,000kg/h. In 1997 the Santa Rosa A only recorded 1 shot with a catch rate above 200 kg/hour while the Illawarra Star recorded 3 shots.

Length Frequency Data

With regard to the size and age composition of the gemfish stock EGAG's interest centres on the size and age composition of the adult breeding stock. Consequently this survey focuses on the size and age composition of the winter breeding aggregations which are thought to give the best indication of this part of the fish stock.

These surveys had difficulty achieving this end during the 1997 season. Many of the gemfish measured were either the by-catch of shots targeting other species or from low catch rate shots taken in the right depth but, judging from the low catch rate, outside the main gemfish aggregations. Less than 3,500 gemfish were measured in 1997 compared to 11,593 in 1996. The 1997 number is low, but the survey team measured the entire gemfish catch for over 90% of the catches they observed.

The low 1997 sample size partly reflects the lower catch rates of the year. But it also reflects the changed relationship with Charissa which recorded most of the high catch rate shots. Operating entirely on her own without observers little of her catch was measured.

Figure 8 shows the length frequency histogram for the gemfish measured during 1997. The females showed a broad mode between 78 and 80cm, the main male mode is at 74cm. Both sexes have distinct sub-adult modes around 42 and 52cm corresponding to 2 and 3 years old sub-adults.

Figure 9a-c shows the data grouped by depth strata; figure 9a is the histogram for fish caught shallower than the gemfish line (>360m), figure 9b those fish caught on the line and figure 9c deeper than the gemfish line (480m). Only small numbers of gemfish (218) were caught deeper than gemfish line, or shallower (398). Shallower than the gemfish line the catch was mainly sub-adults, 2 and 3 year old fish, around 42 and 52cms caudal fork length. Deeper than the line the catches are of mixed sizes.

Figure 10a&b shows two slightly different histograms indicative of the length structure of 1997 gemfish aggregations. In these figures an attempt has been made to exclude the influence of samples taken in gemfish depths but at low catch rates outside gemfish aggregations. Compared to figure 9b there are fewer sub-adult fish from the 42cm and 52cm modes in these figures. In figure 10a each sample is weighted by the catch rate of the shot it was taken from; while in figure 10b only 3 similar sized samples from shots with catch rates >400kg/h have been used. The sample size for this latter sample is only 690 fish.

Figures 10a&b give the clearest approximation of the size structure of the 1997 adult gemfish population. The main differences between it and figure 9b are the lower proportion of sub-adults already mentioned, and the small subsidiary mode of males at 64cm which is more apparent in figure 10a&b. Both techniques for filtering the data suggest a male:female ratio of about 0.45:0.55. which is lower than the 50:50 estimated across the entire sample.

The slightly higher ratio of males across the entire sample is due to difficulty observers have in distinguishing immature females from males within the 42cm mode. Prior to the sexes becoming distinguishable all immature fish appear to be immature males and consequently the recorded sex ratio in this age class is skewed towards males.

Overall the 1997 length composition and male:female ratio is similar to that of 1996. The major difference is that the modes of the males and females have both progressed 2cm. This is indicative of the dominant 1990 year class growing through the population, and of insufficient following recruitment to mask this progression through the size structure.

Sea Surface Temperatures in 1997

Prince (1996) documented a correspondence between water temperature (as observed by satellite at the surface, and mapped at 250m by the RAN) and catch rates of gemfish in 1996. Indeed, fishers have long held that the spawning run follows the northward extent of cold water, being impeded on occasions by warm currents from the north. The extent to which this is true is not known, let alone the reason(s) why it might be true. It is important that the impact of ocean conditions be understood for two reasons:

1. interpretations of CPUE data and
2. influences for spawning success.

Here we focus only on 1), and proceed by looking for a relationship between catch rates and ocean conditions characterised by satellite estimates of SST.

A series of relatively cloud free satellite images showing Sea Surface Temperatures (SST) for the study area have been compiled to show changes in SST through the study area during the period June – August 1997. These have been overlaid with the catch rate data collected from the survey vessels during 1997 (Figures11 a-i).

a) June 4 EAC 24°C separating at Sugarloaf Point (33°S), then 18°C on shelf to Jervis bay, then warm (21°C) eddy to Eden, then cold 15°C shelf water
b) June 21 EAC still separating at 33°S, but now retroflecting towards shelf south of Jervis Bay (35°S). Shelf waters 18°C from Newcastle to Eden. Warm core eddy still centered between 36-37°S and 152-153°E, but less

distinct in the SST. Low catch rates of gemfish were recorded around 36°S on the inside of the eddy.

c) July 4 and 7 (not shown) EAC staying on shelf and pushing south, shelf waters now 20°C+ down to Jervis Bay where current heads offshore as a front. Warm eddy remains relatively stationary moving inshore slightly. Low catch rates down around Cape Howe, catch rates around 36°S increasing.
d) July 13. Fish being caught in SST of 18°C, from Bermagui (36.5°S) to Wollongong especially close to Jervis Bay (35°S) where the front between 18 and 22°C waters has intensified.
e) July 15. provides a better image of this.
f) July 16. also provides a good image. Catches contract towards south.
g) July 21. EAC pushing further south, and re-attaching to the shelf the front between 18 and 22°C runs out from the shore around Sydney and down along the shelf edge to around Ulladulla before running southeast out to sea. Gemfish catches remain along this front.
h) July 30. front between 18 and 22°C weakening and continuing to push south but EAC flow is weak; gemfish catches contracting.
i) August 7. EAC flow intensifies through the area. Catches decline to nothing and the survey ends

The data presented here again suggest a link between the timing and location of the winter gemfish aggregations and the ocean conditions created by the vagaries of the East Australian Current. Peak catch rates occurred where the EAC flowed off the shelf near Jervis Bay, as if it formed a barrier to further northward migration.

Comparison with Previous Years

To further examine the apparent coincidence between gemfish aggregations and the annual oscillations of the Tasman Front, historical SST data were compared with previous catch data from the 1996 Industry Survey, and with commercial shot data from SEF1 returns for the period 1987 - 1993.

1996 Industry Survey

Figure 12a-h shows a series of SST images for winter 1996 superimposed with the catch rate data from the 1996 industry gemfish season.

In late June 1996 the main body of the EAC was visible as a large flow of 24°C+ water separating from the shelf south of Jervis Bay, around latitude 36°S. Between latitudes 37°S and 35°S lay a broad front of 18-20°C water. The first pulse of high catch rates was taken about 26 June to the south of Ulladulla around latitude 36°S (Figure 12a). These catches occurred within a small wedge of 18°C water which had pushed north along the shelf through the broad frontal band of 20°C water.

By the beginning of July the separation point for the main EAC flow had been pushed back to the north and was around Jervis Bay (35°S). A warm core eddy was beginning to form along the shelf between 34°S and 35°S. A strong temperature front was evident to the south of the budding eddy, curving away to the south-east from Jervis Bay. Surface temperatures were cooling rapidly across the area (Figure 12b). The main body of the EAC south of latitude 34°S (Sydney) had cooled to around 20°C+. South of the main front surface waters had also cooled to 14-15°C by late July 1996. During this period high catch rates of gemfish were taken 4 & 10 July just to the south of Jervis Bay, mainly around the southern front of the budding warm core eddy.

During July 1996 cold doming was evident off Wollongong- Sydney and the warm core eddy formed to the north of the EAC's initial point of separation (Figures 12c& d). By 9 July large catches were also being recorded of Wollongong in the vicinity of what would become the northern edge of the warm core eddy. High catch rates continued in this area into early August by which time the area had become the northernmost separation point for the shelf bound EAC flow in 1996 (Figures 12e&f).

Around the beginning of August 1996 the eddy spun off the shelf and moved out to sea. As the eddy moved it away it was largely subsumed back into the main body of the EAC. During this time the EAC's point of separation moved south back towards Jervis Bay (Figures 12f).

SEF1 Catch Statistics 1987-1993

Figures 13-19 show historic 10 day composite SST imagery for 1987-1993 overlaid with the catch rate data reported on SEF1 returns for those years.

1987

During late June and early July 1987 (Figure 13) catches moved rapidly from around Cape Howe (38°S) towards Ulladulla (35°S), clustering in late June where the EAC was detaching from the shelf around (35.5°S). During July a warm core eddy formed in that area and the centre of catches moved to its northern edge off Wollongong (34°S). Through August and September this area was the point of separation for the EAC and during September 1997 a return run occurred in that same area.

1988

In 1988 management influenced the catching patterns of gemfish for the first time so observations about timing and location of gemfish aggregations have to be qualified. In 1988 a 3,000t competitive TAC was implemented and the fishery was closed through late July and early August. The reported catch for the year was 3,500t.

Catches at first clustered around Cape Howe (38°S) during mid-June as the characteristic wedge of cold water pushed north around the Cape Howe (Figure 14). By late June and early July the detachment point for the EAC retreated north to 35°S and catches extended between 38°S and 34°S . During late July and early August the EAC pushed back towards the south and a warm core eddy began forming between 34°S and 35°S. During late July and August a few scattered catches were reported around 34°S on the northern edge of the eddy as it formed. During September a return run of gemfish occurred on the northern edge of this eddy.

1989

In 1989 an allocated TAC of 3,000t was used to manage the fishery and 2,300t was reported caught.

Gemfish catches initially clustered around Cape Howe (38°S) where during the last week of June the EAC was separating from the Continental Shelf (Figure 15). In the ensuing weeks the EAC formed a warm core eddy off Cape Howe and the sea surface temperature to the north cooled rapidly as the point at which the EAC detached from the shelf retreated north to about Wollongong (34°S). Gemfish catches at first remained associated with the warm core eddy but during July as it moved southeast into the Tasman Sea catches moved north towards Wollongong where the main body of the EAC was separating from the shelf. A small return run was reported around Wollongong during August and September.

1990

The allocated TAC in 1990 was 1,750t and 1,200t was reported landed.

In early June the EAC separated from the continental shelf at Cape Howe (38°S) and a warm core eddy slowly formed to the north of this point (Figure 16). Catches were initially reported during around this feature between 38°S and 36°S. As the eddy formed during June the detachment point for the EAC retreated north and by early July it was situated around 34.5°S. During the first half of July catches moved north from the northern edge of the warm core eddy (37°S) and by mid July they were clustered between 34-35°S. During late July the EAC pushed towards the south and a second warm core eddy formed between 34-36°S and began moving south during August. Some back run catches apparently accompanied the inside and northern edge of this eddy as it moved south and slowly away from the shelf.

1991

In 1991 management arrangements reduced the TAC of gemfish to just 500t and a catch of 560t was reported. Consequently very few high catch rate shots were reported.

In June 1991 the EAC was separating from the continental shelf around Cape Howe (Figure 17) and at the end of June a cluster of catches was reported around this characteristic wedge of cold water (38°S). During July 1991 a warm core eddy slowly formed between Cape Howe (38°S) and Jervis Bay (35°S) and by August the attachment point for the main flow of EAC water had retreated north to around 34°S. By mid-July the centre of the small catches being reported had moved north to around 34°S. A scattering of small catches were reported through this area through August and September.

1992

In 1992 management reduced the allocated trawl catch of gemfish to 200t and introduced parallel systems of ITQ for 15 other SEF trawl species.

In 1992 two large warm core eddies slowly formed in the study area after mid-July. The first formed between Cape Howe (38°S) and Jervis Bay (35°S) during late July and mid-August and the second between 37°S and 35°S during late August (Figure 18). As these eddies formed the separation point of the EAC retreated north from Cape Howe (38°S) towards Wollongong – Sydney (34°S) but the frontal area remained ill-defined and indistinct.

Few large catches were reported. Some catches were reported during early July clustered to the south of Jervis Bay (35.5°S) in an area that would become the northern edge of the second warm core eddy to form. During late July and through August several large catches were reported off Wollongong and Sydney in the area which during September became the northern most point of separation for the EAC.

1993
During 1993 a single warm core eddy formed between Cape Howe and Jervis Bay in late June and then took until October to slowly moved south-east away from the coast (Figure 19). The separation point of the EAC was at Cape Howe (38°S) until early July, when the area transformed into the southern edge of the warm core eddy. By mid July the separation point for the EAC had re-established itself around Wollongong – Sydney (33.5°S) where it remained until the end of August.

A zero TAC was imposed on gemfish fishers for the first time and fishers were restricted to 200kg trip limits to cover accidental by-catches. Consequently few high catch rates were reported. The few high catch rates reported are mainly the catches made using 33t of research quota during the 1993 Industry Survey (Prince & Wright 1994). During that survey high catch rates were recorded off Ulladulla 5-8 July where at the same time the Scientific Monitoring Program also recorded a large accidental catch. The first large survey catches off Wollongong were not made until 26 July but continued through until 18 August.

Prince & Wright (1994) also reported anecdotal accounts of incidental catches south of cape Howe during mid to late July, and then east of Eden at the end of July. They were unable to substantiate the levels of these catches. The SEF1 records show that trip limits were being landed from those areas at those times. Co-incidentally there was strong frontal features in the area of the reported catching at these times as the warm core eddy was separating from the shelf during this time.

Interannual Comparisons 1994 -1997

During 1994 and 1995 the fishery was managed with a zero TAC and 100 or 200kg trip limits. Consequently no large catches were reported in the SEF1 catch returns precluding the above comparisons being made. However for the sake of completing the record Figures 21 & 22 present fortnightly composite SST imagery for the June to August period of 1994 and 1995. With the aim of facilitating the comparison of the 1997 season with previous seasons the comparative images for 1996 and 1997 (Figures 23 & 24) are also repeated in the same format.

1994

Figure 20 shows that SST were extremely warm through the study area throughout the June – August gemfish season. Virtually the entire study area north of Cape Howe (38°S) remained >17°C throughout June – August in 1994. A small slim wedge of <15°C water was visible around Cape Howe in late June and along the shoreline to around 36°S through July into August as the adjacent shelf waters slowly cooled.

The main body 20°C+ EAC separated from the shelf around Wollongong (34°S) during June and Jervis Bay (35°S) during July. During August the 20°C+ EAC water flowed south along the shelf from Jervis Bay, rolling itself into a warm core eddy between Cape Howe and Ulladulla, as it pushed south. But this activity all occurred within a broad body of 17°C+ water. In terms of 15°C water the Tasman Front remained anchored around Cape Howe and Eden throughout the season.

1995

The SST pattern of the study area in early June 1995 was similar to that of the previous year but slightly cooler (Figure 21). Most of the area was covered by warm 18°C+ EAC water. North of Jervis Bay (35°S) there was also warmer mass of 20°C+ water. A small wedge of cold 15°C water was pushing north around Cape Howe (38°S) where the EAC detached from the shelf.

Through June and into July the main point of separation from the continental shelf retreated north towards Wollongong, latitude 34°S around where it remained through July, before pushing back south towards Jervis Bay in August. As the point of separation for the EAC retreated north a warm core eddy formed between Cape Howe and Jervis Bay before moving away to the south-east.

1996

By the beginning of June 1996 the separation point for the EAC was already to the north of Cape Howe (Figure 22), somewhere around Bermagui and the Tasman Front ran almost perpendicular from the shoreline out into the Tasman Sea. South of the front SSTs were 16-18°C and cooling. A small cold wedge developed against the shoreline, between Cape Howe and Bermagui during the second half of June.

By late June the main body of the EAC of 24°C+ separating from the shelf around Jervis Bay, latitude 35°S and between latitudes 37°S and 35°S lay a broad front of 18-20°C water. By the beginning of July the separation point of the EAC was still around Jervis Bay as surface temperatures south of the main front cooled rapidly. Doming of cold water was evident along the shelf off Sydney and Wollongong during early July and a warm core eddy began to form between Jervis Bay and Wollongong. Around the beginning of August the eddy spun off the shelf and moved out to sea in an easterly direction out to sea being mainly subsumed back into the main body of the EAC as it moved.

During July and August the EAC's point of separation with the continental shelf oscillate between Wollongong and Jervis Bay. The composite image for late August shows it just south of Wollongong.

1997

Hints that 1997 was going to be unusual can be traced back to early in the year, when an especially large warm core eddy pinched off from the main flow of the EAC and became a seemingly permanent feature off Bermagui. It was not until July, however, that 1997 became clearly anomalous. In a 'normal' July an Warm Core eddy already resident off southern NSW will start to become increasingly isolated off southern NSW will start to become increasingly isolated from the EAC to the north and/or wander seaward of the shelf break, leaving much of the shelf edge bathed in cooler waters. In July 1997, the EAC renewed its southward push early, swamping or displacing the large eddy (Figure 23). By end of August there was very little cold water left visible off southern NSW at all.

The only time comparable events have occurred in the last 10 years was in 1994, when warm waters were also already off Bermagui in August. However, in that year there was no big warm eddy preceding the early southward push of the EAC, and the EAC made its southward push in deeper waters than it did in 1997.

Gemfish Aggregations and the EAC

The body of data presented here support the suggestion that timing and location of winter gemfish aggregations is linked to the seasonal cycling of the East Australian Current. Peak catch rates apparently occur where the EAC flows off the shelf, or where the northern edge of warm core eddies interact with the continental shelf.

The big weakness of SST imagery is of course that it shows only what is happening at the surface. Events at the surface are clearly linked with what is happening at 400m where the gemfish aggregate, but it must be remembered that the link is not a simple one. Two areas having the same SST might have very different temperatures at 400m, depending, for example, on whether they are within pinched-off eddies. It is also worth noting that warm eddies can form cool mixed-layers over them, making them invisible to the satellite. It is therefore only on the basis of related information that we can say that 1997 was anomalous at the depths that matter to gemfish.

Benthic Temperature Data

As a first step towards improving our understanding of how the spawning migration is affected by water temperature, three Vemco temperature-depth recorders (TDRs) were purchased for the project and deployed on the Marina Star between 20 June and 31 July, on the Illawara Star between 20 July and 4 August, and on the Santa Rosa A between 7 July and 4 August.

Viewing Temperature Depth Data

A sample of the raw data collected is provided by figure 24a&b which shows the time line against which depth and temperature measurements were logged by a TDR deployed from the Marina Star on 6 & 7 July, 1997.

These two time-lines map out the typical fishing day for the Marina Star during the 1997 survey. The net was shot away for the first time each day just before dawn, around 06:30 local time. The first shot of each day was about 4 hours long and the trawl was hauled around 10:00-10:30. By around 11:00-11:30 the net would be cleared of catch and shot away for an 3-4 hour afternoon shot.

The four shots shown in figure 24a& were mainly trawled in 450-500m, below the gemfish line, aiming rather to optimise the catch of mirror dory, ling and ocean perch. On 6 July (Figure 24a) the afternoon shot went down almost to 600m near the end of the shot this was probably to see if a scatter of blue grenadier and bigger ling could be added to the catch.

In contrast twice during the morning shot and at the end of the afternoon shot they trawled into 450m or less. This was to sample the gemfish line and determine whether or not they should start fishing along the gemfish line with their next shot.

The fishers think that the size distribution and quantity of gemfish sampled in slanted shots like these give a good indication of whether trawling on the gemfish line is likely to be worthwhile. While they would get more gemfish if they completed an entire shot along the gemfish depth they would also catch considerably less of the other valued species. So before the gemfish aggregations form they mainly fish outside the main gemfish depths.

Marina Star's typical fishing day involved towing mostly deeper than the gemfish line and only occasionally towing on or on the lower edge of the gemfish line. This pattern of fishing was typical of the SET fleet through the area during 1997

With regard to temperature the figures show that the surface temperature on 6 and 7 July was around 17.5°C which is in agreement with the SST imagery for the area (Figure 11c). Bottom temperatures were fairly constant 8-10°C.

Temperature Depth Profiles

A simpler view of these same data can be obtained by removing the time dimension from the data and viewing them as simple Temperature-Depth profiles (TD profiles) as in figures 25a-x.

However in changing view of the data it is useful to remember that these TD profiles actually have two distinct regions of data. The upper right hand segments of the profiles were recorded during the relatively short periods at the beginning and end of each shot, when the net and headlines were falling or being hauled through the water column.

These segments of the TD profiles record a crude cross section of the water column over the trawl ground. These cross sections are crude because they were recorded over relatively short time periods with only 5-8 measurements during each descent or ascent. Furthermore the warming and decompression during the retrieval of the net is likely to cause a small bias within the TDR sensors. The effect of this bias would be that the temperatures registered on the way up will be slightly colder for any depth. This bias would cause the decent profile to differ slightly from the ascent profile even if the actual temperature-depth profile was exactly the same.

Generally ascent profiles appear smoother and less structured than the slightly more accurate descent profiles. Despite the relatively few points and slight bias contained within the data these segments of the TD profiles roughly describe the temperature profile of the water column above the trawl grounds.

Most of the measurements made with the TDRs were recorded as the demersal trawl nets were dragged along the bottom, within a relatively narrow depth band of the shelf break. These records appear as the lower left hand segments of the TD profiles and they report variations in temperatures several meters above the trawl ground. While the segments cover only a small area of the chart they are actually comprised of hundreds of measurements.

In these bottom segments of the TD profiles the height above the substrate remains the same and any a change in depth also equates to a movement inshore or offshore, up or down the continental slope. Not simply up or down in the water column.

The Temperature Depth Profiles of the Marina Star

Figures 25a-x presents the complete time series of TD profiles collected on the Marina Star. This time series is of most interest to this study because it was the longest collected during 1997, and because the Marina Star recorded the highest catch rates of gemfish during the survey.

Only a few selected profiles are presented from the other two Wollongong vessels in order to reduce repetition. They show generally similar features as those of the Marina Star.

Pearce (1981) lists the temperature and salinity characteristics of the water masses found in the Tasman Sea. In our study area these are (listed by increasing average density):

1. Coral Sea (20-26, 35.4-35.6, 1024.3) i.e. East Australian Current
2. Central Tasman (15-20, 35.5-35.7, 1025.8)
3. South-west Tasman (12-15, 35.25-35.4, 1026.5)
4. Bass Strait (12-17, 35.5-35.7, 1026.5)
5. Sub-Antarctic (9-10, 34.6-34.7, 1026.7) widespread at 500m.

Surface Waters
As expected water temperatures through the study area generally decline with increasing depth, from the 20-22°C surface waters of the Eastern Australian Current (EAC) to the 9-10°C Sub-Antarctic Water around 400m.

On some days (23 June, and 8, 15, 22, 24 July; Figures 25d,j,o,s & t, respectively) the temperature profile was relative smooth and the relationship between depth and temperature relatively linear. However characteristically some structure was evident in the temperature profile of the water column, indicative of the water bodies mixing along the Tasman Front and NSW shelf break.

With the exception of the period 23-25 June (Figures 25d-f) when surface temperatures rose above 20°C suggesting an intrusion of Coral Sea water into the area, the surface 100m of the water column was generally a uniform 17-18°C indicative of well mixed waters of the Central Tasman. Consistent with observations made using the SST images the coolest surface temperatures (16.8°C) were measured on 13 July (Figures 25m) when peak catch rates of gemfish were also recorded.

The 100-150m Thermocline
There was usually strong (2-4°C) thermocline around 100-200m between the surface temperatures and temperatures around 14°C indicative of either South-west Tasman of Bass Strait waters. Without salinity sensors we are unable to distinguish between these two alternative water masses however given the location of the study area it is likely that the water is of South-west Tasman origin. As with the entire water column this feature was also variable. Between 23-25 June (Figures 25d-f) and again between 24-30 July (Figures 25t-w) this thermocline was not particularly evident.

South-west Tasman
The extent, depth and temperature of the layer of South-west Tasman water varied considerably through the time series. At the beginning of the times series (20 June - Figure 25a) this layer was between 200 and 400m and about 14.5°C. During the following 4 days it became less pronounced and thinned, lying between 200 and 300m by 24 June (Figure 25e). Around 24 and 29 June (Figure 25g) the layer apparently destabilised as first the water column above it cooled creating a temperature inversion. By 6 July (Figure 25h) it had cooled to around 13.5°C, 7 July (Figure 25i) it had risen to between 100 and 200m, and by 8 July

(Figure 25j) it was not evident in the profile at all. Between 11-14 July (Figure 25k-n) and again on 20 July (Figure 25q) a mixed layer of 13.5°C layer was again evident between 300 and 400m but not as distinctly on 15, 17 July or after 21 July (Figure 25o,p,r respectively).

Sub-Antarctic Water and the 400-450m Thermocline
Continuing down the water column, around 300 - 400m the TD probes detected the colder Sub-Antarctic Waters. At these depths temperature generally declined relatively smoothly with depth, from around 13°C at 300 – 400m down to 9°C at 500 – 600m. But as with the other features of the water column through the study area considerable variability was seen in the temperature and depth of this water body. Around 7 and 8 July (Figure 25i,j) 13°C water had ascended to about 200m and at the end of July (Figure 25v,w) water of that temperature was detected around 150m

However the most interesting variant at these depths were ephemeral thermoclines that were evident between 400 – 450m on 11-14, 17, 20, 21 and 30 July (Figures 25k-n,p,q,r,w). These thermoclines were strongest around 11-14 July, the time of the peak gemfish catches, when temperature differences of up to 3°C were detected within the gemfish depth (400-450m).

A different view of this variability is given by Figures 26a & 26b which show the raw time series data from 7 & 13 July respectively. In these figures the variability that was evident on 13 July (Figure 26b),but not on 7 July(Figure 26a) gives the temperature curve a jagged, saw tooth appearance. This feature was most evident and persistent between 11-14 July around the time that the peak catches of gemfish occurred. A temperature range of 9.5-12.0°C was observed in 400-450m. On other occasions, for example 8 July, a depth change of almost 200m would have been required to achieve this temperature range.

These observations show that there was frontal activity occurring in gemfish depths at the time and location of the peak gemfish catch and strongly suggest that gemfish aggregations were forming around an interface between Sub-Antarctic water and South-west Tasman water.

Acoustic Data

Due to a combination of technical glitches and southern nature of the gemfish season in 1997 the collection of acoustic data from the industry gemfish survey was, again, not as successful as it should have been.

A major problem with the collection of acoustic data during both the1996 and 1997 seasons was caused by the poor configuration of the EchoListener software and the relative lack of acoustic expertise within the project team. The poor configuration of the EchoListener software meant that the EchoListener shut down whenever a key on the EchoListener keyboard was touched, or whenever a certain piece of equipment aboard the Santa Rosa A was activated. The lack of onboard acoustic expertise delayed the detection of problems with acoustic data collection and then the correction of the error.

Some of these problems arose directly because of the low cost approach to this element of these industry surveys. Should acoustic data be collected in future gemfish surveys these problems should be corrected by:

- Increased expenditure on hardware to make it more water proof, compact and generally compatible with shipboard conditions.

- Improved acoustic expertise of field observers so that hardware and software can be serviced from the field NSW and not via Hobart. Currently the acoustic data needs to be handled in the field every few days to make sure the projects objectives are being met.

- Improved design of the EchoListener software to ensure it reboots after inadvertent shutdowns. In various other ways it also needs to be proofed against fools while being fully serviceable by idiots like sleep deprived observers. The capacity of the project team also needs to be developed to ensure that data can be processed by biological observers in the field in NSW. In this way problems with data collection will detected and rectified at the earliest possible point.

Prior to the 1997 season the decision had been made to monitor both the echosounders on the Santa Rosa A using two EchoListeners; and conversely also the decision not to monitor the Marina Star's. This was in the hope of collecting dual frequency acoustic data which might potentially give some species definition. The reasons behind the decision are documented in the Methods section of this report.

Unfortunately no dual frequency acoustic data were collected during 1997. So the potential use of multi-frequency acoustics for measuring the biomass of aggregations of spawning gemfish could not be practically tested.

No dual frequency data were collected because early in the 1997 season it was noticed that the acoustic data being collected were intermittently being badly affected by acoustic interference making acoustic analysis impossible. Interference is the cause of the diagonal streaking that can be seen in the early morning Echogram for the 14 July (Figure 27a).

It was initially assumed that the interference being recorded was between the two sounders of the Santa Rosa A. So one of the vessel's echosounders and an EchoListener were shut down part way during the season and data was only gathered with one frequency. Budgetary restraint did not allow the spare EchoListener to be moved to the Marina Star.

However analysis of the complete acoustic data set after the 1997 season shows that the interference recorded was probably not between the Santa Rosa A's own

EchoListeners. Instead it seems to be from the other vessels working closely around the Santa Rosa A. This is deduced because switching off one of the Santa Rosa A's echosounders had little effect on the level of interference recorded.

In 1996 only the two survey vessels from each port fished for gemfish and we did not detect any problems with interference. In 1997 all four Wollongong vessels would regularly try to fish along the same gemfish ground at the same time of day. Later in the season there were also vessels from southern NSW ports.

To compound the difficulties that were had trying to achieve the acoustic projects objectives, in contrast to 1996, no large gemfish aggregations occurred off Wollongong during the 1997 season.

Despite the litany of woe which continues to surround the use of SonarData's EchoListeners the two Industry Surveys of Gemfish have now gathered a large body of interesting acoustic data and have demonstrated the technical feasibility of collecting scientifically useful acoustic data from fishing vessels. This point is illustrated further by the following discussion of the acoustic data collected during the 1997 survey.

Biology of the deep scattering layers

Despite being the most extensive habitat on the earth's surface little is known about the ecology of ocean's deep midwater habitats (Koslow 1997).

Barham pioneered the study of the inhabitants of the oceanic midwater in the canyons off Monterey during the 1950s using the comparatively primitive 1950s midwater trawl and sonar technology. He described a relatively sparse fauna comprised of deepwater prawns, squid, and arrow worms that resided below 300m during daylight but migrated each night to the surface.

More recently using submersible vehicles to make *in situ* observations in the same area Robison (1995) has described a rich and dynamic multi-specied assemblage living under low light conditions in an environment structured by pelagic jellyfish communities. Most of the midwater species studied by Robison make large vertical migrations on a daily basis; hiding in the dark around or below 500m during the day and over full moons, and rising to feed in the productive surface layers of the ocean under the cover of dark. Most of these midwater species orientate vertically within their habitat, rather than horizontally. They tend to feed upwards by silhouetting their prey against the ambient surface glow, and dive towards safety in the dark when threatened.

The acoustic data gathered during the 1996 and 1997 gemfish seasons show that the species occupying the deep midwater habitat of the SEF also exhibit the same diurnal vertical migrations observed off Monterey.

Figures 27 – 29 show the echograms around sunrise for 14, 21 and 13 July respectively. Each echogram the solid line around 350-400m is the seabed of the continental slope. High above the bottom between 0-100m and around 200m two distinct bands of acoustic returns are often visible.

These acoustically reflective layers are the deep scattering layers that the gemfish fishers call “feed layers”. They believe that gemfish, together with most of the SEF slope species feed and swim within these deep scattering layers. The gemfish fishers say that the feedlayers build up during winter and they associate the gemfish run with periods of the greatest abundance of these “feedlayers”.

The composition of the bycatch taken during the 1996 and 1997 surveys show that like the midwater ecosystem described by Robison and Barham off Monterey many species occur within the midwater feedlayers along the NSW shelf break. Figure 30a-d shows some of the by-catch taken while fishing for gemfish. It is evident from the diverse faunal assemblage caught that, as the fishers claim, the feedlayers off NSW contain an entire food chain of species. At the base of the food chain are plankton and jellyfish eating species, and at the top are fish and squid eating species such as gemfish and frostfish together with school sharks, makos, threshers, juvenile seven gill sharks and oil fish.

The fish within the multi-specied assemblage caught by SEF trawlers predominantly have upward looking eyes and have adaptations to reduce their visibility under low light conditions. To this end minimal profiles and counter shaded colouration in reds, white, blacks and mirror silver are common amongst the fauna of the SEF.

Figures 27-29 shows the typical movement patterns and depth distribution of these “feed layers” around dawn (approx: 07:00) each day during the gemfish season. Prior to sunrise heavy marks are normally observed in the top 100-150m of the water column and also between 200-300m.

On 14 July (Figure 27a-d) there was a heavy mark above 50m around dawn as well as a heavy mark around 250m. Both layers sank in the water column and thinned around 06:30. The continuing layer along the surface after 06:30 is the bubble layer around the hull of the vessel, while the occasional heavy blue lines across all depths are missing data where the role and pitch of the vessel interfered with the acoustic beam.

Immediately prior to dawn (Figure 27a) the 250m layer seemed to receive a “rain” of marks into it from the surface layer above. After dawn this lower band clumped more tightly while sinking in the water column and apparently dissipating. Around 07:00 (Figure 27d) the thinned 250m layer had descended to about 350m and was relatively close to the bottom.

On 21 July (Figure 28a-g) the surface band was thick above 150m depth and extremely light between 250-300m. Around 06:00 (Figure 28c) the surface band had tightened and moved into the surface 50m before starting to dive around 06:15 and slowly dissipate (Figure 28d). By 07:00 the original surface feedlayer had dived down to 200-250m and was greatly reduced in acoustic strength

(Figure 28f). By 07:15 there was virtually no acoustic biomass visible on the echogram (Figure 28g).

The morning echogram from 13 July (Figure 29a-f) shows the bottom line running along in about 260m. A thick but dispersed surface layer in the surface 100m dives down to below 200m before 07:00 (Figure 29c). This 50m thick band lingers approximately 20m above the bottom until around 07:30 when it starts to disperse and disappear (Figure 29c). Between 06.40 and 07.15 there were sporadic dense marks against the bottom between 250 and 260m (Figures 29a-d).

Integration of the strength of acoustic returns for the 13 and 14 July showed that after sunrise the total acoustic biomass in the ensonified water column had declined to <10% of pre-dawn levels. On an occasional basis this change in acoustic biomass could be plausibly rationalised as the acoustic marks moving away laterally, out of the path of the observing vessels. However the consistent timing of these changes with daylight precludes the entire phenomena being explained in this fashion.

Some of the detected decline in acoustic biomass around dawn is probably due to decreasing acoustic reflectivity of the component species in the midwater marks. Thus many of the species may not be moving out of view but becoming less visible to the acoustic beam.

Robison (1995) observations have shown that most of the fish species in the midwater environment orientate vertically. Feeding upwards and diving downwards away from danger and light. Around dawn as these species approach the top of their daily vertical migration and begin to dive away from the approaching light these fish would change from an upward orientation through a lateral orientation to a downward orientation. This change in orientation would cause their acoustic reflectivity to vary greatly. The heads of fish are blunter than their tails and consequently most fish would be more reflective when ascending through the water column, than when diving. But near the surface and swimming laterally those species with swim bladders would present the largest acoustic targets and be most reflective.

However the magnitude of the decrease may also suggest that many species in these midwater marks actually dive down the continental slope to depths greater than the trawl grounds and thus disappear below the bottom horizon of these echograms.

Recent results from archival tags placed in school sharks by John Stevens of CSIRO (FRDC - 96/128) illustrate for a single species found within the feedlayers the diving behaviour recorded acoustically for the species assemblage (Figure 30c). Figure 31 was presented to SharkFAG and shows data downloaded from an archival tag carried by one of school shark tagged and recaptured near Robe, in S.A. Both sharks spent most of their days between 300 and 500m but ascended nightly to above 100m.

Gemfish fishers time their morning shots to coincide with the dawn dive of the feedlayers and hope to trawl through the midwater marks when they are against the seabed and within range of their bottom trawls. Gemfish fishers believe that the acoustic marks need to be within 4-5m of the bottom (the height of their headropes) to ensure good catches

TD Profiles & the Distribution of Deep Scattering Layers

Comparing the TD profiles with the echograms collected it becomes evident that despite their vertical migrations, the distribution of the feedlayers is related to the temperature profile of the water column.

Figure 32a-c shows the TD profiles collected on the Santa Rosa A at the same time as the above echograms shown in figures 27-29. Comparing the Echograms and TD profiles shows that at dawn the upper scattering layer is normally scattered relatively uniformly through the upper 50-100m of the water column in the well mixed 18-20°C EAC waters. While before dawn the deeper scattering layer is dispersed through the 13-15°C South-west Tasman waters around 200-350m.

Before dawn the acoustic biomass appears to avoid the thermocline between these two water masses and this thermocline effectively defines the boundary between the deeper and shallower scattering layers.

While seeming to avoid the thermoclines before dawn the species within the acoustic biomass evidently dive through the thermocline after sunrise. But in approaching and passing through the thermocline the appearance of the scattering layer changes. The feedlayers usually concentrate into smaller denser marks as they move across the thermocline and often dissipate and gradually disappear when they approach or pass through the thermocline.

Echograms of Gemfish

The morning echogram from 13 July (Figure 29a-f) shows the bottom in about 260m. A thick but dispersed surface layer in the surface 100m dived down to below 200m and lingered in a 50m thick band until around 07:30 when it dispersed.

Between 06:40 and 07:15 (Figure 29a-d) there were sporadic dense marks against the bottom between 250 and 260m. These acoustic marks have the appearance that gemfish fishers associate with gemfish.

The Marina Star reported marks like these when they caught approximately 13t on 13 July. For several weeks prior to 13 July large solid midwater marks had been building up over the trawl grounds off Ulladulla. On the morning of 13 July the solid midwater mark remained 20-30m above the trawl ground but small solid feed marks like those seen in 29a-d, dropped down to the bottom out of the midwater mark. The resulting catch was an almost pure catch of gemfish with almost no by-catch.

While the morning echogram collected on the Santa Rosa A 13 July has all the appearance of gemfish marks it is entirely uncertain as to whether or not these marks are in fact gemfish. The shot was completed in only 250-260m while gemfish are normally expected in about 400m and the catch only included 35kg of gemfish.

However there were definitely gemfish aggregations in the area on this day. The Illawara Star towing in 410-430m took 700kg and 750kg in its two shots for the day, while the Santa Rosa A towed in 380m for its afternoon shot and caught 3,805kg of gemfish.

On the afternoon of 13 July (Figure 33a-d) by around 13:30 diffuse marks were rising back into the water column and were visible between 250-300, some distance above the bottom in 340-350m. The afternoon was rough and unfortunately a lot of data is lost due to the strong vertical lines caused by the bubble noise under the transducer and the roll and pitch of the vessel. By 15:00 (Figure 33a) it is possible to see that the feedlayer around 200m is dense and 25m thick. It continues to thicken and has risen to 150m by 15:45 (Figure 33d). Only small and generally light nondescript marks are visible against the bottom during the echogram. Although it is not possible to see much of the bottom zone through the noise after 12:45. The most obvious mark against the bottom was around 11:55 when a relatively small but dense mark 10-15m high was observed within the bottom 20m of the water column.

Bottom Features, Temperature Anomalies & Fish

Combining Echogram and TD profiles also provides a striking example of the way bottom profiles interact with the water column and the distribution of fish.

Figure 34a-c show the cruise track of the Santa Rosa on 21 July, 1997 (a) and two echograms (b&c) made around the southern most part of the cruise track, south of latitude 35° 4.0'S. In that area between 9.30 and 12.00 the Santa Rosa A finished, hauled and sorted the morning shot made towards the SSW, then shot away for an afternoon shot to the NNE inside (to the east of) the morning shot.

The echogram are different views of the same general area. Figure 34b was made 09:30 – 10:00 towards the end of the morning shot as the vessel towed SSW, a solid fish mark can be seen at the center of the echogram close to the bottom in 300-350m. The Santa Rosa A towed through the mark and hauled the gear, finishing her shot on the eastern edge of a rocky bluff .

As the catch and gear was sorted and readied for a second shot the Rosa A slowly zigzagged over the reefy area. Figure 34c is an echogram made of the feature around 11:15 as the vessel moved across the feature to shoot away. The changed colour of the bottom echo in 350-300m, to the extreme right of the echogram, shows that the area being ensonified is rocky. Acoustic marks are gathered around the bluff between 350-400m and stretch away into the midwater between 400-450m.

The rocky bluff and fish mark in these echograms was associated with the temperature anomaly seen in figure 32b. Bottom temperature around the fish mark in figure 34b, and around the shallower side of figure 34c, was around 11°C while the surrounding water at that depth as above 13°C.

Other researchers of SEF ecology have noted the co-incidence between geological features and oceanographic and biological phenomena. Nick Bax of CSIRO (personal communication) has monitored water flow down the water column near Cape Howe and has observed that shelf edge features several meters high create measurable pressure waves up to 80m above the bottom. They observed acoustic marks to be associated with these pressure waves.

McClatchie *et al.* (1995) postulate that steep features along the edge of the continental shelf of temperate NZ intensify the rate at which EAC and Sub-Antarctic waters mix, thus intensifying phytoplankton production in the Sub-Tropical Convergence.

Discussion of Acoustic Results

The dynamic aggregation behaviour, and multi-species composition of the acoustic biomass surrounding gemfish aggregations will never be highly conducive for the accurate assessment of gemfish biomass using acoustic techniques. The results to date from these industry surveys at least demonstrate this point. Assessment of gemfish biomass with acoustic techniques is not feasible given current technology and even with expected technology advances it is always likely to be problematic.

The multi-species nature of the acoustic biomass presents major obstacles to the use of acoustic techniques for measuring gemfish biomass. A certain ability to distinguish gemfish from the mass of other species will be essential if acoustic techniques are ever likely to be useful in the situation. Multi-frequency acoustic techniques offer some hope of this. If any further acoustic work is to be carried out it should use multi-frequency techniques.

