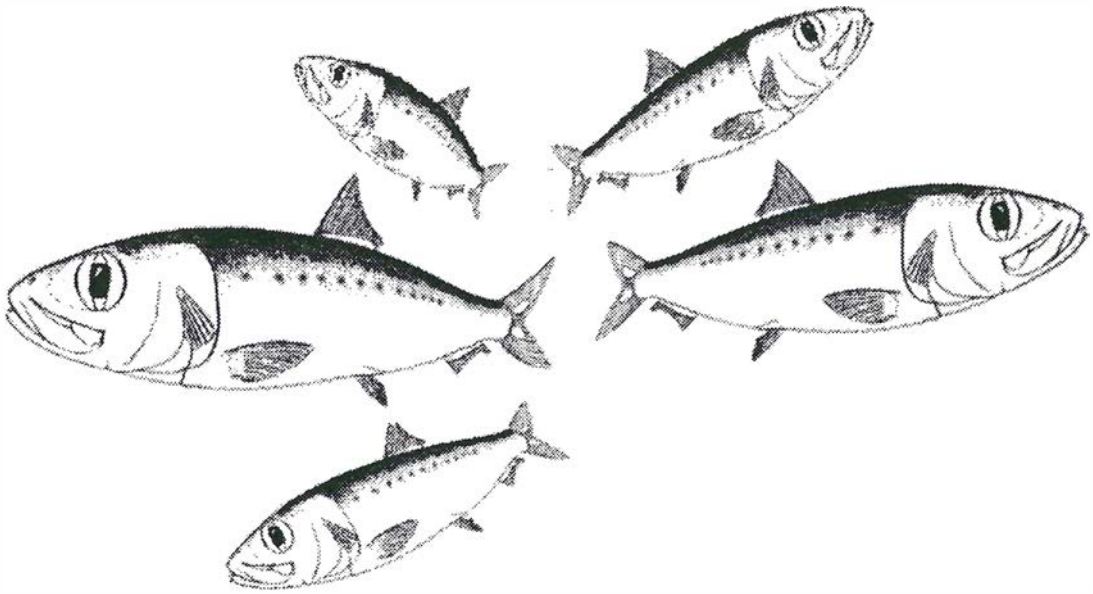
S A R D I

Baseline information on the fisheries biology of pilchards (*Sardinops sagax neopilchardus*) in South Australian waters.

Project No. T94/126

Final report to the Fishing Industry Research and Development Corporation



Keith Jones, Wetjens Dimmlich and Frank Hoedt

SARDI

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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INTRODUCTION

The pilchard fishery in South Australia is made up of two components. Since the early 1960's, the tuna pole and line fishery has utilised this species for live bait and in 1992 a developing purse seine fishery began catching pilchards to supply feed for the expanding cage-culture tuna industry at Port Lincoln. The pole and line baitfishery is estimated to take around 50 tonnes of pilchard annually (SCP 1983). The catch taken by the purse seine fishery has risen rapidly from 154 tonnes in 1991/92 to 1230 tonnes in 1992/93, and 2377 tonnes in 1993/94. Given the rapid growth of this fishery and the predicted increase in demand for pilchards as food for caged-culture tuna, the initiation of research into the pilchard has been recognised as a high priority by the managers of the fishery.

The purse seine fishery is presently managed by setting total allowable catches (TACs). These are set by the Integrated Management Committee (Scalefish Fisheries); the present TAC for this fishery is 3500 tonnes. To date, the annual TAC was determined using very limited biological data on the South Australian pilchard. Management recognises that information on the stock structure and biomass of the pilchard stock are needed before biologically acceptable TACs can be implemented. Representatives of fisheries research agencies from several Australian states have outlined the main research needs for Australian pilchards (FRDC proposal #94/029). They considered the Daily Egg Production Method (DEPM) to be the most suitable and cost effective technique for estimating stock biomass of pilchards. Before this technique can be implemented in South Australia, preliminary information on the reproductive biology and distribution of pilchards in these waters is needed. Other information identified as important for management of this fishery are reliable age and growth estimates and detailed monitoring of the catch composition and catch trends by the pilchard fisheries.

In light of the urgent need for research on the pilchard in South Australian waters, SARDI submitted a proposal to the South Australian Fisheries Research and Development Board in August, 1993, outlining a preliminary study of the biology and fishery of the pilchard in South Australian waters.

The initial objectives of the study were as follows:

- To carry out a literature search on pilchards and other small pelagic fish species.
- To collate and analyse all existing research catch log book data provided by the developing SA purse seine fishery.
- To initiate a research log book scheme for the traditional live bait fishery for the pole and line fishery for southern bluefin tuna.
- To collect length frequency information, and otolith samples from pilchard samples for later age determination.
- To provide preliminary information on the variability of timing of the pilchard spawning season, determined from ageing otoliths of pilchard larvae collected from S.A. waters during 1988-92.
- To collect samples of pilchards from all main fishing areas in SA and send to the University of New South Wales for genetic analysis, and otolith microchemistry at the Western Australian Marine Research Laboratories.

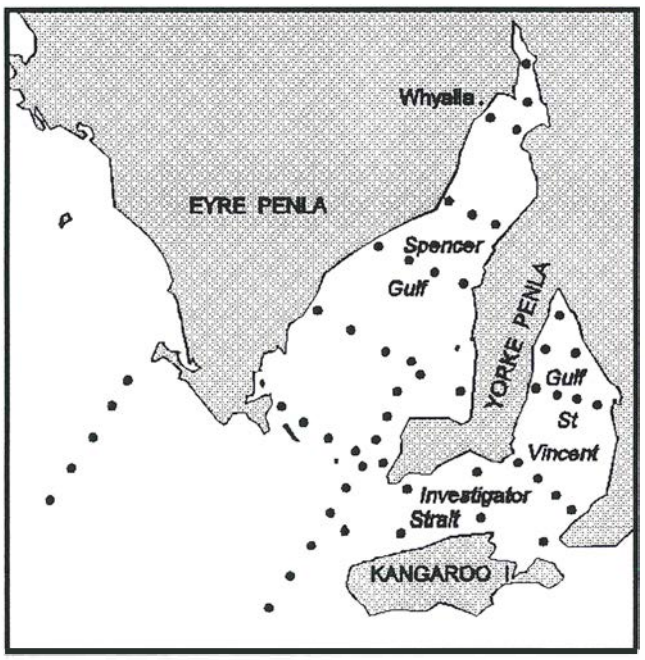
On consideration of the proposal for the preliminary pilchard study the South Australian Fisheries Research and Development Board recommended that an interstate collaborative proposal for research on pilchards in Australian waters be drafted. The latter project was subsequently funded and commenced in December 1994. This project had a strong focus on the pilchard in South Australia. An outcome of the implementation of a collaborative study is that several of the objectives of the state funded FRDC project are also included in the collaborative project. In particular, reviews of the literature on pilchards and other small pelagic baitfish species, description of the stock structure, and studies of the biology of the pilchard (age and growth, reproductive cycles and fecundity) were proposed and can now be done in greater detail over the three year time frame of the collaborative project. In this report, the results to date of these ongoing components of the state funded study and completed components are given.

METHODS

Larval clupeoid study

Larval fish were collected by Dr. Barry Bruce (then of SARDI) between 1986 and 1992. These were sampled using a bongo net (mouth diameter of 70cm and 500 micron mesh) fitted with two Rigosha flowmeters. The two replicate plankton samples from each tow were preserved in 5% formaldehyde and 70% alcohol. The stations sampled during the study are shown in Figure 1. Samples from 1986 and 1987 were available for the present study. Most samples during this period were from stations in the two gulfs; Investigator Strait was sampled for several months in 1987. A series of samples were also collected across the shelf outside of Spencer Gulf but these were unavailable as Dr. Bruce is currently examining these in Hobart. He will pass these on to SARDI in the near future.

Figure 1. Sampling stations for larval fish between 1986 and 1992.



The fish larvae collection from these cruises were located at the South Australian Museum (Natural History Division). A computer database file of these samples (*dBase*[*]) was available and we updated this to a *Microsoft Access*[†] file. Temperature, salinity and flowmeter readings from the original cruise data sheets were entered into this data base for our analysis. Using the computer records as a guide, samples were collected from the SA Museum and brought to the South Australian Aquatic Sciences Centre (SAASC) laboratories for sorting. Here, clupeoids were separated from other fish larvae and then identified to species level. Identifications were made using identification keys (Neira *et al,* in prep) provided by Dr. Barry Bruce. Larval counts for each sample were converted to density measures (numbers per $100m^3$) using the formula $(100\pi r^2(\text{Flowno.}))/10.2$. Here 'Flowno.' is the flowmeter reading and 'r' is the net mouth radius (0.35m). The spatial pattern of environmental parameters (salinity and temperature) and larval densities were analysed using the *Mapinfo*[‡] Geographic Information System and *Surfer for Windows*[§] contour and surface mapping software packages.

The main aim of this study was to obtain information on the reproductive period of the pilchard. However, larval anchovy and other species of clupeoids were also extracted and analysed. This report therefore includes information on the distribution, abundance and spawning season of pilchard, anchovy, blue sprat and round herring.

It was initially hoped to use otoliths from these larval clupeoids to back-calculate birth dates and thus identify spawning periods. However, the otoliths of these larvae had deteriorated and were considered unreliable for ageing. Monthly abundances of larvae give a reliable index of adult spawning times provided the approximate age of these larvae can be estimated. Published growth information is available for several species of temperate larval clupeoids and these were used to approximate the birth dates of cohorts of larvae.

Catch sampling and laboratory analysis of samples from the purse seine fishery.

In March 1995, regular sampling of the catches in the purse seine fishery began. Samples were collected by an industry-funded pilchard quota management officer (Sid Hansen), who was provided with plastic bags and water proof pens. Since the beginning of the sampling, the purse seine fleet has landed virtually all their catch at Pt. Lincoln, with samples collected during routine inspection of catches from as many vessels as possible.

Fish were randomly sampled (scooped from within the catch); each bag containing approximately 40 - 50 fish. In most cases , the purse seine vessels carry out a single shot per fishing trip, and therefore, a bag represents the catch from one fishing trip by an individual vessel. Each sample was individually frozen, and groups of samples periodically transported in insulated containers to SAASC for analysis.

Initially (in the March samples), all fish were measured (total, standard and fork length), and weighed. Fish were then dissected, sexed and gonads weighed and assigned a maturity stage. Otoliths (sagittae) were also removed from each fish. In months when catches were good, large numbers of fish were sampled and it was decided to collect gonad weights and otoliths from a subsample of 10 randomly selected fish in each bag. To assess seasonal trends in gonad development, gonad weights were converted to gonado-somatic indices (g.s.i.) using the formula, g.s.i. = (gonad

[*] dBase is a registered trademark of Ashton-Tate Corporation.
[†] Microsoft Access is a registered trademark of Microsoft Corporation.
[‡] MapInfo is a registered trademark of MapInfo Corporation.
[§] Surfer for Windows is a registered trademark of Golden Software, Inc.

weight)*100/(body weight). The mean g.s.i. was calculated for each month and these plotted to detect trends in reproductive activity. Size-at-maturity was estimated for fish from March. Sexually mature fish were classed as those with Stage III (or later) gonads (Stevens *et al*, 1984). The numbers of immature and mature fish in different size-classes were plotted as a length-frequency histogram.

