CSIRO Marine Laboratories
Report 217

Larval distributions across the Leeuwin Current: Report on RV *Franklin* cruise FR8/87 in August/September 1987

A. F. Pearce, B. F. Phillips and C. J. Crossland

CSIRO
AUSTRALIA

1992

CSIRO Marine Laboratories Report 217

Larval distributions across the Leeuwin Current: Report on RV *Franklin* cruise FR8/87 in August/September 1987

A.F. Pearce, B.F. Phillips and C.J. Crossland

CSIRO Division of Fisheries
Marine Laboratories
PO Box 20, North Beach
W. Australia 6020

Abstract

Larval sampling across the Leeuwin Current off the Houtman Abrolhos Islands was carried out from the RV *Franklin* in August/September 1987. The Current was flowing strongly along the shelf-break, with a small offshore meander near the islands. Water temperature, salinity and nutrients were well-mixed across the shelf, but the distributions of various planktonic components were appreciably different offshore of, within, and inshore of the Current. *Panulirus cygnus* larvae were concentrated off the shelf, suggesting that the metamorphosis to the puerulus stage takes place near the shelfbreak. Early stages of *Scyllarus bicuspidatus* larvae were found on the shelf and later stages near the shelfbreak, while the larvae of an unknown species *Scyllarides* sp. *a* were present in the Leeuwin Current, possibly transported to this area from the north.

National Library of Australia Cataloguing-in-Publication

Pearce, Alan, 1940–
Larval distributions across the Leeuwin Current: Report on RV *Franklin* cruise FR8/87 in August/September 1987.

ISBN 0 643 05260 7.
ISSN 0725–4598

1. Marine plankton – Indian Ocean. 2. Leeuwin Current.
I. Phillips, Bruce F. (Bruce Frank). II. Crossland, C.J.
III. CSIRO. Marine Laboratories. IV. Title. (Series : Report (CSIRO. Marine Laboratories); 217).

574.92

Introduction

The life history of the western rock lobster *Panulirus cygnus* includes an open-ocean phase during which the larval stages (known as phyllosomata) spend a few months drifting in the southeastern Indian Ocean (Phillips 1981). At the end of this phase, some of the late-stage phyllosomata transform from the larval form to a free-swimming puerulus which then crosses the continental shelf and settles in the coastal reefs. There is evidence that the level of puerulus settlement along the coast is related in some way to the Leeuwin Current (Pearce and Phillips 1988). However, the mechanisms for the metamorphosis and settlement are as yet unclear, partly because of inadequate information on the distributions of larvae and puerulus off the shelf.

Among the objectives of RV *Franklin* cruise FR8/87 in August/ September 1987 was an investigation of the distributions of larvae and pueruli in relation to the Leeuwin Current. As a separate study, measurements of the sea-surface temperature were also made for comparison with satellite-derived data (see Barton and Cechet 1989). This cruise was part of the Leeuwin Current Interdisciplinary Experiment (LUCIE) series; a summary of the oceanographic characteristics of the Leeuwin Current determined during LUCIE has been reported by Church et al. (1989).

Methods

The area surveyed in the present study was off the Houtman Abrolhos Islands (Figure 1), and consisted essentially of three transects across the continental shelf at 28°S, 29°07'S and 29°45'S over the period 27 August to 5 September 1987.

Surface temperature and salinity were monitored continuously on a thermosalinograph, while subsurface profiles of those two parameters as well as nitrate, phosphate and silicate were made with a CTD (Conductivity-Temperature-Depth) recorder and a rosette sampler. The CTD station positions and depths are listed in the Appendix. Currents were measured with an acoustic Doppler current profiler (ADCP), using fixes from GPS and SATNAV. AVHRR (Advanced Very High Resolution Radiometer) images from the NOAA-9 satellite were used to determine the position of the Leeuwin Current at the time of the cruise so that larval samples could be taken in relation to the larger-scale flow patterns.

Particulate organic and inorganic matter of <1 mm size was determined from hydrocast water samples using weight and ashing techniques. In some cases, particulate matter was fractionated (1000-560 μm, 560-212 μm, 212-84 μm, 84-10 μm, and <10 μm) by passing water through a plankton mesh series before weight determinations.

Surface larval hauls were made using a 1 square metre 100 μm mesh net operated from a boom on the starboard side of the vessel. The net was fitted with a General Oceanics digital flowmeter for determining the volume of water filtered. A new multi-closing subsurface net (the EZ net) was also tested, with the aim of determining the depth distribution of pueruli near the coast. However, this failed to operate successfully and no subsurface larval samples were obtained.