The variability of the aggregations in time and space also presents formidable difficulties for designing a cost effective fishery independent survey of the aggregations with any technique. The hourly, daily and weekly variability of the aggregations between June and August, together with their mobility between Lakes Entrance and Newcastle means that surveys planned in advance for restricted time slots and localities will run a high risk of occasionally failing to observe aggregations. To minimise the risk of failing to survey gemfish aggregations structured surveys would need to use multiple survey vessels and have them available to survey throughout the 3 month gemfish season. Such a survey will by its nature be expensive to conduct.

The above arguments are not meant to imply that there is no further role for acoustic studies of the gemfish run.

Little is known about the pelagic ecosystems of the ocean's midwaters. The temperate trawl fisheries along Australia's and New Zealand's shelf edge are unusual in their targeting of these deep midwater species. The industry based acoustic techniques applied during these surveys offer a powerful tool that could be used cost effectively to study these ecosystems in the SEF.

1997 Eastern Gemfish Stock Assessment

In negotiating funding for this project FRDC requested that this report include a summary of the 1997 stock assessment for eastern gemfish. It should be noted that while this project collected data that formed part of the basis for 1997 stock assessment of eastern gemfish this project did not complete the assessment. The Eastern Gemfish Assessment Group (EGAG) undertook the 1997 assessment of the eastern gemfish stock with Andre Punt of CSIRO developing much of the analytical software used in the analysis. It is the work of EGAG which is summarized in this section.

Eastern Gemfish Assessment Group (EGAG)

EGAG was established as a consequence of an eastern gemfish workshop held in April 1996. EGAG's objectives are to:

- provide advice and information on the review, development and coordination of research on eastern gemfish, to SEFAG and other relevant groups
- develop an assessment of the status of the eastern gemfish resource as part of the preparation of stock assessment reports by SEFAG
- develop and evaluate harvest strategies for managing eastern gemfish.

EGAG consists of members with a variety of skills, and includes fishers, population modelers, biologists, economists, conservationists and managers. It has met nine times. EGAG has tried to use all relevant information on eastern gemfish in its assessment and advice. This information includes existing fisheries and scientific data, hypotheses about the biology of the stock, direct experience with the fishery, and historical knowledge about the fishery. EGAG has produced one previous stock assessment report, in March 1997 (the 1996 assessment). It has also developed a five year research strategy for eastern gemfish.

In 1997 the participants in EGAG were:

Members

Tony Smith, CSIRO (Chair)
Jeremy Prince, Biospherics P/L
Kevin Rowling, NSW FRI
Peter Bell, Industry
Anthony Jubb, Industry
Con Poulos, Industry
Andre Punt, CSIRO
Barry Kaufmann, Consultant
Bill Foster, Humane Society International
Katrina Maguire, AFMA
Jon Harford, AFMA
Kendall Nihill, AFMA (Secretary)

Invited Participants

Jean Chesson, BRS
Richard Tilzey, BRS
K Radway Allen, NSW FRI
Chris Grieve, AFMA
Geoff Diver, Biospherics P/L
David Griffin, CSIRO

This extract of EGAG's October 1997 report provides the most recent information about the status and productivity of the eastern gemfish population, and about the implications of some alternative harvest strategies.

EGAG Report October, 1997 - Executive summary

- The current biomass of eastern gemfish is estimated to lie between 2300-4500t or 12 to 31% of the unexploited equilibrium level. The stock is assessed to be decreasing as the strong 1990 year class starts to decline, and is replaced by weaker year classes spawned from 1992 to 1994. The current base case assessments suggest that the stock is below the reference point of 40% of the 1979 level.

- The assessment of time trends in biomass and recruitment is in broad agreement with previous assessments, and indicates that the biomass declined in the early 1980s and that several weak year classes were spawned in the late 1980s.

- The level of uncertainty in this year's assessment is greater than in last year's. The results are particularly sensitive to the inclusion or exclusion of the 1997 catch rate estimates.

- The low catch rate during 1997 reflects several factors including; the size of the gemfish stock, the poor weather conditions for fishing, the response of fishers, and the influence of oceanographic factors on catchability. Although it is recognised that these factors influence catch rate it should be noted that the exact relationships and relative influences are unknown for this and most other fisheries.

- A set of alternative harvest strategies in the range of 0 to 1500t per year is evaluated. This evaluation highlights the importance of natural variability in recruitment of gemfish.

Catches in the range considered in this report are unlikely to produce catch rate information suitable for inclusion in the 1998 stock assessment. EGAG recommends a survey in 1998 to provide an adequate index of abundance. This would require the setting of a research quota.

Model specifications

The model used in the assessment was developed specifically for the gemfish fishery, and incorporates a number of aspects of the stock and fishery suggested by members of EGAG. It is age- and sex-structured and takes account of both the summer and the winter fisheries. Values for the parameters of the model are estimated by fitting it to the data sources listed below under 'data inputs' above. Maximum likelihood and Bayesian estimation frameworks were used. The maximum likelihood method estimates a single best fit to the data given the model and data specifications, and was used to investigate the impact of a wide range of changes to the specifications (both data and model structure) of the basic assessment. The Bayesian method takes greater account of uncertainty about the fit of the model to the data, and therefore provides a more suitable basis for evaluating the outcomes and risks associated with future possible harvest strategies. Full technical specifications of the assessment are provided by Punt (1997).

The results of the maximum likelihood analyses were used to:

- identify the sensitivity of important management-related outputs (for example, current depletion) to the data and model specifications,
- understand the behaviour of the model, and
- assess the impact of the various data sources on the assessment results (for example, the choice of the time series of historical catches).

The Bayesian method was applied to a selected set of the sensitivity analyses undertaken for the maximum likelihood approach. These tests included sensitivity to the weight assigned to the catch rate data, the possibility that selectivity to the winter fishery is density dependent, and the possibility that the strengths of successive year classes are correlated.

Results of the 1996 assessment

The results were generally insensitive to changes to the specifications of the model and the data used. The estimates of current stock size ranged from 4,000 to 5,700t for series A and 4,100 to 6,100t for series B. The estimates of current $5^+/6^+$ biomass relative to that in 1979 (E_{96}/E_{79}) ranged from 44 - 63% for catch series A and 48 - 72% for catch series B. The probability that E_{96} was larger than 40% of E_{79} was greater than 0.99 for both catch series, which exceeded the management criteria for stock rebuilding.

The choice of historical catch data series had a major impact on the estimates of unexploited equilibrium biomass B_0 and current (1996) depletion. For the Bayesian assessment, estimates of current depletion of the mid-season winter biomass (B_{96}/B_0) ranged between 30% - 46%[1] (catch series A), and 24% - 38% (catch series B). B_0 was estimated to lie between 11,000 and 15,000t for series A and between 15,000 and 19,000t for series B.

The results were also sensitive to

- how representative the 1996 survey was of previous fishing patterns,
- whether catch rates are directly proportional to abundance (the consistency of these results with those of Allen (1989), which did not rely on catch rates, suggest this may not be a major problem), and
- the relationship between spawning stock size and consequent recruitment.

The influence of recruitment variability on the stock dynamics was found to be substantial. The results indicated that the year-classes spawned in the 1970s and early 1980s were consistently larger than expected, given the sizes of the spawning stock, while those spawned during the late 1980s were consistently smaller than expected. The 1990 and 1991 year-classes were larger than expected from the small size of the spawning stock. Recruitment of these year-classes to the mature population was the major reason for the recent increase in the biomass. The 1992 and 1993 year-classes were estimated to be smaller than expected, while preliminary information suggested that the 1994 year-class was larger than expected.

The results of the 1996 assessment were in broad agreement with previous assessments of the gemfish stock in a number of important respects. For example, the biomass trajectories for the assessment based on both catch series were in good agreement with the assessment of Allen (1989) for comparable periods. The assessment also supported previous advice that recruitment of cohorts spawned in the late 1980s was substantially less than in previous years.

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1 The ranges defined here are 90% probability intervals.

The 1997 Assessment

Data inputs

The data used in the 1997 assessment are of the same type as in the previous. Changes or additions to the data inputs for the 1997 assessment are described below.

Catches

The two catch series used in the previous assessment were retained, but modified to exclude catches prior to 1968. Catches for 1997 up to September were included in the analysis..

Catch rates

The standardised time series of daily catch rates for the winter trawl fishery used in the 1996 assessment was updated using data from the 1997 commercial trawl fishery rather than the 1997 Industry Survey. This was because EGAG decided that the Industry Survey Data documented fishing patterns that were representative of the whole fleet. With that view the use of SEF1 data for the whole fleet was preferred over the four vessel Industry Survey data with relatively few data points.

Age and length

Length data for the 1997 assessment used the data gathered by the 1997 Industry Survey rather than the NSW FRI market measuring data. EGAG considered that the survey data from shots in gemfish depths gave the best estimate of the size structure of the adult gemfish stock.

No new age data were available for this assessment.

Model specifications

The model used for the 1997 assessment differs slightly from that used during the 1996 assessment. Full technical specifications of the assessment are provided by Punt (1997b). Only the Bayesian estimation framework was used for the current assessment. This is because it takes greater account of uncertainty about the fit of the model to the data.

The Bayesian method was applied to a set of sensitivity analyses. These included sensitivity to the choice of catch series, whether the strengths of successive year-class are correlated, and whether selectivity to the winter fishery is density-dependent. Further sensitivity analyses are based on excluding either the 1996 or 1997 catch rates.

Results

- Estimated trends in biomass and recruitment from 1968 to 1994 are very similar to those for the 1996 assessment. Results for the 1997 base case assessment include:
- mean estimates of depletion relative to pre-fishing levels are 18% to 22% depending on the catch series assumed;
- the probability that the 1997 spawning biomass exceeds the reference point of 40% of 1979 level is estimated to be very low; the mean estimates of 1997 spawning biomass relative to the 1979 level are 28% to 30% depending on the catch series assumed.;

- as in previous assessments the current assessment explains the age, length and sex ratio data well

- the model does not adequately explain the observed decline in catch rate between 1996 and 1997 seasons
- the assessment confirms an increase in biomass occurred during the mid 1990s, but suggests a decline from 1996 to 1997
- the population is dominated by the year class spawned in 1990. In that year an unexpectedly large number of young was produced from a relatively low level of spawning stock.
- the year classes between 1987 and 1995 are on average only about 20% of those between 1973 and 1986; this could be either an effect of reduced breeding stock or a shift in environmental conditions or a combination of the two.

Notable features of the 1997 assessment results relative to those for the 1996 assessment include:

- the 1997 assessment gives a higher but more uncertain estimate of pre-fishing biomass than the 1996 assessment
- the 1997 assessment indicates that the 1996 biomass was smaller than estimated in the 1996 assessment
- there is an increased probability that the stock was below 40% of 1979 levels in 1996, based on the 1997 assessment.

Results of the 1997 assessment are very sensitive to the catch rate data for the last two years. This is illustrated in Table 3 which shows the effects of leaving out either the 1996 or 1997 catch rate, relative to the base case analysis (which includes both data points). The results show that (for both historical catch series):

- leaving out either point significantly improves the fit to the catch rate series;
- there is little impact on fits to the age, length and sex composition data
- the “no 1997” assessment produces a slightly better fit to the data
- estimates of current depletion and status relative to the 1979 level are very sensitive to these data
- estimates of stock productivity are also very sensitive to recent catch rates. The scenario that ignores the 1996 catch rate data and uses catch series A gives implausibly low estimates of productivity. However the estimate of biomass for this scenario is not implausible.

Considerable sensitivity to catch rate data highlights the need to develop better methods to understand the impact of the environment and fishing practice on catch rates. Research to address this issue is by nature long term and complex, however every attempt should be made at collecting and storing information which relate to these topics. This may ultimately involve the collection of additional data during fishing operations.

In summary, the 1997 assessment is broadly consistent with the 1996 assessment in terms of historical trends in biomass and recruitment, but the base case 1997 assessment is more pessimistic with regard to the current status of the stock. The 1997 assessments include a greater range of uncertainties. The major uncertainty concerns the reliability and interpretation of recent catch rate data. Sensitivity to the 1996 or 1997 catch rate information represents the greatest source of uncertainty in the assessment. With the exception of the 1990 year class, recruitment is estimated to have been low in recent years.

Management of Eastern Gemfish in 1998

The board of AFMA ratified SETMAC's recommendation that in 1998 there should be no targeted fishery for eastern gemfish. However provisions have been made to manage a by-catch and research catch of up to 500t. One hundred tonnes has been set aside for a research quota, 100t to cover non-trawl by-catch and 300t has been allocated to the trawl fishery.

General Discussion

The addition of the 1997 catch rates to EGAG's stock assessment increased the uncertainty of the assessment. This is not an extremely encouraging result for this project which is aimed at resolving uncertainties about the status of the high profile eastern gemfish stock.

The Eastern Gemfish Assessment Group used the results of these industry surveys together with SEF1 data to estimate that daily landings of gemfish were 50% below the level recorded in 1996. The assessment model could not fully explain a decline of this magnitude between years in terms of declining biomass. Instead of matching the trend the model described a new trend lying between the 1996 and 1997 estimates of daily landing. Consequently the model has also increased the uncertainty attached to the assessment.

Why were daily landings so different between years?

Changes in Biomass

The 1996 assessment predicted that the biomass of eastern gemfish was likely to decline in 1997 and over the next few years even without fishing. This is because the numerically strong 1990 year class is growing through the fishery and has now started to die off, by 2000 their influence on the stock will be nearly finished. The 1990 year class continues to dominate the stock because it was relatively large, but also because the year classes 1991 – 1993 all appear to be relatively small. So as the 1990 year classes dies off adult biomass levels are likely to decline unless some strong new year classes are recruited.

However in 1996 EGAG’s model expected that the processes of growth, natural mortality and variable recruitment would approximately balance each other, and that any decline in biomass would be relatively small (5-10%). In the light of the 1997 estimate of daily landings the model has made its assessment considerably more pessimistic. In fact if the 1996 estimate of daily landings is excluded the assessment suggests that the stock does not have a sustainable yield. However even the latest assessment can still only explain 15-20% of the 50% decline observed between years.

Fishing Patterns

A number of factors caused a major and unanticipated change in fishing patterns between the 1996 and 1997 seasons.

There was no eastern gemfish quota issued to the trawl sector in 1996 and all research fishing was carried out under scientific permit. The 1996 season was characterized by having the research boats “shooting the line” for two shots each fishing day. That is, the boats stayed between 360 to 480m, examined the catch after each shot and based the second shot of the day on the results of the first.

Depending on the catch, the boats would either “come in” (fish closer to 360m), “go out wide” (closer to 480m), go north, or go south.

In 1996 the vessels completed 1.6 shots on the line per day of fishing.

In 1997, 1,000 t of eastern gemfish quota was issued to the trawl sector meaning that each of the four research vessels held some of their own quota in addition to quota issued by the research project. At the beginning of the 1997 season, the research boats made the decision to fish their own quota before changing to the research quota. They therefore fished to maximise their individual financial return, rather than purely to locate the gemfish aggregation as was the case in 1996. The fishing pattern deployed was often one of spending one shot looking for the gemfish, and the second and sometimes third shot of the day fishing the waters likely to produce the best income. In some cases this meant staying on the “gemfish line”, and in others it meant targeting other SEF species. Slanted shots that ranged over a wide range of depths were also widely deployed (see Figure 24a&b) to attain an indication of gemfish density in their depth band while optimising the catch of other species.

In 1997 the survey vessels only completed 1.1 shots per day on the gemfish line.

It is to be expected that daily landings will be related to the level of targeted fishing that is occurring.

In Ulladulla, especially early in the season, fishing for other species was typically aimed at attaining a mixed catch of ling, ocean perch or mirror dory. Low (<100kg) catch rates of gemfish would normally result from these shots. While off Wollongong non-gemfish fishing was usually aimed at redfish in about 300m where the by-catch of gemfish was also minimal (<50kg). Wollongong boats also fished in <200m for flathead and various species of shark, virtually no gemfish (<5kg) is caught during these shots. Consequently daily landings of gemfish should be higher if more time is spent trawling on the gemfish line each day.

The performance of the survey vessels in 1997 confirms this expectation. There was a strong relationship between the number of shots per day each vessel made on the gemfish line and their daily landing of gemfish (Figure 35).

Based on the relationship suggested by figure 35, the decline in shots per day between 1996 and 1997 could explain daily landings declining from around 1,400kg/day to 900kg/day, a decline of 35%.

This graphically demonstrates within the context of the SEF the impact management regimes have on fishing patterns and crudely aggregated estimates of catch rate.

Clearly if EGAG wants to reduce the uncertainty attached to its assessment of the eastern gemfish stock it needs to develop a method for estimating modern catch rates that is superior to the crude estimates of daily landings made necessary by early data collected from co-operatives.

Oceanographic and Weather Conditions

Oceanographic and weather conditions varied greatly between 1996 and 1997.

One feature which was noticeably absent during 1997 was a period of westerly winds. The weather pattern over much of winter was producing fresh south-easterly winds (20 knots or above). The main cause of this was a series of fairly intense high pressure systems which formed and then remained stationary over the centre of the country. These conditions prevented fishing for much of the season and particularly around the time when peak catches were occurring.

Fishers have long claimed that strong westerly winds were historically associated with high catch rates. In 1997 they claimed that large feedlayers containing promising gemfish like marks consistently formed 50-100m off the bottom but that they rarely came within range of the bottom trawls. It is possible that by driving upwelling along the NSW coast westerly winds might draw gemfish aggregations down to the bottom and concentrate them into shoreward moving boundary layers within the range of demersal trawls.

In addition to these factors, the general movement of the Tasman Front, and the general oceanographic currents differed greatly between 1996 and 1997. Surface temperatures through the study area were much warmer in 1997 than they were in 1996 because the Tasman Front did not move as far north as it does in many years. The point where the East Australian Current detaches from the NSW shelf did move past Wollongong in 1997 but remained around Wreck Point where the peak catch was taken.

In contrast to 1996 it appears that the main gemfish aggregations did not reach the Wollongong grounds. This is consistent with the claims of fishers at Wollongong who say that the deep currents from the south and south-east which they associate with gemfish were only detected off Wollongong for one day (13 July) during the entire season.

These factors may well have played a role in reducing the level of daily landings between 1996 and 1997 although it is not possible to conclude this definitely or to estimate the likely size of possible impacts.

Time series of observations will be needed if any light is to be shed on these factors.

However a real and immediate question exists as to how the stock assessment should use the catch rates from an area where aggregations do not occur? Were the low catch rates at Wollongong indicative of low biomass and an unproductive stock? or do they indicate that the aggregations did not occur in that area? Was it a valid measurement of the strength and density of aggregations? Or was it actually a non-measurement?

Diesel Fuel Rebate

During the 1997 season Biospherics P/L was informed that survey vessels operating on AFMA's Scientific Permits would be denied the Diesel Fuel Rebate. This meant that the project budget has had to find $8-10,000 to fund past liabilities for Diesel Fuel Rebate.

This has immediate ramifications for the budget of future Industry Surveys of Gemfish but it also has potential implications for all other industry based research projects in Australian fisheries.

For general information the notifying letter from the Australian Customs Service has been copied below.

Letter from Paul Macklin

Of the Australian Customs Service

"Dear Dr Prince

I refer to your correspondence regarding eligibility for rebate on diesel fuel used during the gemfish surveys carried out by commercial fishermen on behalf of your organisation.

Information supplied by yourself and the commercial fishermen indicate that during the 1997 survey, fishermen have gemfish quota allocated to them or purchase gemfish quota allowing them to catch gemfish as part of their normal fishing operations.

During this (the 1997) fishing survey a voluntary observer survey mechanism allows Biospherics P/L to observe this operation for later reporting to AFMA.

During normal fishing operations Biospherics P/L maintain no control over this operation or the subsequent sale of the catch.

Should fishermen use all their issued or obtained quota they can lease survey quota from the project, the proceeds from this operation are divided between the fishermen and the project.

Scientific permits issued by the AFMA clearly set down the conditions which apply to the fishermen when the survey sampling is conducted.

Proceeds from the fish caught are by the terms of the Scientific Permit sold to the benefit of Biospherics P/L (Schedule 4 Item 15.16)

Section 164 (1) of the Customs Act in part states.   A rebate is payable to a person who purchases diesel fuel for use by him.

> (aa) In primary production (otherwise than for the purposes of propelling a road vehicle on a public road.

Section 164 (7)

(b) “Primary production means fishing operations

The legislation also states that the definition of fishing operation does not include any operations that are not conducted, in whole or in part, for the purposes of a business.

For the 1997 season it can therefore be concluded that the diesel fuel used to catch fish caught under the Scientific Permit (Survey Quota) conditions are caught in part for scientific evaluation. They are not caught entirely for the purposes of conducting commercial fishing operation.

Accordingly, the following decisions have been reached:

1. That rebate be refused on fuel used to take gemfish under the scientific permit / research quota.
2. That rebate be paid on fuel used to take gemfish within the quota allowed under the normal fishing permit, whether or not the vessels carry scientific observers.

That diesel fuel rebate claimants who participated in the 1996 and 1997 surveys will be notified of the position of the Australian Customs Service in relation to the eligibility of these survey operations.

If you have any questions please call me on (02) 9213 2690

Your’s sincerely

Paul Macklin
Diesel Fuel Rebate
Sydney

BENEFITS

Timely Catch Rate and Length Frequency Data

The primary aim of this project, and the immediate benefit flowing from it, was the timely provision of 1997 catch rate and length frequency data to the Eastern Gemfish Assessment Group (EGAG). This enabled EGAG to update the assessment of the Eastern Gemfish stock by October 1997 so that the South East Trawl Management Advisory Committee (SETMAC) could make an informed decision about management arrangements for 1998.

Oceanographic Influences on Gemfish Aggregations

The Eastern Gemfish Assessment Group commented in their 1997 assessment that:

"Considerable sensitivity to catch rate data highlights the need to develop better methods to understand the impact of the environment and fishing practice on catch rates. Research to address this issue is by nature long term and complex, however every attempt should be made at collecting and storing information which relate to these topics. This may ultimately involve the collection of additional data during fishinu operations."

Over several years this project has begun to describe the oceanographic context of the gemfish season seeking to understand the factors that determine the timing and location of gemfish aggregations. This work has primarily been in response to the concern of fishers that the scientific community does not understand the biology of the stock sufficiently to make an accurate stock assessment.

Many of the industry claims about influence of oceanographic influences on gemfish have been supported by the results reported here. These results are giving EGAG a clearer understanding of the variability observed with this stock and in time this may allow the described variability to be factored into the existing assessment framework to make the assessment more reliable.

Understanding the temporal and spatial variability of the gemfish run is also an essential prerequisite for eventually designing a fishery independent survey for this species which would further improve stock assessment for this species. This is because any fishery independent technique will need to aim at measuring some relatively standard part of the stock each year. This will only be possible if the spatial and temporal variability of the run is clearly understood.

General contribution to the study of SEF fisheries ecology

By serving as an in depth case study this research is also having a major impact on our understanding of the SEF species in general. Three primary factors for which these surveys have extended our generally understanding of the SEF are:

- The analysis of catch rates.
- The effect of fishing pattern on catch rates.
- The influence of oceanographic factors on catchability.

Feasibility of acoustic surveying of gemfish

Prior to this study there was a proposal from CSIRO before EGAG to embark upon a large project ($1-2 million over 3 years) to investigate the application of acoustic techniques to the stock assessment of eastern gemfish.

These surveys have demonstrated the extreme difficulty which confronts the use of acoustic techniques for the quantitative assessment of eastern gemfish. These difficulties relate to:

- The multi-species composition of the acoustic marks, and
- The temporal and spatial variability of the gemfish aggregations.

In the light of these results the CSIRO proposal has been withdrawn, potentially saving the SEF a considerable amount of research funding.

FURTHER DEVELOPMENT

These industry surveys of eastern gemfish are planned to continue on an annual basis, supported by AFMA in 1998 and through the sale of the catch in subsequent years. Modeling by CSIRO has indicated that due to the variable nature of this species and relatively short life cycle stock assessment for this species will remain critically dependent on annual information about catch rates and size structure.

In the immediate future the project will continue to collect oceanographic and acoustic data in addition to the core catch rate and length data.

At the conclusion of the 1998 survey it is anticipated that enough data will have been collected to publish an initial description of the coincidence between gemfish aggregations and EAC flow in a refereed journal. It is hoped that this body of work will in time allow survey techniques to be developed which account for this natural variability.

The aim of the acoustic studies is to document the annual behaviour and nature of the midwater marks through the study area during the gemfish season. In 1997 fishers observed large marks which did not settle down over the trawl grounds. The fishers believed the marks contained gemfish which were not catchable. It is hoped that the acoustic techniques can be developed sufficiently to start recording quantitatively this type of information. This may allow the catchability of gemfish to be studied and industry claims about its impact on stock assessment to be tested.

CONCLUSION

The daily landings documented by the 1997 industry survey of eastern gemfish were approximately 50% lower than in 1996. In 1996 approximately 27 shots were recorded with catch rates >500kg/h in 1997 the survey vessels recorded only 10 catch rates >500kg/h.

The results of this study show that in part this reflected changed fishing patterns by the gemfish fleet and the effect of the 1997 oceanographic conditions on catchability. The extent to which this result reflected lower than expected stock abundance is not entirely clear, however the stock assessment for gemfish has been revised to incorporate these 1997 catch rate data and consequently the assessment suggests a substantially more pessimistic outlook for the stock.

A total catch of less than 500t has been planned for 1998.

The results of this study show that the location and timing of gemfish aggregations is determined by the annual north-south oscillations of the East Australian Current. Aggregations apparently form around ephemeral interfaces between Sub-Antarctic and South-west Tasman waters. Designs for potential fishery independent surveys of this stock will need to account for this variability.

The results of this study also demonstrate that acoustic techniques will be extremely difficult to apply to this stock because of the:

- The multi-species composition of the acoustic marks, and
- The temporal and spatial variability of the gemfish aggregations.

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Special thanks go to the team of observers who made themselves available at short notice; Stephen Rush, Geoffrey Diver and Ashley Godwin.

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.

APPENDIX I

Intellectual Property

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

APPENDIX II

Staff

Supervision, Liaison & Reporting
Jeremy D. Prince

Full-Time Scientific Observers
Geoff Diver
Steve Rush
Ashley Godwin

Oceanographic Consultant
David Griffin

Acoustic Consultant
Ian Higginbottom
Mark Underwood

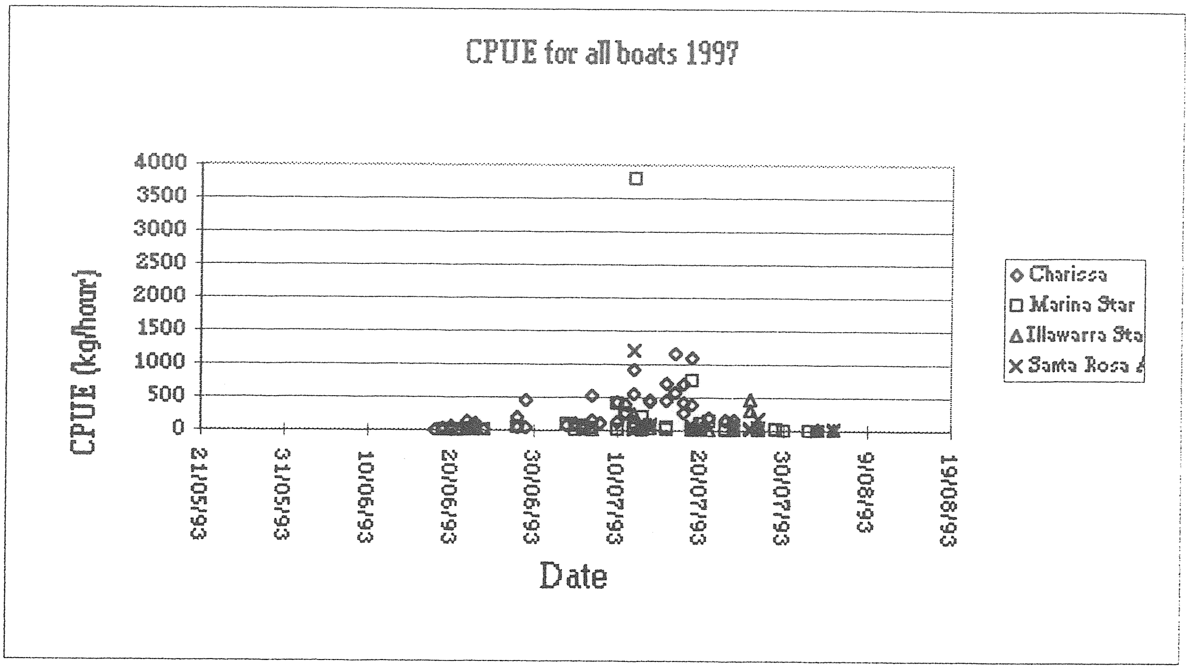


Figure 1a

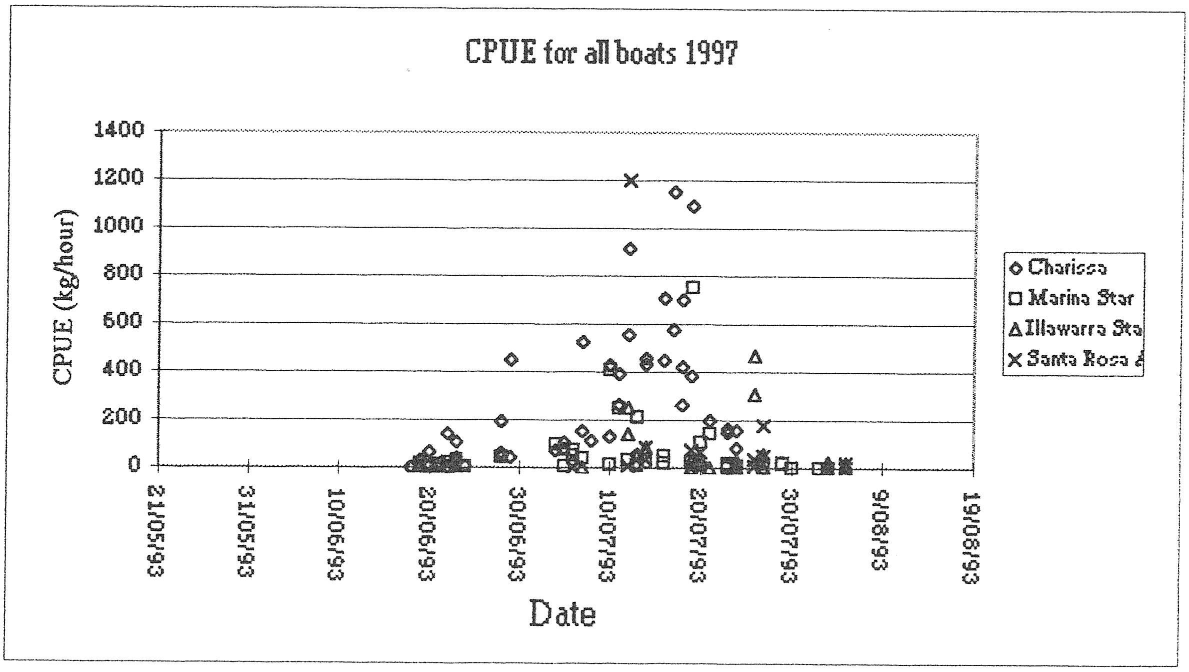


Figure 1b

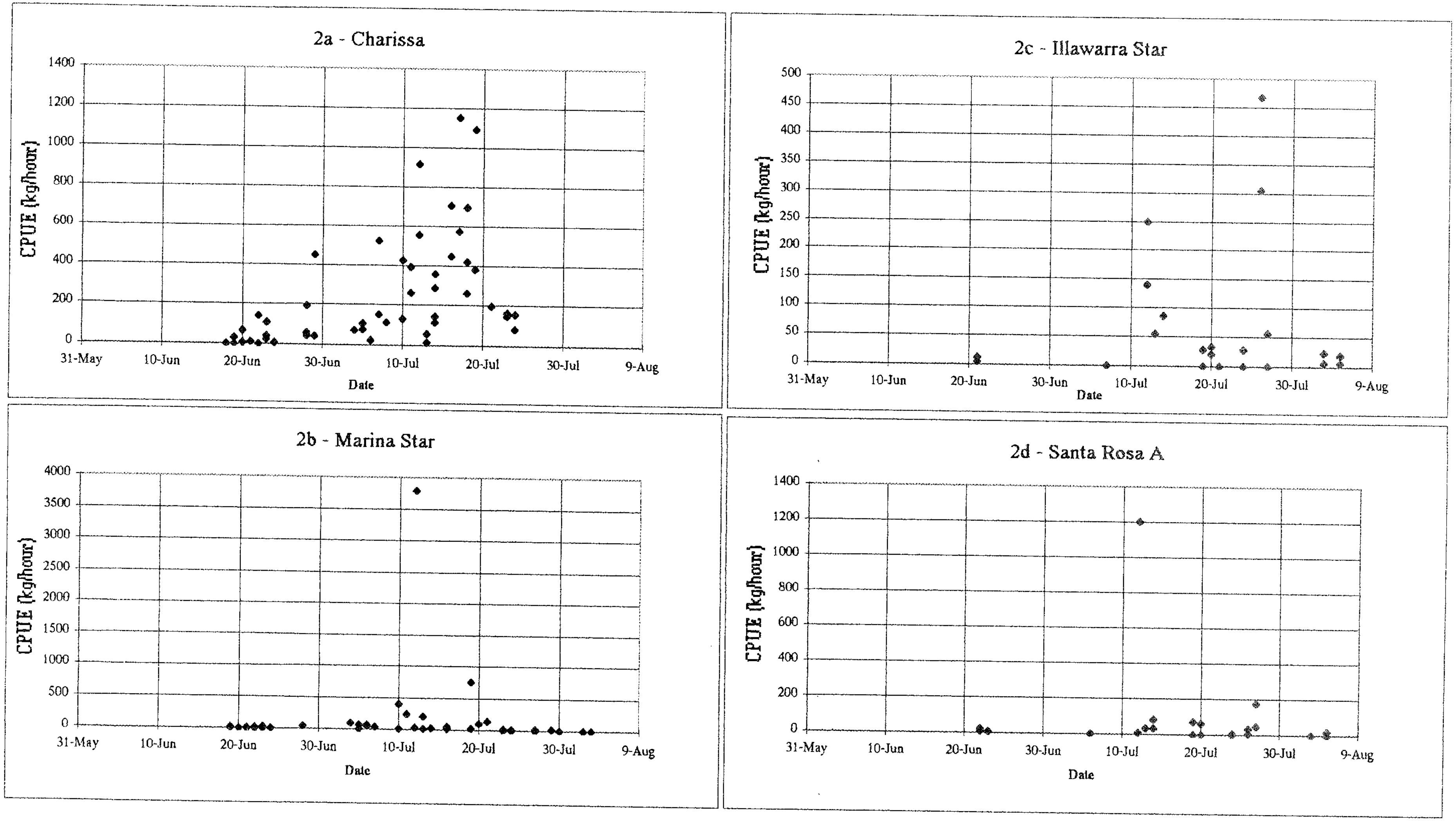

2a - Charissa
CPUE (kg/hour)
1400
1200
1000
800
600
400
200
0
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
Date
2c - Illawarra Star
CPUE (kg/hour)
500
450
400
350
300
250
200
150
100
50
0
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
Date
2b - Marina Star
CPUE (kg/hour)
4000
3500
3000
2500
2000
1500
1000
500
0
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
Date
2d - Santa Rosa A
CPUE (kg/hour)
1400
1200
1000
800
600
400
200
0
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
Date

Figure 2a-d

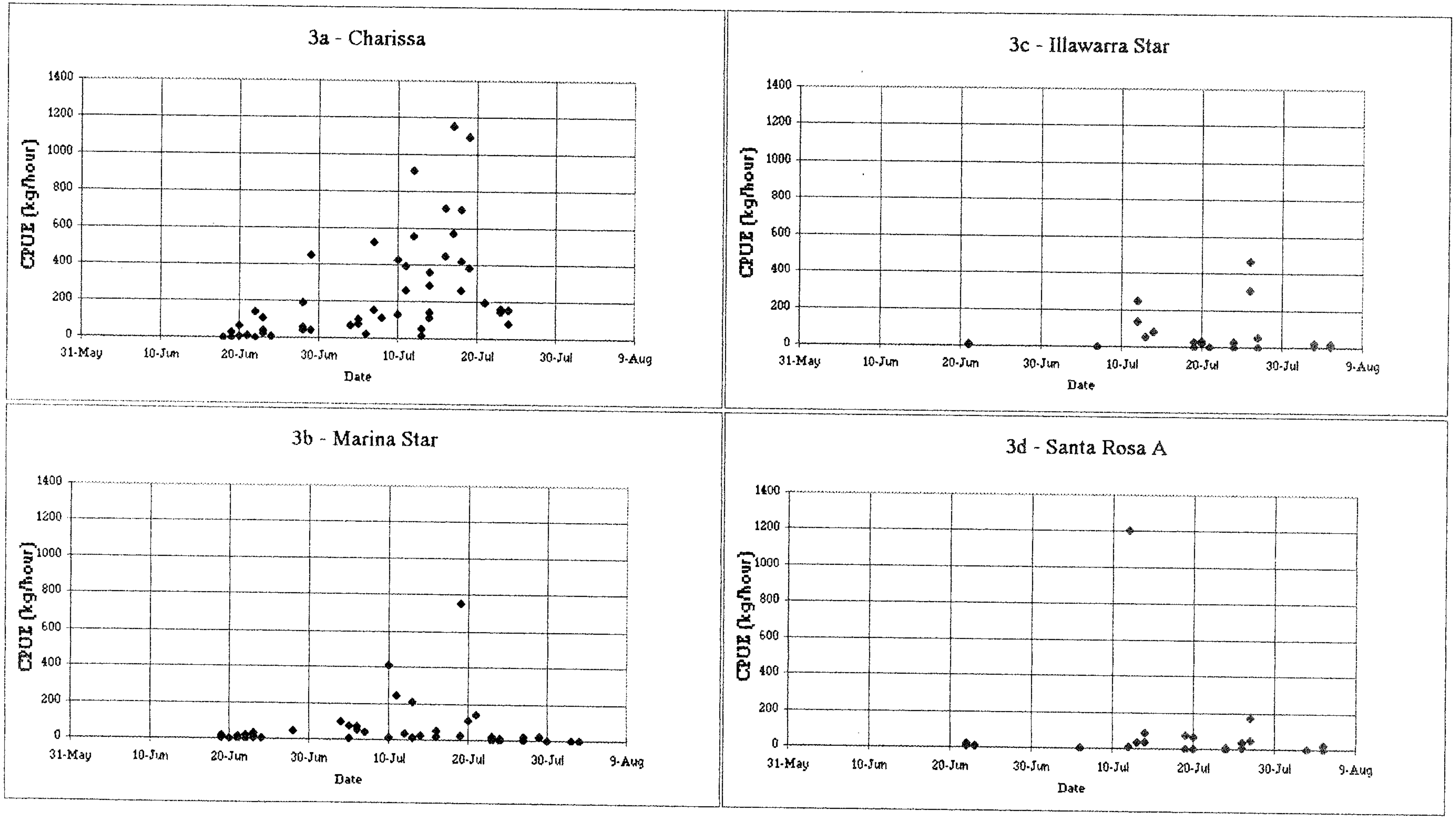
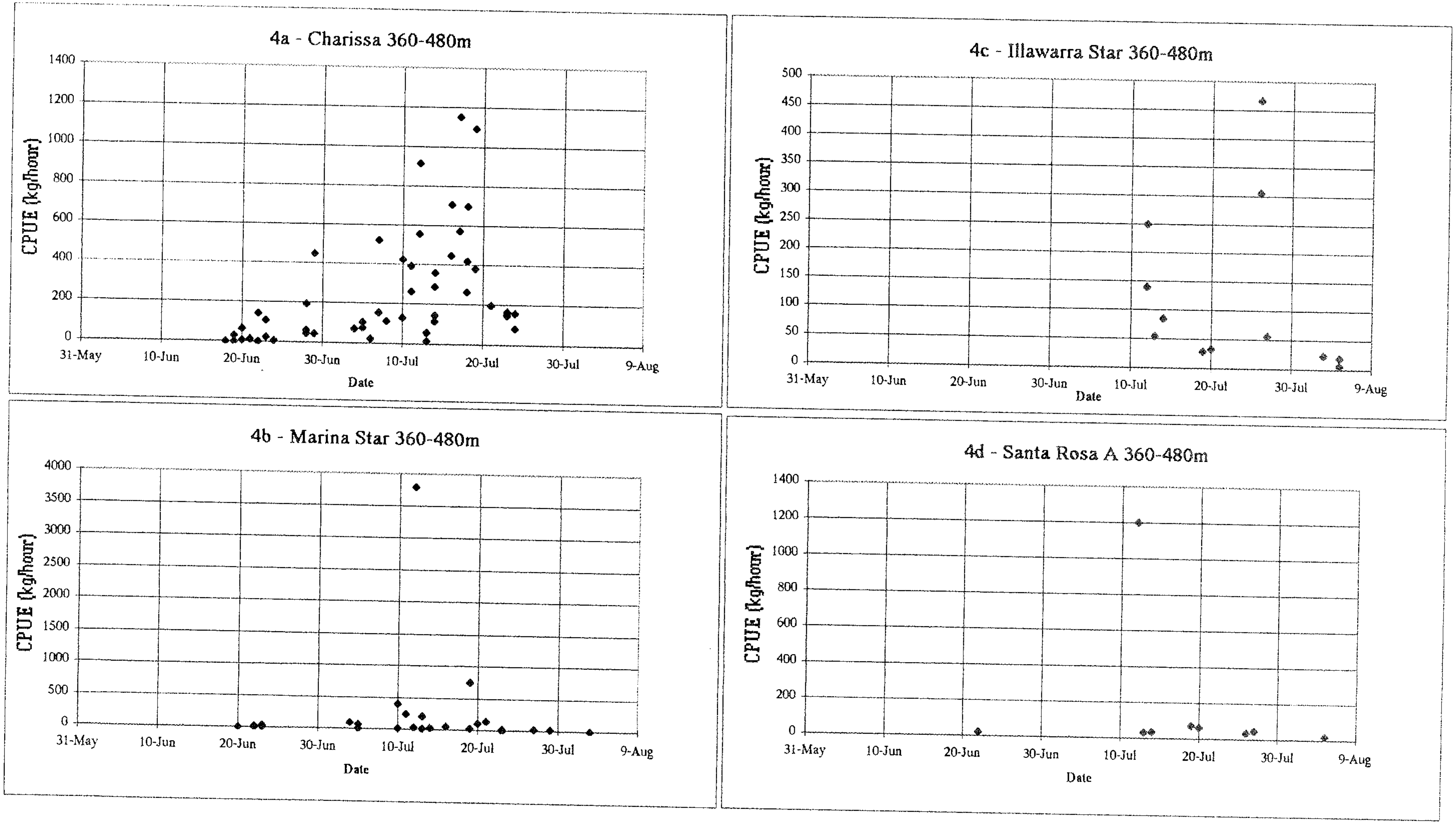