Collection and analysis of catch and effort information in the purse seine fishery.

The purse seine fleet is made up from two managed fisheries, which initially had differing requirements for catch and effort monitoring.

The first group were from state managed marine scalefish fishers with ministerial permits to catch pilchards. As part of their Marine Scalefish licence, they were compulsorily required to fill out general marine scalefish catch and effort forms on a monthly basis (see Form 1, Appendix). These forms were not suitable for recording detailed fishing effort in the purse seine fishery, and have only been used for monitoring effort, in terms of boat days. As part of their ministerial permit requirements, they were required to fill out detailed daily research logs over the experimental phase of the fishery (see Form 2, Appendix). The data collected from these latter forms have been used since the beginning of the purse seine fishery (January, 1992) for monitoring catch and effort. On these forms, fishing effort was separated into the searching and fishing phases, with information on the estimated size and number of pilchard schools sighted during the searching phase. As all vessels have possessed sonars since the inception of the fishery, it was considered that this information could be gathered relatively easily.

The second group were from the Australian Tuna-boat Owner's Association who were not required to fill out the general marine scalefish forms, but were required to fill out the detailed research log forms.

Both forms 1 and 2 were sent to SAASC, and catches were checked with both from records of trip catches reported on Catch Disposal Record (CDR) forms, as part of the quota monitoring program, as well as inspection of catches by the quota management officer and these showed good agreement.

Log book data from the purse seine fishery was entered into a database software file (*Lotus 1-2-3*[**]) for analysis. Seasonal trends in catch (tonnes), catch per unit effort and catch location were plotted from this data. Catch per unit effort was calculated in terms of tonnes per boat day, and catch/hr searched for the first research log.

Revised Research Log Forms

During 1994, following several meetings with the purse seine fishers, as well as observations on the searching and catching method employed by the purse seiners, a revised research log was implemented on June 1, 1995 (see Form 3, Appendix). The form was also devised so that the data was comparable with those collected on the previous research forms.

An important feature of the new research log is that the details from each shot is recorded with time, location (lat. & long.), surface temperature, quantity of fish actually caught as well as the quantity of fish lost from the shot.

[**] Lotus 1-2-3 is a registered trademark of Lotus Corporation.

A new and important piece of information in the research log is "total engine hours" which provides an alternative and probably the best quantifiable estimate of fishing effort. This was different to "fuel usage" used in the assessment of the pilchard fishery in Western Australia, where the size of the vessels in their fleet were similar (in South Australia there is a large variation in the sizes of vessels and refrigeration is used by some at times to keep pilchards on the vessels while they are at the wharf. These vessels were thus unable to separate out the relative amounts of fuel used for fishing and refrigeration.

Literature review

Literature on pilchards and other baitfish species has been collated using resources at the SAASC library since January 1995. Relevant topics were chosen and literature searches are done on the Fisheries and Aquatic Sciences Abstracts (CD Rom) for the periods 1978-88 and 1988-94. Inter-library loans were used to procure references unavailable at the library.

Stock discrimination

Individual frozen samples of approximately 100 pilchards are collected from catch samples and are sent to the University of New South Wales (Dr. Pat Dixon) for stock discrimination analysis. Samples are chosen to represent different areas within the fishing grounds.

Analysis of log book data from the pole and line tuna bait fishery and implementation of a new log book.

The southern bluefin tuna pole and line fishery has provided some information on catch and effort on their baitfish for a number of years. Semi-quantitative information on baitfish catches by tuna pole fishers in South Australian waters between 1971 - 82 are available from SA Dept. Fisheries forms filled out by these fishers during this period. Information included:

- species of baitfish used
- area of capture
- quantity of baitfish caught
- number of days baiting

Catch records from the pole and line tuna fishery for the period of 1981/82 to 1992/93 were obtained from AFMA. Catch trends and locations were analysed from this information. Design and implementation of a new log book are still underway.

RESULTS AND DISCUSSION

Larval clupeoid study

A total of 8694 clupeoid larvae were extracted and identified from the samples. These were comprised of 5224 pilchard (*Sardinops sagax neopilchardus*), 3231 anchovy (*Engraulis australis*), 235 blue sprat (*Spratelloides robustus*) and 4 round herring (*Etrumeus teres*). Pilchard followed by anchovy were the dominant clupeoids in the area sampled.

Estimation of spawning period of adult clupeoids

Most of the larvae in the samples analysed were between 3 and 10mm in length. Based on published accounts of larval clupeoid growth rates (growth analysed from otolith increments), these larvae are probably well below one month of age (Table 1). This is further supported by growth estimates for *Engraulis encrasicolus* in the Mediterranean Sea which attain a length of 23 mm in 20 days (Palomera *et al.* 1988).

Table 1. Calculated lengths (mm) of temperate clupeoid larvae at age 30 and 60 days from published literature.

Species	Location	Temp. (°C)	Length (30d)	Length (60d)
Clupea harengus [1]	USA	1-15	11.3	17.4
Engraulis japonicus [2]	Japan	--	31.2	49.5
Sardina pilchardus [3]	Portugal	15.6	26.1	43.1
Etrumeus teres [4]	Gulf/Mexico	16-22	20.0	--
Brevoortia patronus [4]	Gulf/Mexico	16-22	18.0	30.0
Average lengths			21.3	35

1-Townsend *et al.* (1989), 2-Mitani (1988); 3-Re (1984); 4-Chen *et al.* (1992)

These studies indicate that our larvae are less than 15 days old, therefore monthly abundances of clupeoid larvae in these samples may only lag the actual times of adult spawning by a short period.

Pilchard larvae were present in all months sampled (Figs. 2-10). These data suggest that the pilchard has an extended spawning season at least from September to June. High mean larval densities occurred in March and April in 1986 and March to May in 1987 (Table 2). Mean larval densities were highest in April 1986 and May 1987 (Table 2). Given the possible time lag of several weeks between larval production and spawning, the time of peak spawning by adult pilchards probably lies between February and May and peaks in late March. Stevens *et al.* (1984) collected large numbers of pilchard larvae in the Great Australian Bight (GAB) in April and May, this broadly agreeing with our findings. Stevens *et al.* (1984) also found that pilchard gonads from fish collected in the G.A.B. were mature between September and May with a peak in March-April. Our results are consistent with these findings.

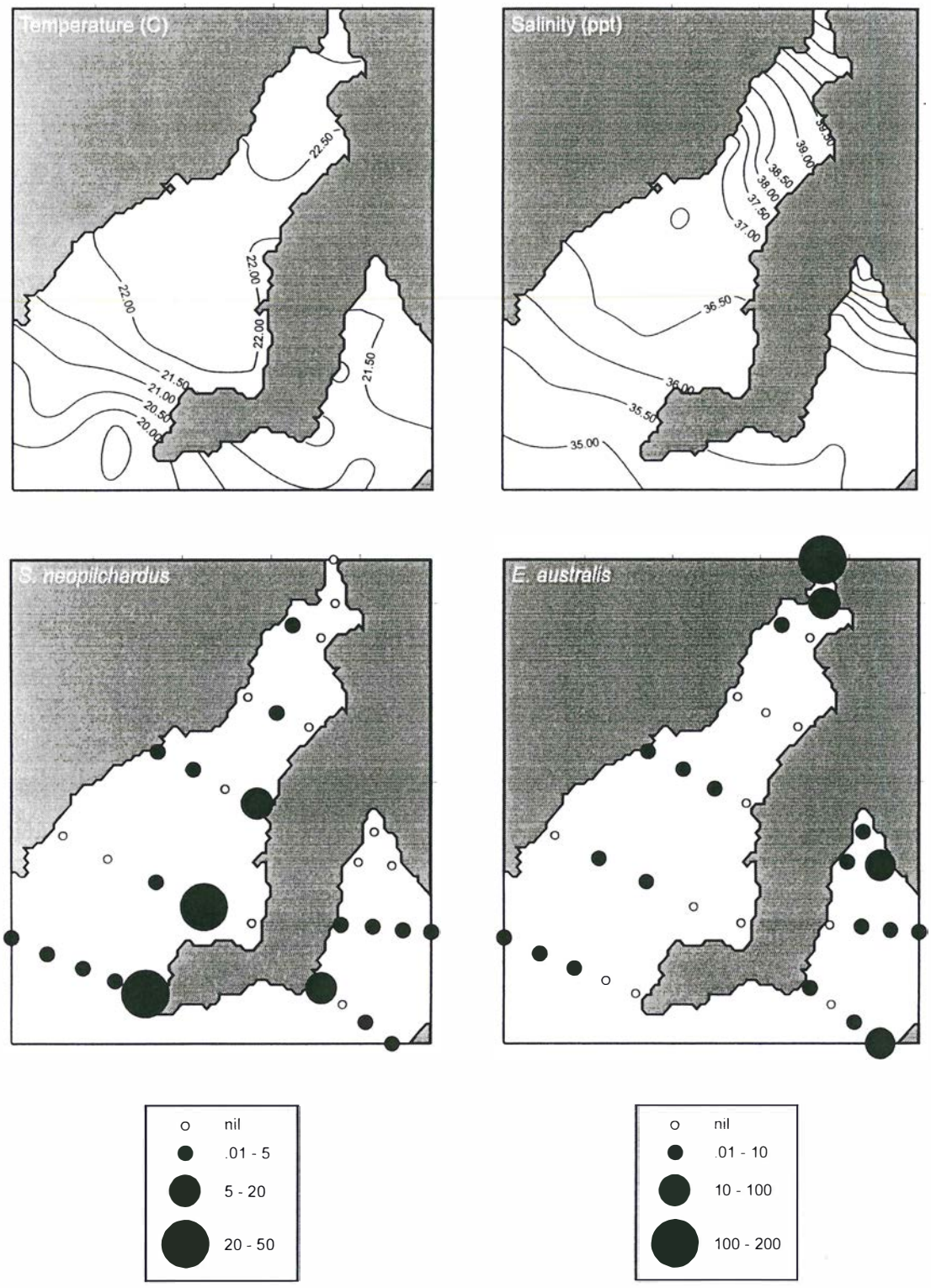


Figure 2. Clupeoid larval densities (100m^{-3}), temperatures and salinities for March, 1986.