3a - Charissa
3c - Illawarra Star
3b - Marina Star
3d - Santa Rosa A
CPUE (kg/hour)
Date
1400
1200
1000
800
600
400
200
0
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug

Figure 3a-d


4a - Charissa 360-480m
CPUE (kg/hour)
1400
1200
1000
800
600
400
200
0
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
Date
4c - Illawarra Star 360-480m
CPUE (kg/hour)
500
450
400
350
300
250
200
150
100
50
0
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
Date
4b - Marina Star 360-480m
CPUE (kg/hour)
4000
3500
3000
2500
2000
1500
1000
500
0
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
Date
4d - Santa Rosa A 360-480m
CPUE (kg/hour)
1400
1200
1000
800
600
400
200
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31-May
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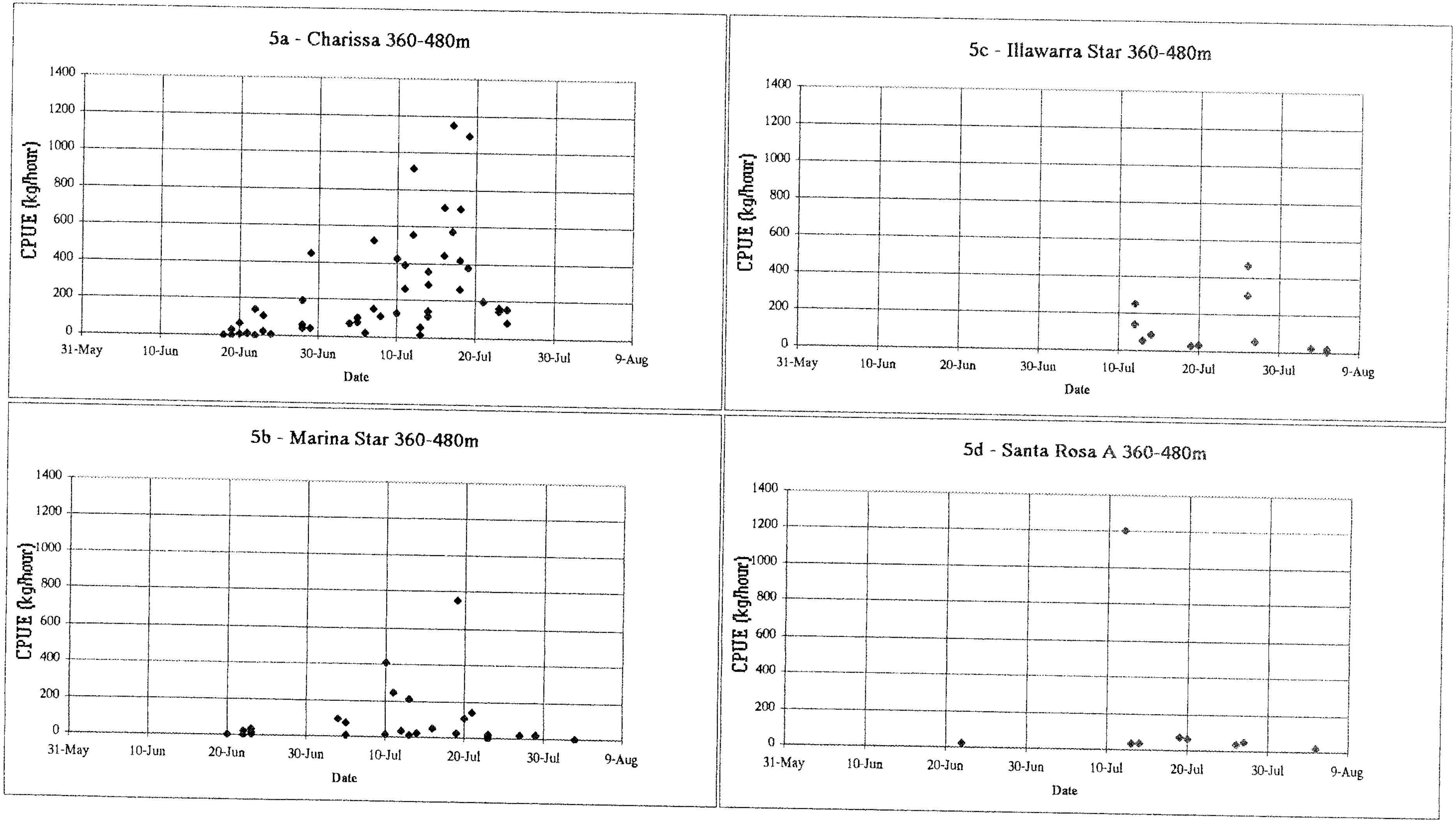
20-Jul
30-Jul
9-Aug
Date

Figure 4a-d



5a - Charissa 360-480m
CPUE (kg/hour)
1400
1200
1000
800
600
400
200
0
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
Date
5c - Illawarra Star 360-480m
CPUE (kg/hour)
Date
5b - Marina Star 360-480m
CPUE (kg/hour)
Date
5d - Santa Rosa A 360-480m
CPUE (kg/hour)
Date

Figure 5a-d

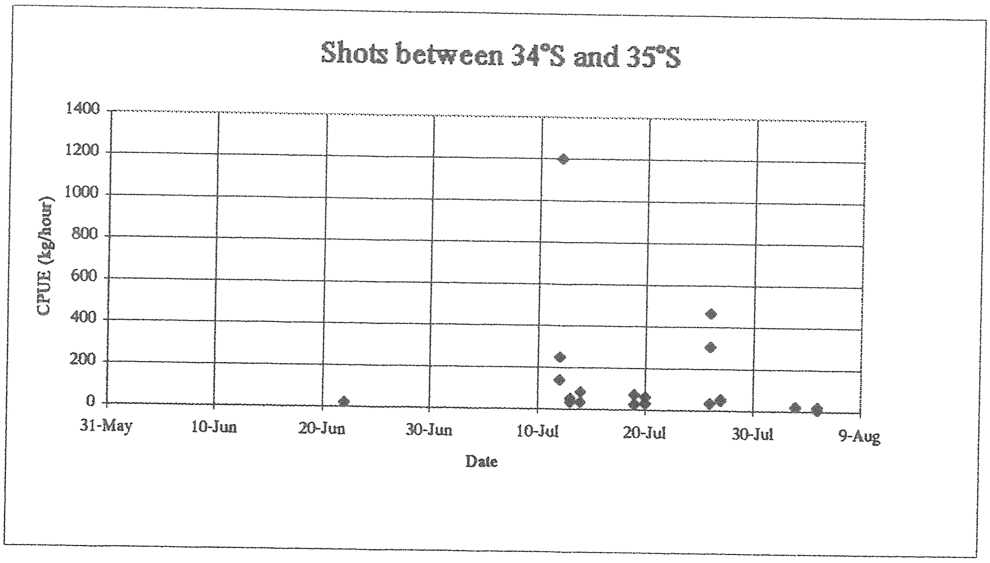


Figure 6a

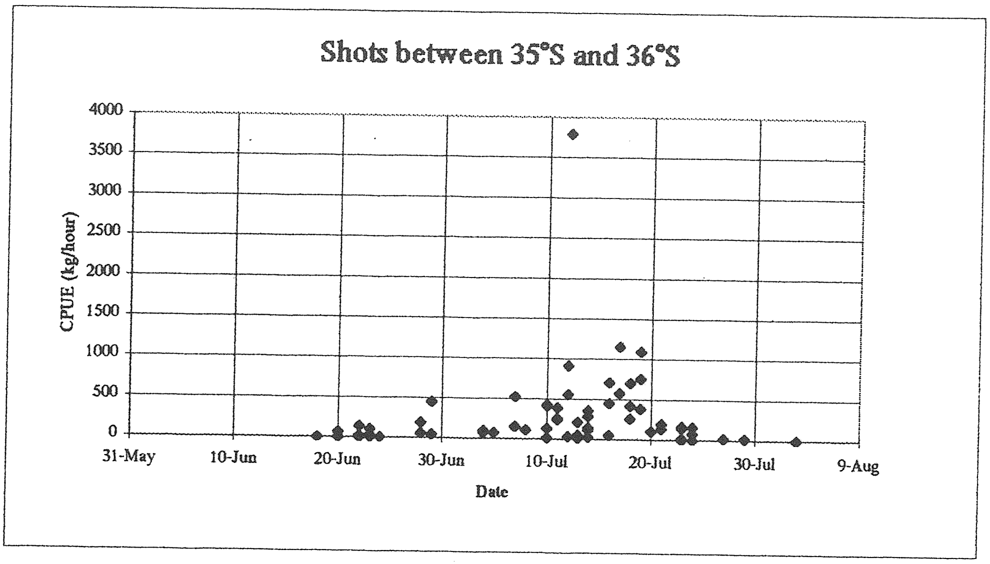


Figure 6b

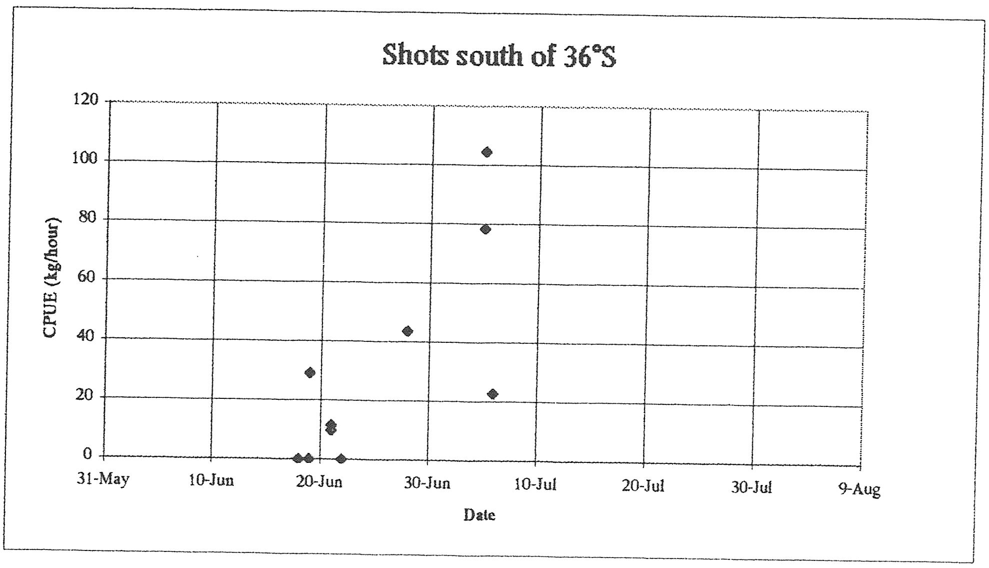


Figure 6c

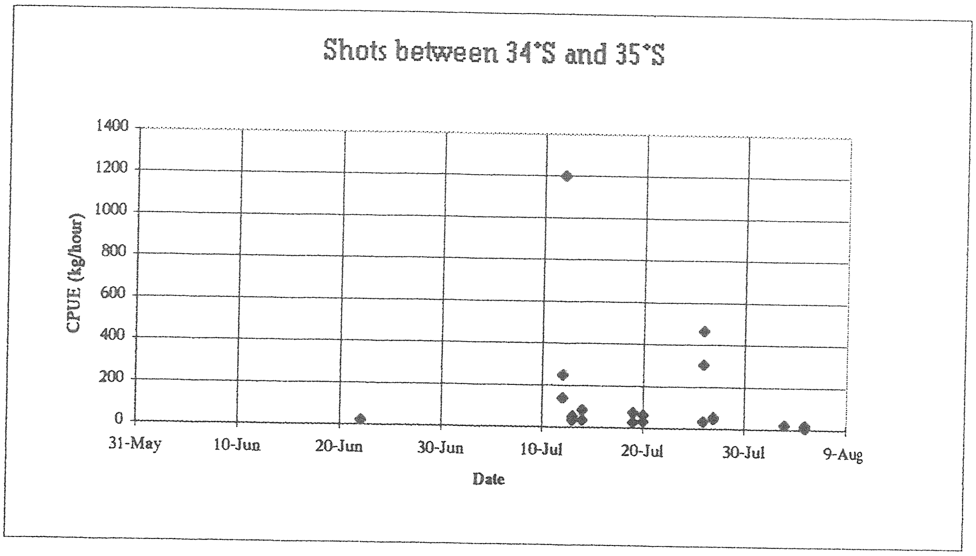


Figure 7a

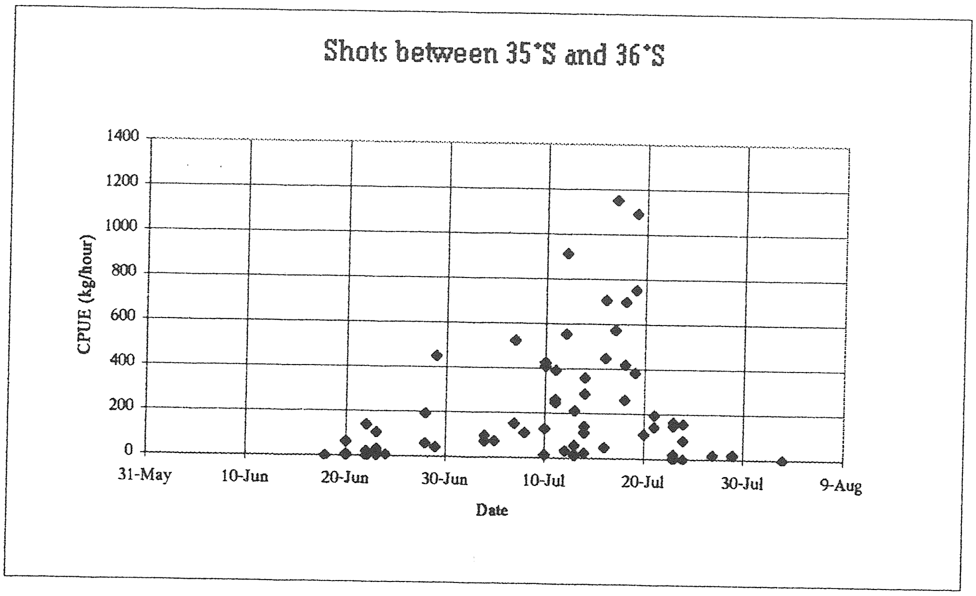


Figure 7b

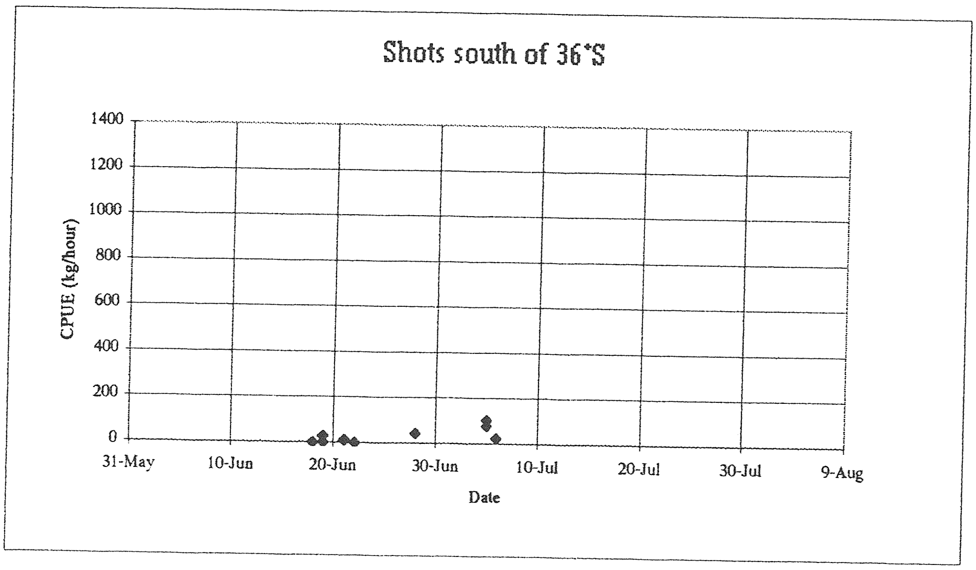


Figure 7c

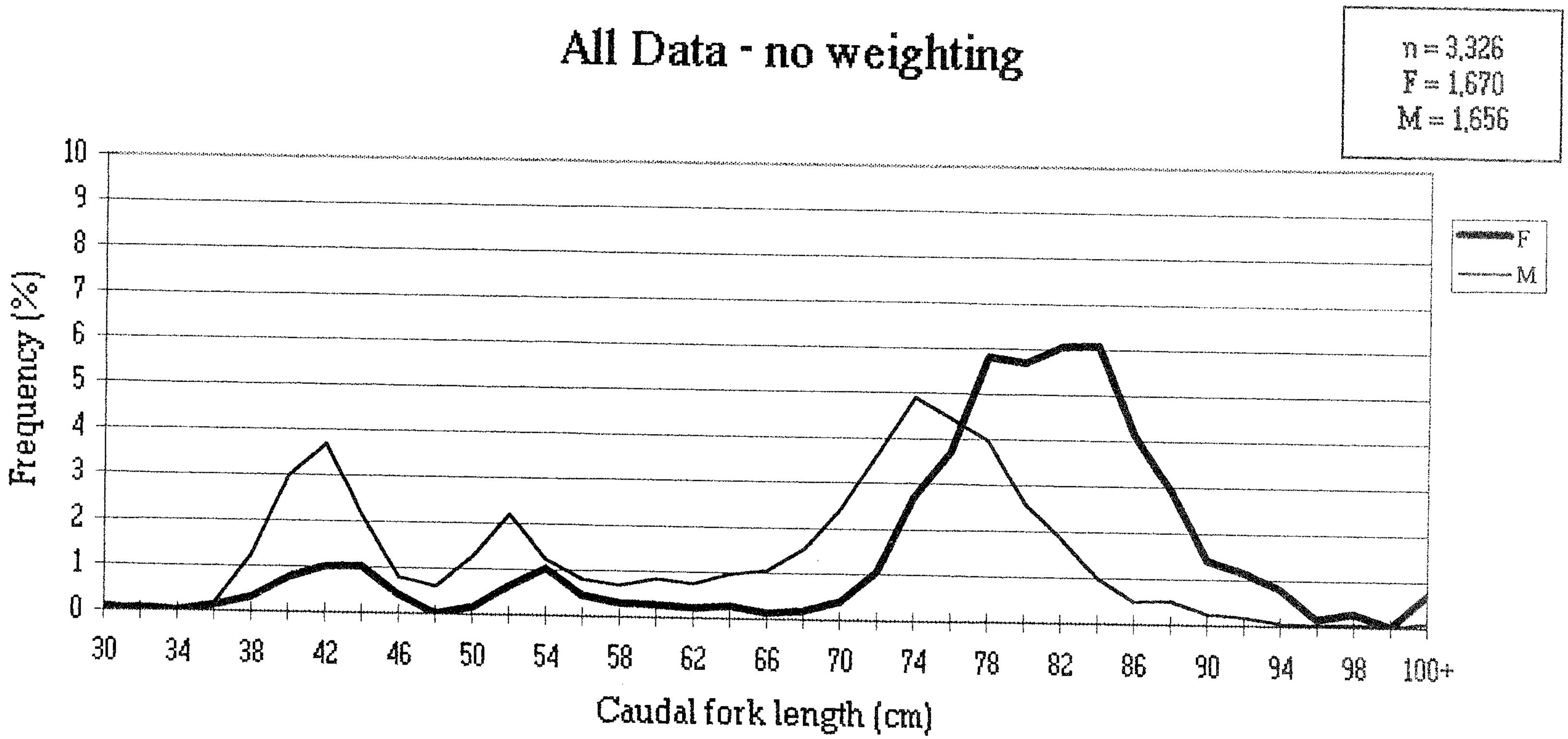

All Data - no weighting
n = 3,326
F = 1,670
M = 1,656
F
M
Frequency (%)
10
9
8
7
6
5
4
3
2
1
0
30
34
38
42
46
50
54
58
62
66
70
74
78
82
86
90
94
98
100+
Caudal fork length (cm)

Figure 8

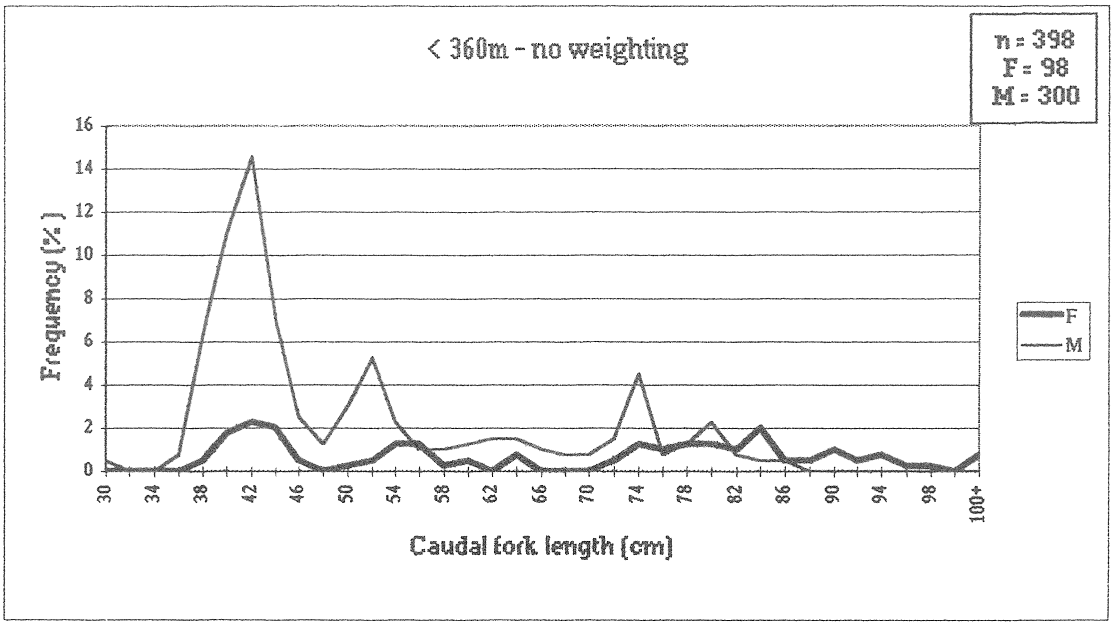


Figure 9a

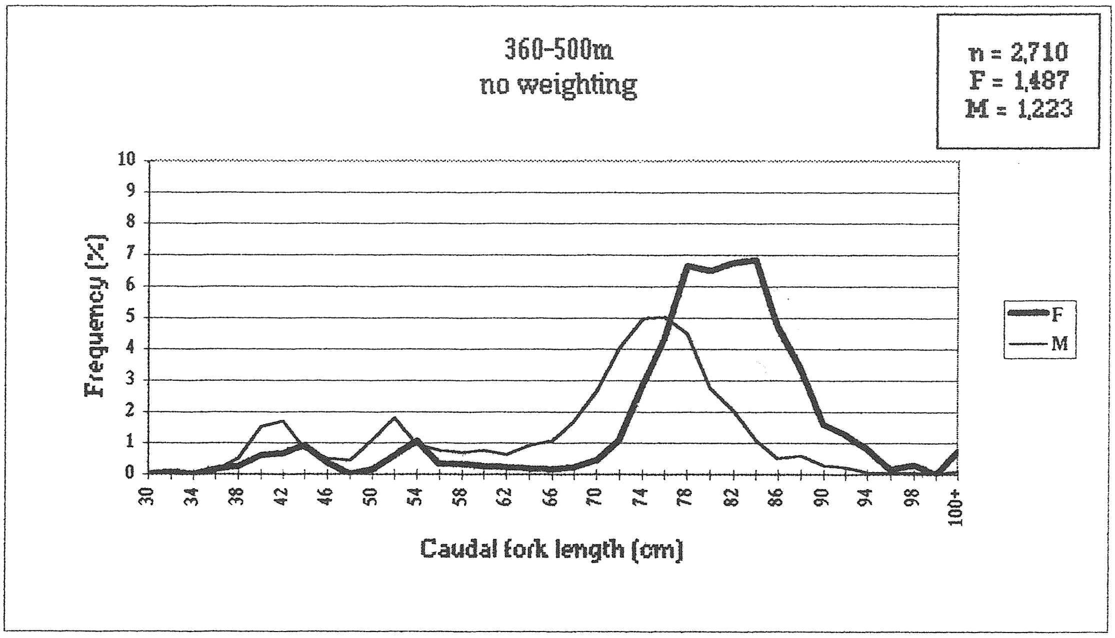


Figure 9b

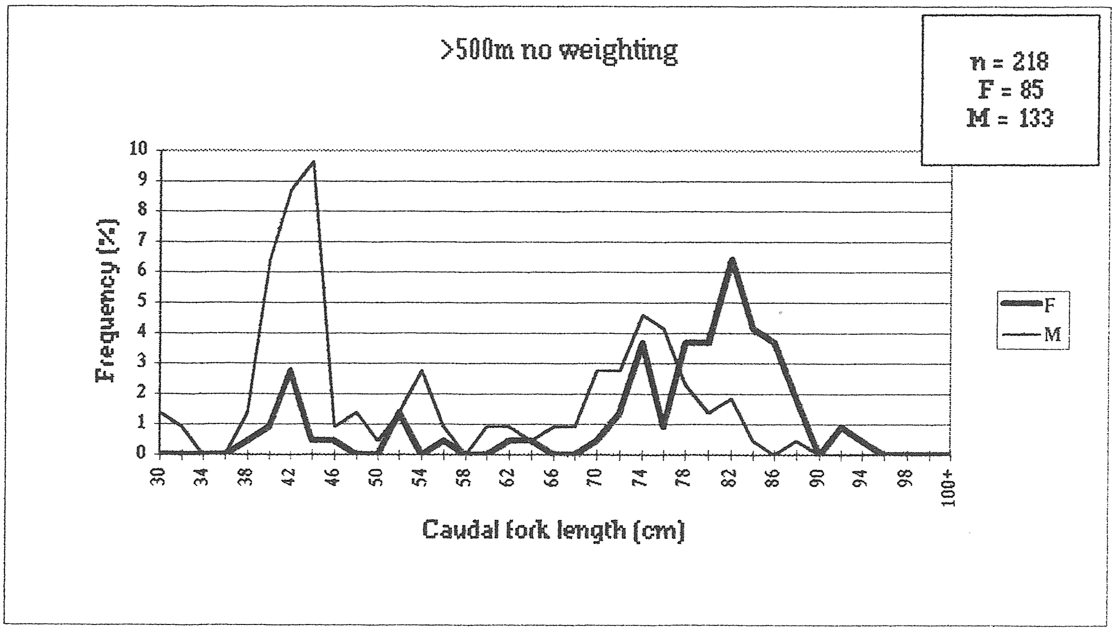


Figure 9c

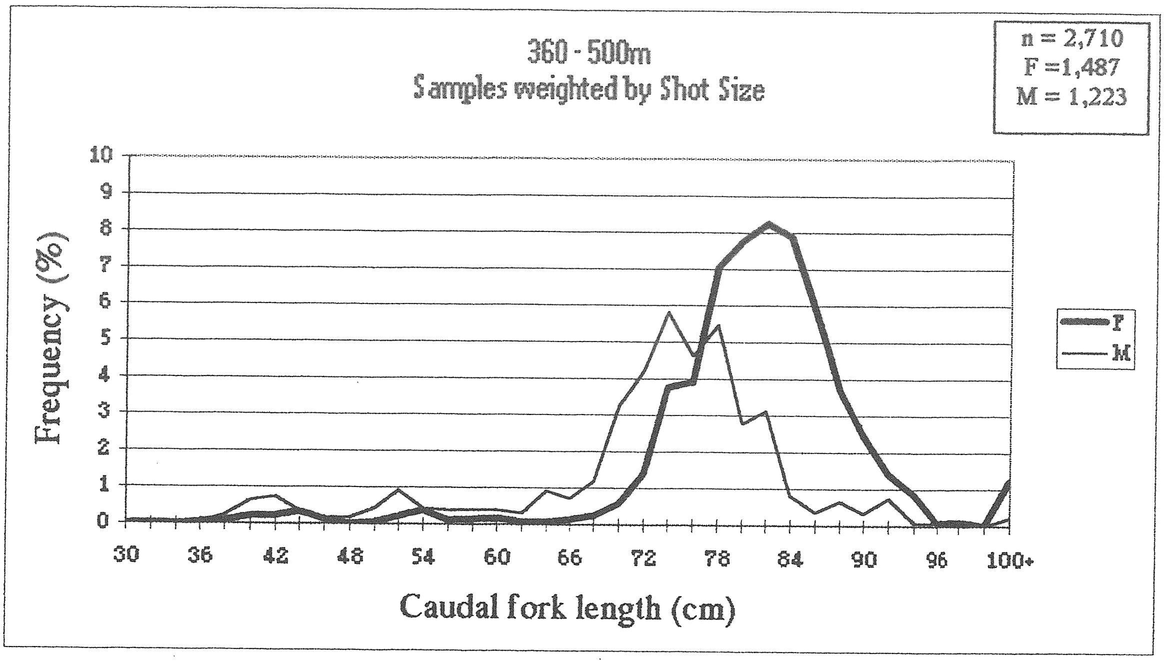


Figure 10a

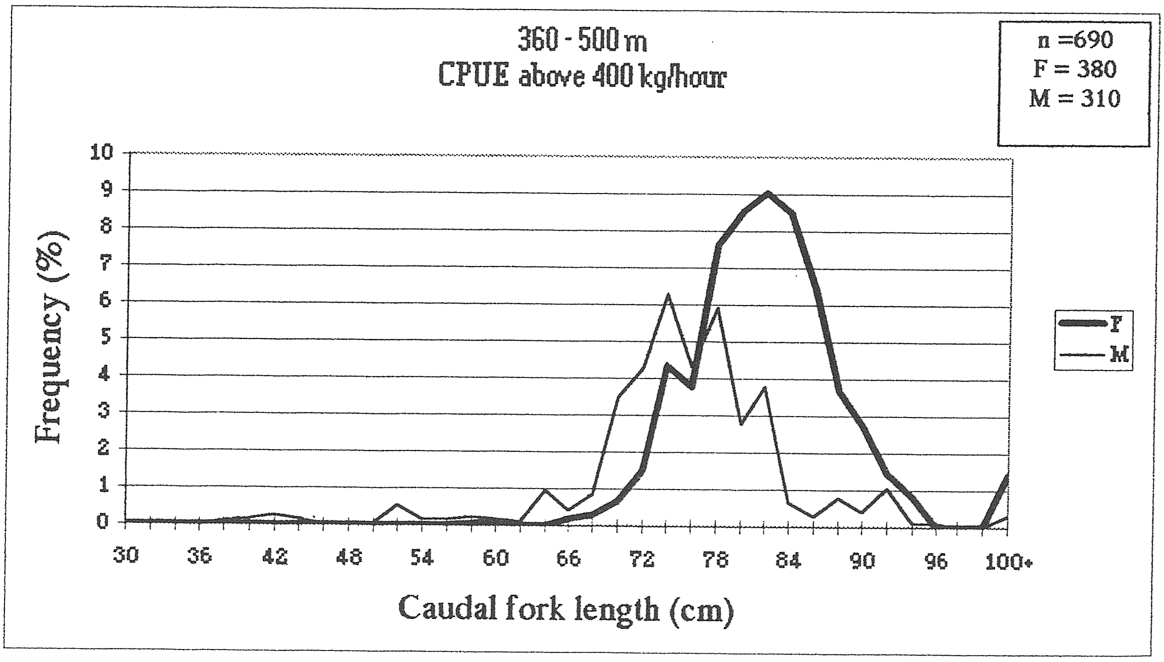


Figure 10b

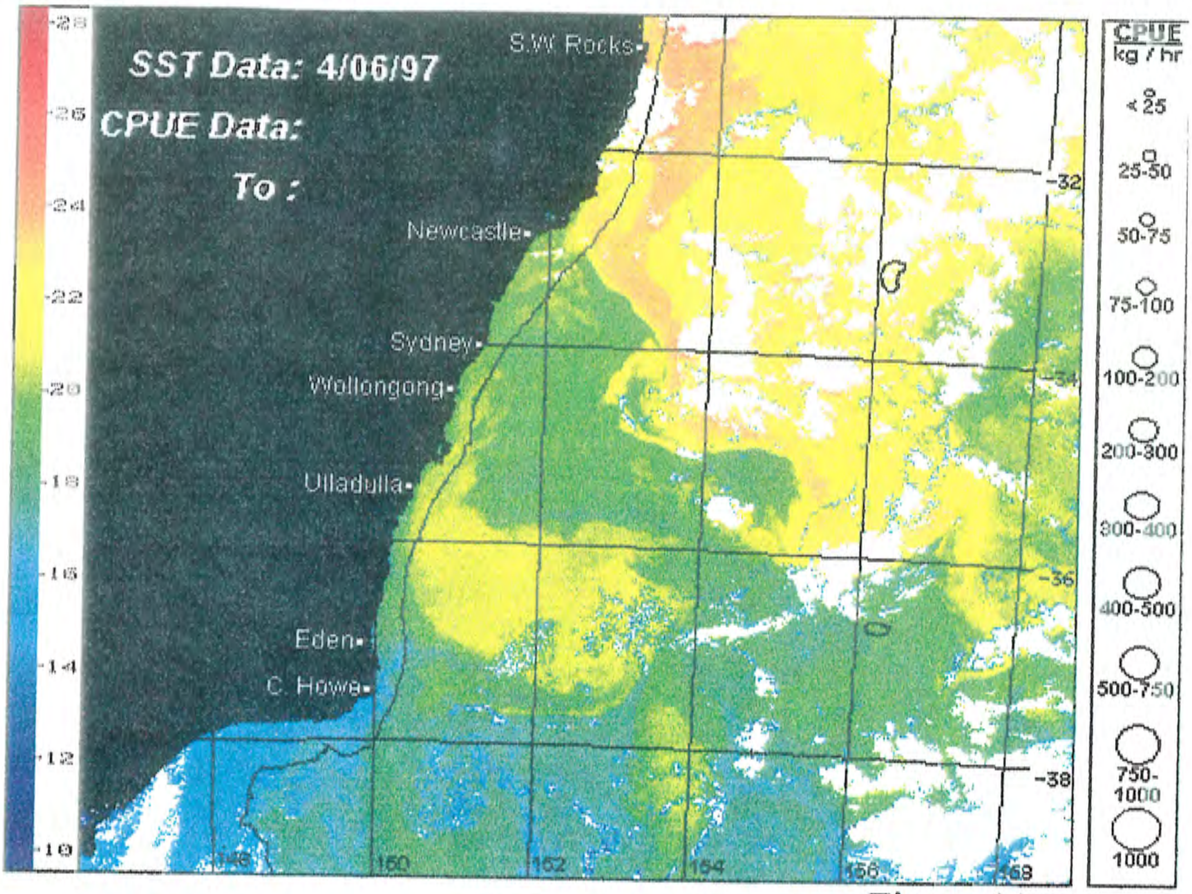


Figure 11a

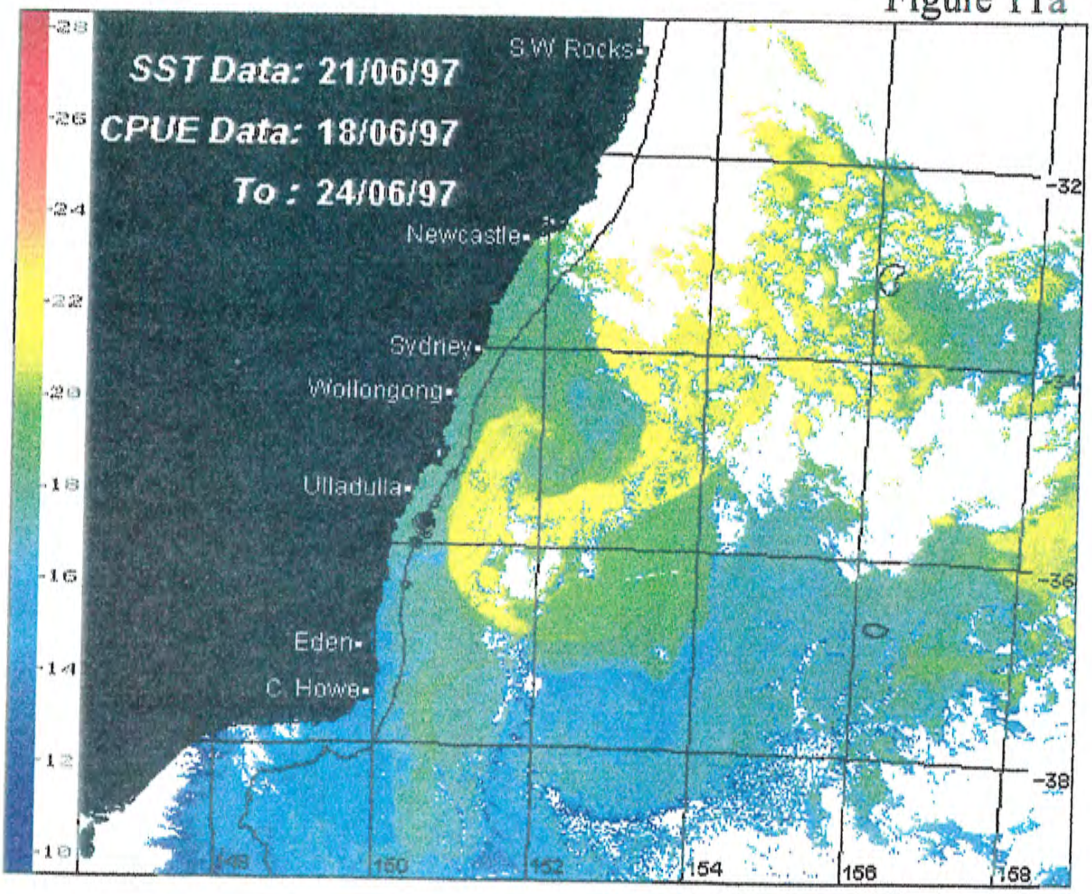


Figure 11b

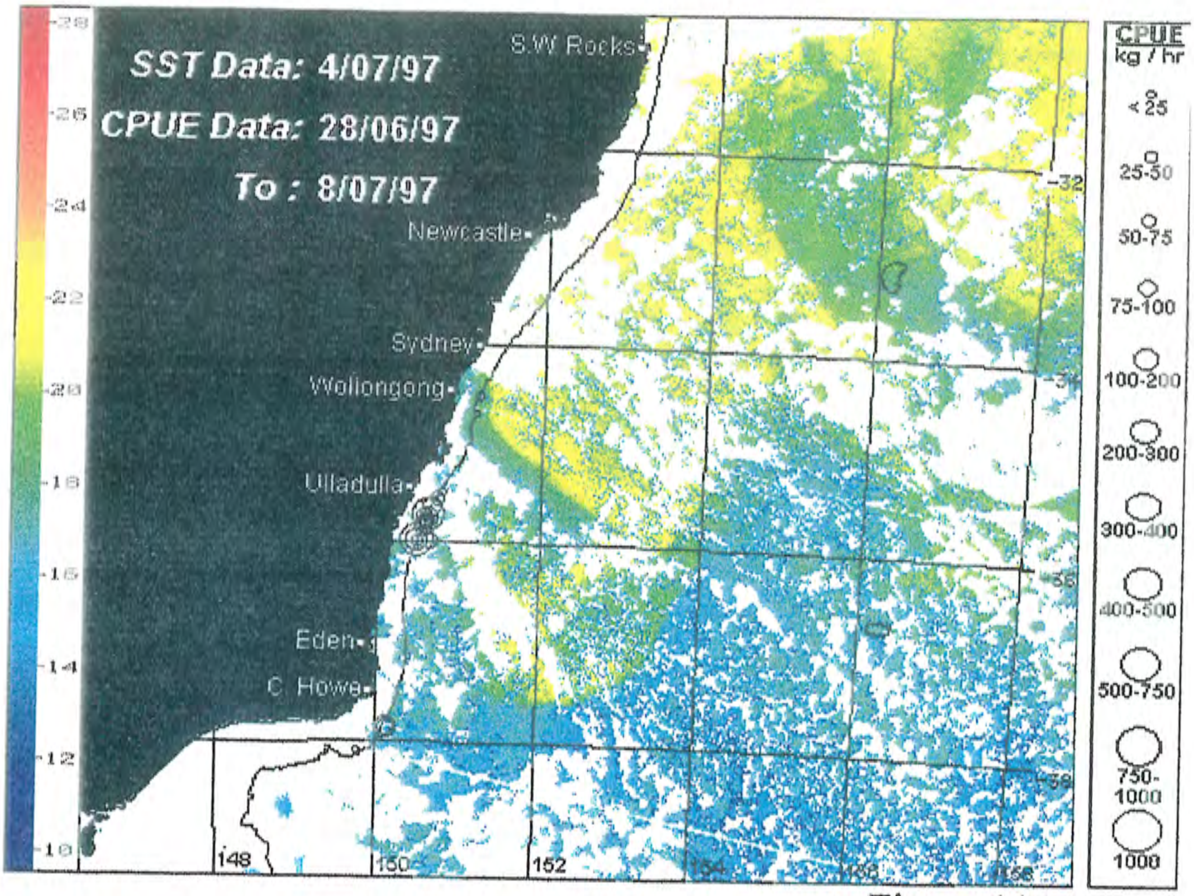


Figure 11c

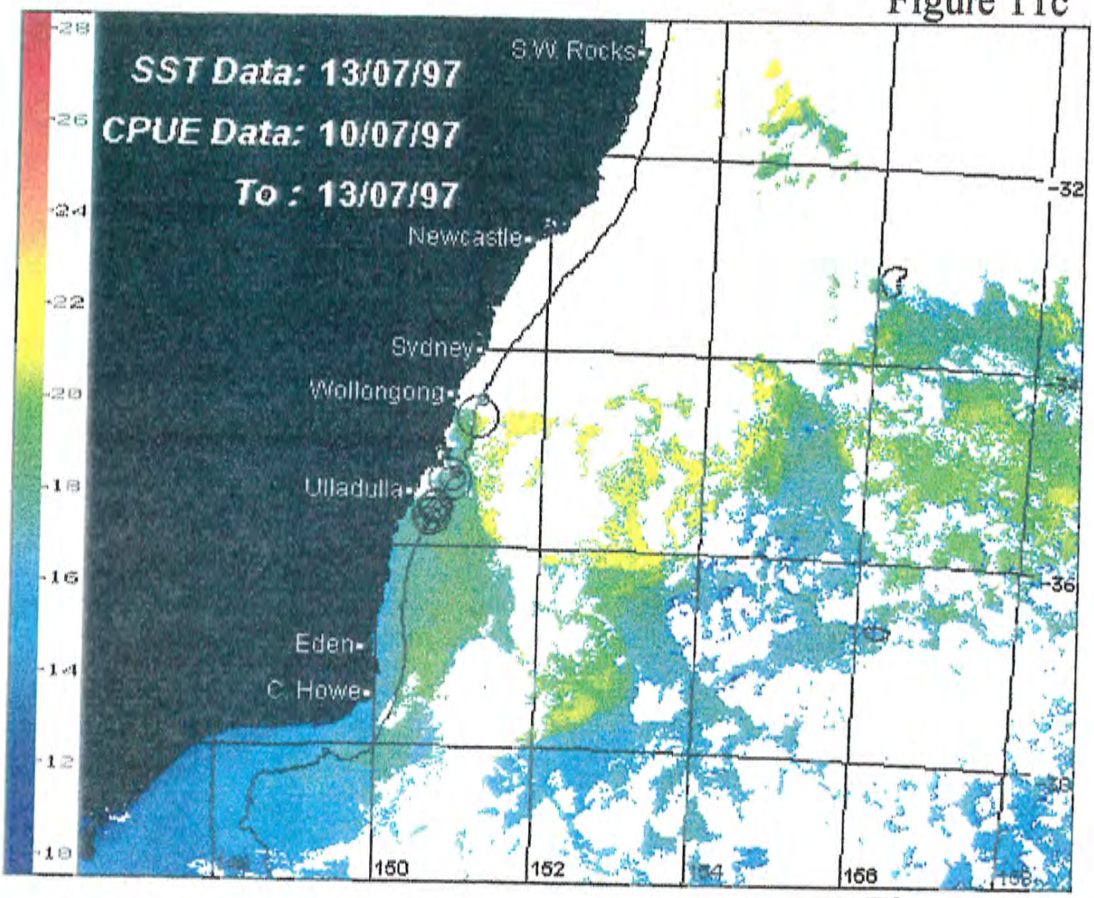


Figure 11d

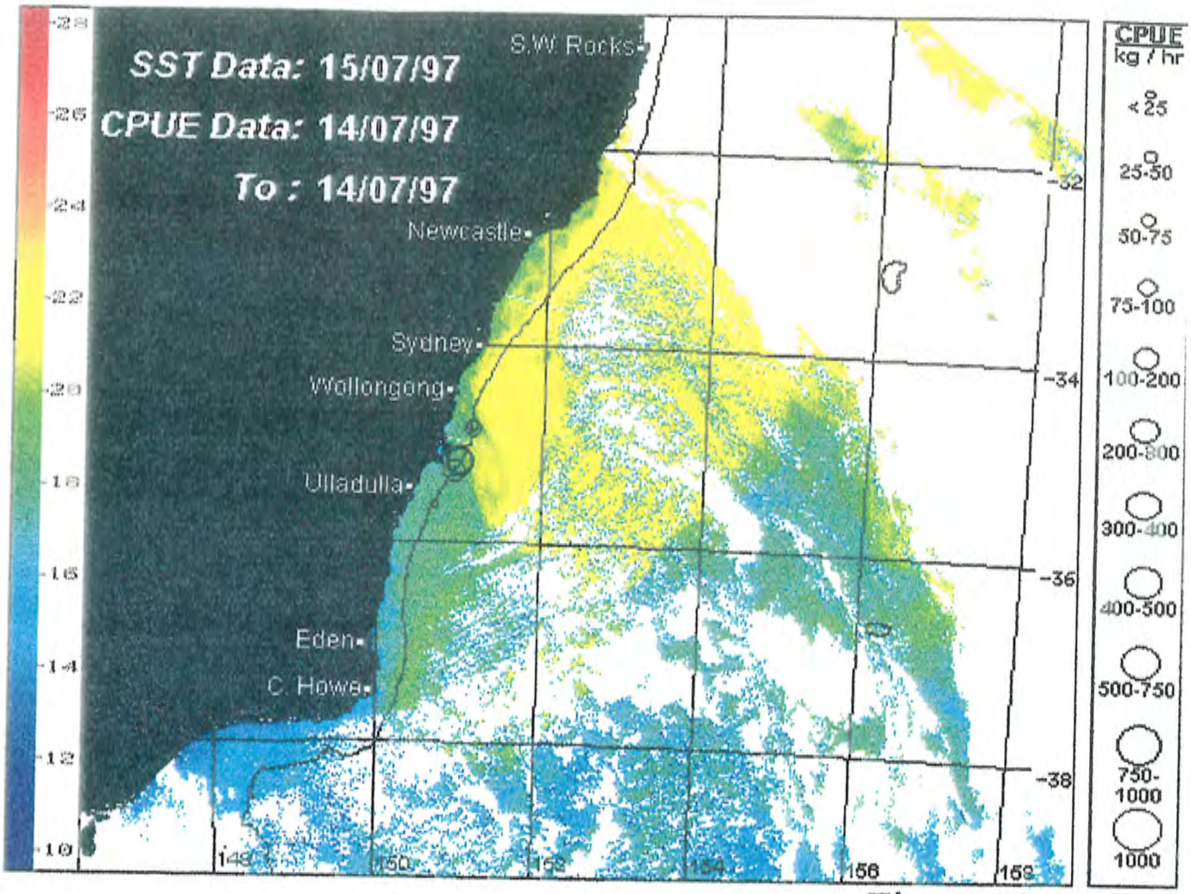


Figure 11e

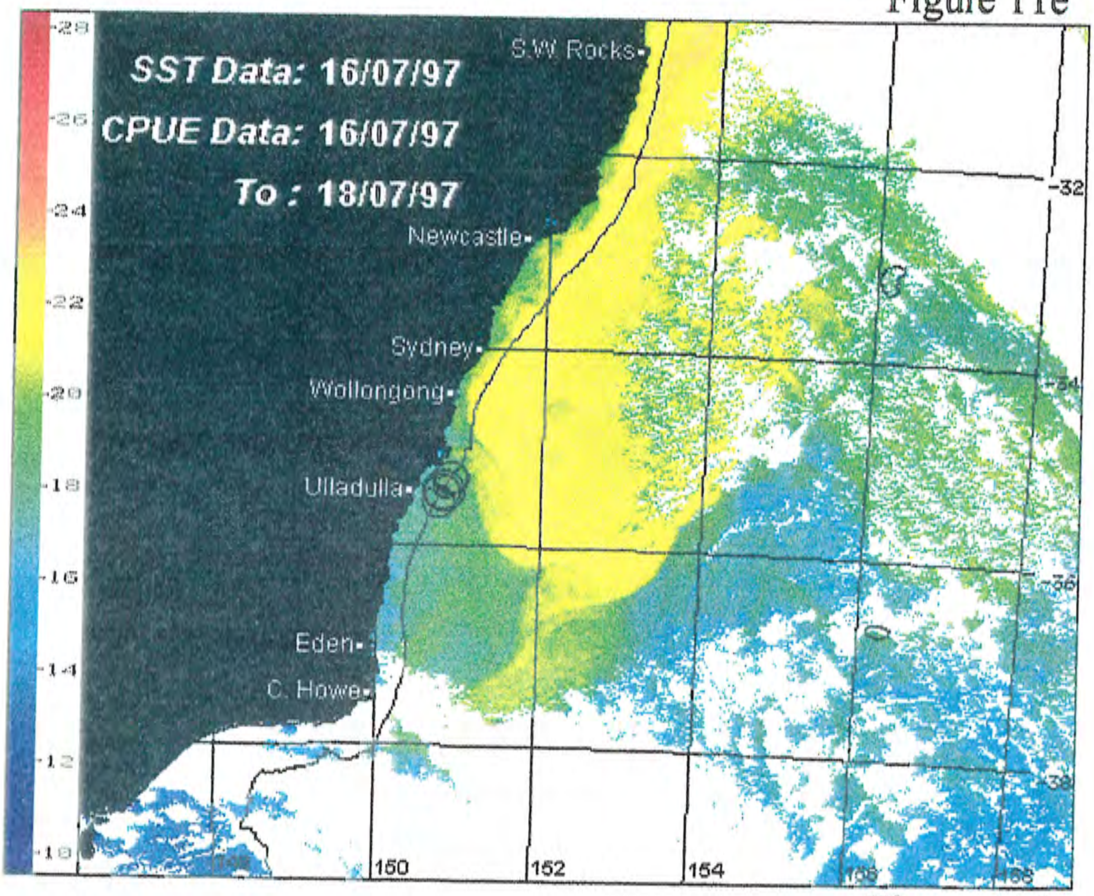


Figure 11f

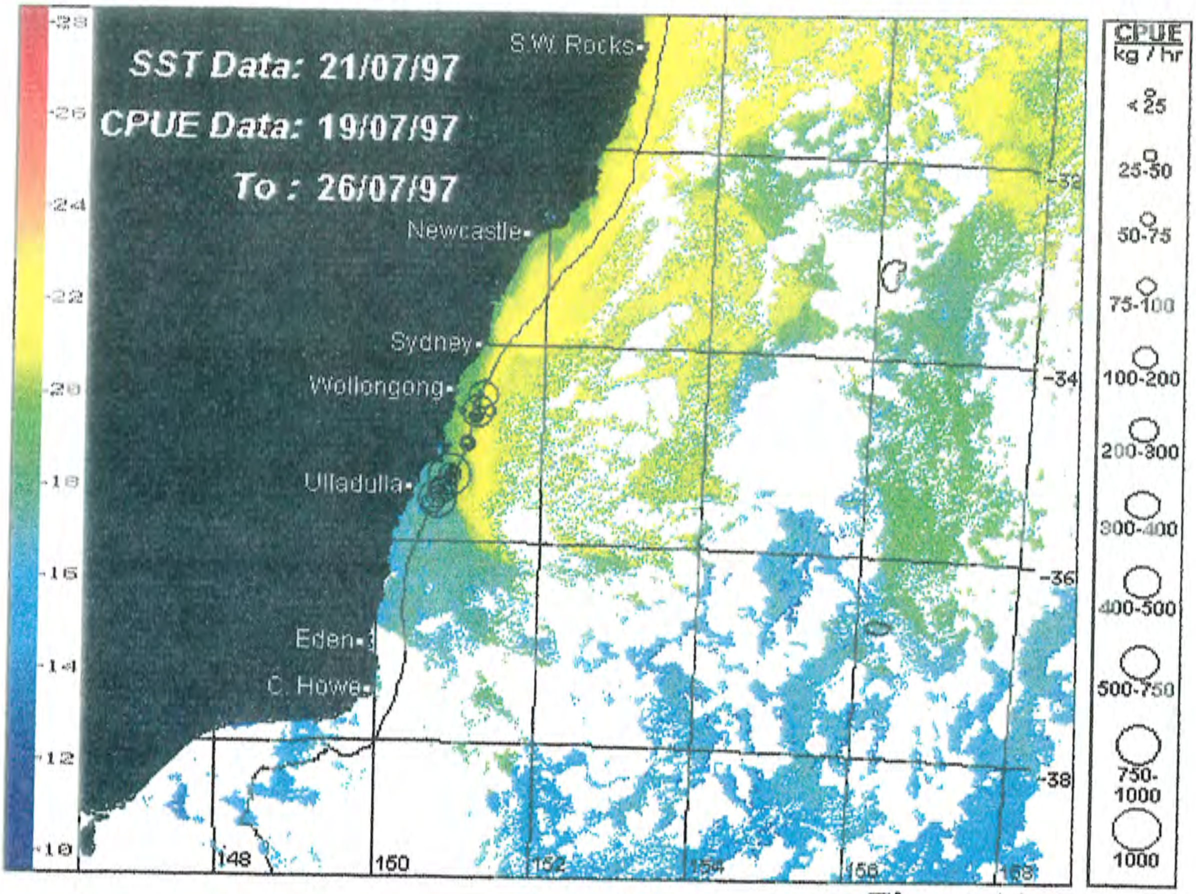


Figure 11g

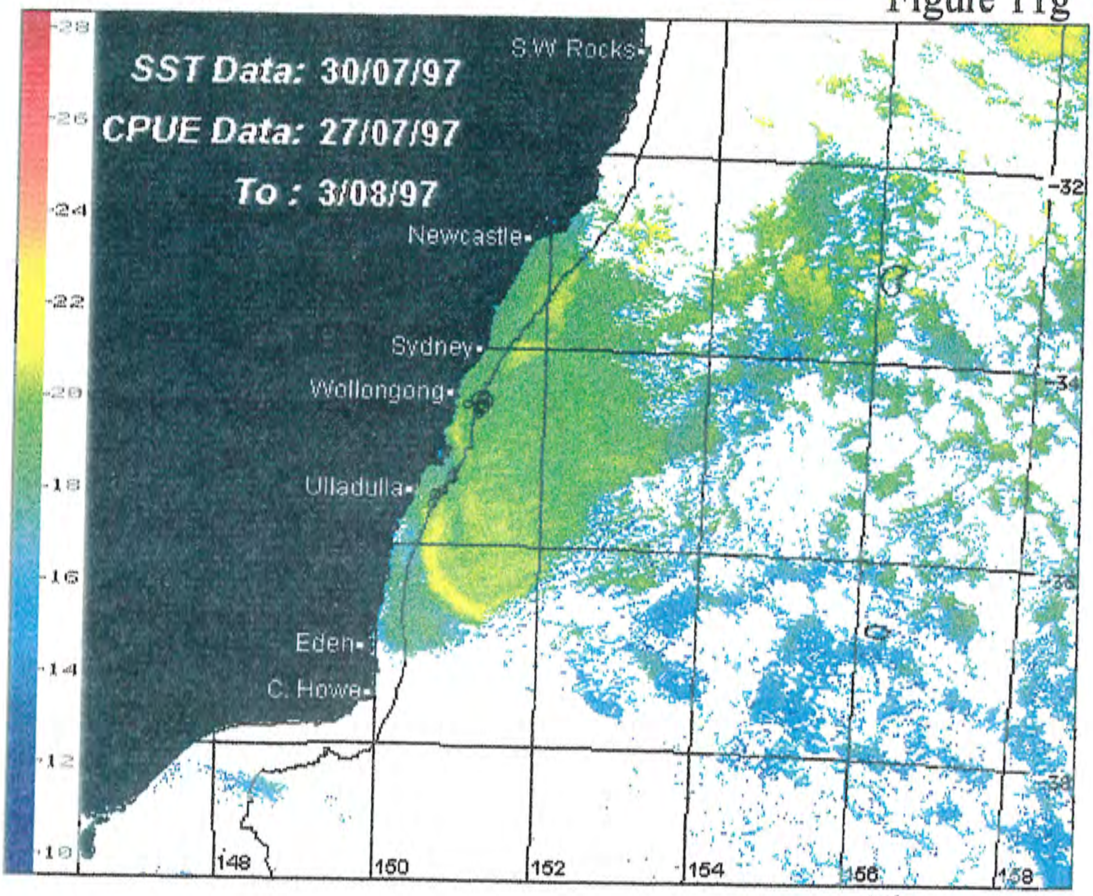


Figure 11h

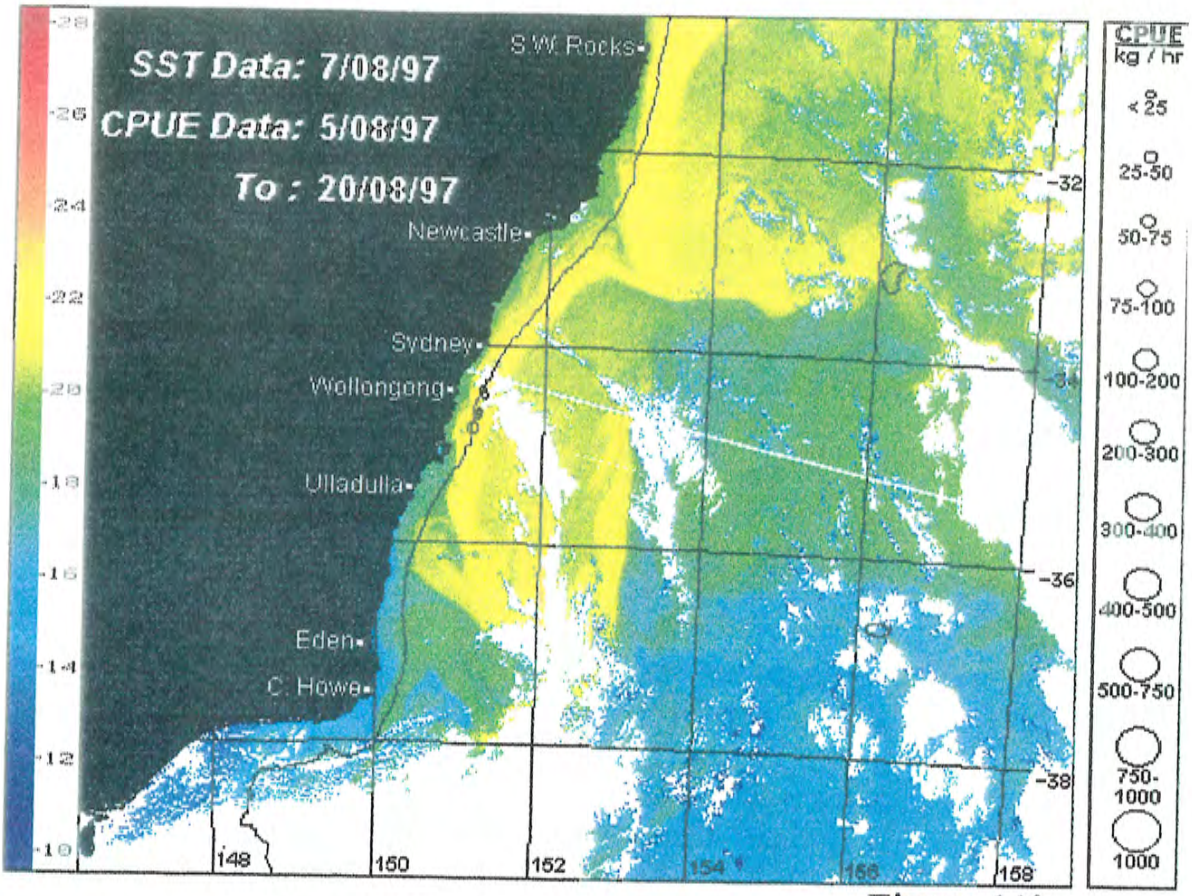

SST Data: 7/08/97
CPUE Data: 5/08/97
To : 20/08/97
S.W. Rocks
Newcastle
Sydney
Wollongong
Ulladulla
Eden
C. Howe
28
26
24
22
20
18
16
14
12
10
148
150
152
154
158
-32
-36
-38
CPUE
kg / hr
< 25
25-50
50-75
75-100
100-200
200-300
300-400
400-500
500-750
750-
1000
1000

Figure 11i

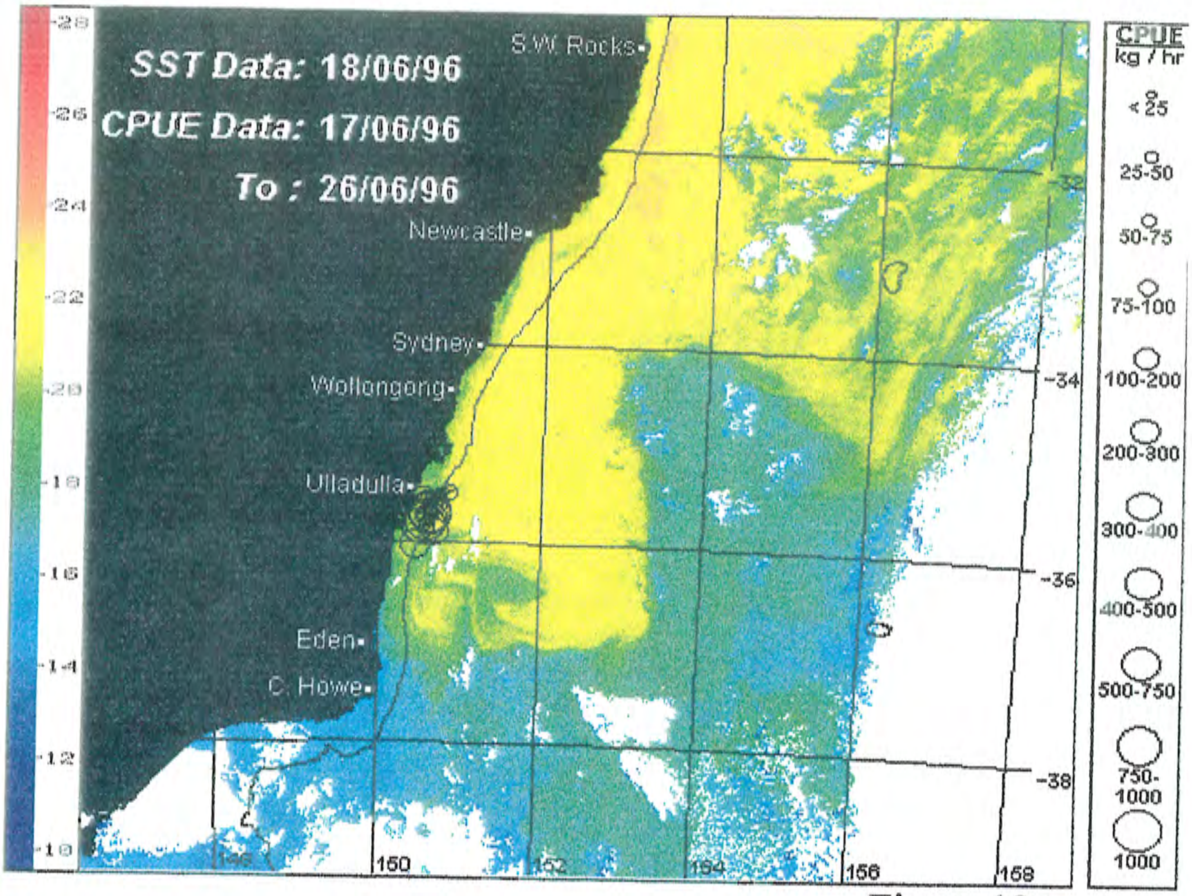


Figure 12a

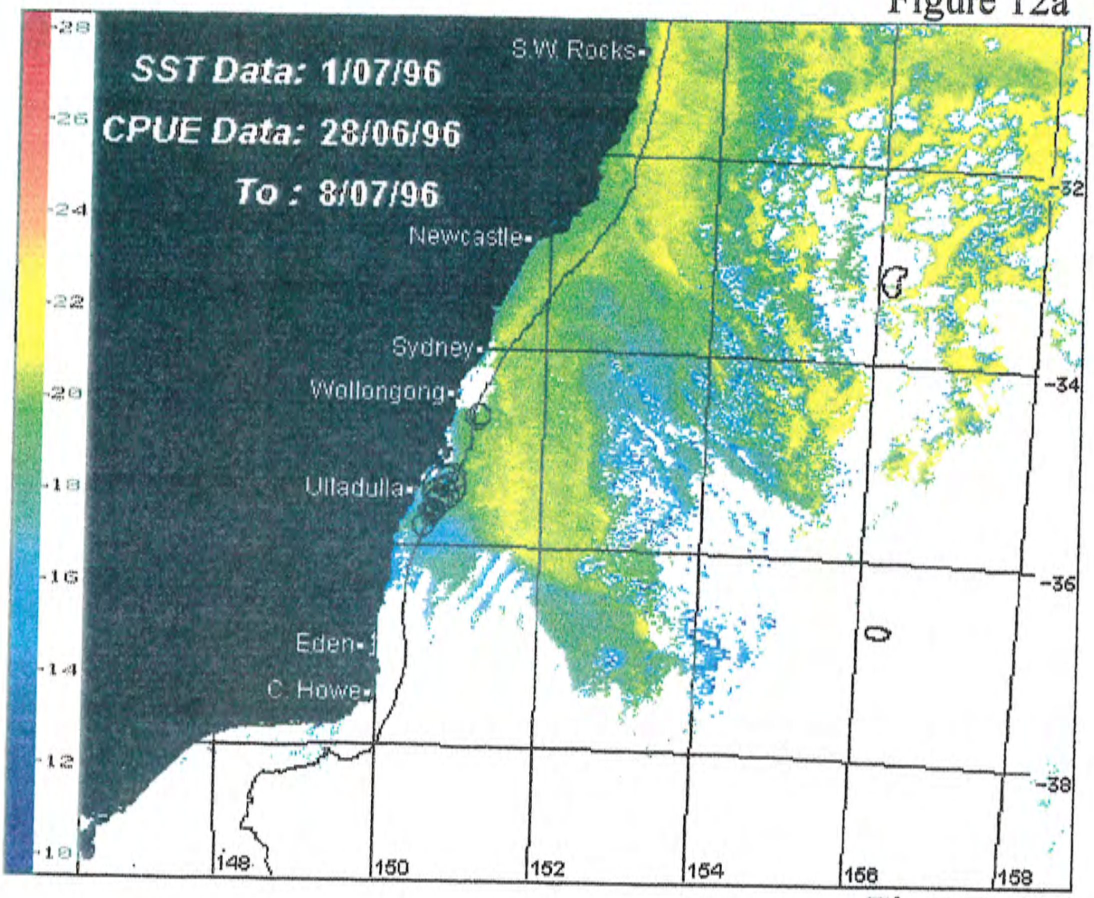


Figure 12b

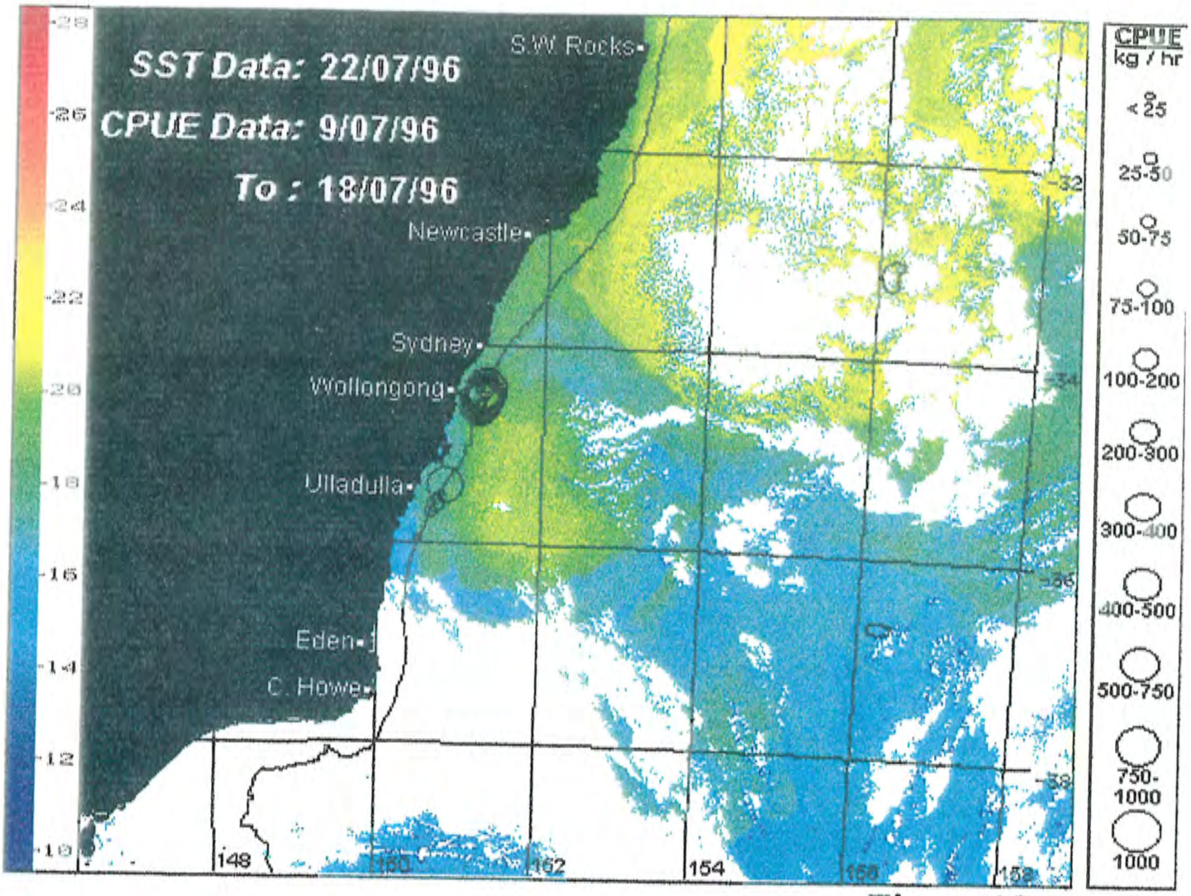


Figure 12c

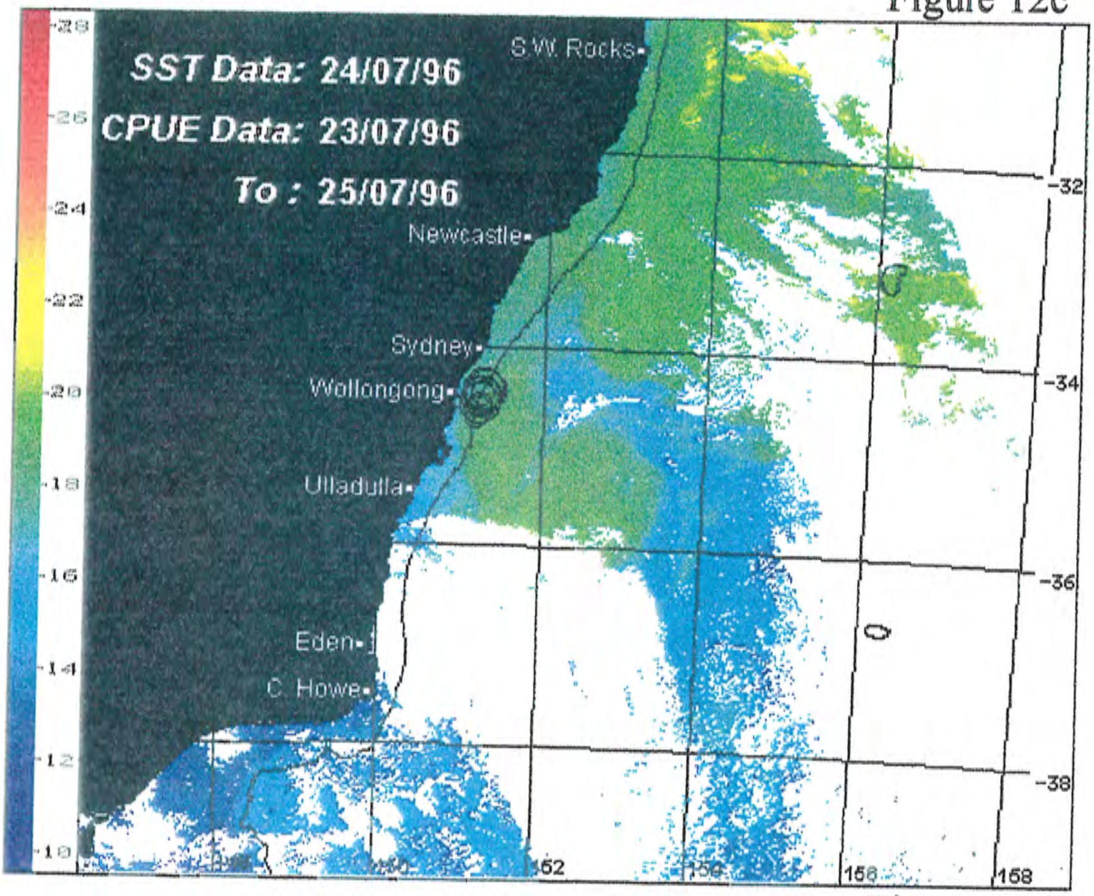


Figure 12d

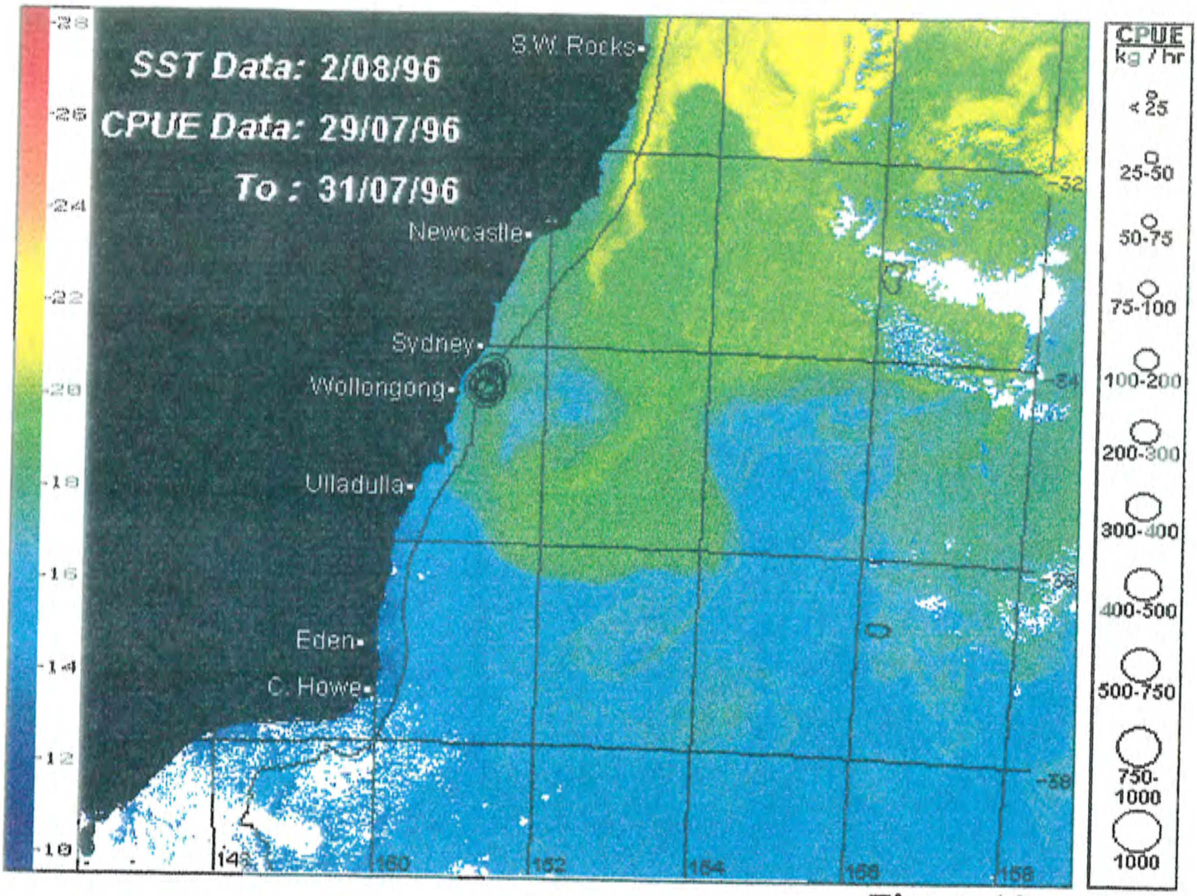


Figure 12e

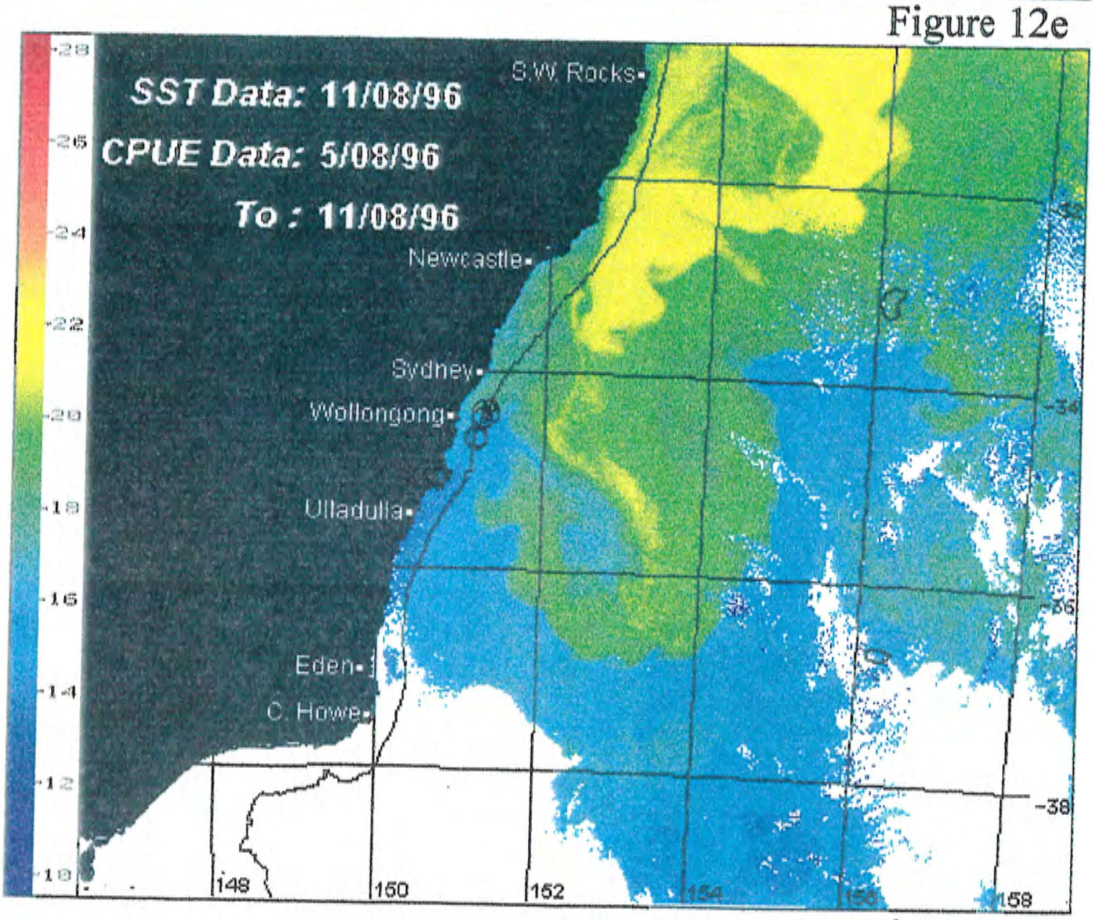


Figure 12f

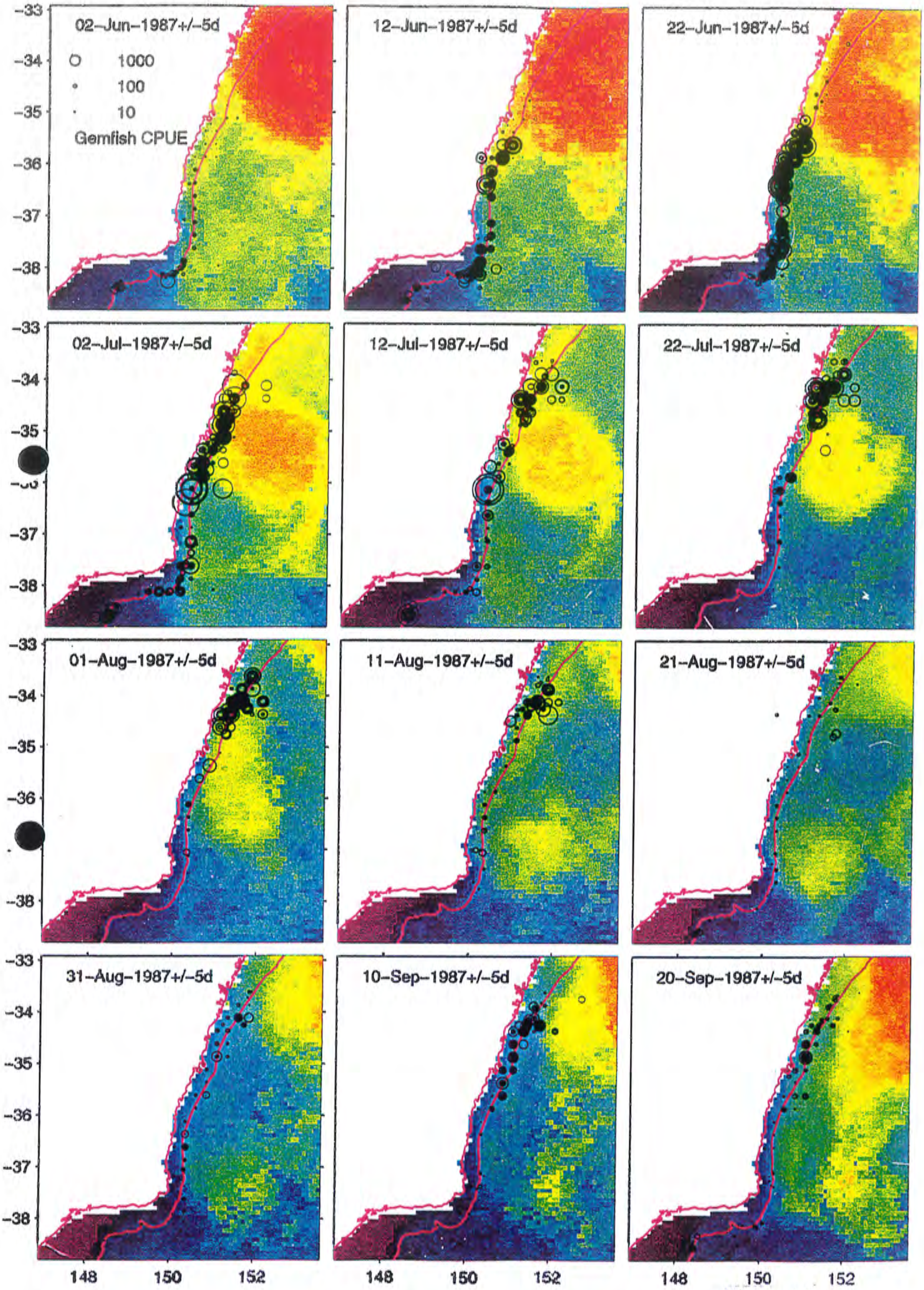

02-Jun-1987+/-5d
1000
100
10
Gemfish CPUE
12-Jun-1987+/-5d
22-Jun-1987+/-5d
02-Jul-1987+/-5d
12-Jul-1987+/-5d
22-Jul-1987+/-5d
01-Aug-1987+/-5d
11-Aug-1987+/-5d
21-Aug-1987+/-5d
31-Aug-1987+/-5d
10-Sep-1987+/-5d
20-Sep-1987+/-5d
-33
-34
-35
-36
-37
-38
148
150
152