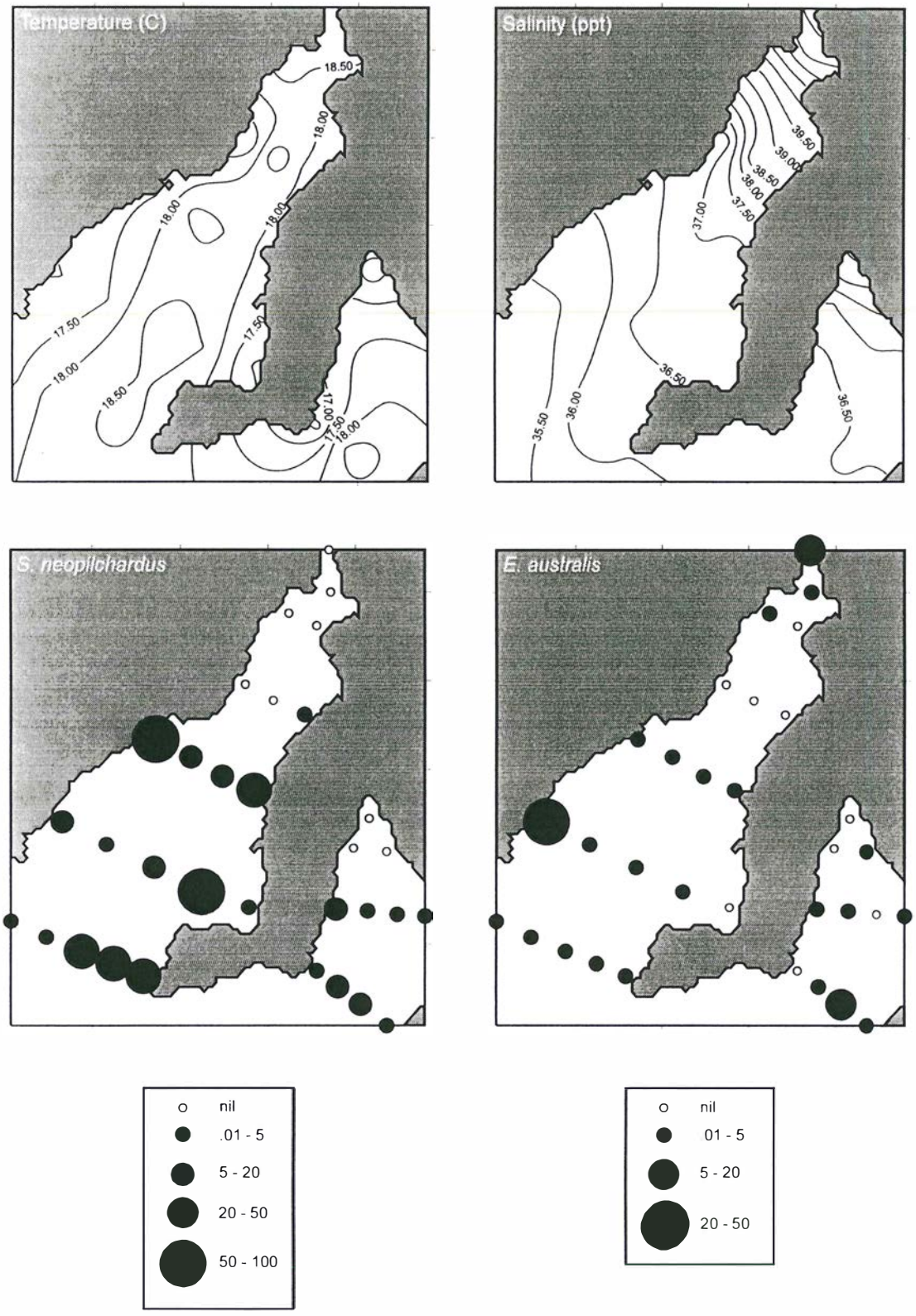


Figure 3. Clupeoid larval densities (100m^{-3}), temperatures and salinities for April, 1986.

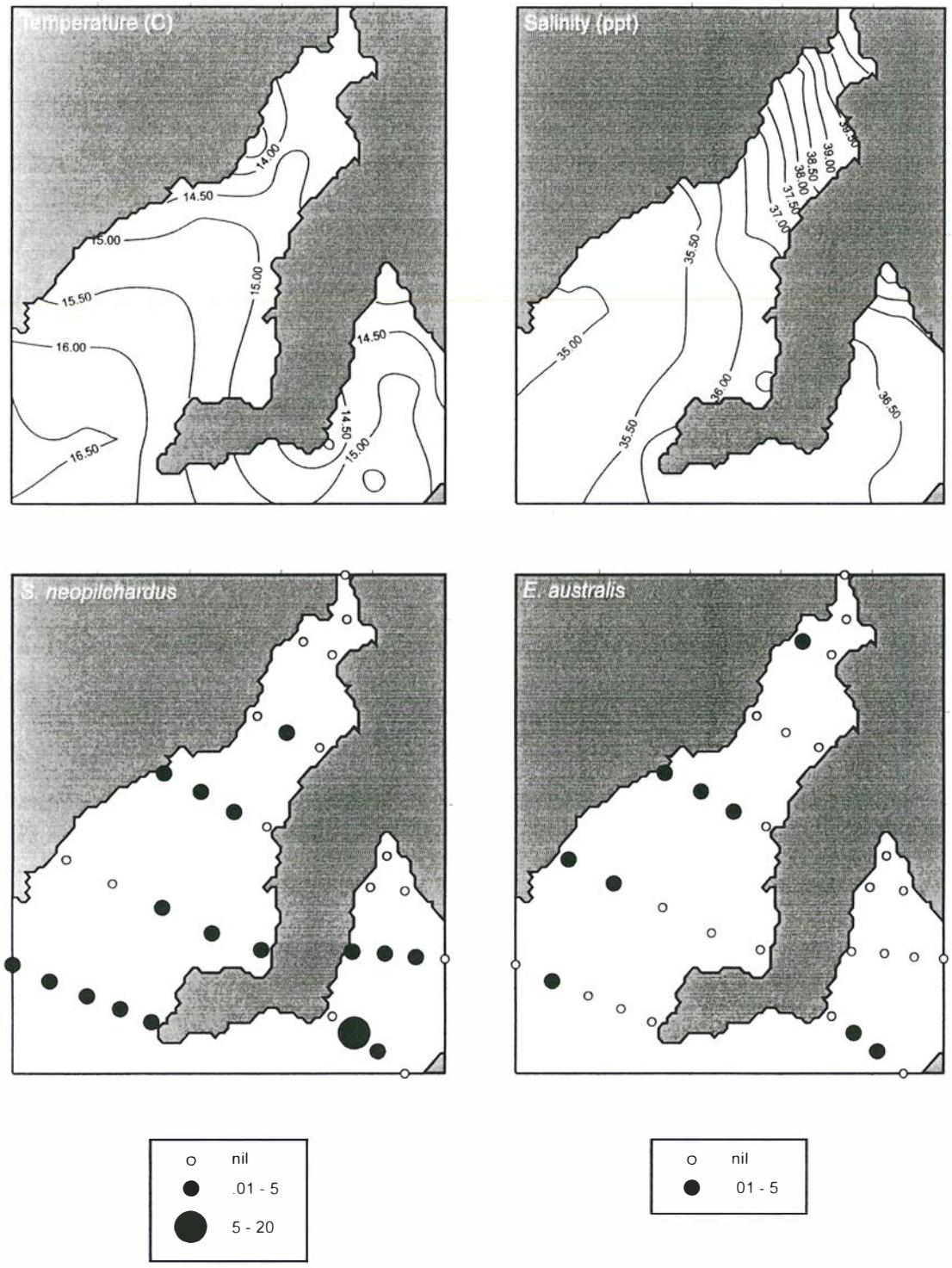


Figure 4. Clupeoid larval densities (100m^{-3}), temperatures and salinities for June, 1986.

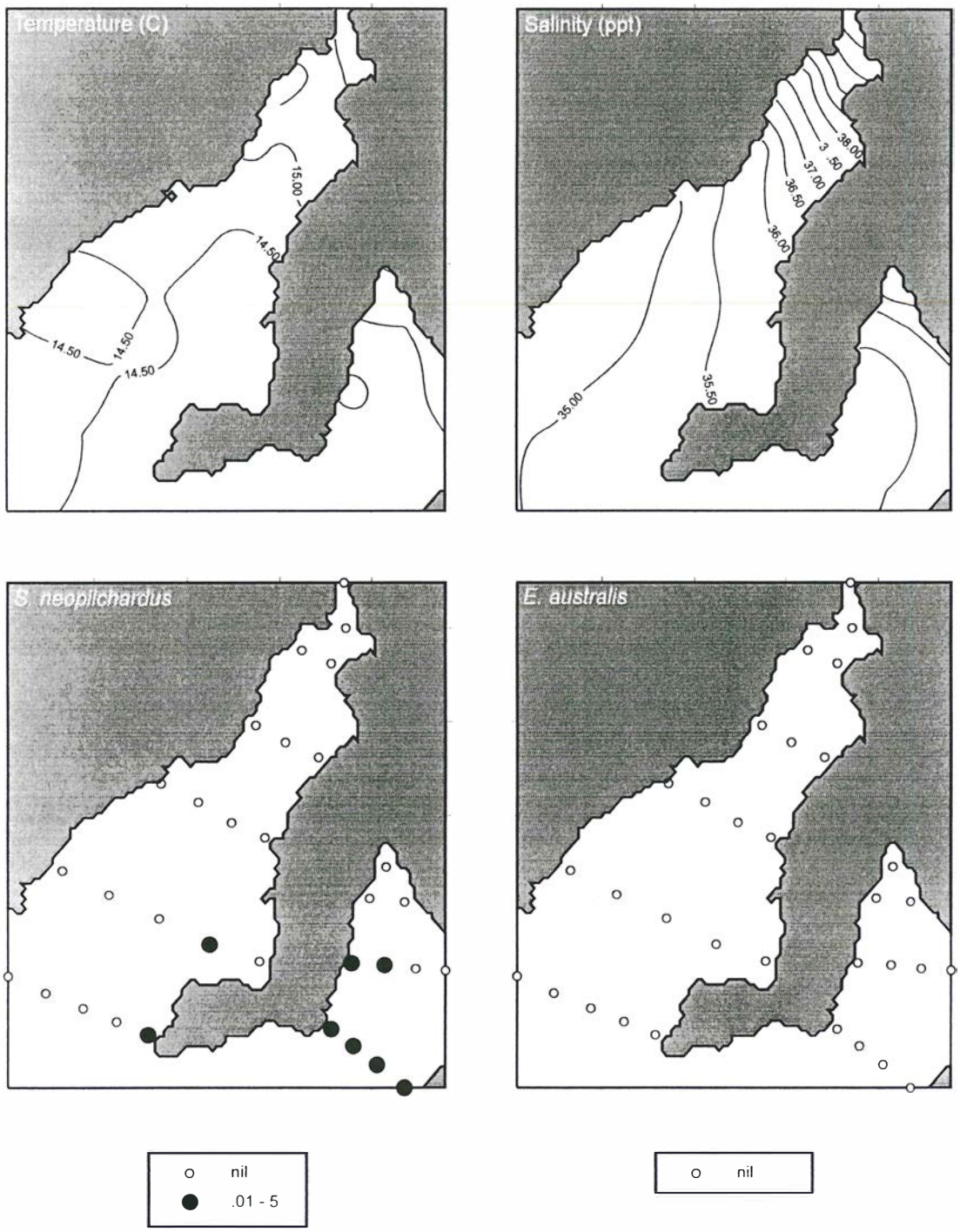


Figure 5. Clupeoid larval densities (100m^{-3}), temperatures and salinities for September, 1986.