Figure 13

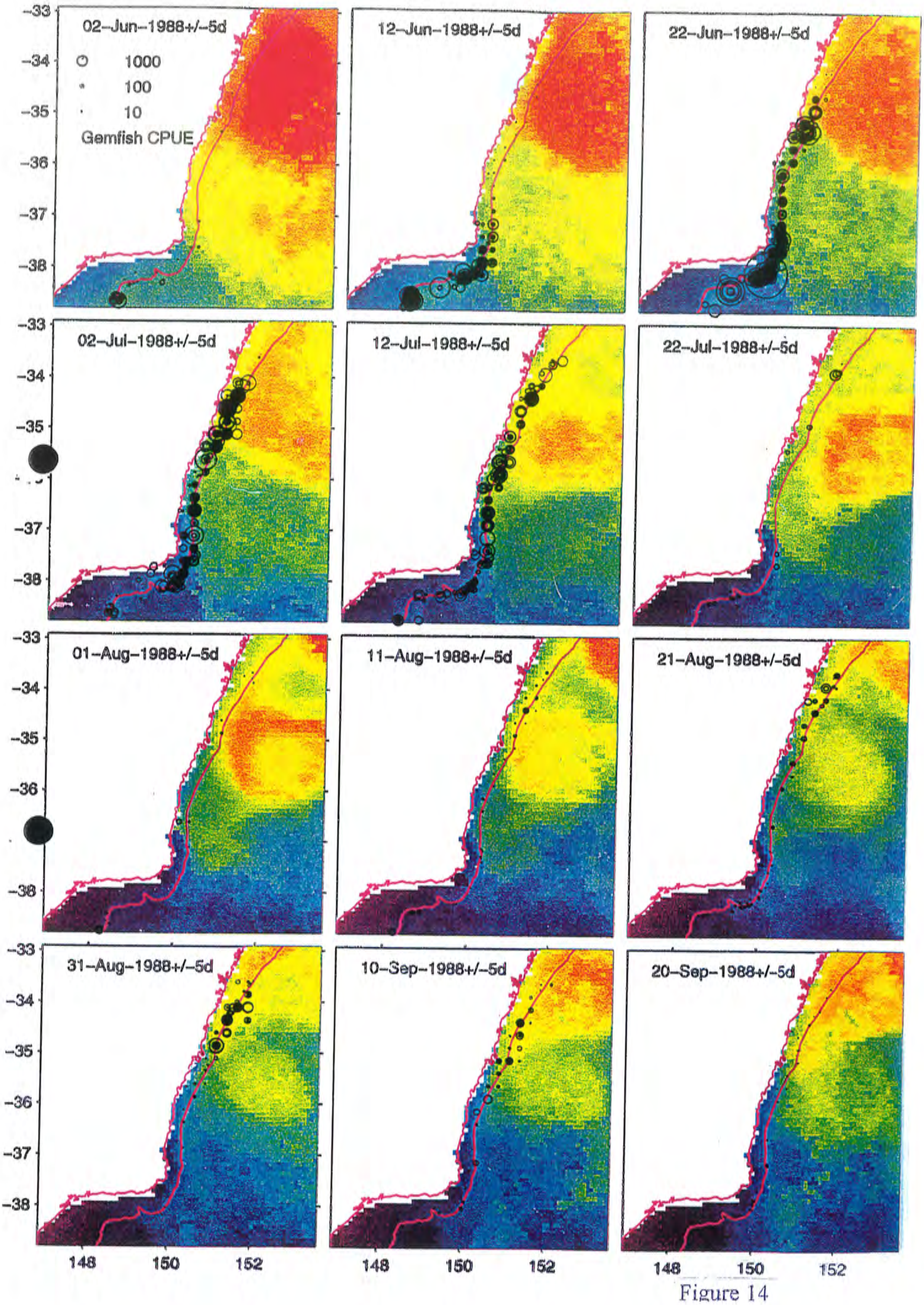

02-Jun-1988+/-5d
12-Jun-1988+/-5d
22-Jun-1988+/-5d
02-Jul-1988+/-5d
12-Jul-1988+/-5d
22-Jul-1988+/-5d
01-Aug-1988+/-5d
11-Aug-1988+/-5d
21-Aug-1988+/-5d
31-Aug-1988+/-5d
10-Sep-1988+/-5d
20-Sep-1988+/-5d
1000
100
10
Gemfish CPUE
-33
-34
-35
-36
-37
-38
148
150
152

Figure 14

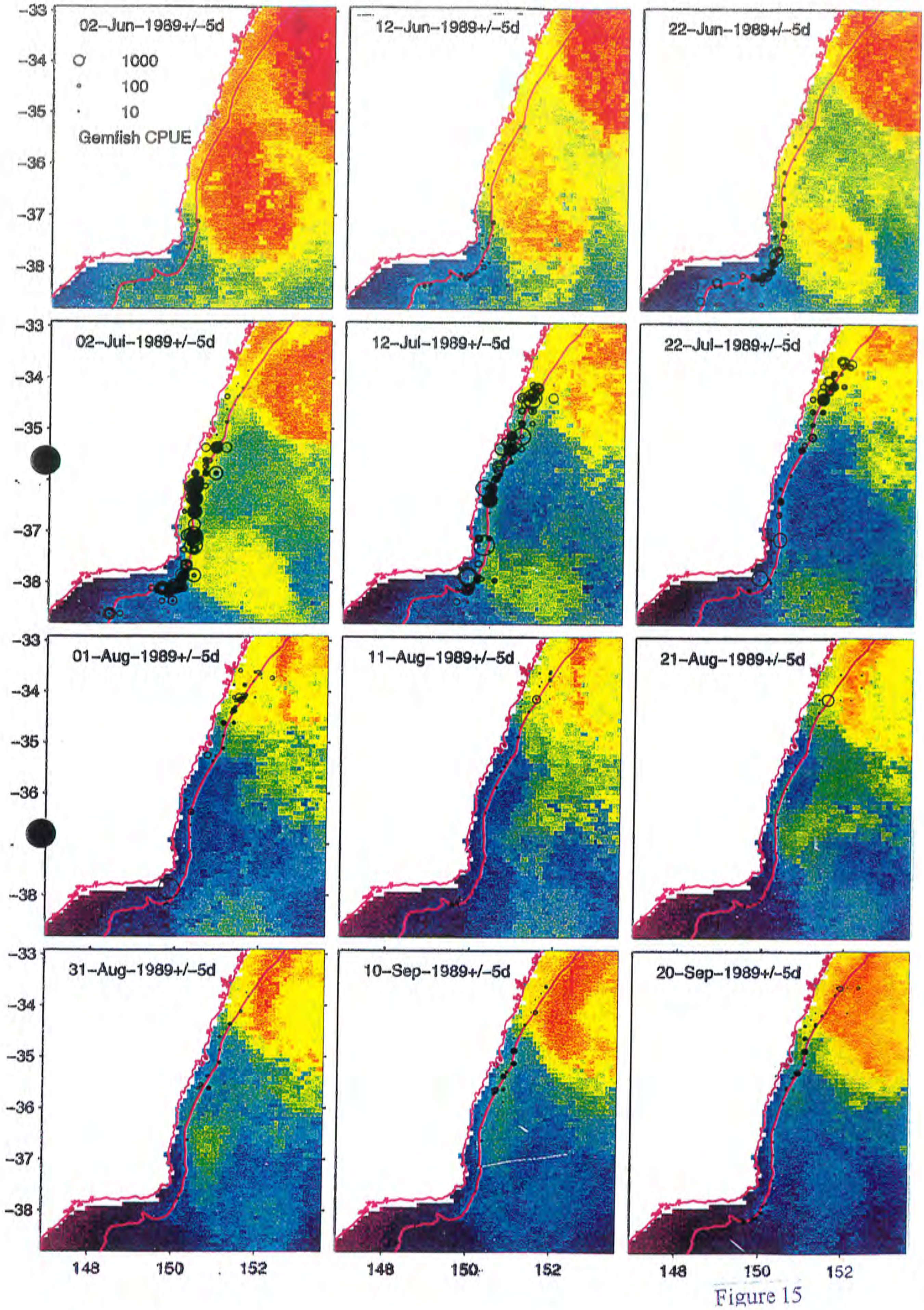

02-Jun-1989+/-5d
1000
100
10
Gemfish CPUE
12-Jun-1989+/-5d
22-Jun-1989+/-5d
02-Jul-1989+/-5d
12-Jul-1989+/-5d
22-Jul-1989+/-5d
01-Aug-1989+/-5d
11-Aug-1989+/-5d
21-Aug-1989+/-5d
31-Aug-1989+/-5d
10-Sep-1989+/-5d
20-Sep-1989+/-5d
-33
-34
-35
-36
-37
-38
148
150
152

Figure 15

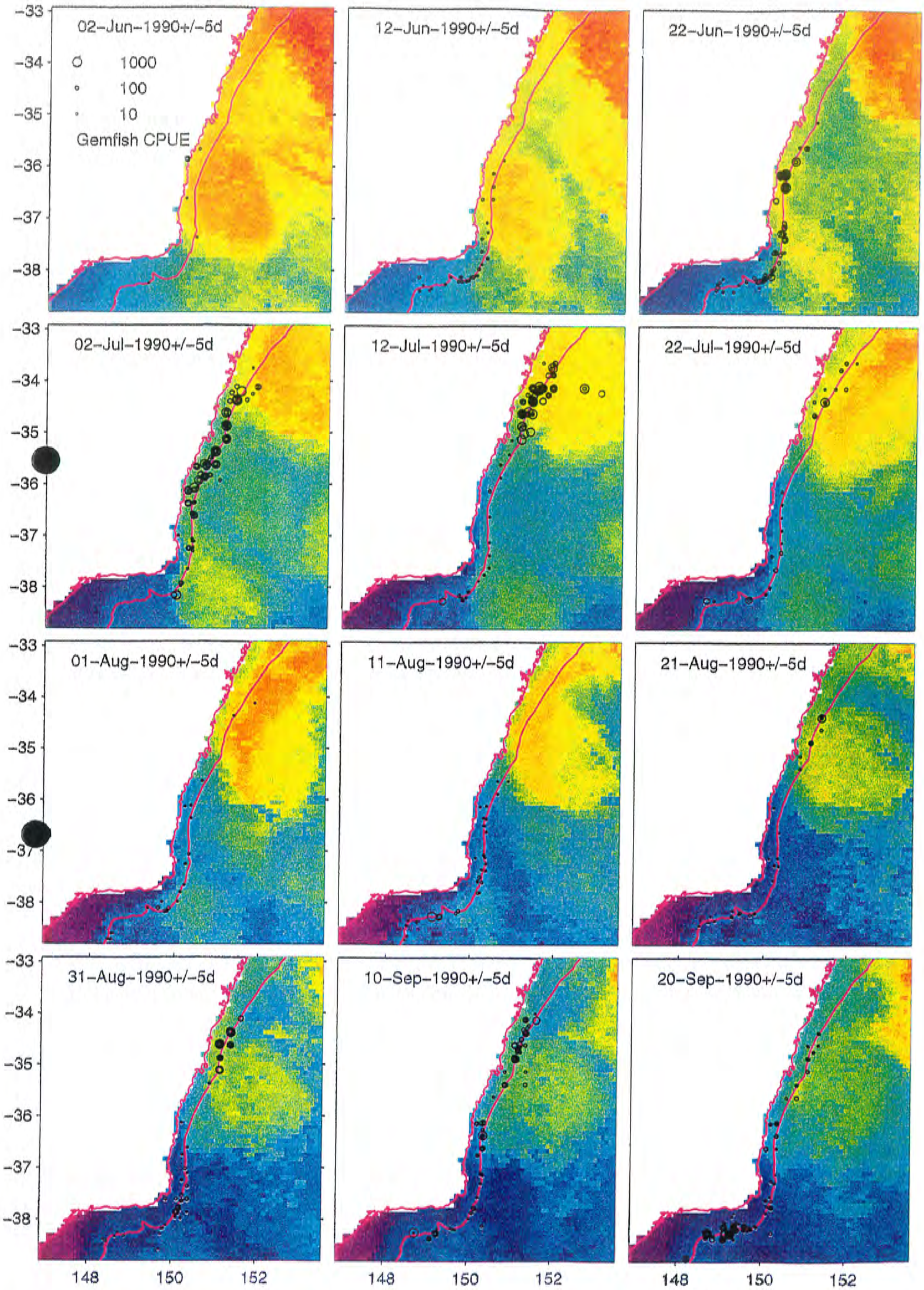

02-Jun-1990+/-5d
1000
100
10
Gemfish CPUE
12-Jun-1990+/-5d
22-Jun-1990+/-5d
02-Jul-1990+/-5d
12-Jul-1990+/-5d
22-Jul-1990+/-5d
01-Aug-1990+/-5d
11-Aug-1990+/-5d
21-Aug-1990+/-5d
31-Aug-1990+/-5d
10-Sep-1990+/-5d
20-Sep-1990+/-5d
-33
-34
-35
-36
-37
-38
148
150
152

Figure 16

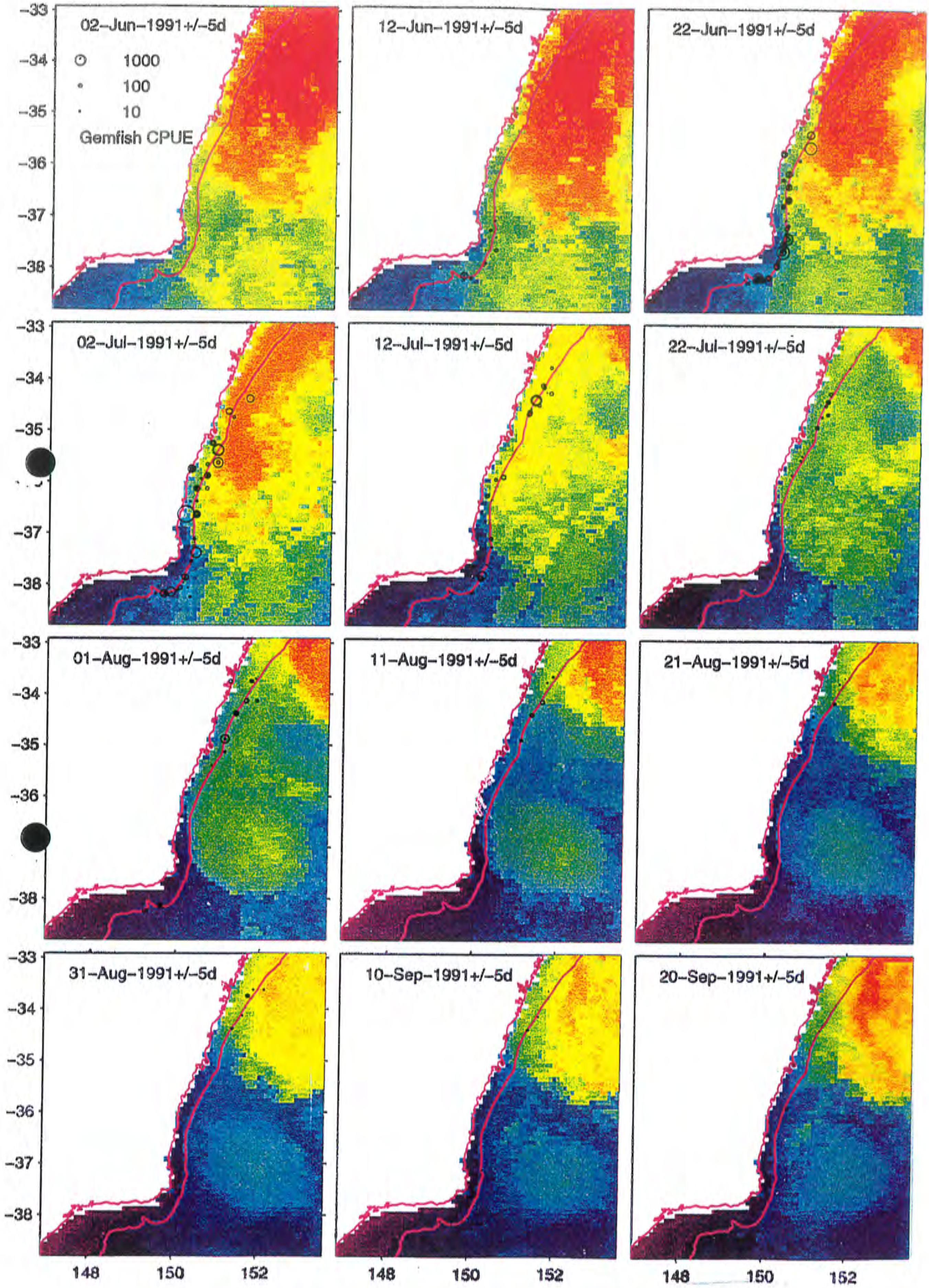
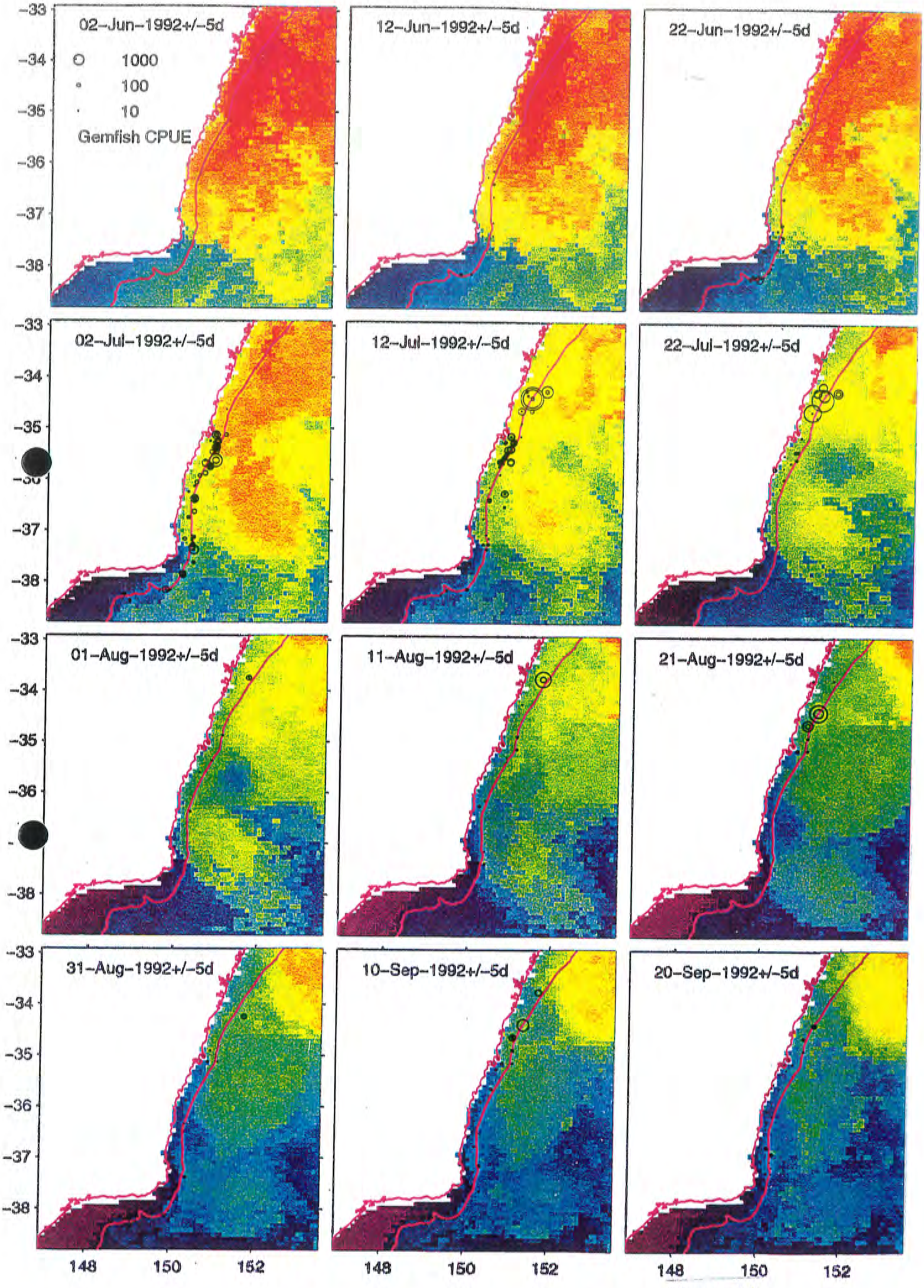

02-Jun-1991+/-5d
12-Jun-1991+/-5d
22-Jun-1991+/-5d
02-Jul-1991+/-5d
12-Jul-1991+/-5d
22-Jul-1991+/-5d
01-Aug-1991+/-5d
11-Aug-1991+/-5d
21-Aug-1991+/-5d
31-Aug-1991+/-5d
10-Sep-1991+/-5d
20-Sep-1991+/-5d
1000
100
10
Gemfish CPUE
-33
-34
-35
-36
-37
-38
148
150
152

Figure 17



02-Jun-1992+/-5d
O 1000
100
10
Gemfish CPUE
12-Jun-1992+/-5d
22-Jun-1992+/-5d
02-Jul-1992+/-5d
12-Jul-1992+/-5d
22-Jul-1992+/-5d
01-Aug-1992+/-5d
11-Aug-1992+/-5d
21-Aug-1992+/-5d
31-Aug-1992+/-5d
10-Sep-1992+/-5d
20-Sep-1992+/-5d
-33
-34
-35
-36
-37
-38
148
150
152

Figure 18

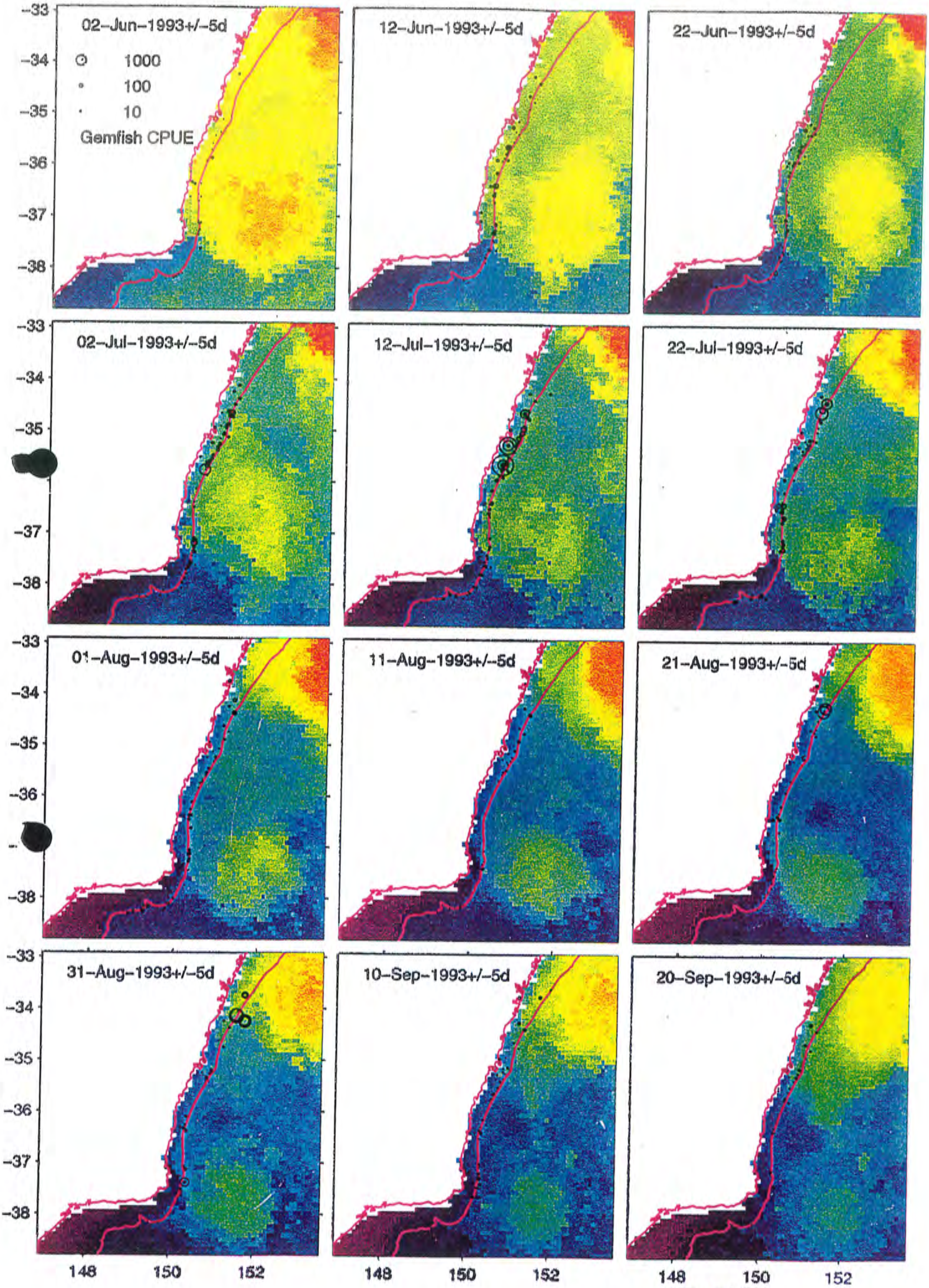

02-Jun-1993+/-5d
1000
100
10
Gemfish CPUE
12-Jun-1993+/-5d
22-Jun-1993+/-5d
02-Jul-1993+/-5d
12-Jul-1993+/-5d
22-Jul-1993+/-5d
01-Aug-1993+/-5d
11-Aug-1993+/-5d
21-Aug-1993+/-5d
31-Aug-1993+/-5d
10-Sep-1993+/-5d
20-Sep-1993+/-5d
-33
-34
-35
-36
-37
-38
148
150
152

Figure 19

Sea surface temperature, June - August 1994

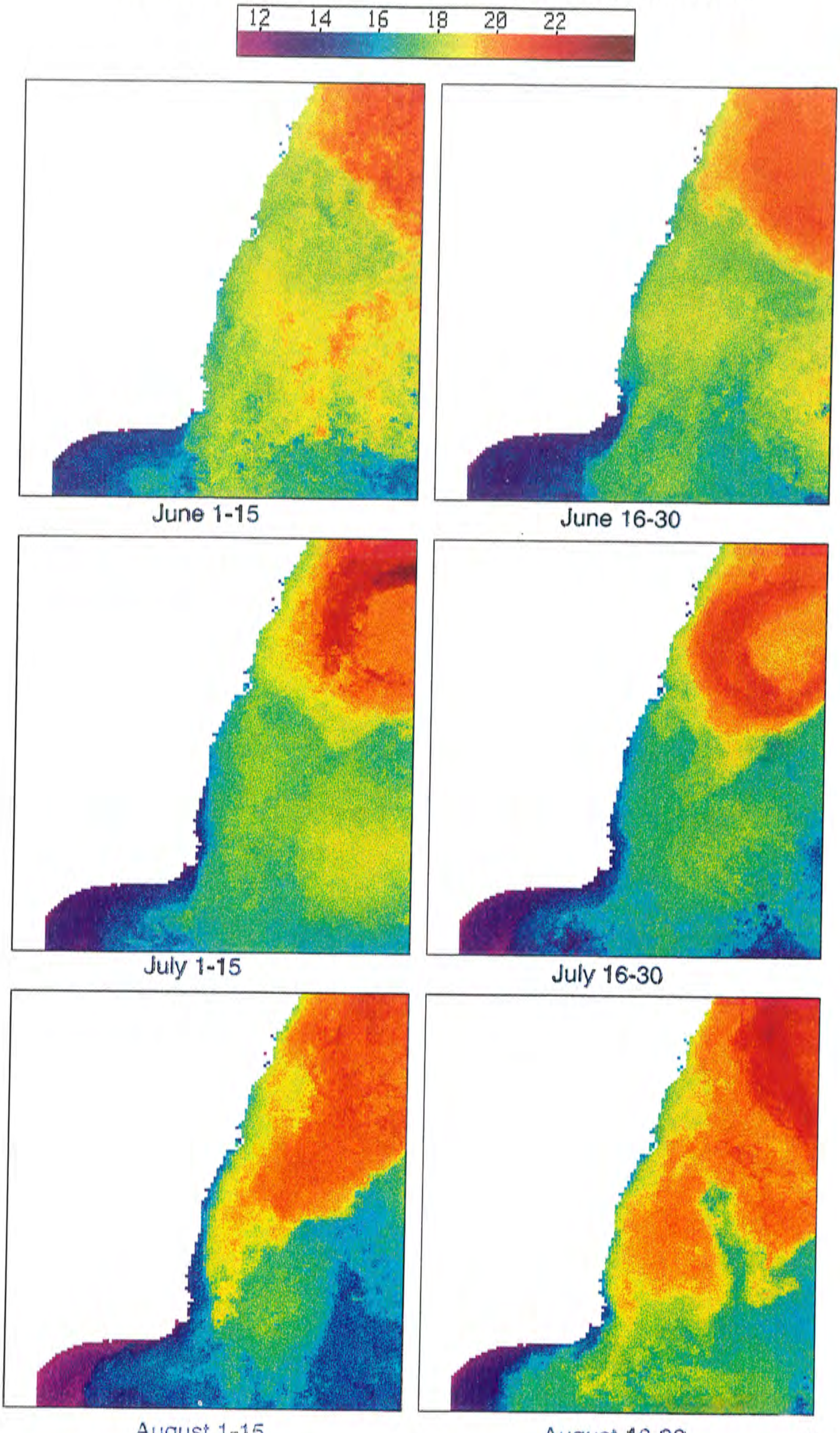


Figure 20

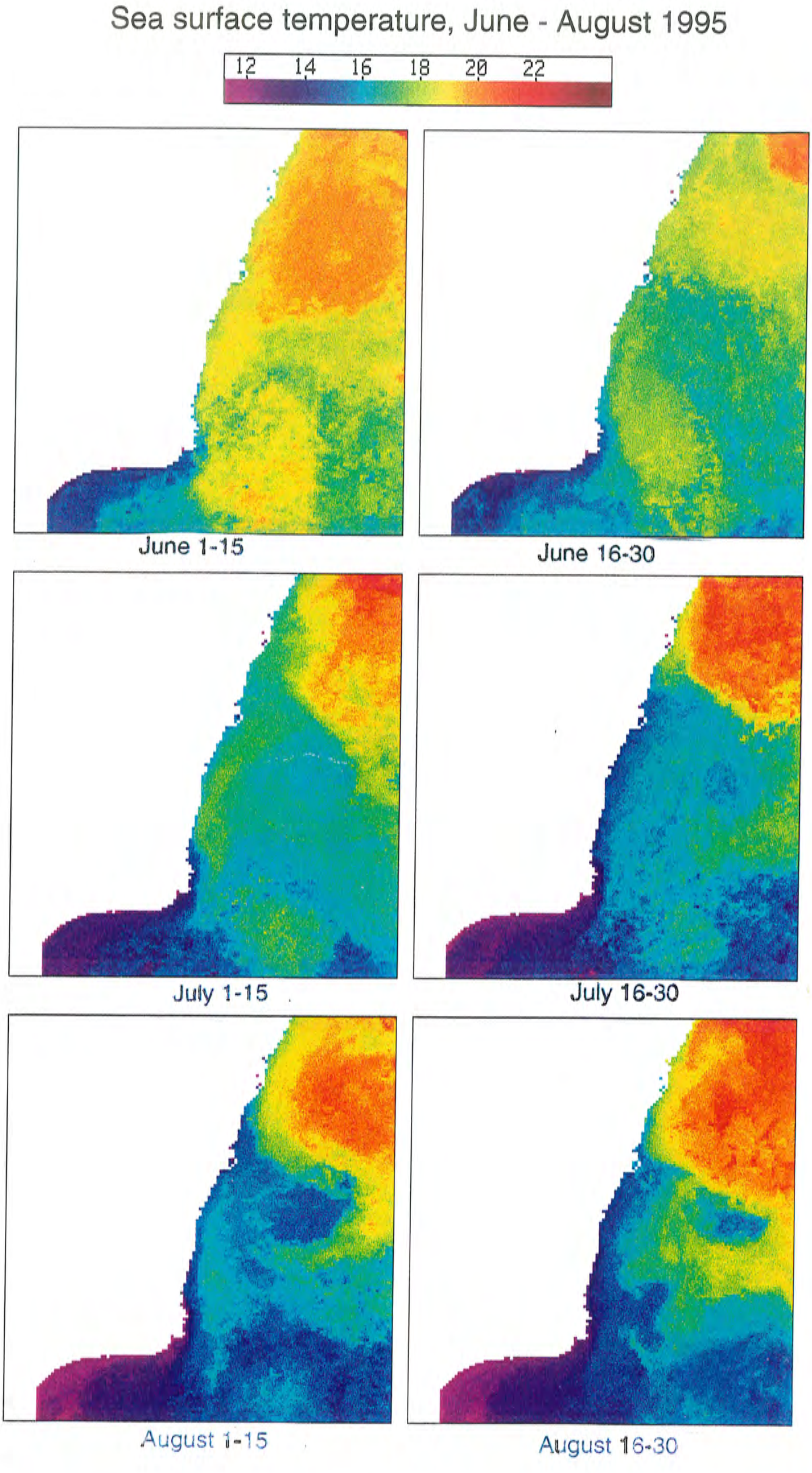

Sea surface temperature, June - August 1995
12
14
16
18
20
22
June 1-15
June 16-30
July 1-15
July 16-30
August 1-15
August 16-30

Figure 21

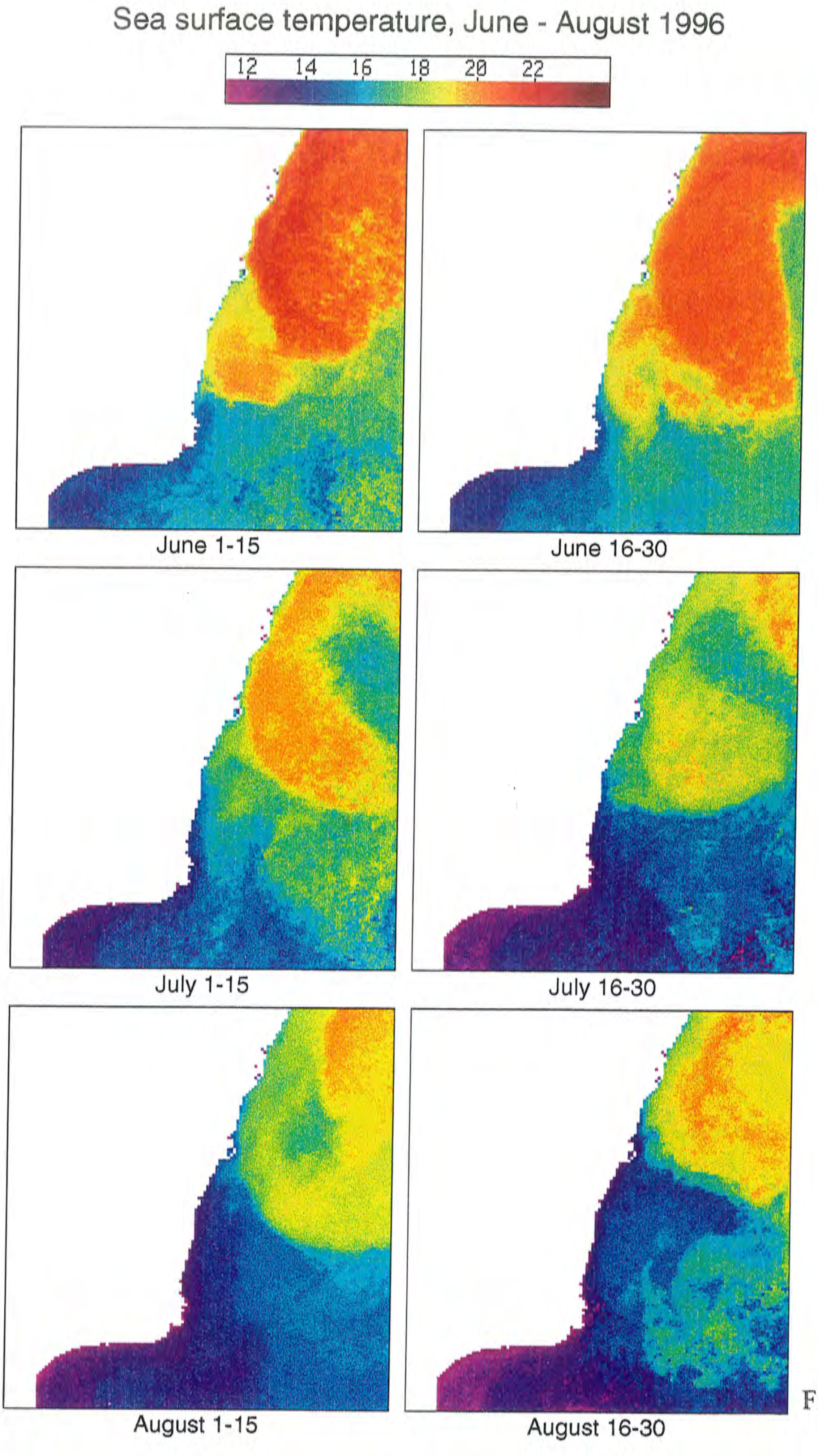

Sea surface temperature, June - August 1996
12
14
16
18
20
22
June 1-15
June 16-30
July 1-15
July 16-30
August 1-15
August 16-30