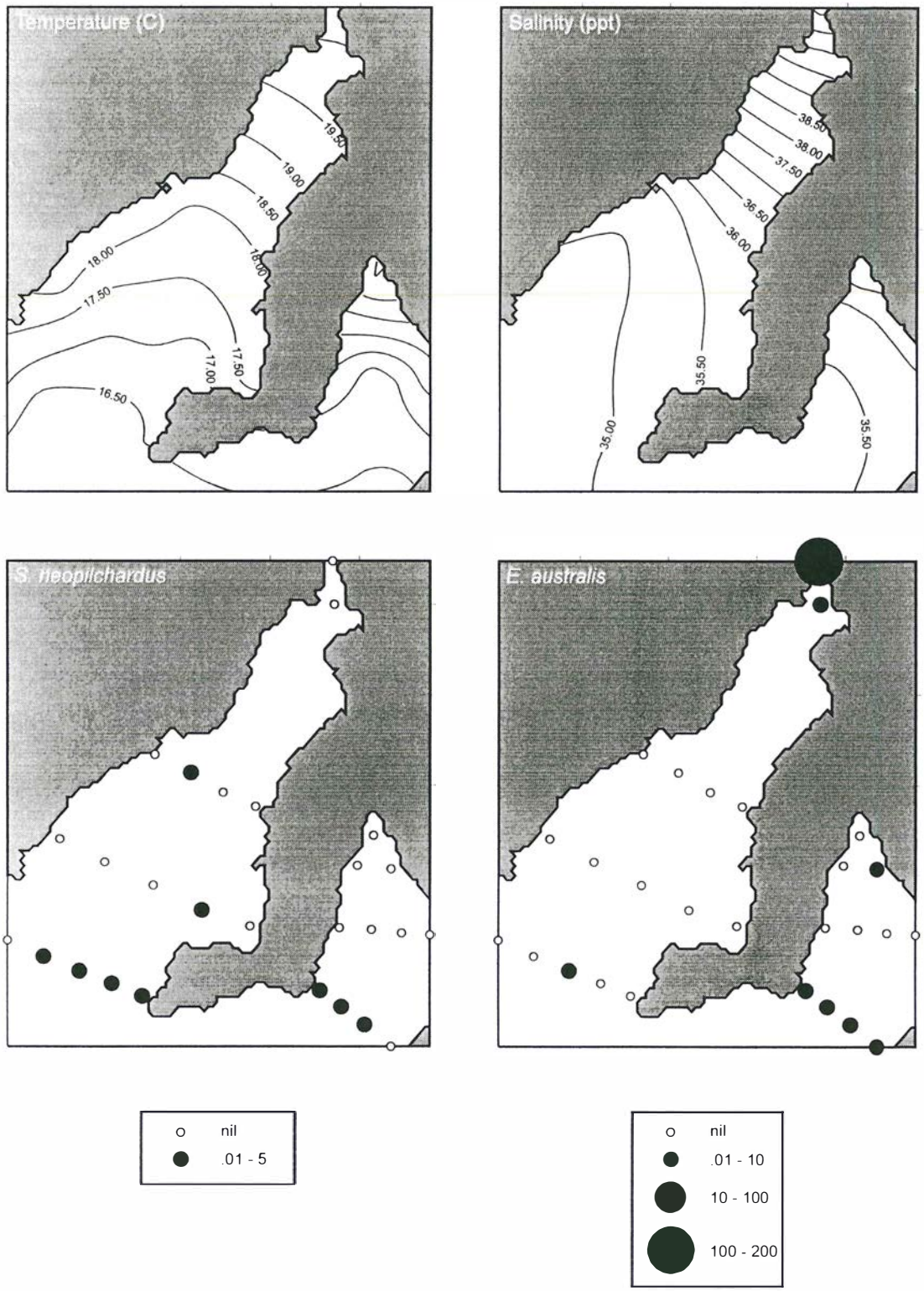


Figure 6. Clupeoid larval densities ($100m^{-3}$), temperatures and salinities for November, 1986.

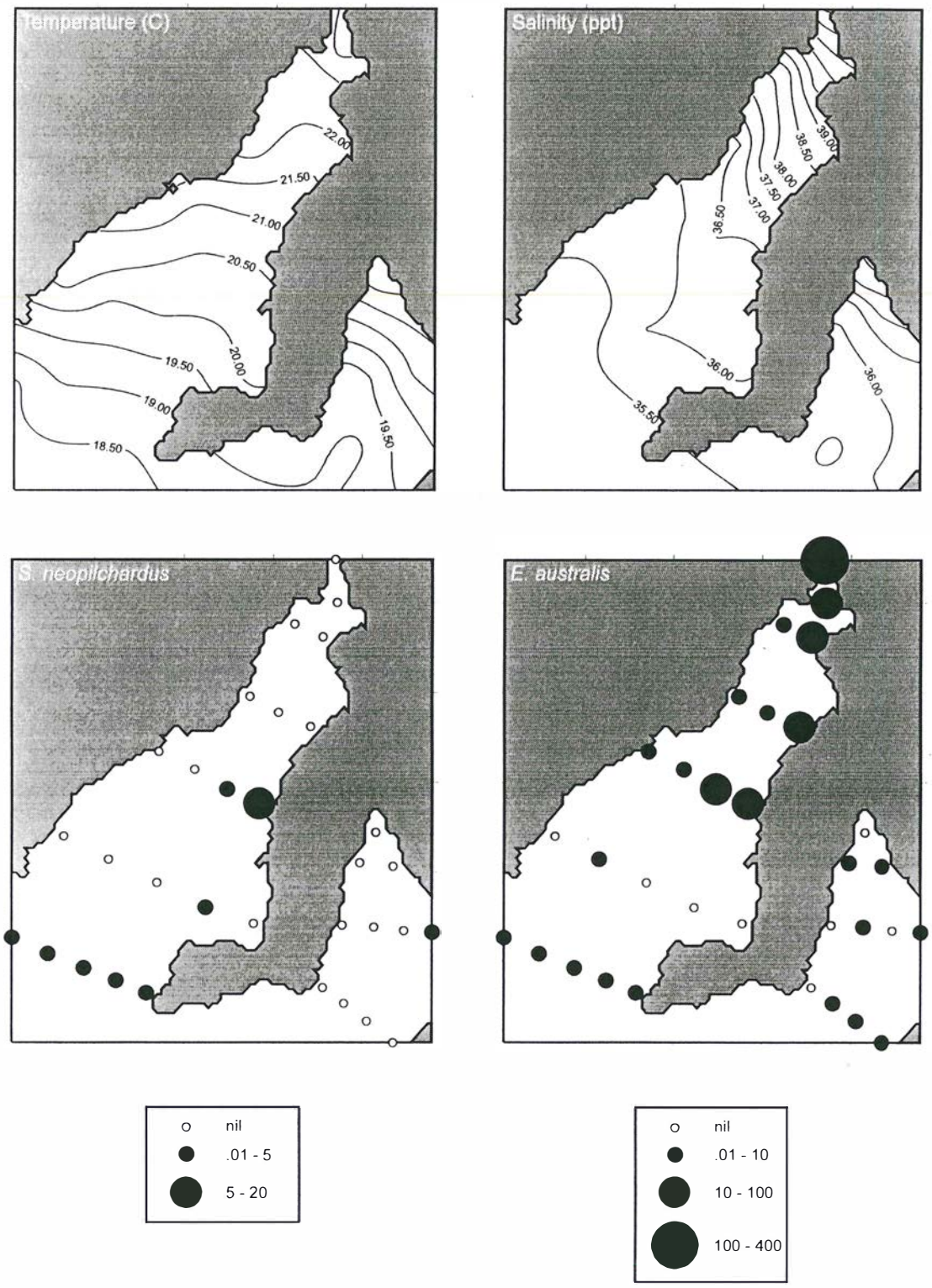


Figure 7. Clupeoid larval densities (100m^{-3}), temperatures and salinities for January, 1987.

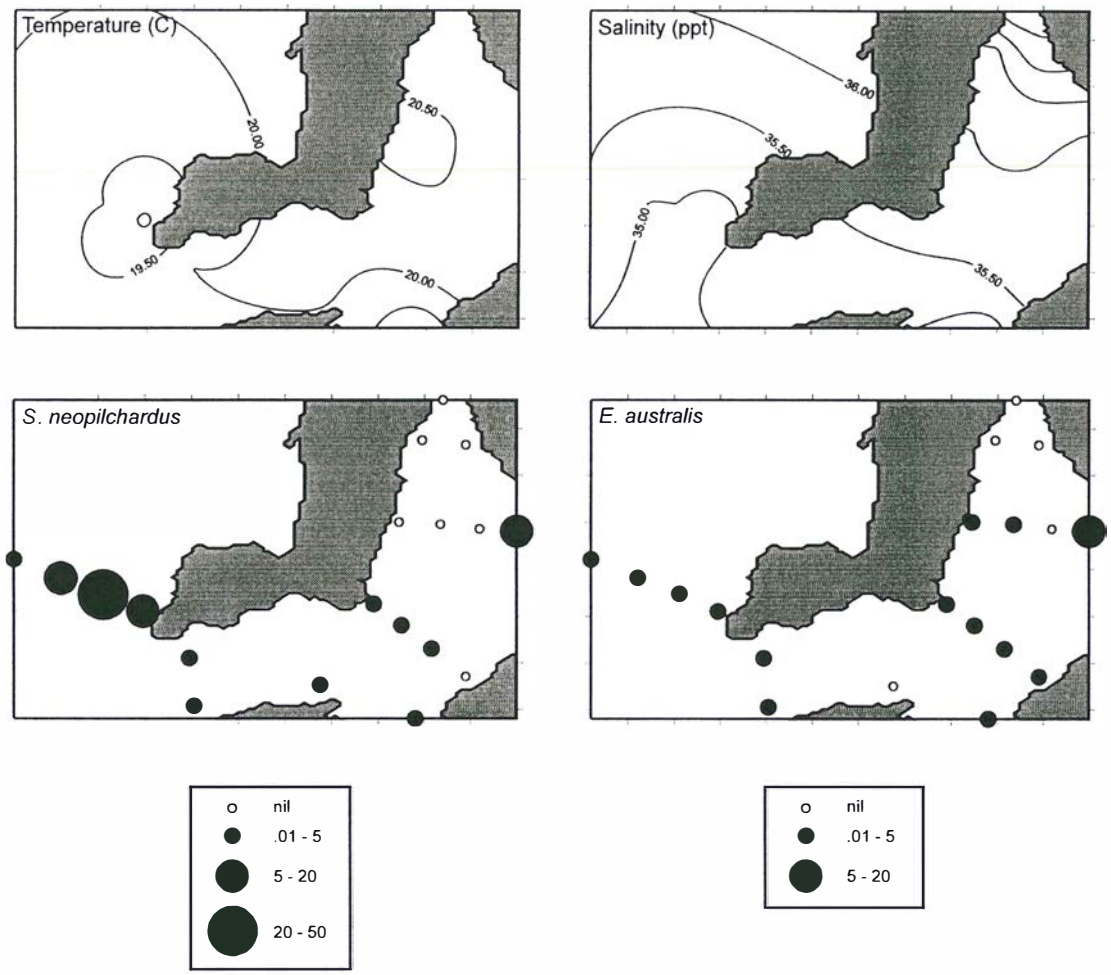


Figure 8. Clupeoid larval densities ($100m^{-3}$), temperatures and salinities for March, 1987.

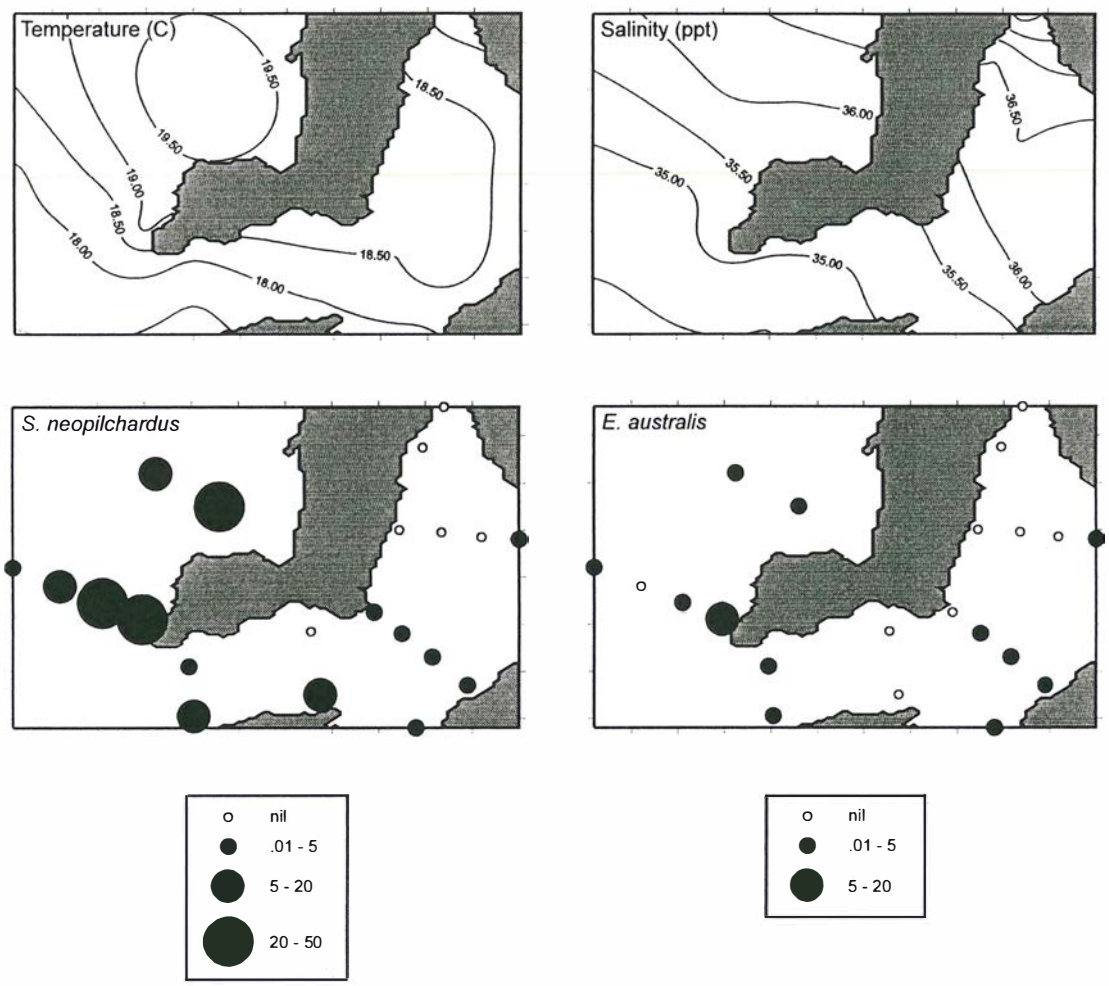


Figure 9. Clupeoid larval densities ($100m^{-3}$), temperatures and salinities for April, 1987.

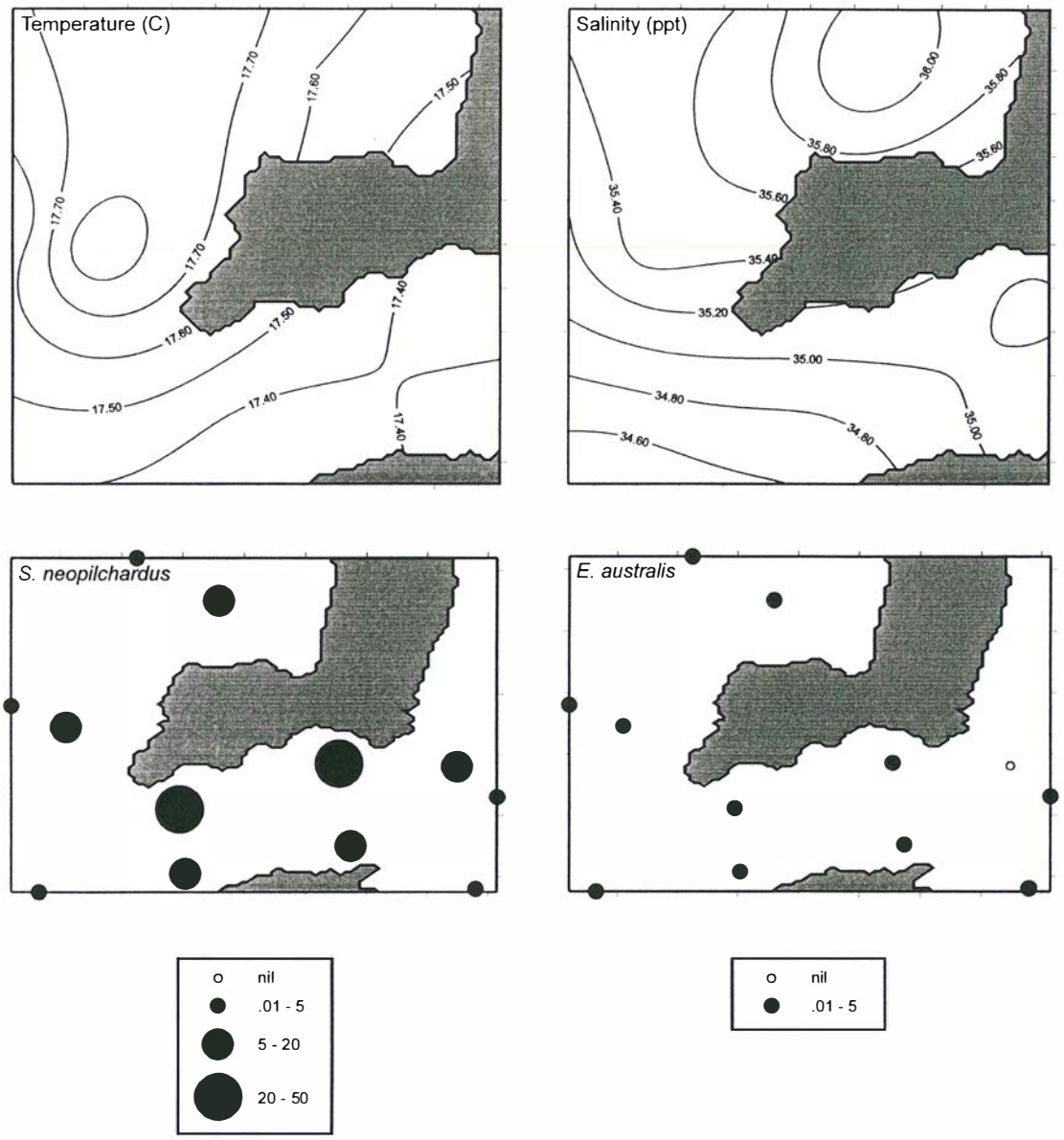


Figure 10. Clupeoid larval densities ($100m^{-3}$), temperatures and salinities for May, 1987

Anchovy larvae were collected in all months sampled except September (Table 2). The spawning season of the anchovy is therefore at least from November to June. The lack of larvae in September indicates that spawning is minimal in winter. Highest mean larval densities were in March 1986 and January 1987. (Table 2). This suggests that larval anchovy production peaks in the months of January to March. Spawning by the anchovy may therefore be earlier than in the pilchard and this is probably related to their distribution at the top of the Gulfs where the water would warm earlier than in the southern gulf and shelf. Blackburn (1950a) also reported anchovies in South Australia to be probably spawning during summer months (December, February and March); however, these were the only months when plankton sampling took place.

Table 1. Numbers of larvae of each clupeoid species identified in samples from different months. Total numbers and mean monthly station density (in brackets) are given.

		Pilchard	Anchovy	Blue sprat	Round herring
1986	Mar.	747 (23.34)	1478 (46.19)	74 (2.31)	nil
	Apr.	2436 (76.13)	262 (8.19)	8 (0.25)	nil
	Jun.	157 (4.91)	32 (1.00)	1 (0.03)	nil
	Sep.	42 (1.31)	nil	nil	nil
	Nov.	16 (0.59)	308 (11.41)	18 (0.67)	nil
1987	Jan.	49 (1.53)	878 (27.43)	112 (3.50)	nil
	Mar.	334 (17.57)	96 (5.05)	21 (1.11)	1 (0.05)
	Apr.	723 (34.43)	132 (6.29)	1 (0.05)	2 (0.10)
	May.	657 (50.54)	52 (4.00)	nil	nil

Seasonal patterns of larval distribution

Pilchard

Pilchard larvae were present in all samples (Table 2, Figs. 2-10). Larvae of this species were most abundant in the southern half of both gulfs. In Spencer Gulf, pilchard larvae were occasionally collected as far north as Whyalla (eg. March 1986), but never at the two northernmost sampling stations (Figs. 2-10). These results suggest that pilchards exhibit a preference for southern gulf waters. Larvae were also common in Investigator Strait showing that they spawn in shelf waters also. Pilchard larvae were most widely distributed within the gulfs in the March to June period (Figs. 2-10).

During months of high larval densities, pilchard larvae were sometimes present at higher densities on the eastern side of the southern Spencer Gulf transects than on the western side (Figs. 2,3,8 and 9). Thus, larval densities were relatively high in the area near the tip of Yorke Peninsula which may be an important habitat for larvae of this species (Figs. 2,3,8,9).

Pilchard larvae were collected in Investigator Strait in March, April and May 1987 (Figs. 8.9.10). Here pilchard larvae were present at the highest densities in May (Fig. 10). In March and April, pilchard larvae were more dense in Spencer Gulf near tip of Yorke Peninsula than in Investigator Strait (Figs. 8 & 9). This again suggests that the south eastern Spencer Gulf may be an important area for larval pilchard within this region.

Anchovy

Anchovy larvae were widely distributed in both gulfs and were also present in Investigator Strait (Figs. 1-10). Of these three regions, anchovy larvae were most

abundant in Spencer Gulf indicating the importance of this area as nursery ground for this species. Numbers of larvae were low in Investigator Strait for the months examined (Figs. 7-10), suggesting that less spawning occurs in shelf waters than in the gulfs. In March, April and November 1986 and January 1987, very high larval densities were recorded at the northern most station in the Spencer Gulf (Figs. 2,3,6,7). In March 1986, there was also a relatively dense patch of anchovy larvae at the head of Gulf St. Vincent (Fig. 2). This indicates a preference by this species for shallow waters in these gulfs. These results show that the distribution of anchovy larvae differs from that of pilchards, the latter having a preference for the deeper areas of the gulfs and shelf waters.