Figure 22

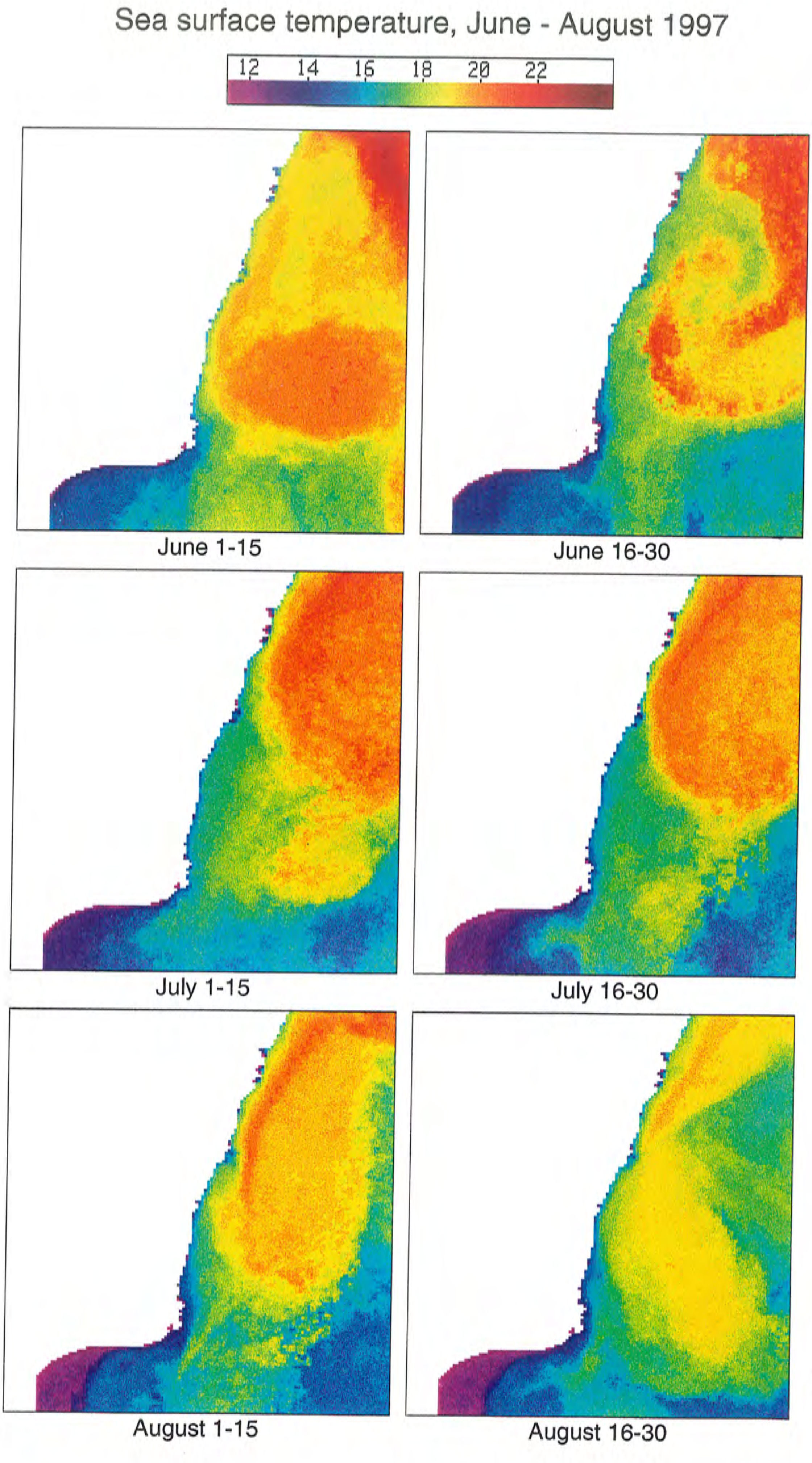

Sea surface temperature, June - August 1997
12 14 16 18 20 22
June 1-15
June 16-30
July 1-15
July 16-30
August 1-15
August 16-30

Figure 23

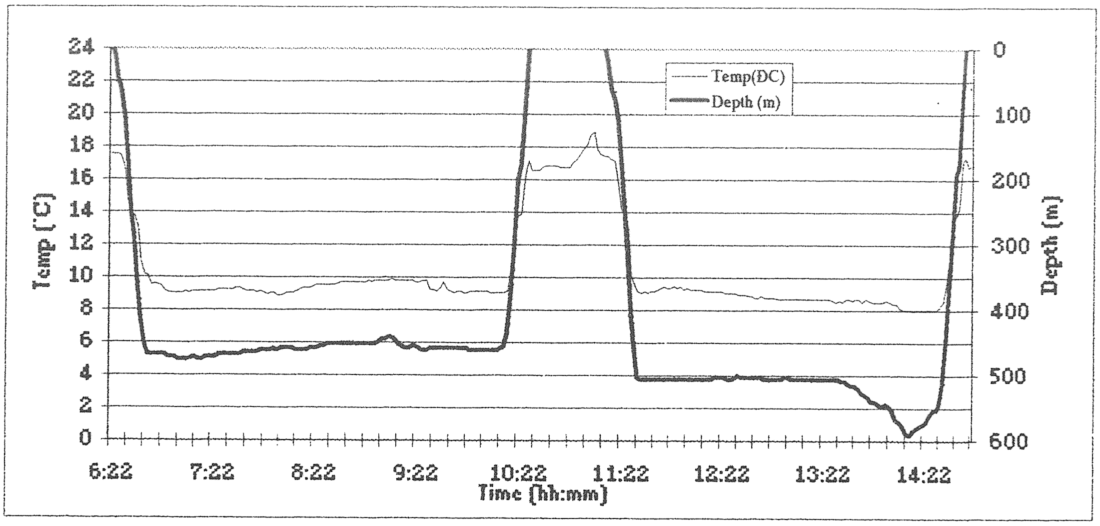


Figure 24a

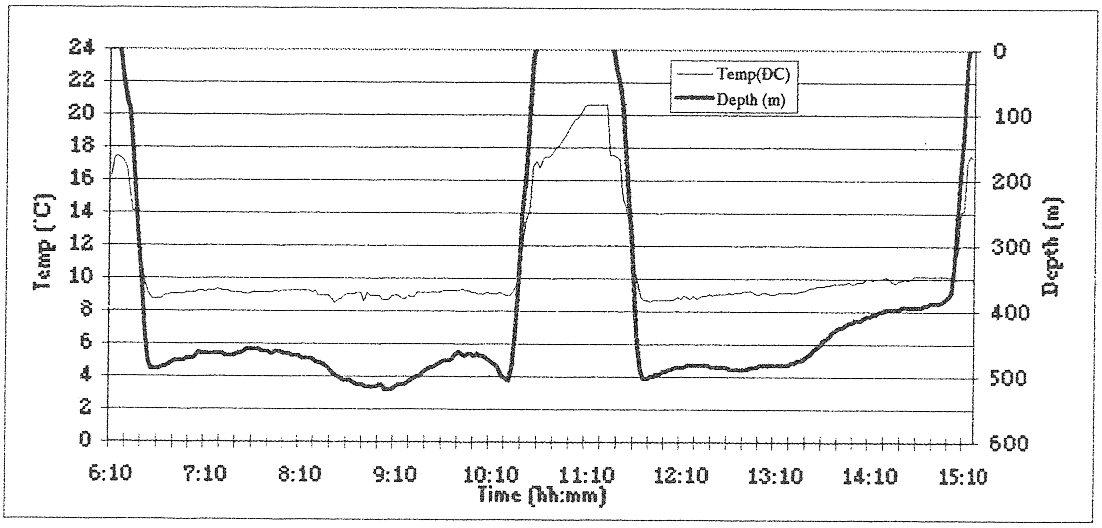


Figure 24b

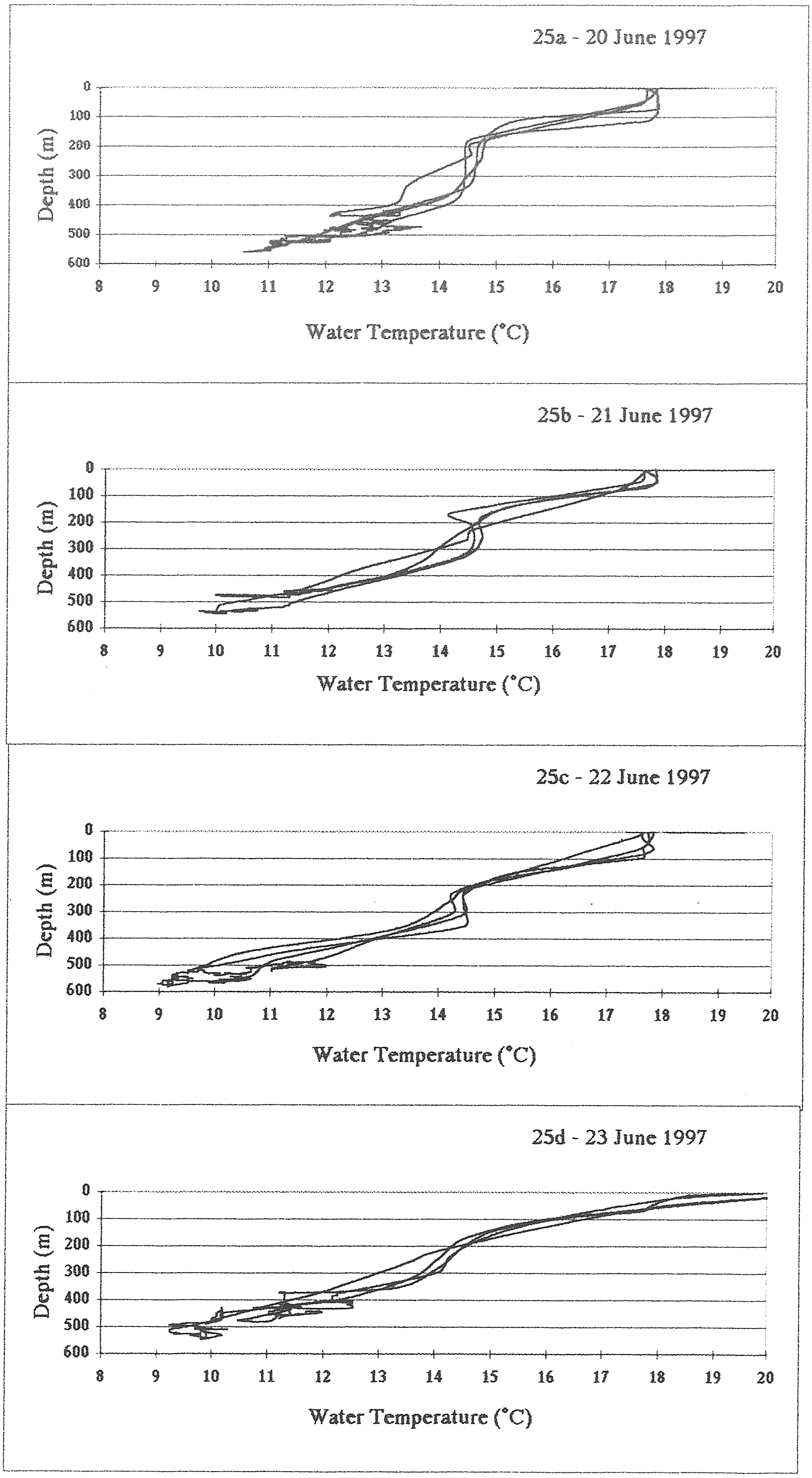

25a - 20 June 1997
Depth (m)
0
100
200
300
400
500
600
8
9
10
11
12
13
14
15
16
17
18
19
20
Water Temperature (°C)
25b - 21 June 1997
Depth (m)
Water Temperature (°C)
25c - 22 June 1997
Depth (m)
Water Temperature (°C)
25d - 23 June 1997
Depth (m)
Water Temperature (°C)

Figure 25a-d

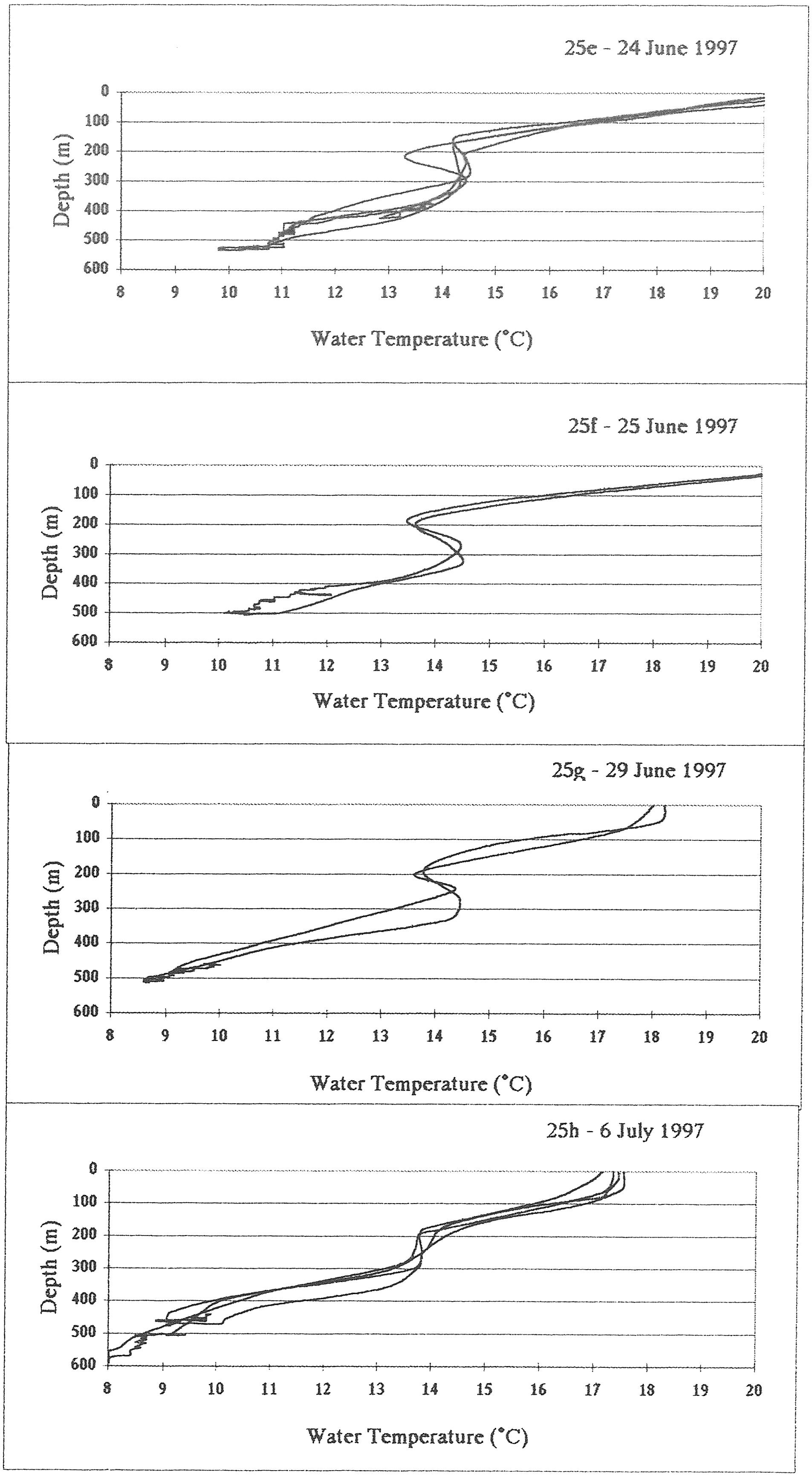

25e - 24 June 1997
Depth (m)
0
100
200
300
400
500
600
8
9
10
11
12
13
14
15
16
17
18
19
20
Water Temperature (°C)
25f - 25 June 1997
Depth (m)
0
100
200
300
400
500
600
8
9
10
11
12
13
14
15
16
17
18
19
20
Water Temperature (°C)
25g - 29 June 1997
Depth (m)
0
100
200
300
400
500
600
8
9
10
11
12
13
14
15
16
17
18
19
20
Water Temperature (°C)
25h - 6 July 1997
Depth (m)
0
100
200
300
400
500
600
8
9
10
11
12
13
14
15
16
17
18
19
20
Water Temperature (°C)

Figure 25e-h

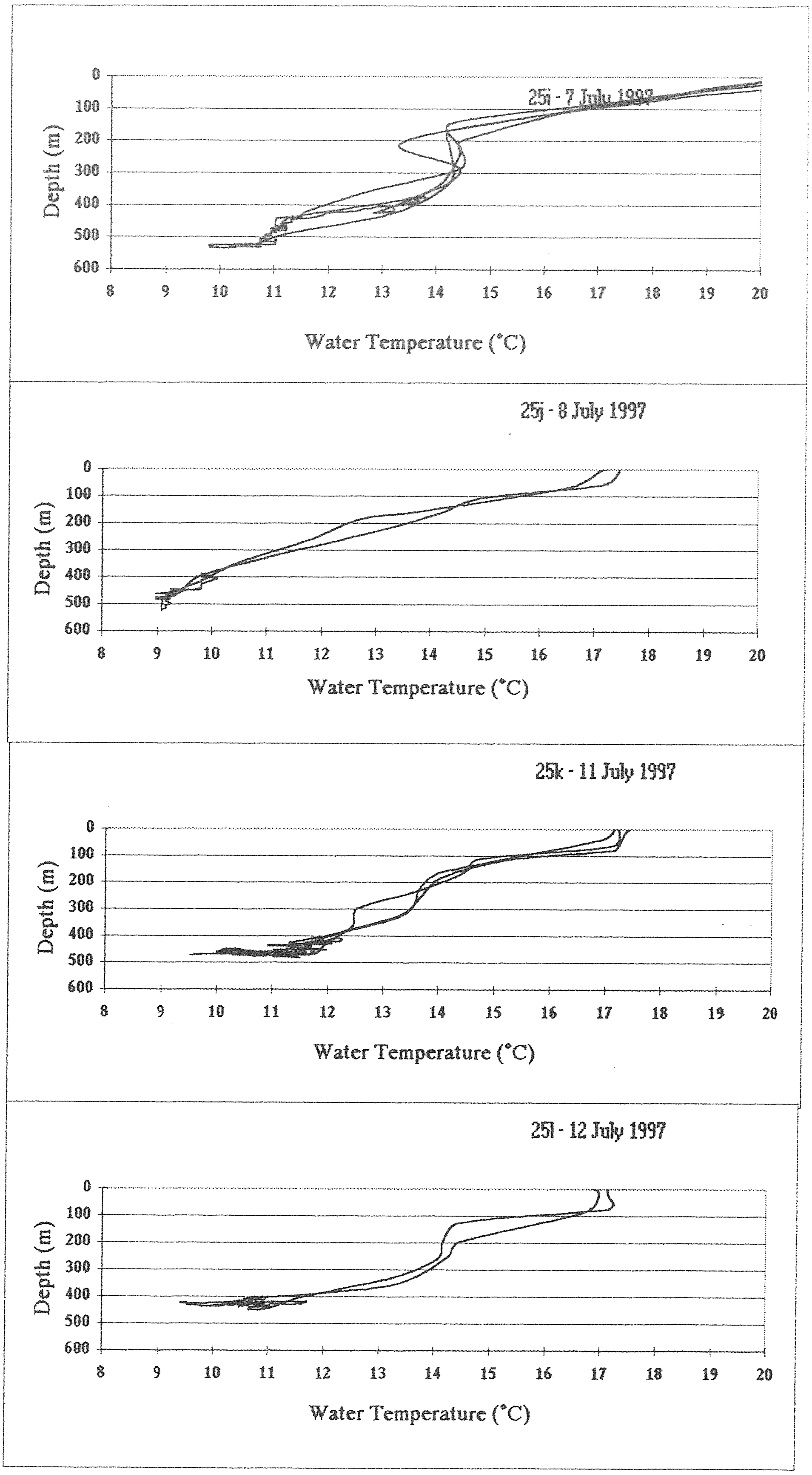

25i - 7 July 1997
Depth (m)
0
100
200
300
400
500
600
8
9
10
11
12
13
14
15
16
17
18
19
20
Water Temperature (°C)
25j - 8 July 1997
Depth (m)
Water Temperature (°C)
25k - 11 July 1997
Depth (m)
Water Temperature (°C)
25l - 12 July 1997
Depth (m)
Water Temperature (°C)

Figure 25i-l

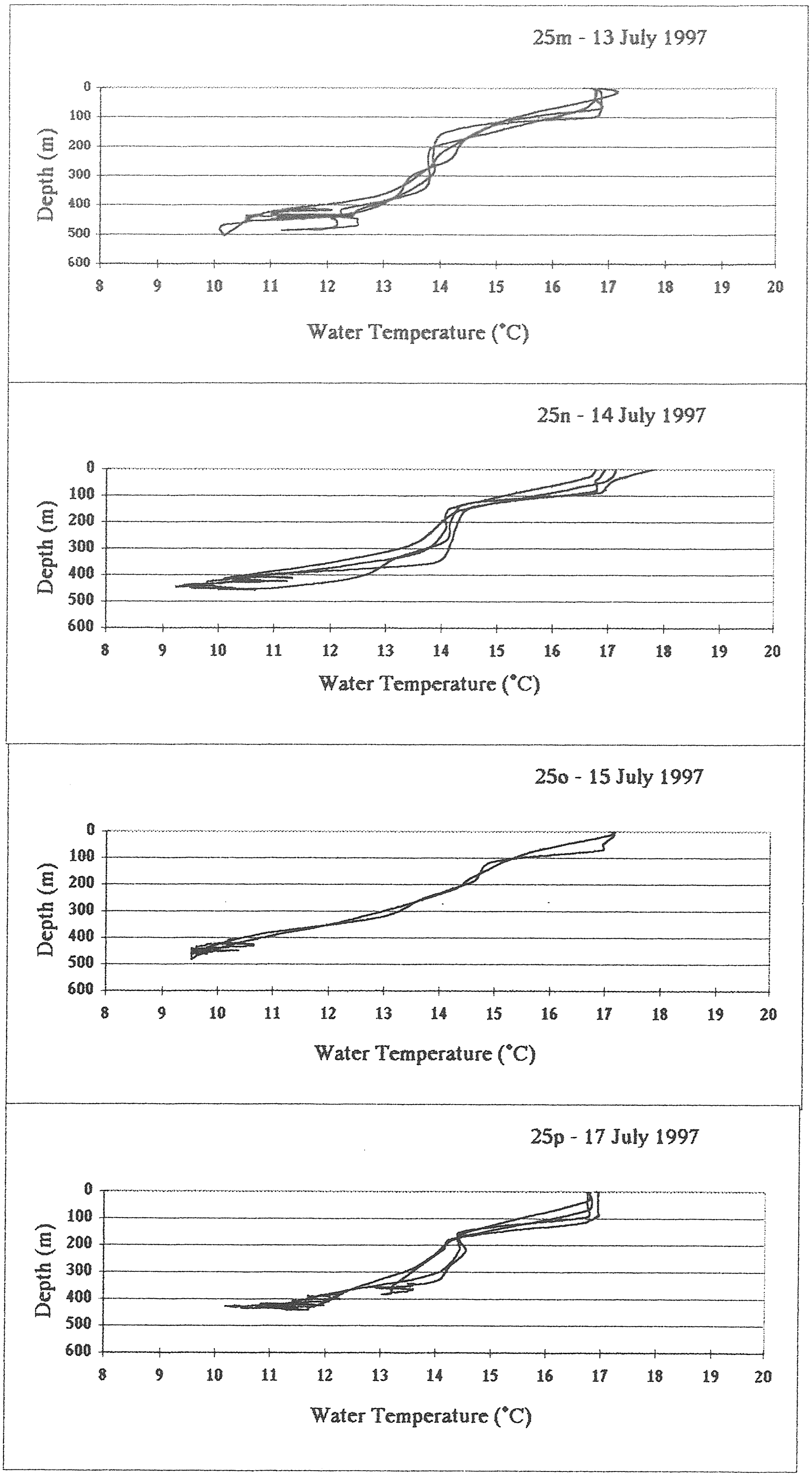

25m - 13 July 1997
Depth (m)
0
100
200
300
400
500
600
8
9
10
11
12
13
14
15
16
17
18
19
20
Water Temperature (°C)
25n - 14 July 1997
Depth (m)
Water Temperature (°C)
25o - 15 July 1997
Depth (m)
Water Temperature (°C)
25p - 17 July 1997
Depth (m)
Water Temperature (°C)

Figure 25m-p

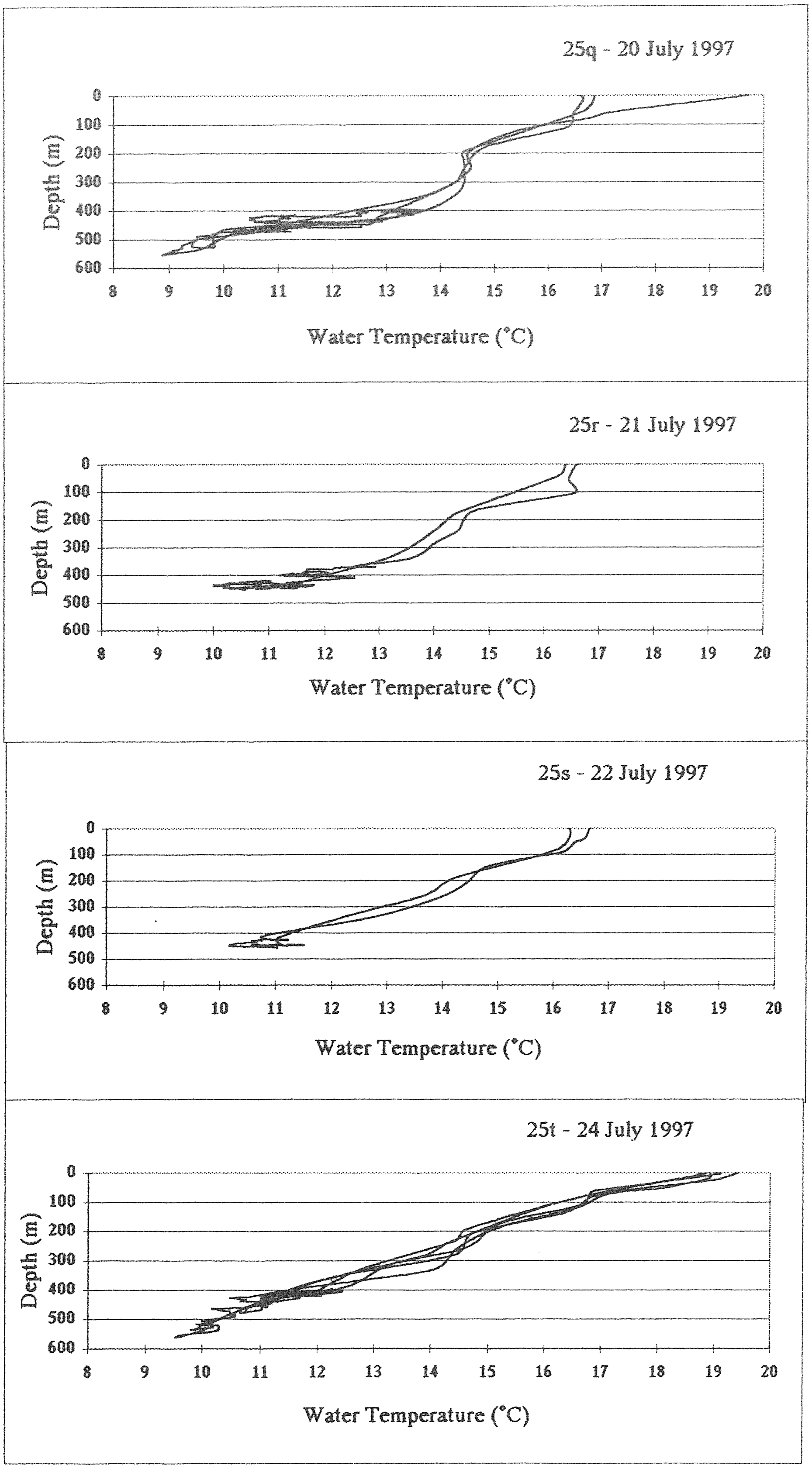

25q - 20 July 1997
Depth (m)
0
100
200
300
400
500
600
8
9
10
11
12
13
14
15
16
17
18
19
20
Water Temperature (°C)
25r - 21 July 1997
Depth (m)
Water Temperature (°C)
25s - 22 July 1997
Depth (m)
Water Temperature (°C)
25t - 24 July 1997
Depth (m)
Water Temperature (°C)

Figure 25q-t

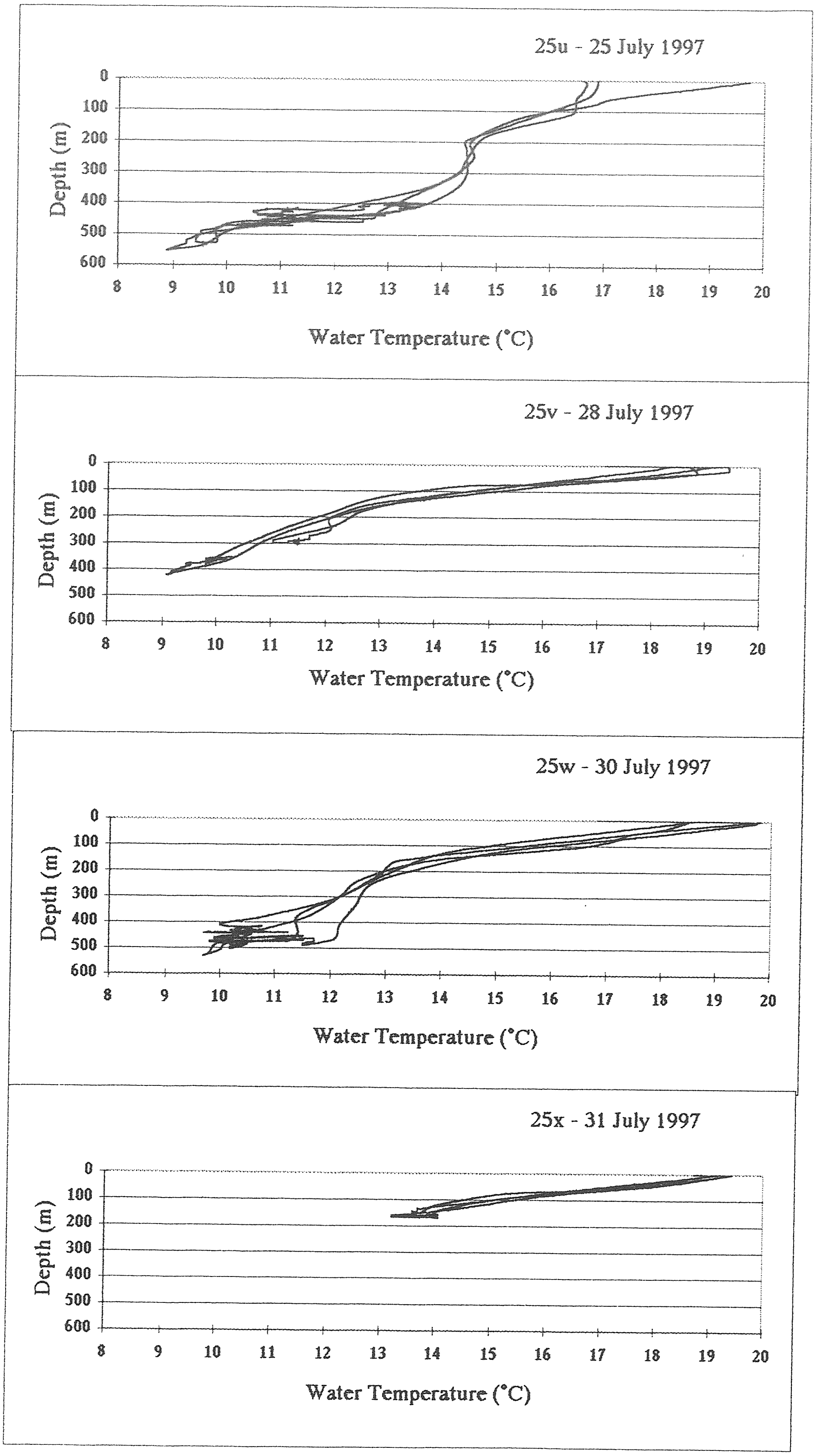

25u - 25 July 1997
25v - 28 July 1997
25w - 30 July 1997
25x - 31 July 1997
Depth (m)
0
100
200
300
400
500
600
8
9
10
11
12
13
14
15
16
17
18
19
20
Water Temperature (°C)