In March, April, June and November 1986 and January 1987, there was evidence that anchovy larvae in the Spencer Gulf exhibit a disjunct distribution with a patch in the northern gulf separate from one at the outer gulf (Figs. 2,3,4,6 and 7). This suggests that there may be two spawning units in this region. Possibly younger adults spawn inshore and older ones offshore as suggested for Victorian anchovy by Hoedt *et al.* (in press).

Blue Sprat

Blue sprat larvae were present in consistently low numbers in the months November through April. Peak densities occurred from January to March (Table 2).

Larvae were collected at all stations across both gulfs with higher densities occurring at the mid-gulf stations of Spencer Gulf.

Environmental parameters

Pilchard

In March 1986 and April 1987 there was a temperature front at the mouth of the Spencer Gulf on the eastern side (Fig 2, Fig. 9). High larval pilchard densities occurred on the eastern side of the two southernmost transects in association with this front (Fig. 8, Fig. 9). Bruce and Short (1992) found that this frontal zone concentrated larvae from a number of fish families. These authors suggested that the physical water movement associated with the frontal zone concentrates larvae. Furthermore, they stated that this front is likely to have higher plankton densities than surrounding areas and this may enhance larval survival. In March 1987, a cell of cool water (possibly upwelling) was present off the tip of the Yorke Peninsula and again larval pilchards were relatively dense over this cell (Fig. 8). These findings suggest that the southern Spencer Gulf may be an important area for pilchard larvae and seasonal oceanographic processes in this region may act to concentrate larvae.

Anchovy

The high density patches of anchovy larvae at the head of Spencer Gulf (January-April) were located in an environment where temperatures were mostly above 20°C and salinities over 40ppt (Fig 2, Fig. 3). High densities of anchovy larvae were found in the northern region waters where salinity increased rapidly. This contrasts with the spawning distribution of anchovy in Victorian bays and estuaries where anchovy are generally found at lower than normal salinities (Arnott and McKinnon 1985). These findings confirm the euryhaline characteristics of this species (it has been noted that this species tolerated salinities as low as 15ppt in Gippsland Lakes, Victoria (Arnott and McKinnon 1985). In March 1986, when there was a frontal zone near the tip of Yorke Peninsula, anchovy larvae where absent from that area, unlike pilchard larvae which were present in higher densities there (Fig. 2).

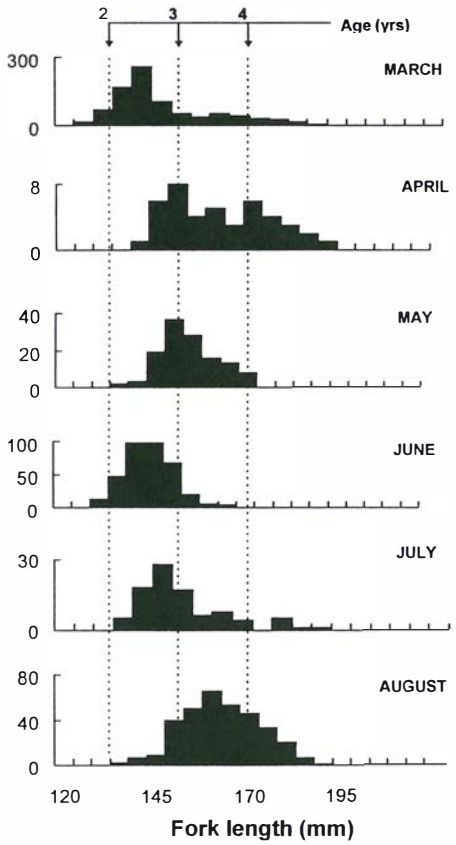
Lengths, age composition and reproductive biology of pilchards in catch samples

Bags of fish from the purse seine catches have been collected between March September at the time of writing (Table 3). Laboratory analysis is complete for samples between March and August; some bags from September have been analysed (Table 3). A total of 2774 pilchards, 33 anchovy, 4 round herring and 1 yellowtail scad were identified in these samples. Pilchard far outnumber any other bait species taken by the fishery.

Table 3. A summary of the catch samples collected from the purse seine fishery in 1995 which have been analysed.

Month	Bags	Number of pilchards
March	24	1205
April	1	51
May	4	127
June	10	527
July	4	210
August	24	852
September	2	89

Figure 11. Monthly length-frequency histograms for pilchards sampled from the purse seine fishery.



Monthly and combined length-frequency data from these samples are given in Figures 11 and 12 (the validity of combining monthly length-frequencies was checked by correlating the monthly sample sizes with the respective monthly catch and a positive relationship was shown to exist). Superimposed on these figures are preliminary age estimates (mean ages at length from four published growth estimates for Australian pilchards, see-Table 4). The monthly length-frequency histograms of pilchard catches show that a similar size-range of fish are caught each month, these mostly falling within 130 to 180mm (fork length). In March, June and July relatively small fish dominated the catch. In April, May and August a significant proportion of fish were in the larger size-range (Fig. 11). The age estimates on this figure are of a preliminary nature but these indicate that most of the catch is 2 to 4 year old fish (Fig. 11). The combined length-frequency histogram shows that the range of sizes taken in that period are between 125 and 185mm and the dominant modal size group is at 140 mm (Fig. 12). Again this figure shows that 2-4 year olds dominate the fishery.

Figure 12. Combined length-frequency data for pilchards sampled from the purse seine fishery.

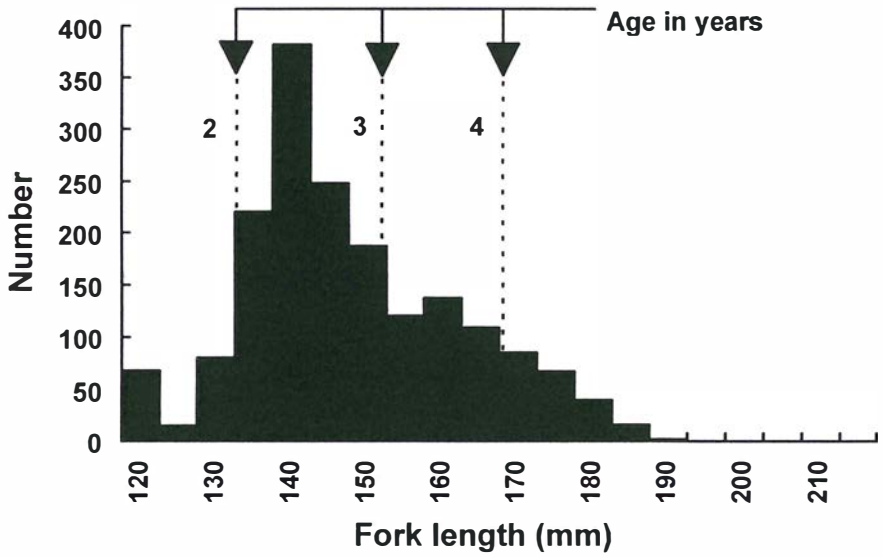


Table 4. Published estimates of length-at-age (fork length) for Australian pilchards.

Study location	1 year	2 year	3 year	4 year
NSW[1]	95	127	-	171
NSW[2]	86	111	132	147
VIC[3]	81	137	168	183
SA[4]	126	143	154	160
Mean length	97	130	151	165

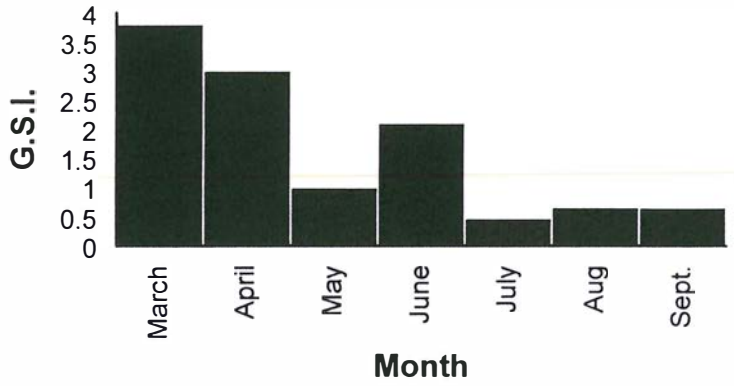
1-Blackburn 1949; 2-Joseph 1981; 3-Blackburn 1950b; 4-Stevens et al. 1984.

Otoliths have been removed from fish in each sample and are presently being analysed at the Victorian Fishery Research Institute to determine age-length keys.

Information on the spawning season of the pilchard in South Australia was obtained from the monthly pattern of gonad weights in fish from catch samples (Fig. 13). The

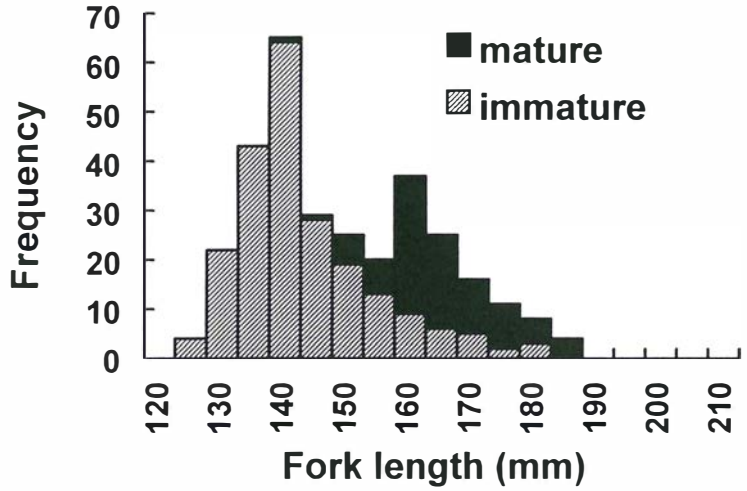
g.s.i. values were high in March and April and low in May and July-September (Fig. 13). The g.s.i. value was highest in March. The small peak in June may be misleading because only four gonads were weighed that month (Fig. 13). The heavy gonads in March and April are consistent with the high larval densities for this species in these months (see 'larval clupeoid study' section).

Figure 13. Gonado-somatic indices for pilchards sampled from the purse seine fishery.



Another important reproductive parameter is size-at-maturity. In March, when the proportion of mature gonads was greatest, we estimated size-at-maturity by plotting the numbers of immature and mature fish for different size categories (Fig. 14). This figure shows that first maturity occurred at 140 mm and the majority of fish are mature at 160mm (Fig. 14). Stevens *et al.* (1984) found that the smallest fish with mature gonads in samples from G.A.B was 120mm. More data collected in months of reproductive activity is needed to accurately determine size-at-maturity for this species.

Figure 14. Numbers of mature and immature pilchards collected from the purse seine fishery in March.