Figure 25u-x

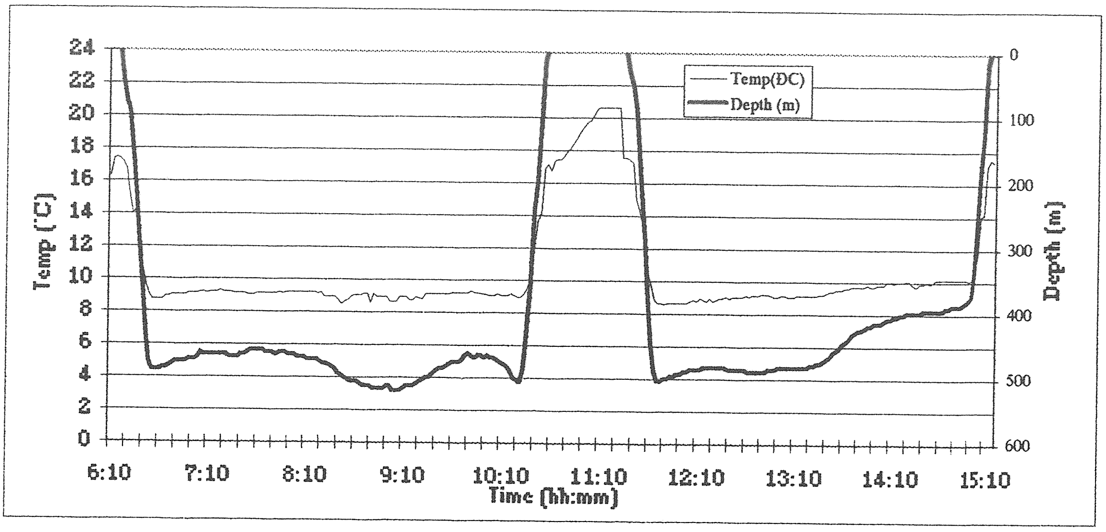


Figure 26a

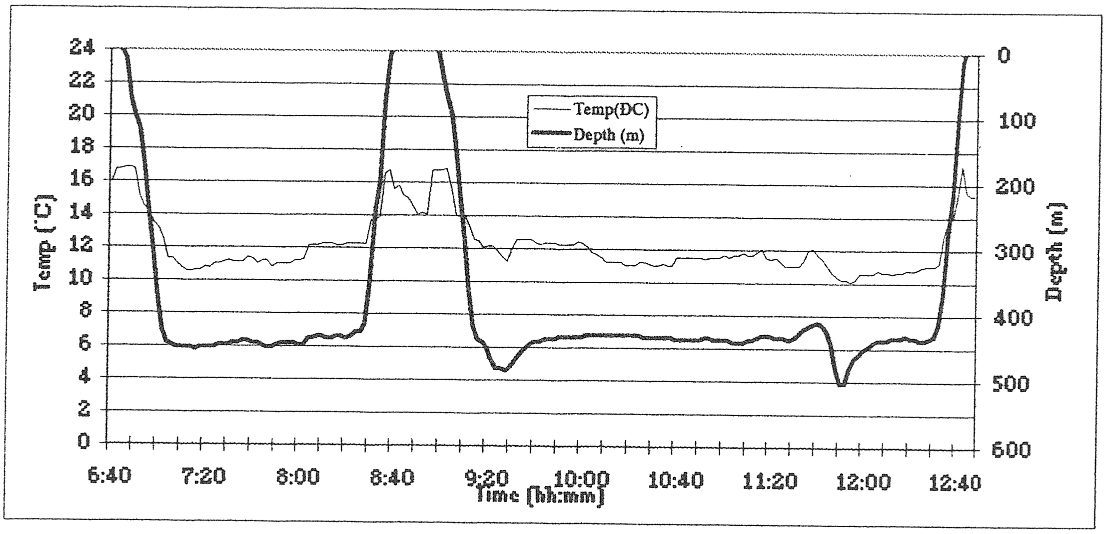


Figure 26b

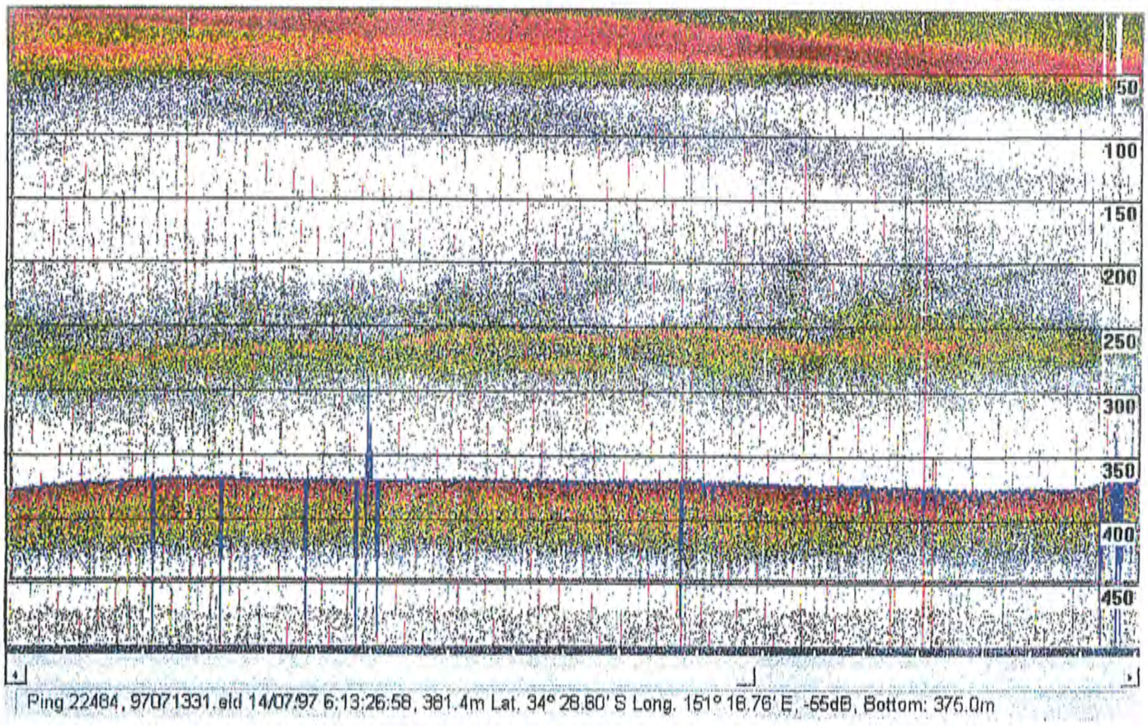


Figure 27a

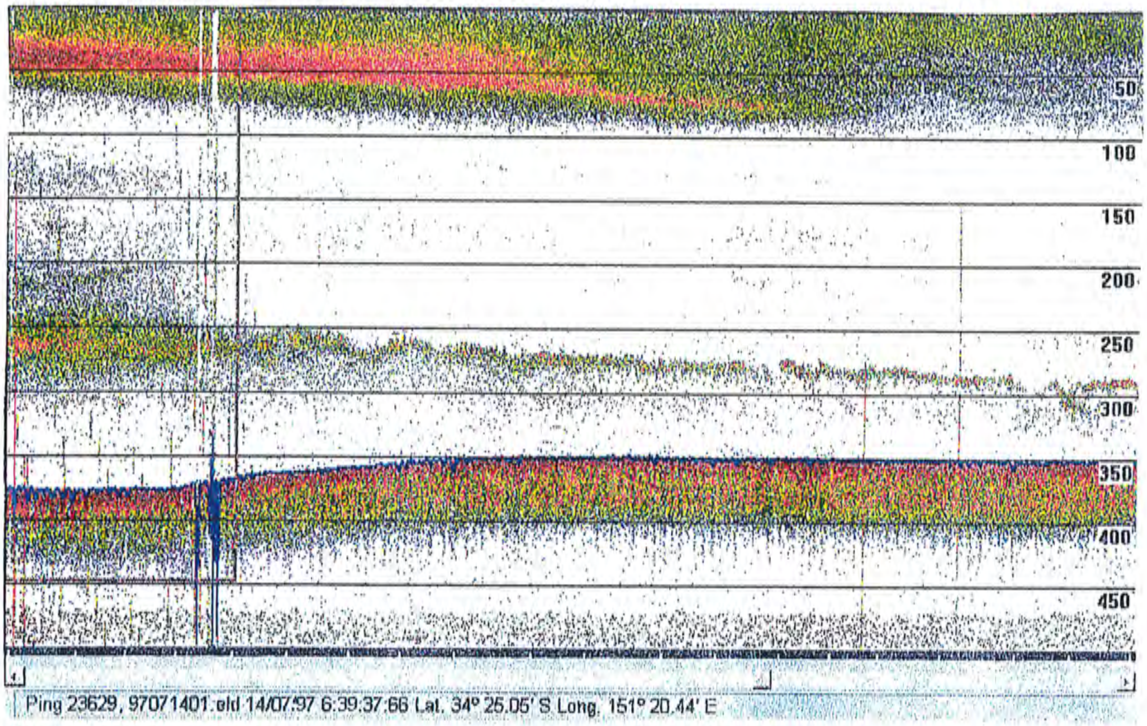


Figure 27b

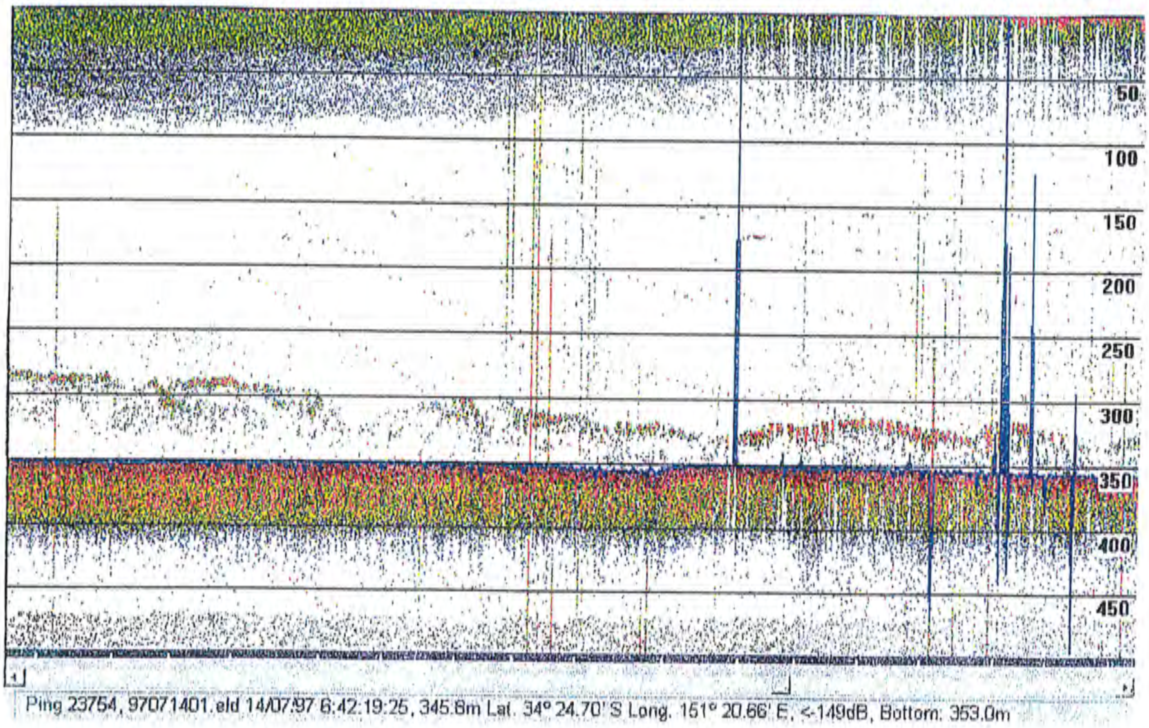


Figure 27c

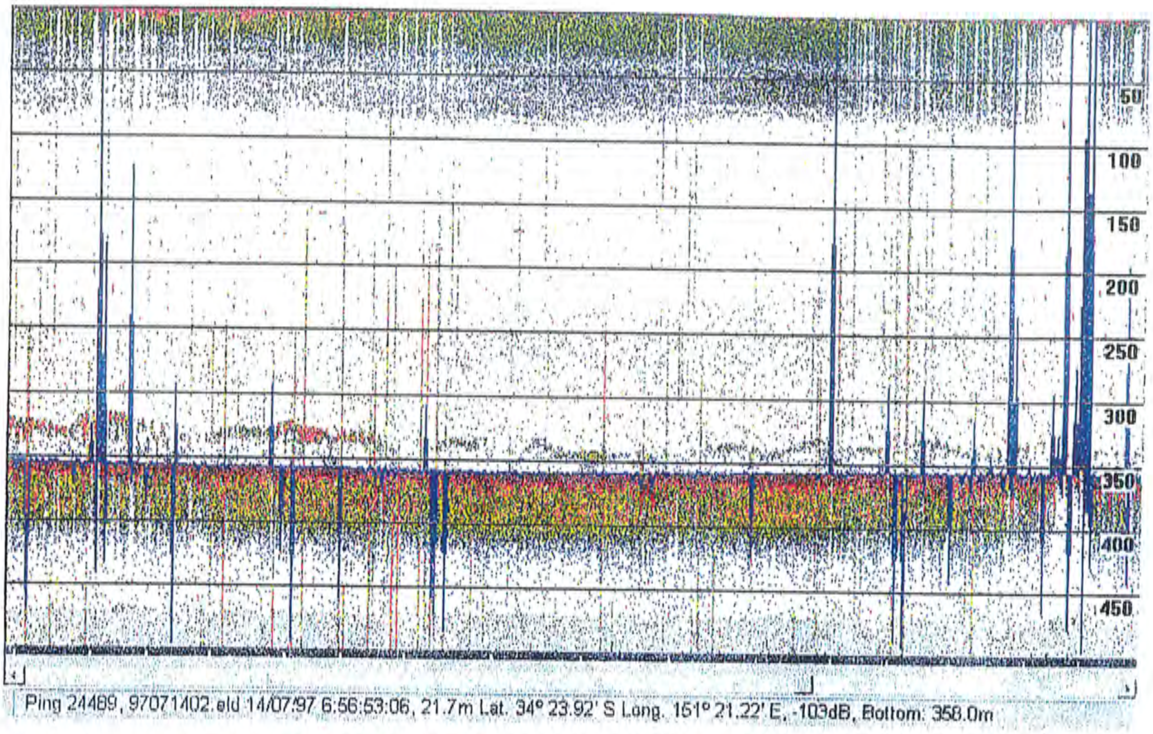

50
100
150
200
250
300
350
400
450
Ping 24489, 97071402.eld 14/07/97 6:56:53:06, 21.7m Lat. 34° 23.92' S Long. 151° 21.22' E, -103dB, Bottom: 358.0m

Figure 27d

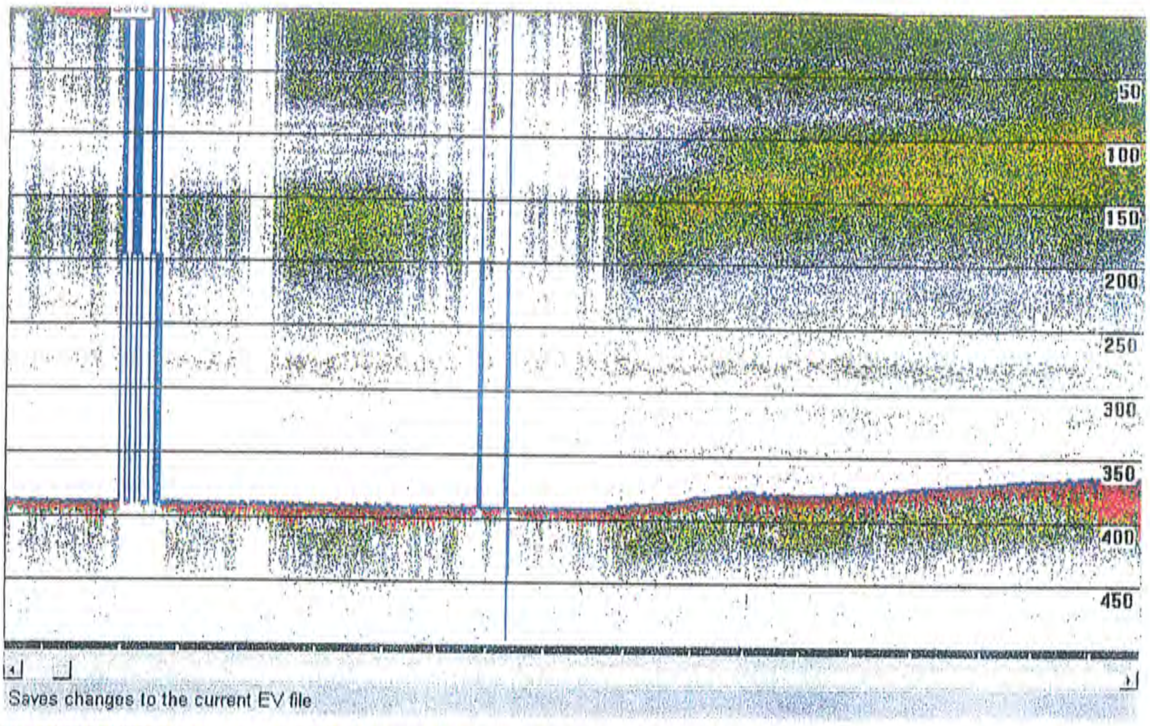


Figure 28a

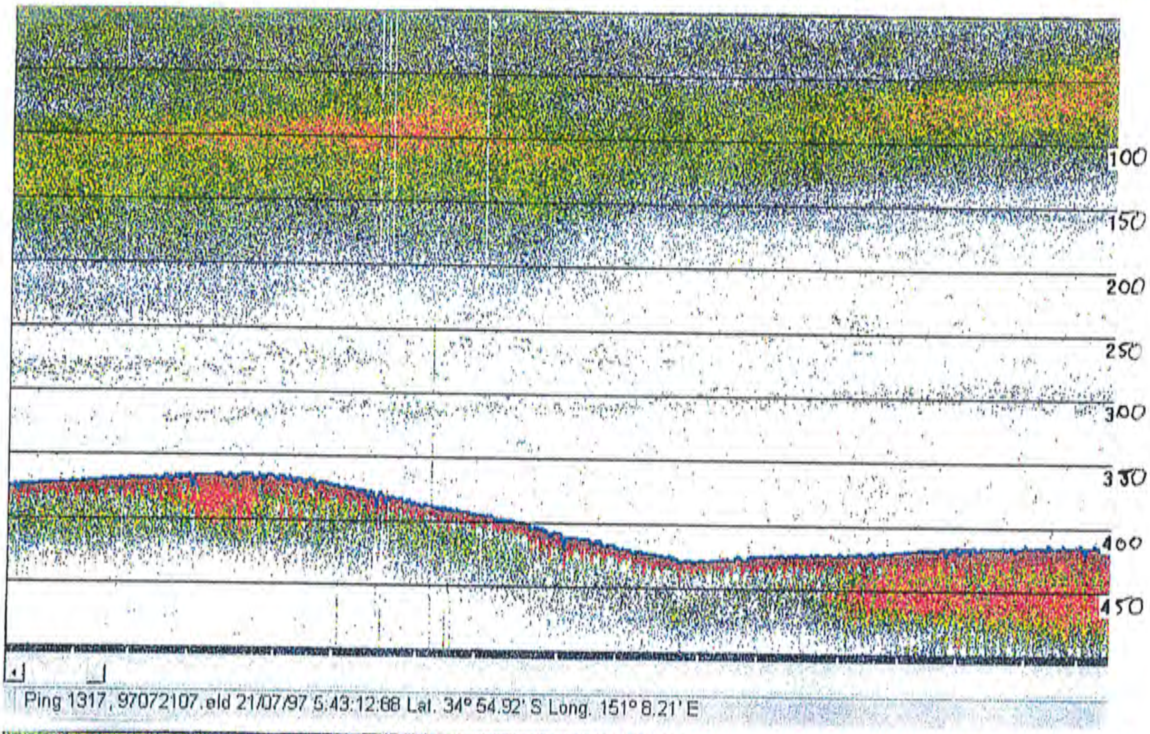


Figure 28b

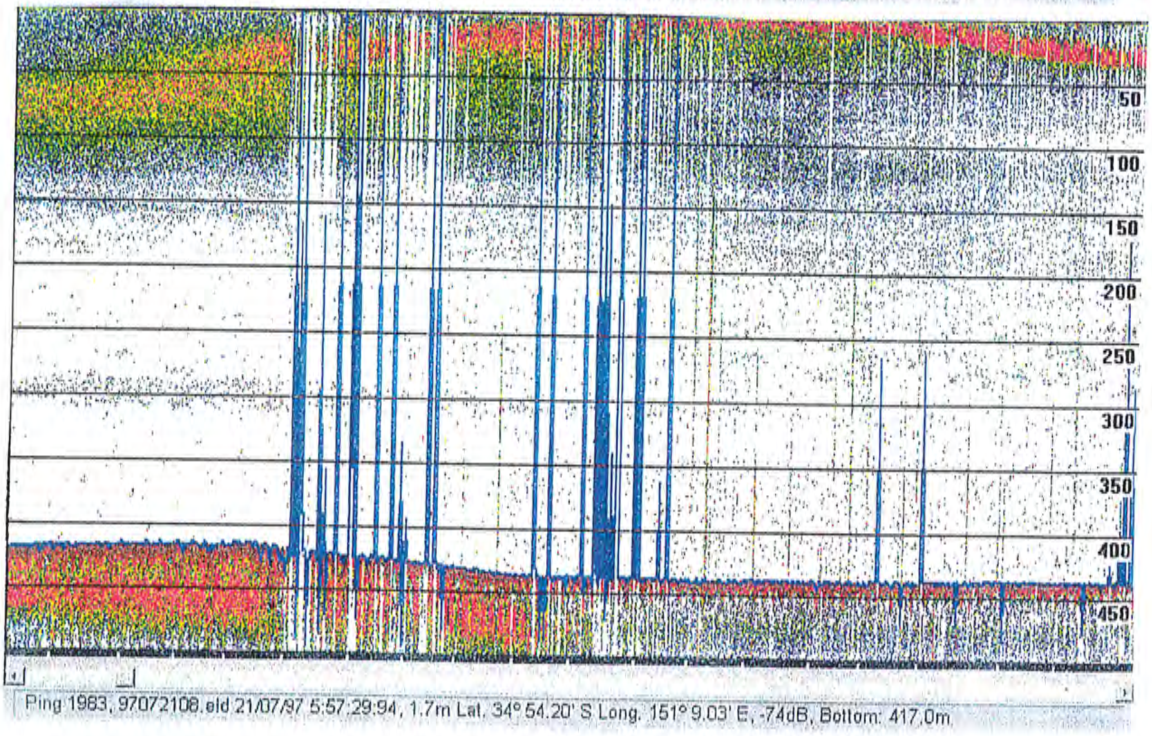


Figure 28c

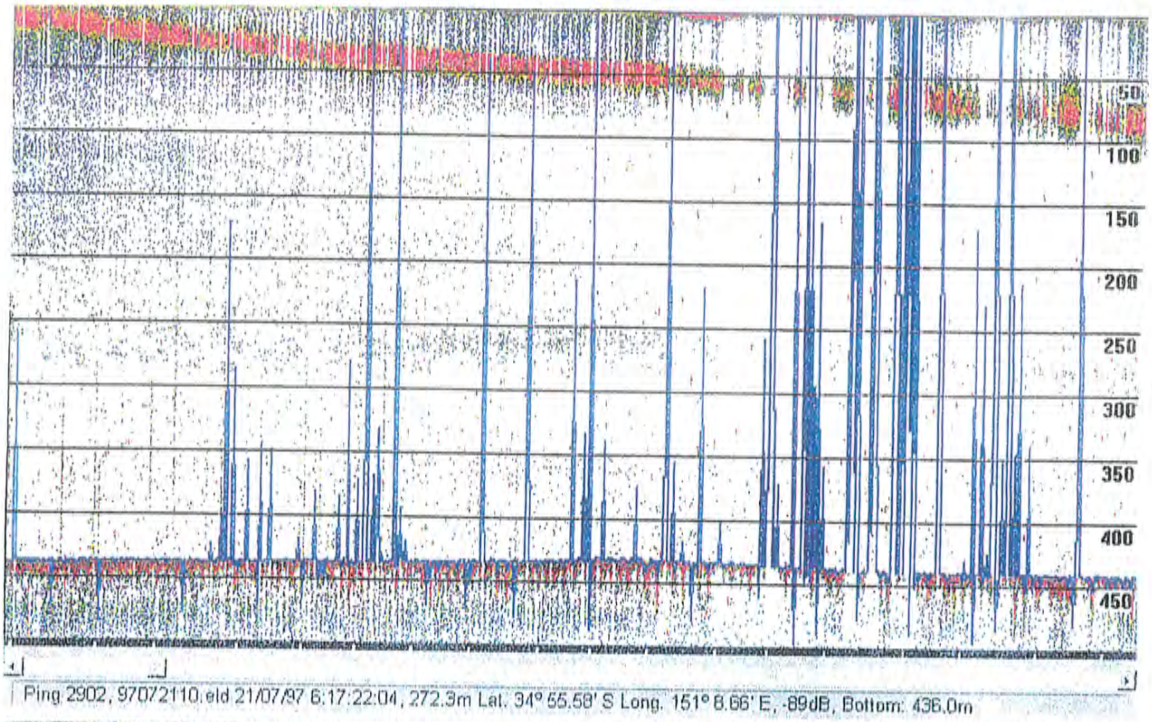


Figure 28d

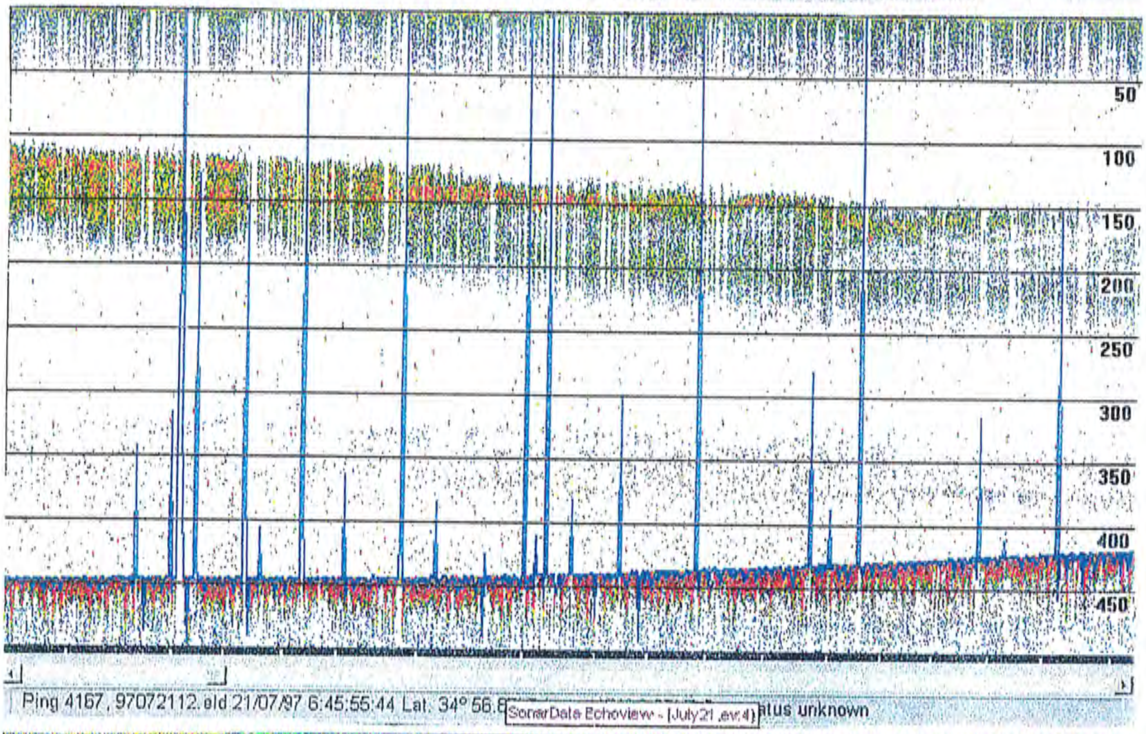


Figure 28e

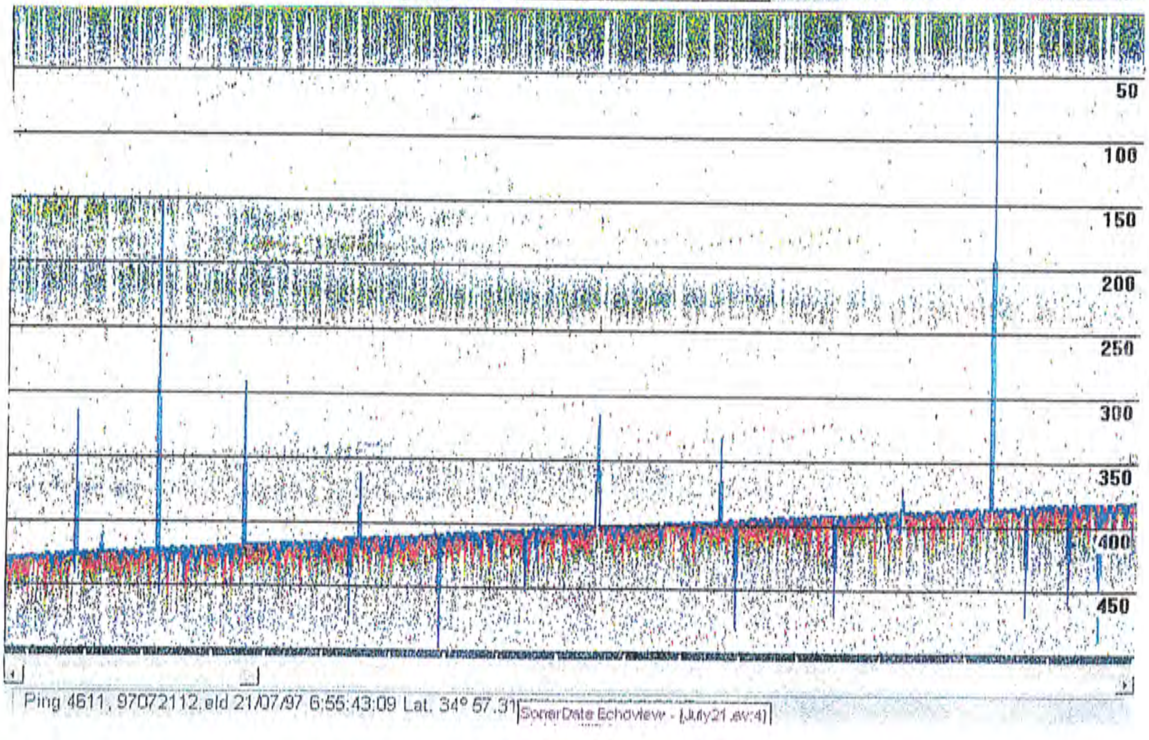


Figure 28f

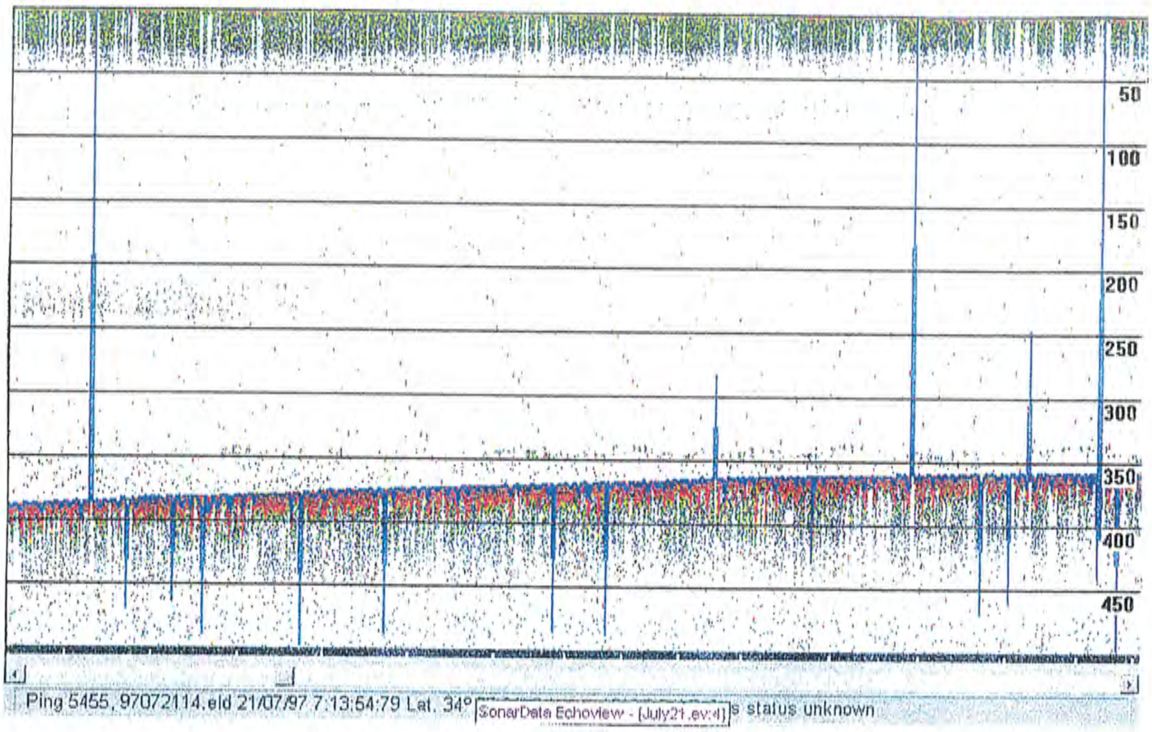

50
100
150
200
250
300
350
400
450
Ping 5455, 97072114.eld 21/07/97 7:13:54:79 Lat. 34°
SonarData Echoview - [July21.ev:4]
s status unknown

Figure 28g

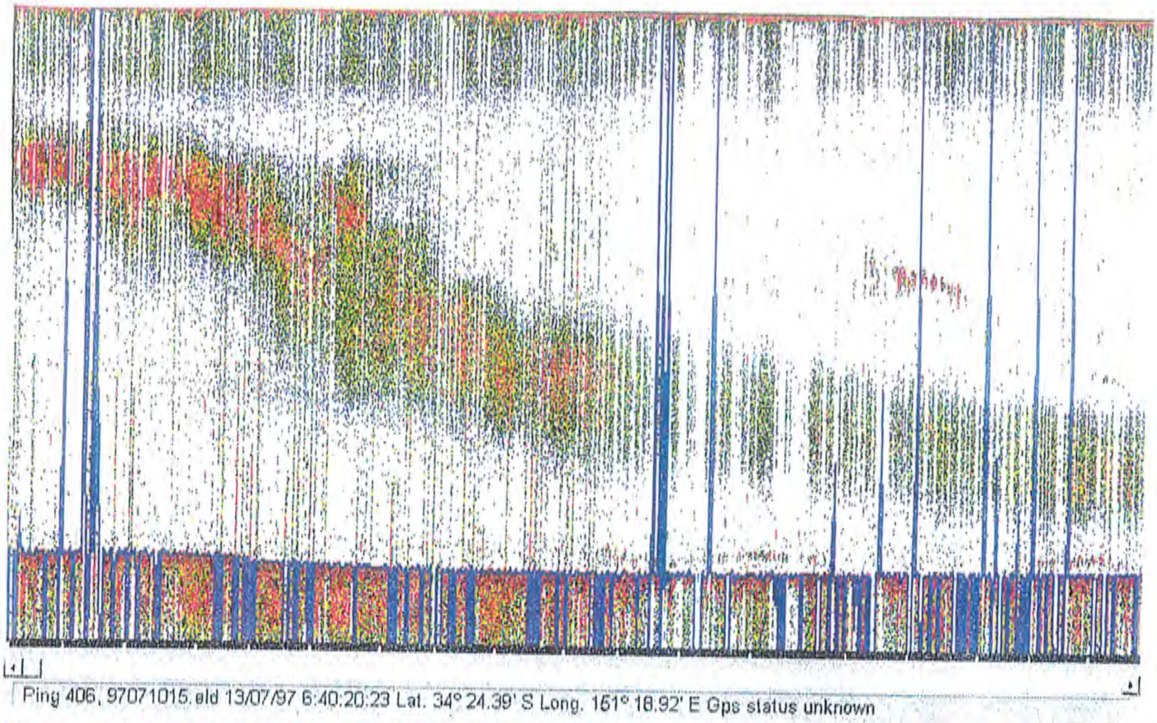


Figure 29a

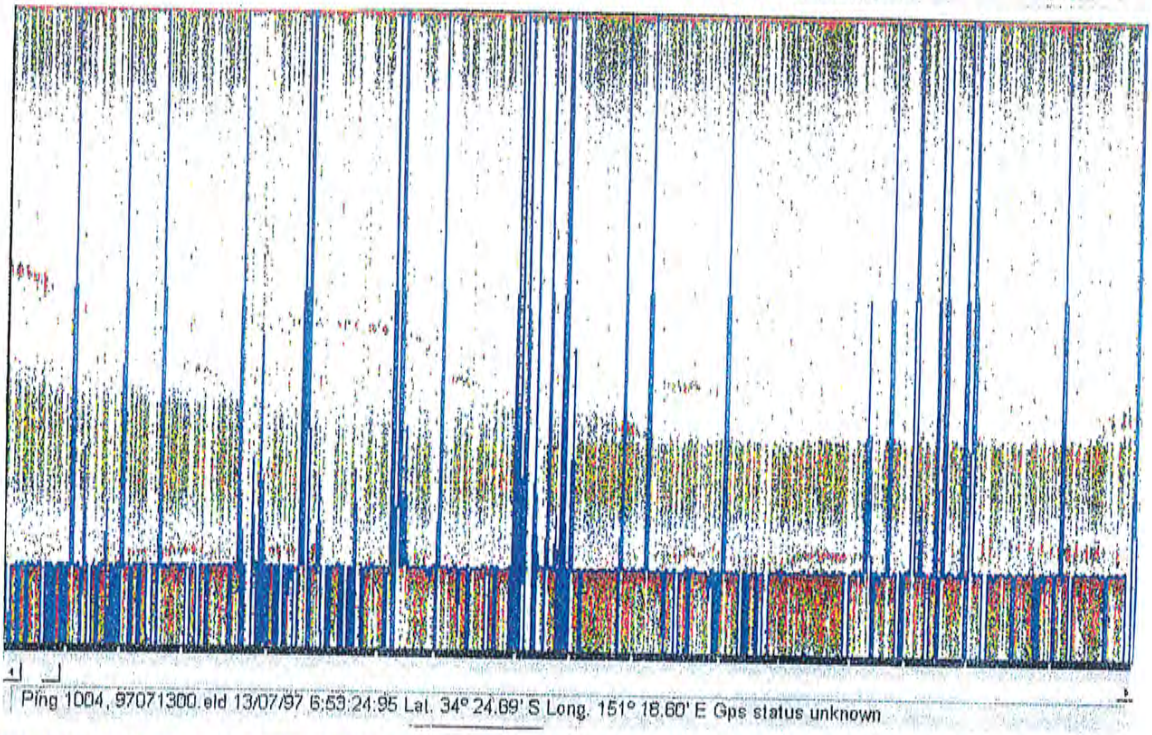


Figure 29b

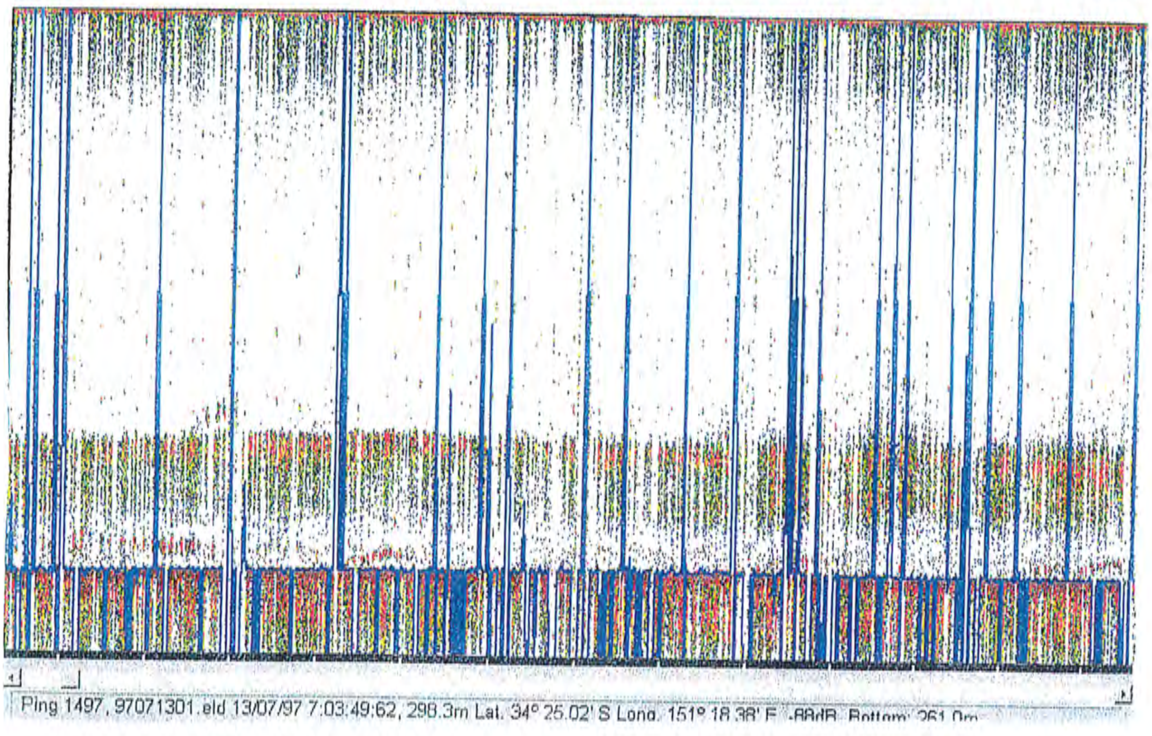


Figure 29c

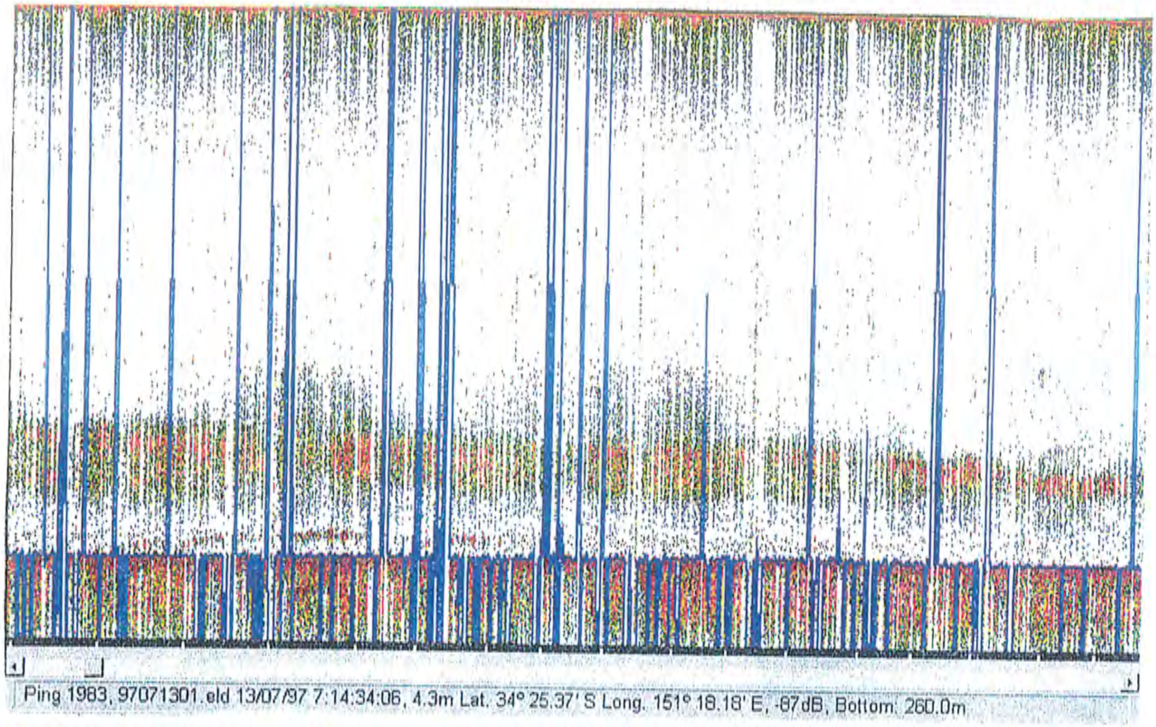


Figure 29d

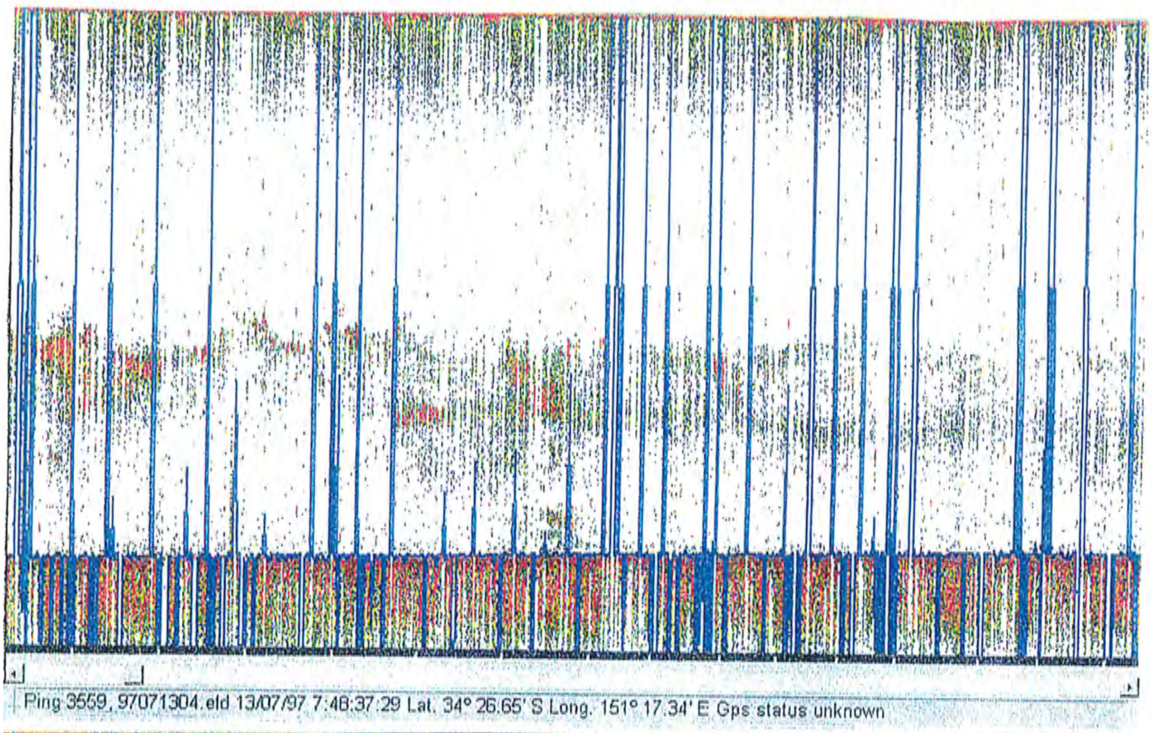


Figure 29e

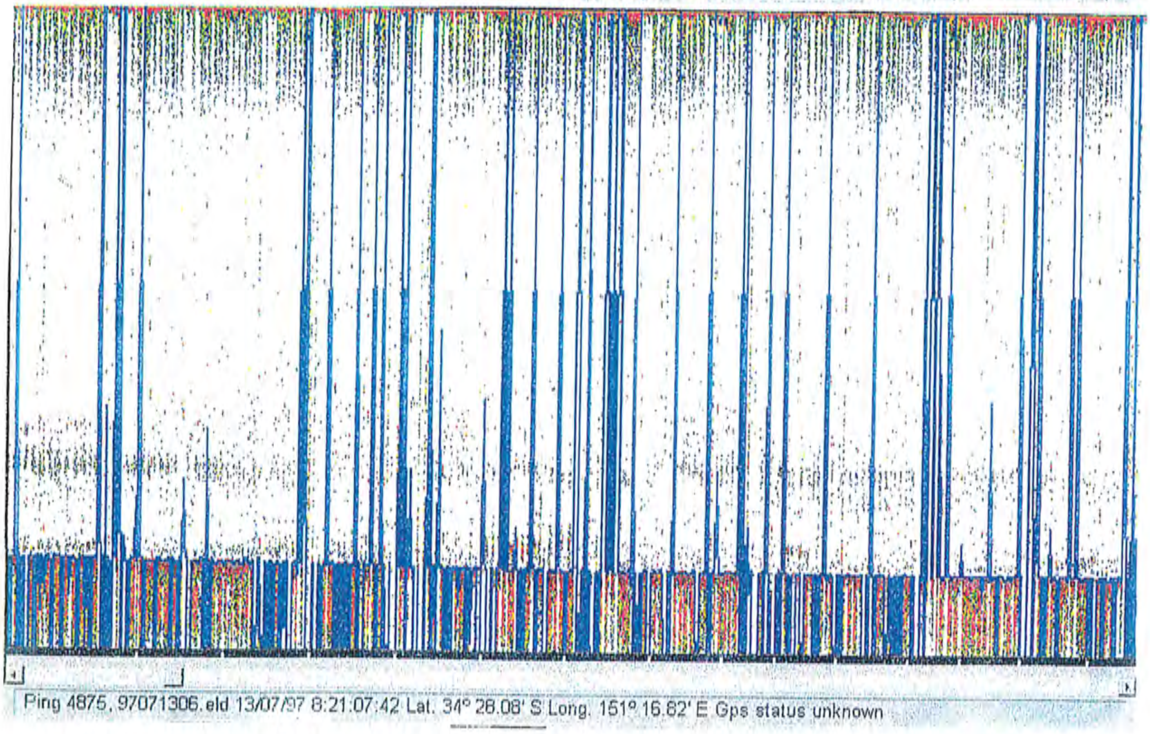


Figure 29f

Figure 30a

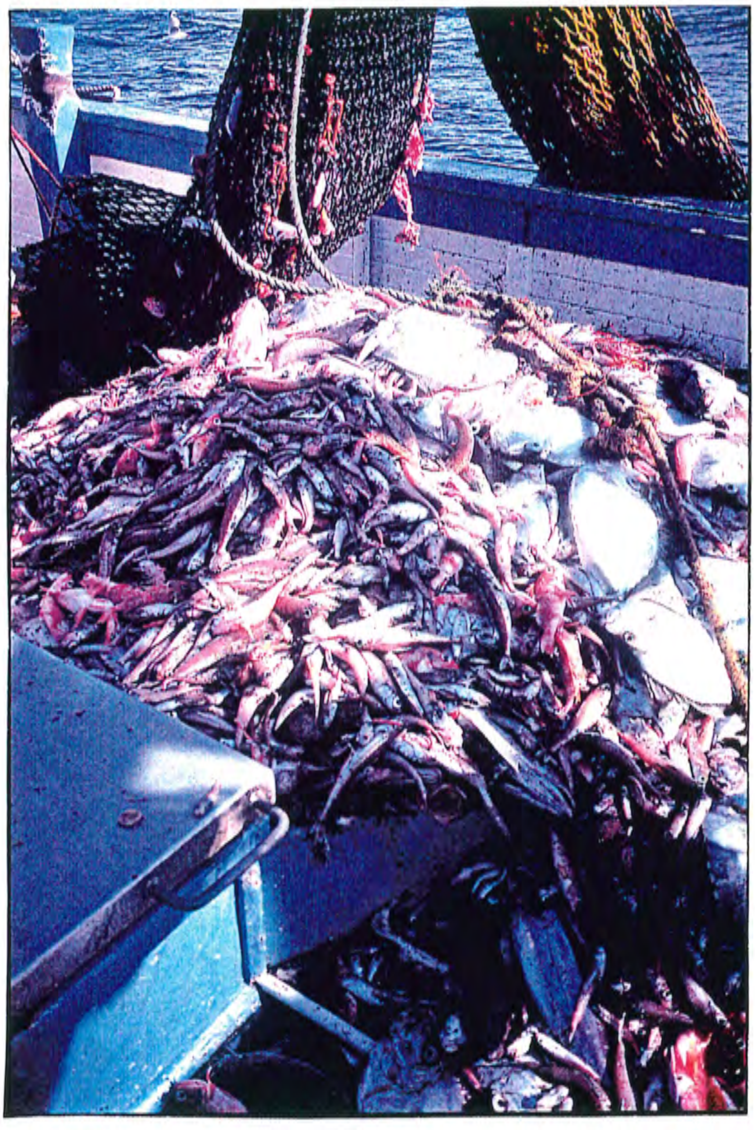


Figure 30b

Figure 30c

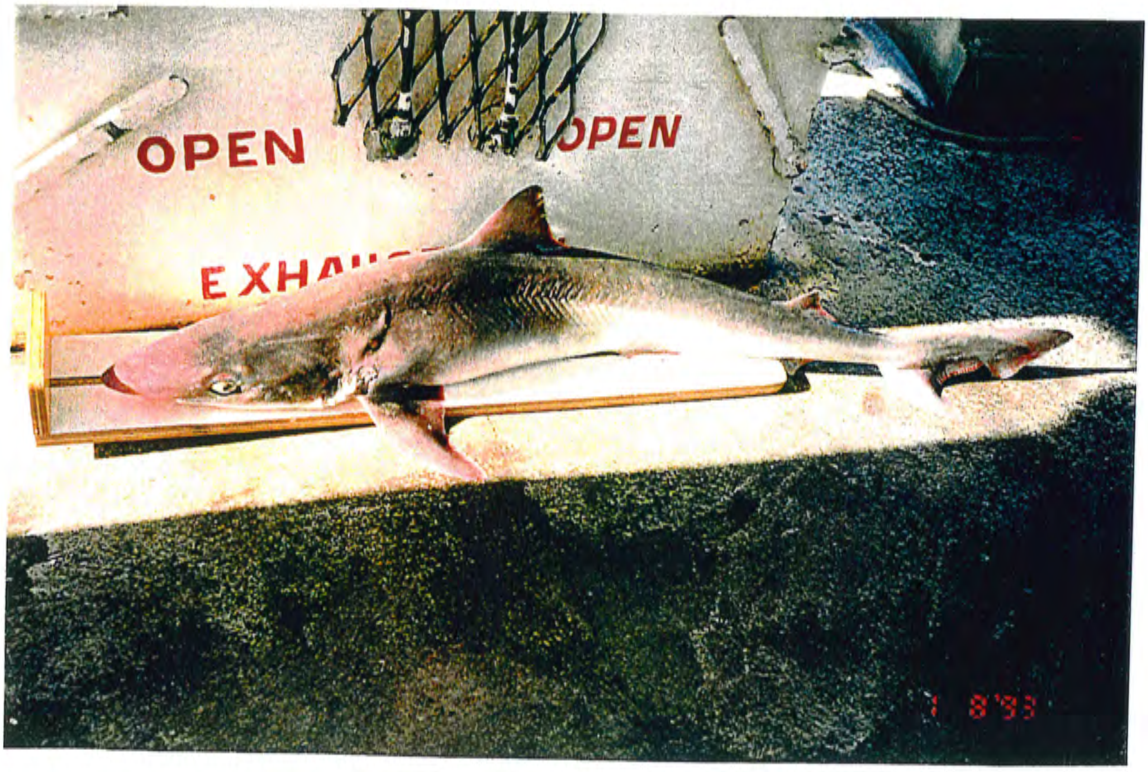


Figure 30d

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

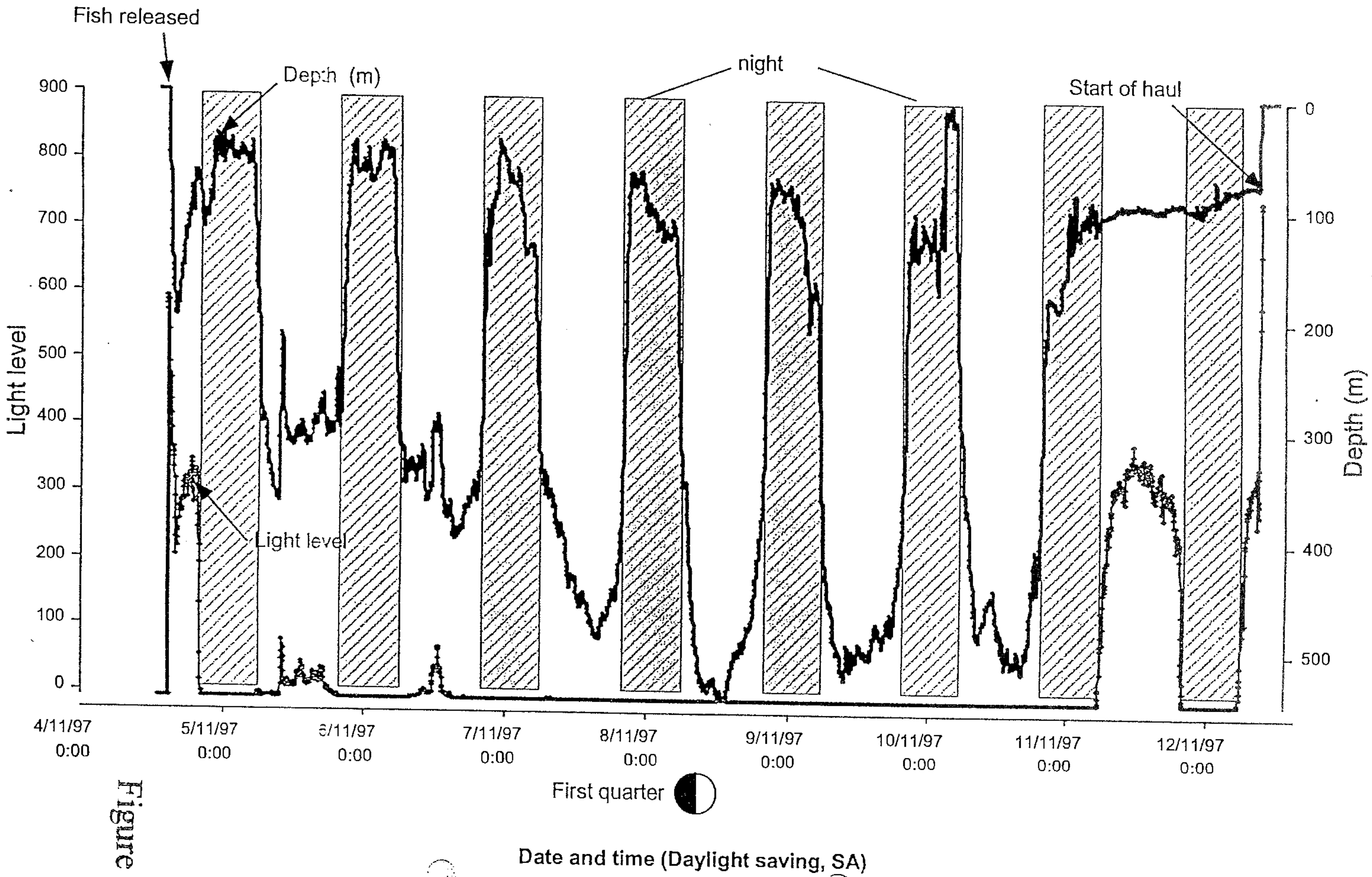


Figure 31

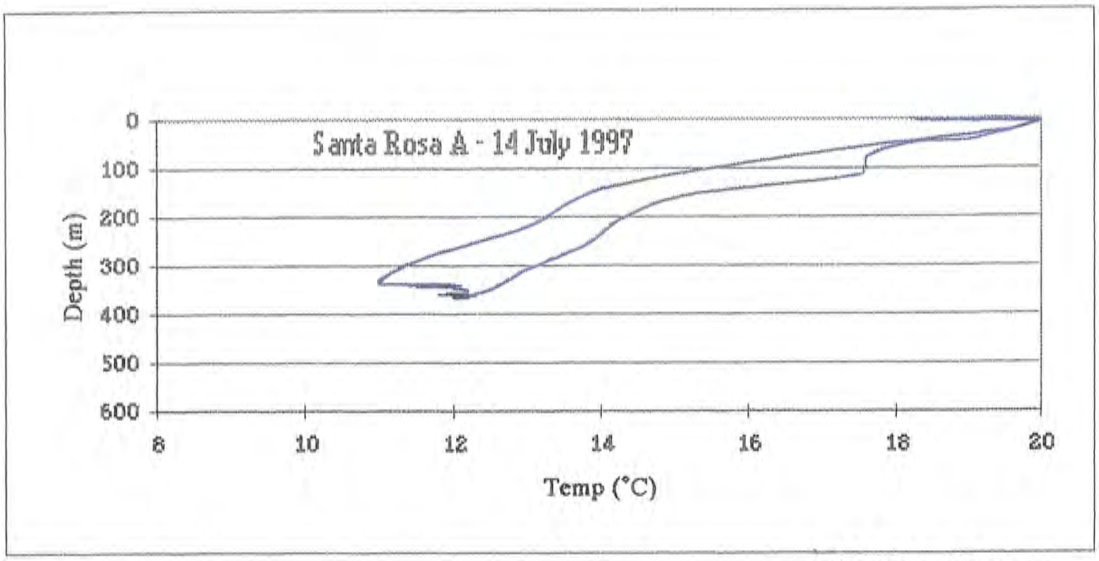


Figure 32a

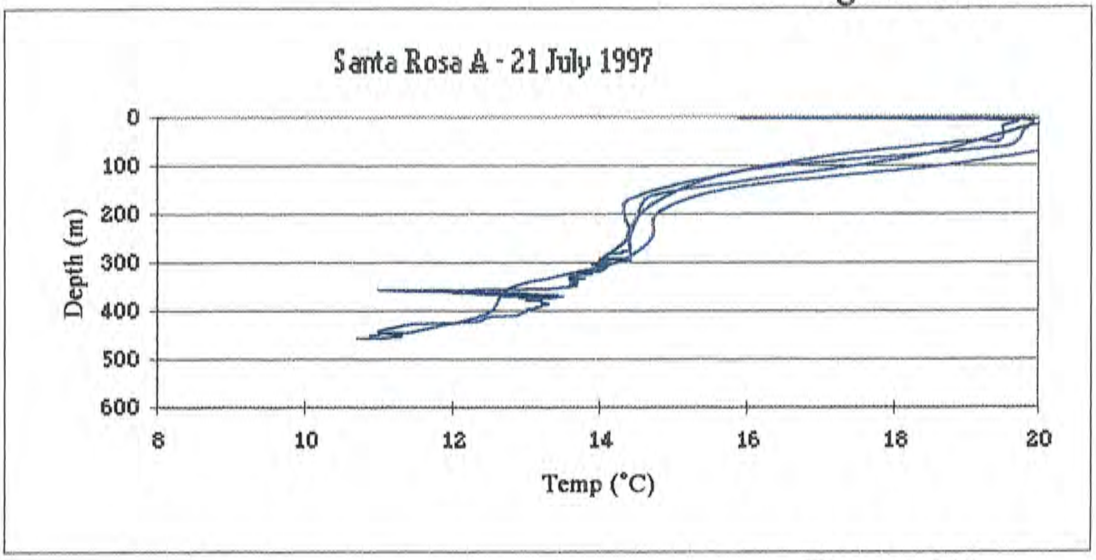


Figure 32b

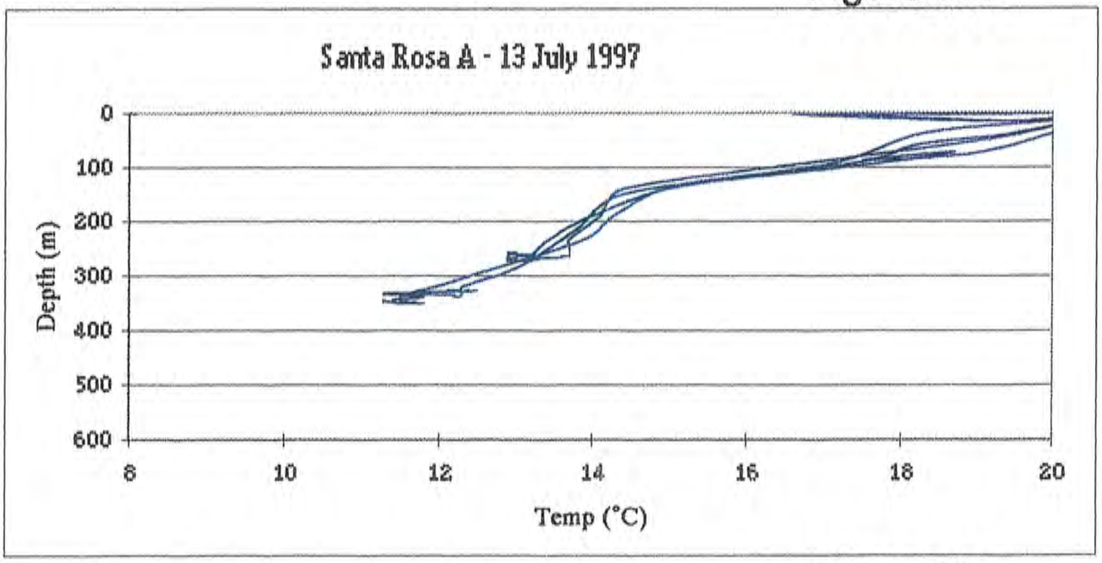


Figure 32c

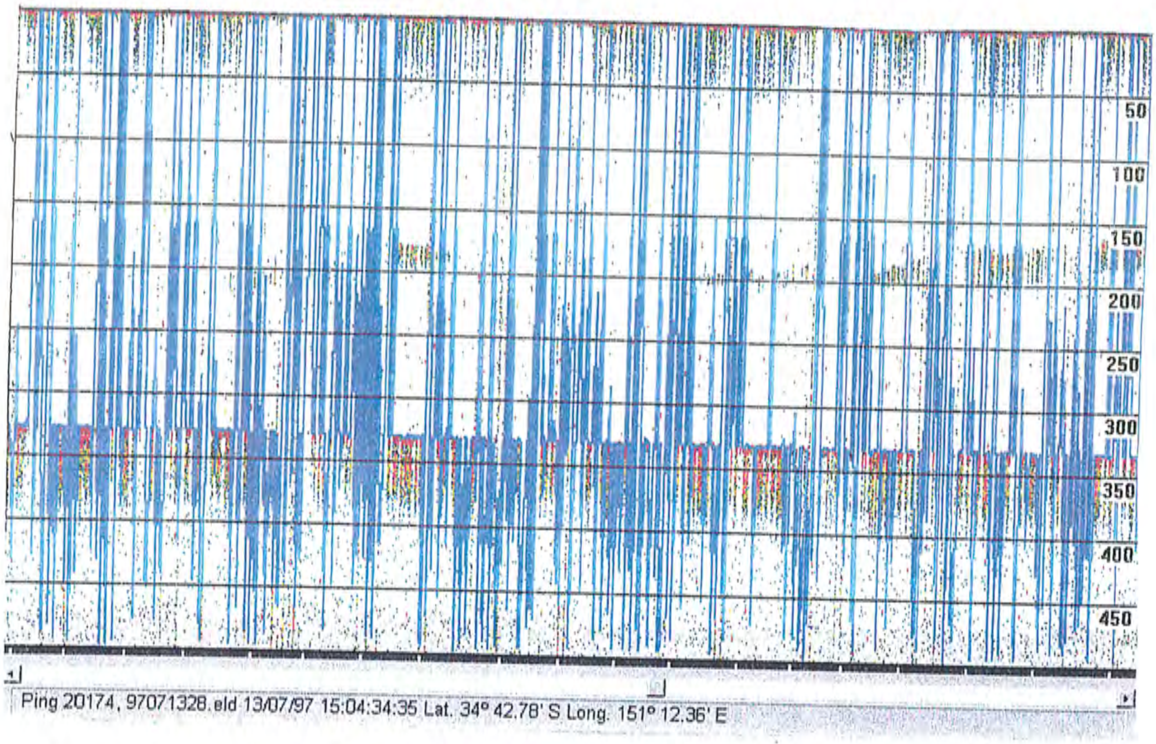


Figure 33a

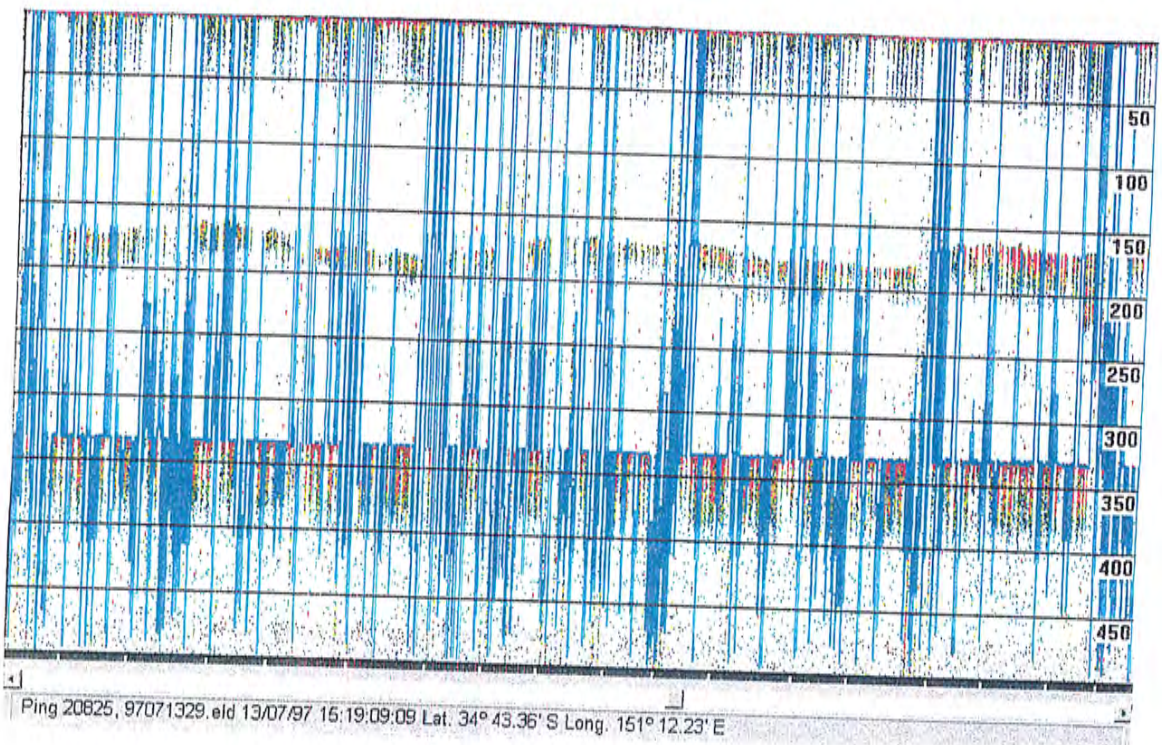


Figure 33b

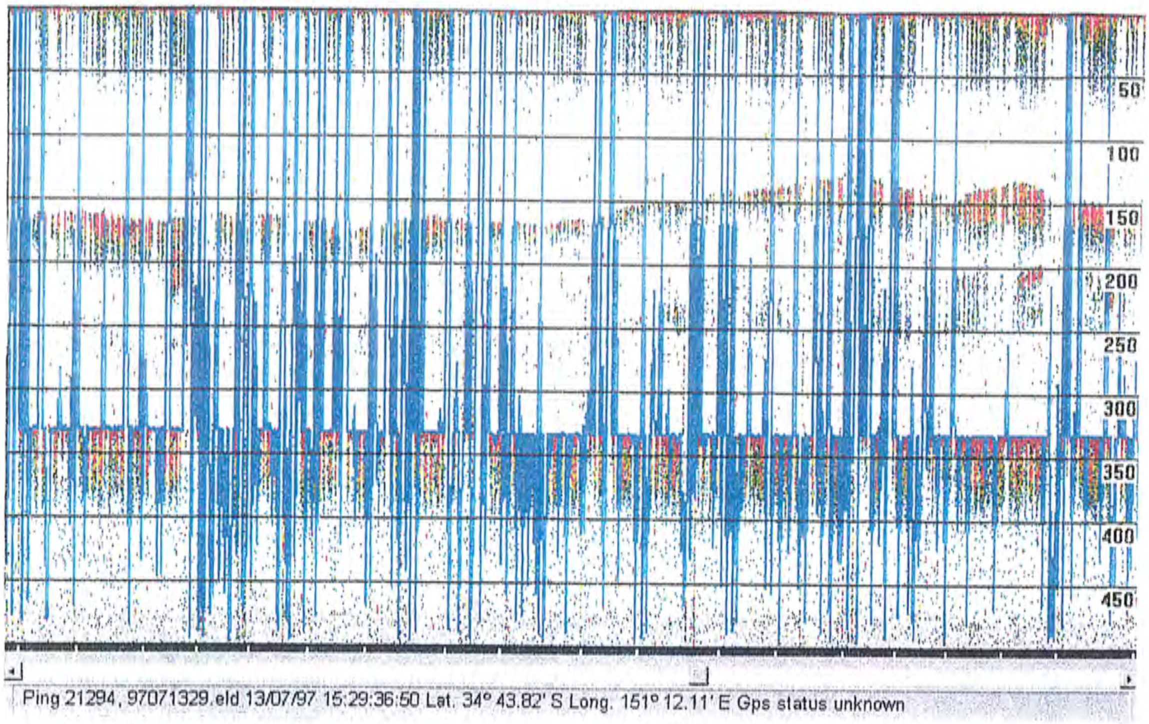


Figure 33c

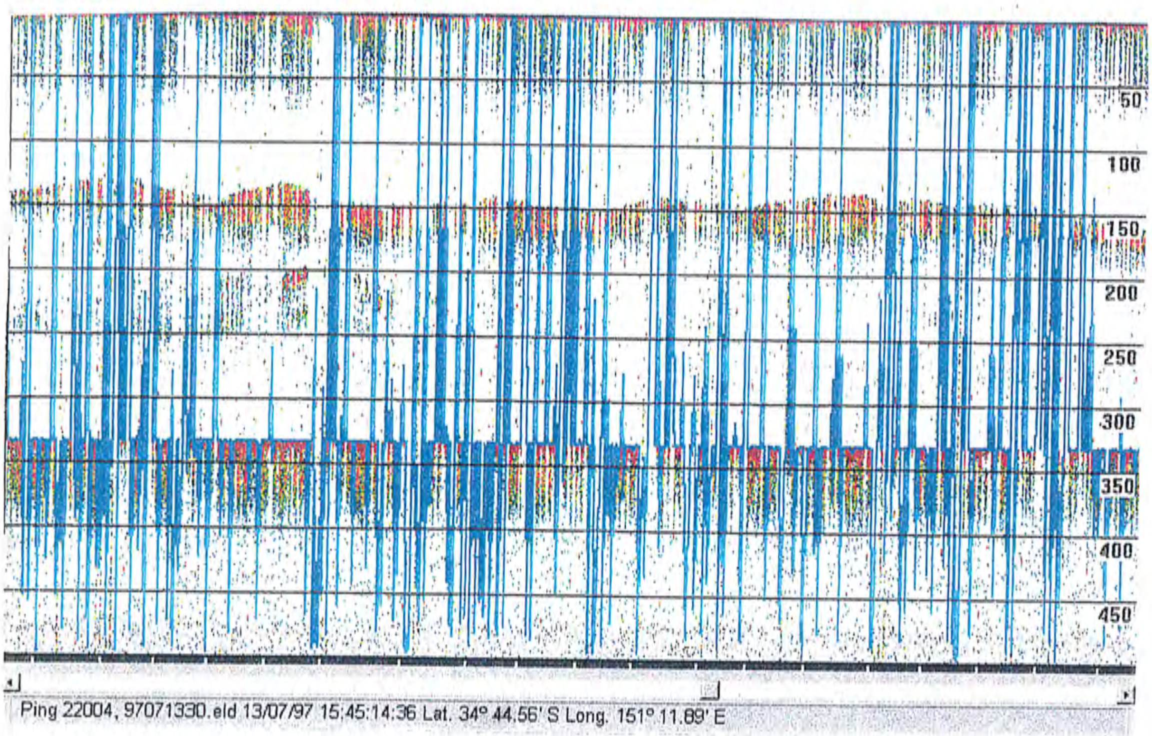


Figure 33d

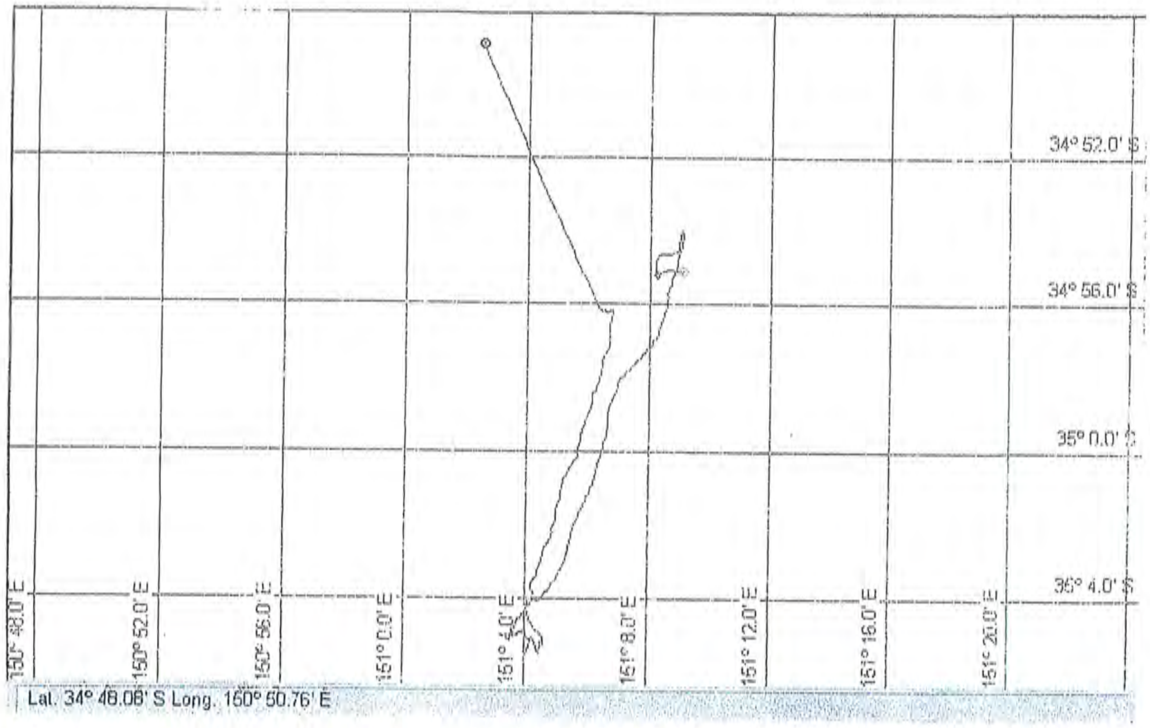


Figure 34a

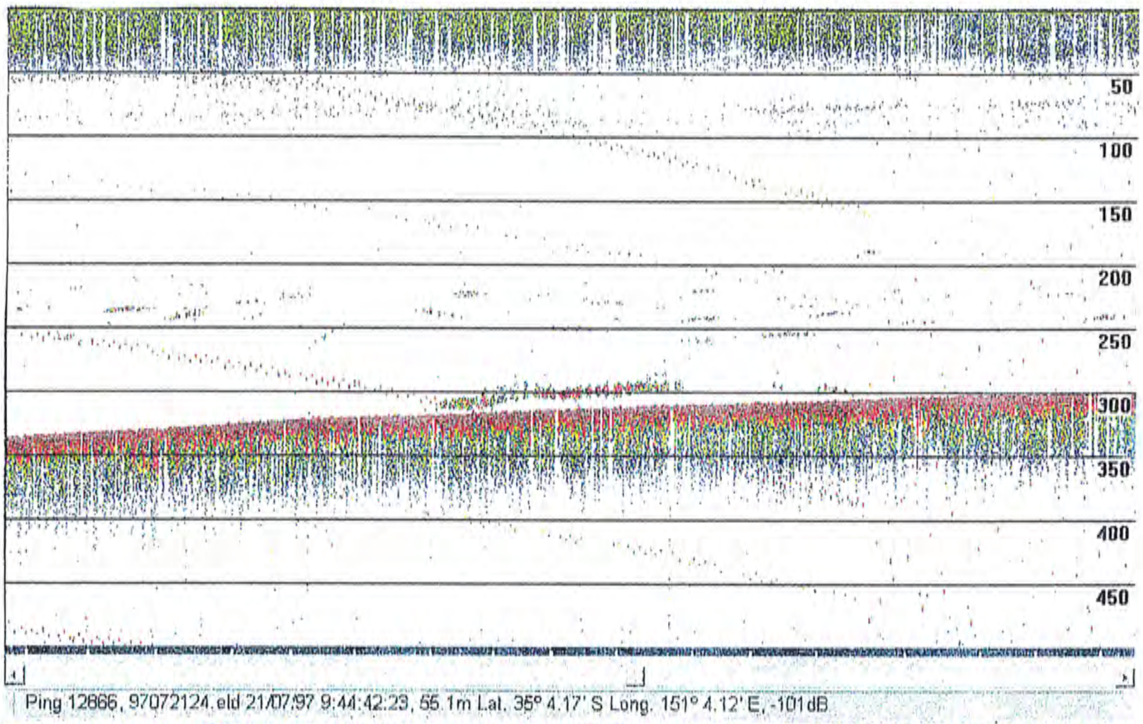


Figure 34b

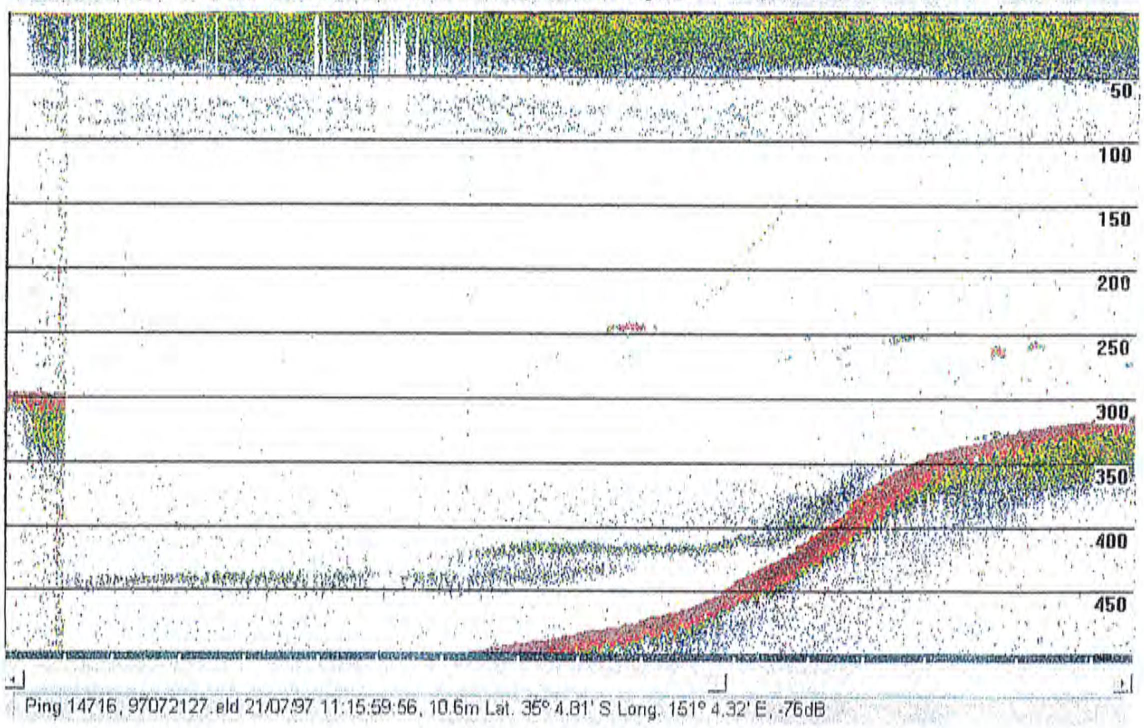


Figure 34c

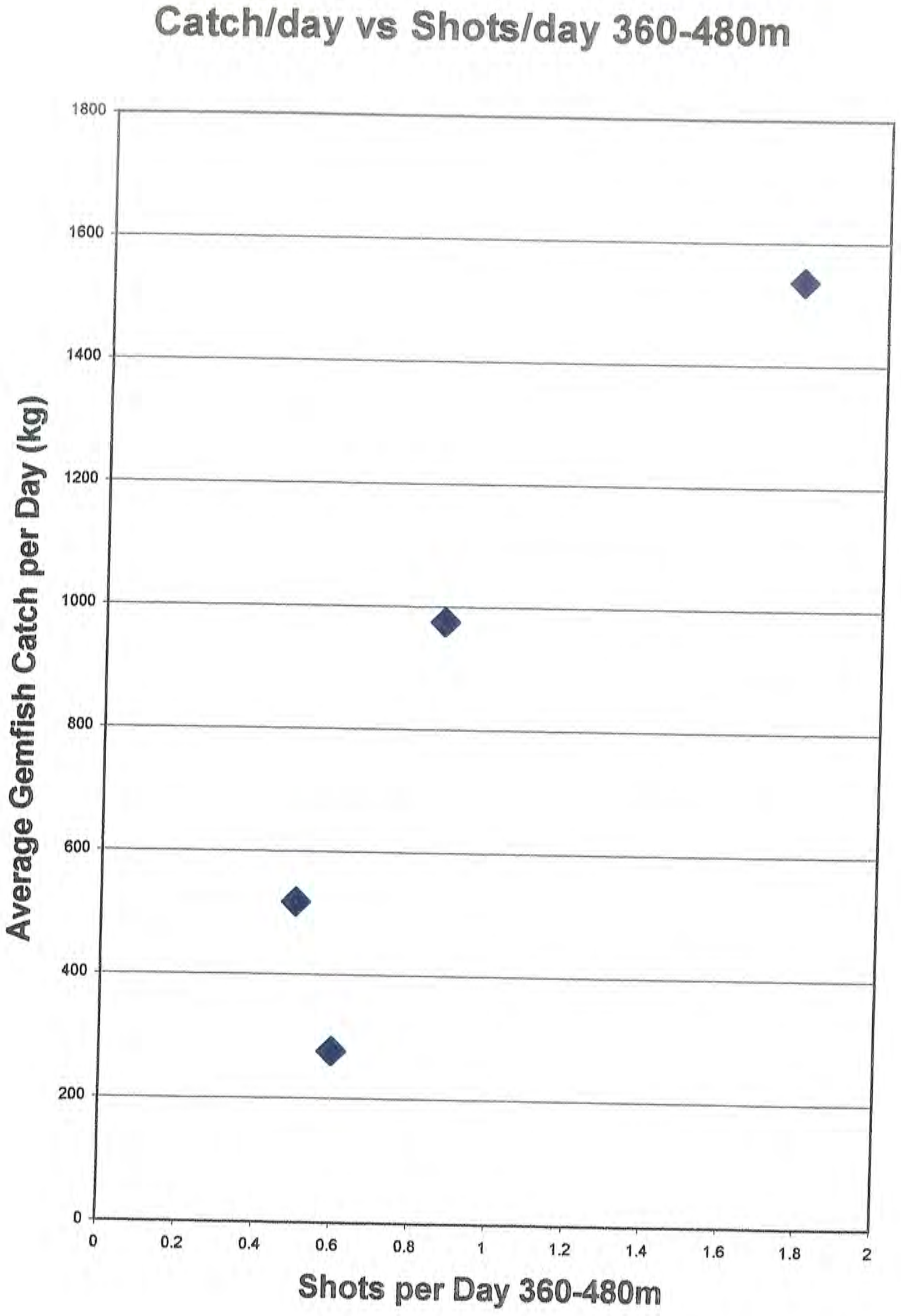

Catch/day vs Shots/day 360-480m
1800
1600
1400
1200
1000
800
600
400
200
0
Average Gemfish Catch per Day (kg)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Shots per Day 360-480m

Figure 35