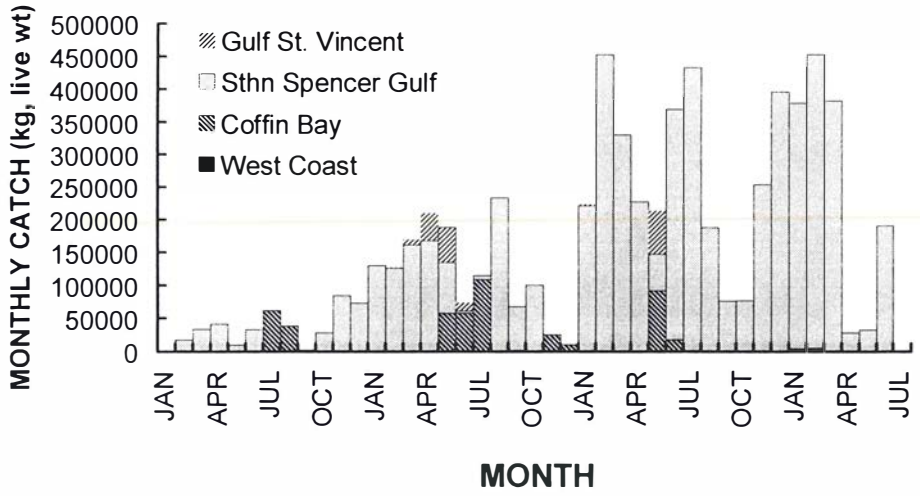


Analysis of catch data from log books filled out by the purse seine fishery for the period January 1992 to July 1995.

Using this information monthly catches by area were plotted (Fig. 15). Most of the catch was taken in the southern Spencer Gulf during this period (Fig. 15). The next most important area was Coffin Bay which was fished in the autumn/winter months

each year and occasionally at other times (Fig. 15). Pilchard fishermen report that catches in the southern Spencer Gulf decline around April-June each year suggesting that pilchards migrate from the area. Some catches were also taken in Gulf St. Vincent and a very small quantity on the west coast (Fig. 15).

Figure 15. Pilchard monthly catch, S.A. waters, Jan. 1992 - Jun. 1995.



Monthly catches exhibited evidence of a seasonal pattern. Good catches were generally made in summer and autumn (December/January to March/May) (Fig. 15). A short period of good catches also occurred around July in all years (Fig. 15). Periods during which low catches typically occurred were April-June and September-November (Fig. 15). Monthly effort by the fishery was also seasonal (Fig. 16). Effort was typically high in the late spring, summer and autumn months (Fig. 16). Effort decreased in winter and early spring (Fig. 16) which may be partly due to inclement weather in those months. Catch per unit effort (cpue) has exhibited a general trend of increase over the period of the fishery (Fig. 17). This is believed to be partly a result of increased experience and hence catch success by the fishers. Strong peaks in cpue occurred in August and October in 1993, February and July 1994, January and June 1995 (Fig. 17). Small peaks in cpue occurred in February 1992, March to May 1993 and February 1994 (Fig. 17). This indicates that the January-February period is consistently a time when more fish are available. The July-August period also appears to yield high cpue each year.

Figure 16. Pilchard monthly effort, S.A. waters, Jan. 1992 - Jun. 1995.

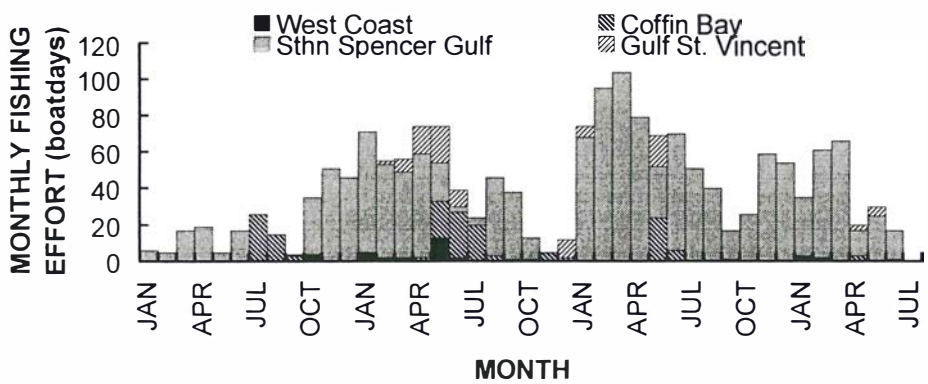
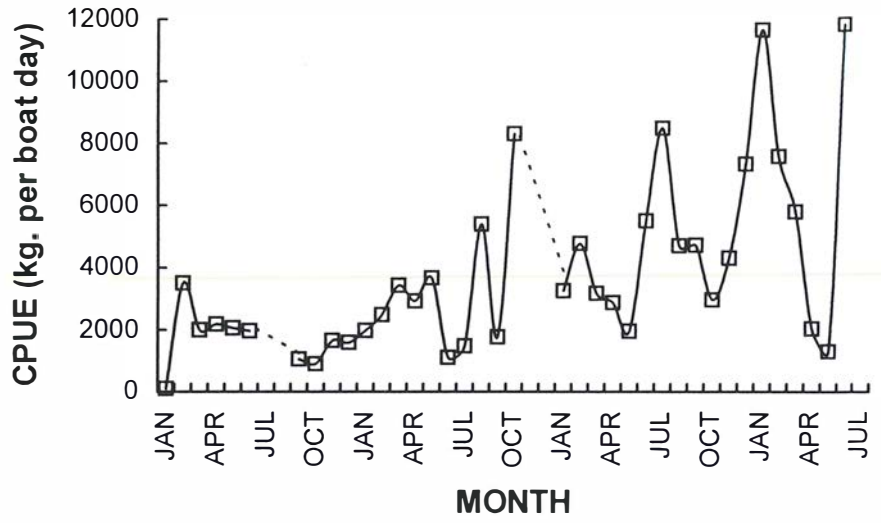


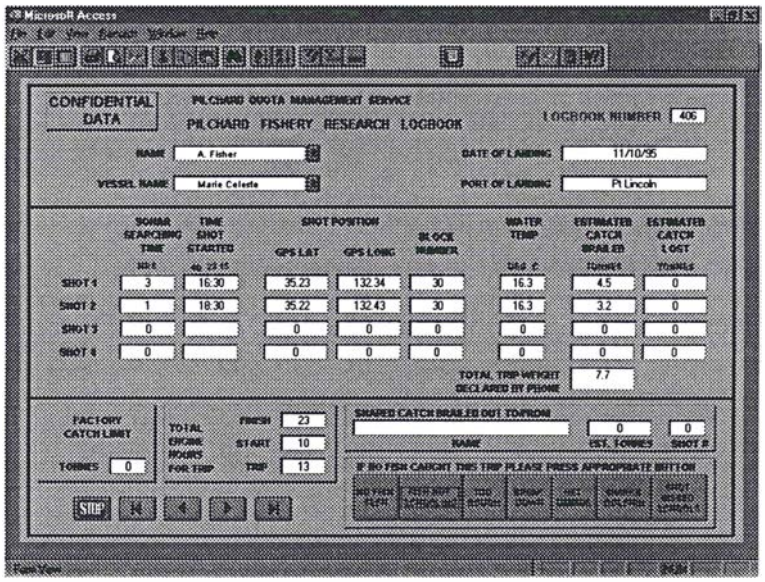
Figure 17. Pilchard average monthly cpue, sthn Spencer Gulf, Jan. 1992 - Jun. 1995.



Implementation of the new research log book

The research log has been recorded as a data entry sheet in *Microsoft Access* (see Fig. 18 for screen image), and data is presently being entered. This computer program allows analyses of data (eg. monthly cpue), output presentations (including graphical analyses) and these presentations are automatically updated as new data is entered. The system is therefore an advanced method for recording fishery information.

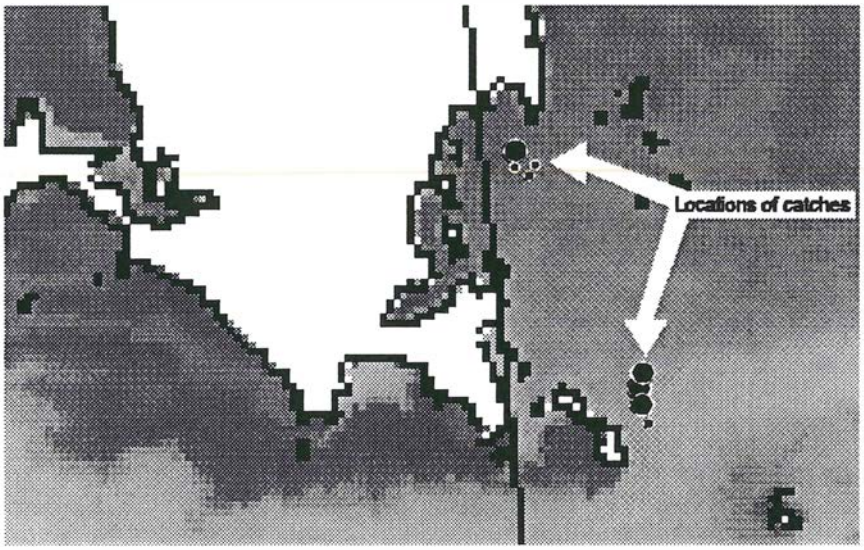
Figure 18. Screenshot of research logbook database entry form (mock data).



In addition to undertaking normal fishery analyses (monthly catch, cpue etc.) we plan to use the information from the research log book to examine the interaction between environment and catches. We use desktop mapping software (*MapInfo*) to overlay

catch data (locations and weight) over satellite images of sea surface temperature (these will soon be available fortnightly at SAASC). We have preliminary evidence that sea surface temperature patterns are good indicators of pilchard distribution. This type of analysis may shed some light on the seasonal fluctuations in pilchard availability to the fishery. Figure 19 is an example of the type of image we can produce (using mock catch data).

Figure 19. A satellite image of sea-surface temperature with mock fishery catch information superimposed.



Literature review

Key topics were chosen for the review of literature on pilchards and other baitfish species. These were:

- Age and growth of pilchards and other clupeoid fishes
- Reproductive biology of clupeoids and other pelagic fishes
- Spawning biomass estimates on clupeoids and other species
- Other stock assessment techniques for clupeoids
- Trophic relationships of pilchards (diet and predators)
- Environmental influences on distribution and abundance
- Clupeoid egg and larval distribution and abundance studies

All references from 1978 to 1994 on the pilchard and anchovy have been extracted from ASFA software at the SAASC library. Key references prior to 1978 have also been located from bibliographies in the 1978-94 references. Topics 3, 5, 6 and 7 have been thoroughly searched and key references collated. Searches have been completed for the remaining topics and titles and abstracts are stored on computer disk. Copies of key papers in these areas have been made. All of these references are presently being entered onto a computer database called *Papyrus*[††], a dedicated reference management system. This will provide an accessible system for future work

[††] Papyrus is a registered trademark of Research Software Design

relating to pilchards. The literature review is ongoing work within the national project and this will enable newly published references to be collated in the coming two years.

Stock discrimination

In April 1995, samples from Streaky Bay (far west region of the fishery), Coffin Bay and Port Lincoln were sent to University of New South Wales for Stock Discrimination analysis. As sampling and fishing continues in the three year project more samples will be sent. No results on the analyses are available at present.

Analysis of tuna pole and line fishery catch data

The patchiness of the 1971 - 82 information does not make it possible to quantify the baitfish catch; however, the following observations can be made. The main species taken for bait was pilchards, with the following other species also being taken at times: yellowtail scad (*Trachurus novaezealandiae*), anchovies (*Engraulis australis*) and tommy ruffs (*Arripis georgiana*).

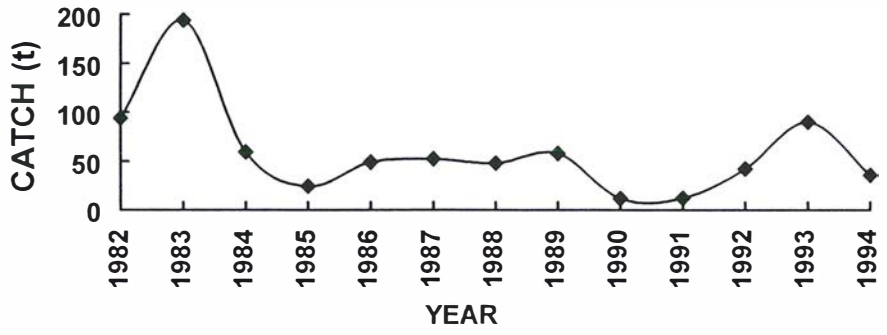
The main areas where baitfish were taken included Boston Bay, outer Coffin Bay and northern Streaky Bay. Other areas where catches were reported included the Sir Joseph Banks Group, Thistle Island, Rocky Island (west of Coffin Bay), Flinders Island and St. Francis Island.

The baiting season ran from December to June, at the times when southern bluefin tuna were found in waters offshore from South Australia. Baitfish catches were recorded as either the number of scoops used to chum the tuna schools or the weight caught during baiting operations. Catches of 100 - 300 kg per night were reported during the season; however, there is insufficient information to determine if there was any seasonality of the catch rates or fishing effort.

The baitfish catch data from tuna vessels which has been provided to AFMA on the commonwealth log book forms between 1982 and 1994 give a very conservative estimate of the baitfish catch, as they only include pilchard catches taken on the same day as the main tuna fishing activity was undertaken. Figure 20 shows the quantity of pilchards taken from 1982 - 1994. Over the period there was a decline in the pilchard catch by pole fishers, probably brought about by the decline in the catches of southern bluefin tuna.

In order to obtain information on the total baitfish catch taken by tuna pole fishers, the revised research log presently being filled out by the purse seine fleet is being sent to all tuna pole boat fishers for the start of the 1995/96 season.

Figure 20. SBT pole fishery, 1982 - 94, recorded bait catch.



SUMMARY

- The larval clupeoid fauna in the Spencer Gulf and Gulf St. Vincent was dominated by pilchards, closely followed by anchovy in the 1986-87 period. The spawning seasons of pilchard and anchovy are September-June (peak in March-May) and November-June (peak in January-March) respectively. Anchovy were most abundant at the northern half of the gulfs while pilchards were more abundant in the southern areas. Larvae of both species were present in the gulfs and the Investigator Strait.

- The pilchard fishery has been catching fish between 125 and 185mm with most fish being around 140mm in length. Age estimates indicate that most of the catch falls within the 2-4 year age-range. There is some size variation in the catch between months. Seasonal changes in gonad weights in sampled pilchards indicate that March and April are times of most reproductive activity. No samples were available for November-February. The smallest mature fish was 140mm in March and most fish were mature at 160mm.

- Catches and catch per unit effort in the purse seine fishery exhibit definite seasonal trends. Good catches generally occurred between December and May and again in July and at other times catches were low to moderate. Catch per unit effort has been highest in January-February and July-August in most years, and there was generally an upward trend in cpue over the period 1992 - 95, probably due to increased skill by the fishers.

ACKNOWLEDGMENTS

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REFERENCES

Arnott, G.H. and McKinnon, A.D. (1985) Distribution and abundance of eggs of the anchovy, *Engraulis australis* in relation to temperature and salinity in the Gippsland Lakes. Australian Journal of Marine and Freshwater Res. 36: 433-439.

Blackbum M. (1949) The age, rate of growth and general life-history of the Australian pilchard (*Sardinops neopilchardus*) in New South Wales. *Bulletin of the Science and Industry Research Organisation, Melbourne* 138, 17-47.

Blackbum, M. (1950a) A biological study of the anchovy, Engraulis australis (White), in Australian waters. *Australian Journal of Marine and Freshwater Res.* **1**: 3-84

Blackbum, M. (1950b) Studies on the age, growth and life-history of the pilchard, *Sardinops neopilchardus* (Steindachner) in southern and Western Australia. *Australian Journal of Marine and Freshwater Res.* **1**: 221-258.

Bruce, B., and Short, D.A. (1992) Observations on the distribution of larval fish in relation to a frontal zone at the mouth of Spencer Gulf, South Australia. In: Larval Biology (Hancock, D.A. ed.). Proceedings of the Australian Society for Fish Biology Workshop held at Hobart on 20th August 1991. *Department of Primary Industries and Energy, Bureau of Natural Resources Proceedings* **15**. Canberra.

Chen, W., Govoni, J.J., and Warien, S.M. (1992) Comparison of feeding and growth of larval round herring *Etrumeus teres* and gulf menhaden *Brevoortia patronus. U.S. National Marine Fishery Service, Fishery Bulletin* **90**, 183-89.

Hoedt, F.E., Dimmlich, W.F., and Dann, P. (in press) Seasonal variation in the species and size-composition of clupeoid assemblages in Western Port , Victoria. *Marine and Freshwater Res.* **46**, 7.

Joseph, B.D.L. (1981) Pilchard fishery at Jervis Bay- Biology, fishery and population dynamics. M.Sc. Thesis 135pp. University of New South Wales.

Mitani, I. (1988) Characteristics of daily age composition of larvae of Japanese anchovy *Engraulis japonica* in the fishing ground of Sagami Bay. *Nippon Suisan Gakkaishi* **54**(2), 209-14.

Palomera, I., Morales-nin, B. and Lleonart, J. (1988) Larval growth of anchovy, *Engraulis encrasicolus*, in the western Mediterranean Sea. *Marine Biology* **99**, 283-91.

Re, P. (1984) Evidence of daily and hourly growth of pilchard larvae based on otolith growth increments, *Sardina pilchardus* (Walbaum, 1792). *Cybium* **8**(1), 33-38.

Stevens et al. (1984) Stevens, J.D., Hausfeld, H.F., Davenport, S.R. (1984) Observations on the biology, distribution and abundance of *Trachurus declivis*, *Sardinops neo*pilchard*us*, *Scomber australasicus* in the Great Australian bight. *C.S.I.R.O. Marine Laboratories Report Hobart* **164**:1-27.

Townsend, D.W., Radtke, R.L., Morrison, M.A., and Folsom, S.D. (1989) Recruitment implications of larval herring overwintering distributions in the Gulf of Maine, inferred using a new otolith technique. *Marine Ecology Progress Series* **55**, 1-13

APPENDIX

SOUTH AUSTRALIAN PILCHARD FISHERY LOG BOOK

Searching Method *Method of Fish Attraction*

Licence Number: ..... Name of Licence Holder: ..... Boat ☐ Sonar ☐ Berley ☐

Plane ☐ Other ☐ Lights ☐

Month: ..... Year: ..... No. of Crew: ☐

DATE	SEARCHING INFORMATION					FISHING INFORMATION						REMARKS
	AREA SEARCHED*	SEARCHING TIME (hrs.)	No. SCHOOL SEEN	TONNAGE/ SCHOOL	TOTAL TONNAGE	AREA FISHED*	No. SCHOOLS FISHED	No. SHOTS	PILCHARD TONNAGE CAUGHT	OTHER SPECIES	TONNAGE CAUGHT	e.g. Sea conditions, water temperature, birds diving
TOTAL:												

* Codes for searching and fishing areas (see overside)

(all enquiries, please phone 08 - 226 0626 — reverse charges

SOUTH AUSTRALIAN COMMERCIAL FISHING DAILY LOG

D 82

Licensee Name

Licence Number

Main place of landing (or) Code

Month Year

Months during which you will not be fishing

ADVANCE NIL RETURNS

Fish dealer/Processor sold to

1.

2.

3. Tick any other methods of disposal

- [ ] Personal use
- [ ] Public sale
- [ ] Bait

Number of days on which fishing took place

	Average number times set during 24 hours	Average length of net set (m)	Predominant mesh (cm)
Shark nets			
Gill nets			
Set lines			

Average number of hooks set

HAULING NETS (tick methods)

- [ ] Ring shot
- [ ] Power haul
- [ ] Other

I certify that the information on this form is complete and correct:

Signature:

LANDED CATCH (kg) and CONDITION (Whole, Headed, Gutted)

DAY OF MONTH	MAN DAYS	MAIN AREA (code)	TARGET SPECIES	GEAR (code)	Species	Species	Species	Species	Species	Species	Species	Species	Species	Species
					Code	Code	Code	Code	Code	Code	Code	Code	Code	Code
					Condition W H G	W H G	W H G	W H G	W H G	W H G	W H G	W H G	W H G	W H G
				TOTAL CATCH										

TP05 Logbook (actual size 345 mm x 240 mm)

Log No..

5 0 1 C	3906

1 4 5 8

Starting Date for Page

Day Month Year (19..)

9 10 11 12 13 14

TUNA POLE & BAIT LOG

Boat Name: ....

Skipper: ....

Australian Boat Registration Number

15 ← 22

State of Registration (first 2 initials of State Name)

24

ACTIVITY (fill in every day) Ⓐ				BAITING (fill in on days baiting finishes) Ⓑ			SEARCHING (fill in on days when you are searching) Ⓒ									ESTIMATED CATCH (fill in on days when you catch fish) Ⓓ							ACTUAL LANDINGS (fill in on days when you land fish) Ⓔ			
At sea tuna fishing (or baiting) on any part of day .... 0 At sea, but: — weather prevents any fishing .... 1 — broken down all day .... 3 — neither tuna fishing nor baiting .... 7 In port for whole day 2				Main species of bait caught: — pilchards .... P — yellowtail .... Y (chow) — Mixed or others ...... M			Noon Position (local time)				Number of hours spent searching (to nearest hour)	Type of Searching: 1. Without air support 2. With air support			1 - 3 B C D	13 - 15 S B F Southern Bluefin Tuna		16 - 18 Other Species (see front of book for codes) Code:	19 - 21 Code:	Surface Temperature where fish taken	If purse seiner helped give code (see front of book)	22 - 24 S B F Southern Bluefin Tuna	25 - 27 Other Species (see front of book for codes) Code:	28 - 30 Code:	Port Code (see front of book; code should only be shown on days when landings of fish are made)
DATE				Number of hours spent baiting (to nearest hour)			Latitude		Longitude				Number of Patches		Catch	Fish Average Weight									
	Day	Month	Code	(hrs)	Number of Scoops	Code	Deg.	Min.	Deg.	Min.	(hrs)	Code	Found	Fished	(tonnes)	(kg)	Catch (tonnes)	Catch (tonnes)	(°C)	Code	Landings (tonnes)	Landings (tonnes)	Landings (tonnes)	
1 - 3	9 -	12	13	14 - 15	16 - 19	20	21 -	24	25 -	29	30-31	32	33 -	36	37 - 39 40	41-42	43 - 45 46	47 - 49 50	51 - 52 53	54	55 - 57 58 - 60	61 - 63 64 - 66	67 - 69 70 - 72	73 - 76
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Comments:
(give date where necessary

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Tag Recoveries:
(see forms at back of book also;
please complete details on these)

Tag No.	Date

Department of Primary Industry
English (V4) TP05
June 1982