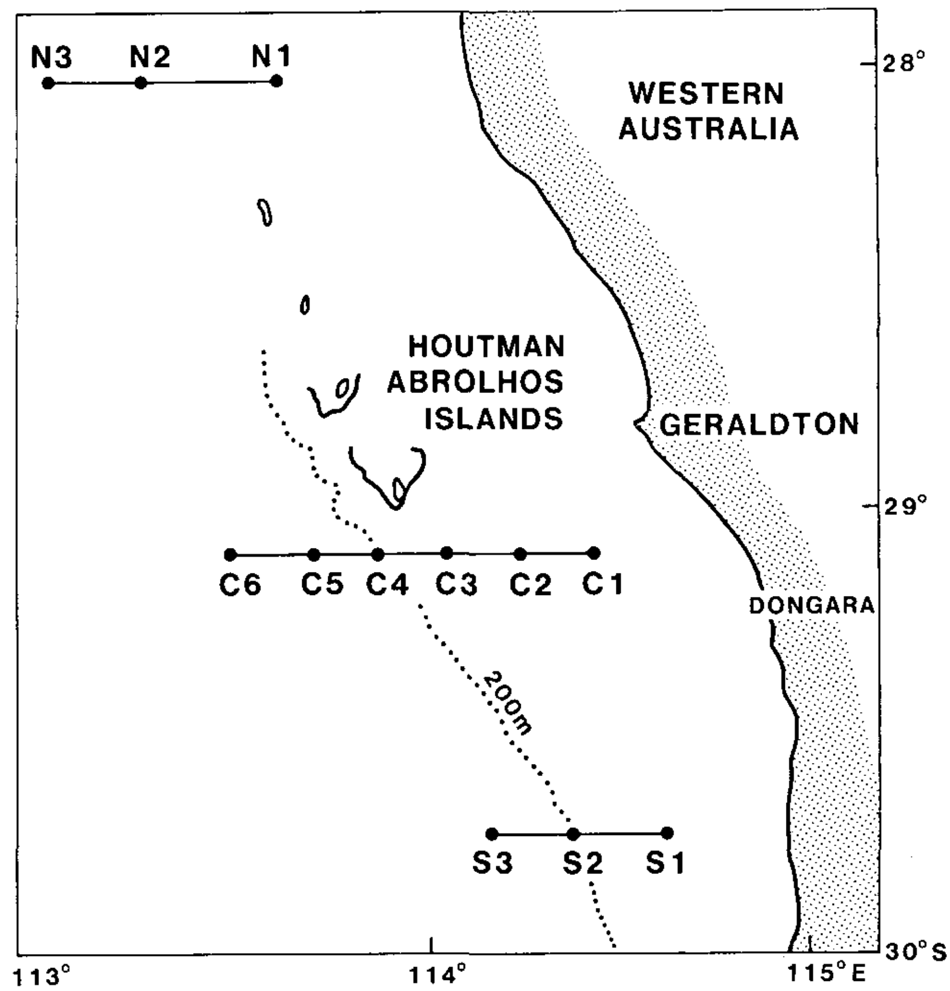

Figure 1 :
CTD station positions for *Franklin* cruise Fr 8/87 near the Houtman Abrolhos Islands in August/September 1987. There were three zonal transects (filled circles N1 to N3, C1 to C6, S1 to S3). The 200 m contour is dotted.

The surface layer

An AVHRR image obtained a week before the cruise showed that the Leeuwin Current was flowing strongly down the shelf-break south of Shark Bay, and a small meander was developing just offshore of the Abrolhos Islands in the area of the *Franklin* survey (Figures 2 and 3). Further south, the Current followed the shelf-break before swinging offshore in a large meander which was in the process of "pinching-off" into a warm-core (anti-clockwise) eddy.

The development of the meander off the Abrolhos Islands was partially obscured by cloud; by the time of the cruise the meander had extended a little further offshore (Figure 3c) and a week later it appeared to have drifted northwards (Figure 3d). The northern transect cut across the Current upstream of the meander, the central transect was immediately south of the feature, and the southern transect intersected the strong jet of the current along the shelf-break.

The surface hydrographic data (Figure 4) confirm the picture suggested by the satellite imagery. Cool, relatively high salinity water was present at the offshore stations of all three transects, while the warmer, less saline water of the Leeuwin Current flowed around the meander and southwards along the shelf-break. The temperature-salinity (T-S) plot in Figure 4c shows that

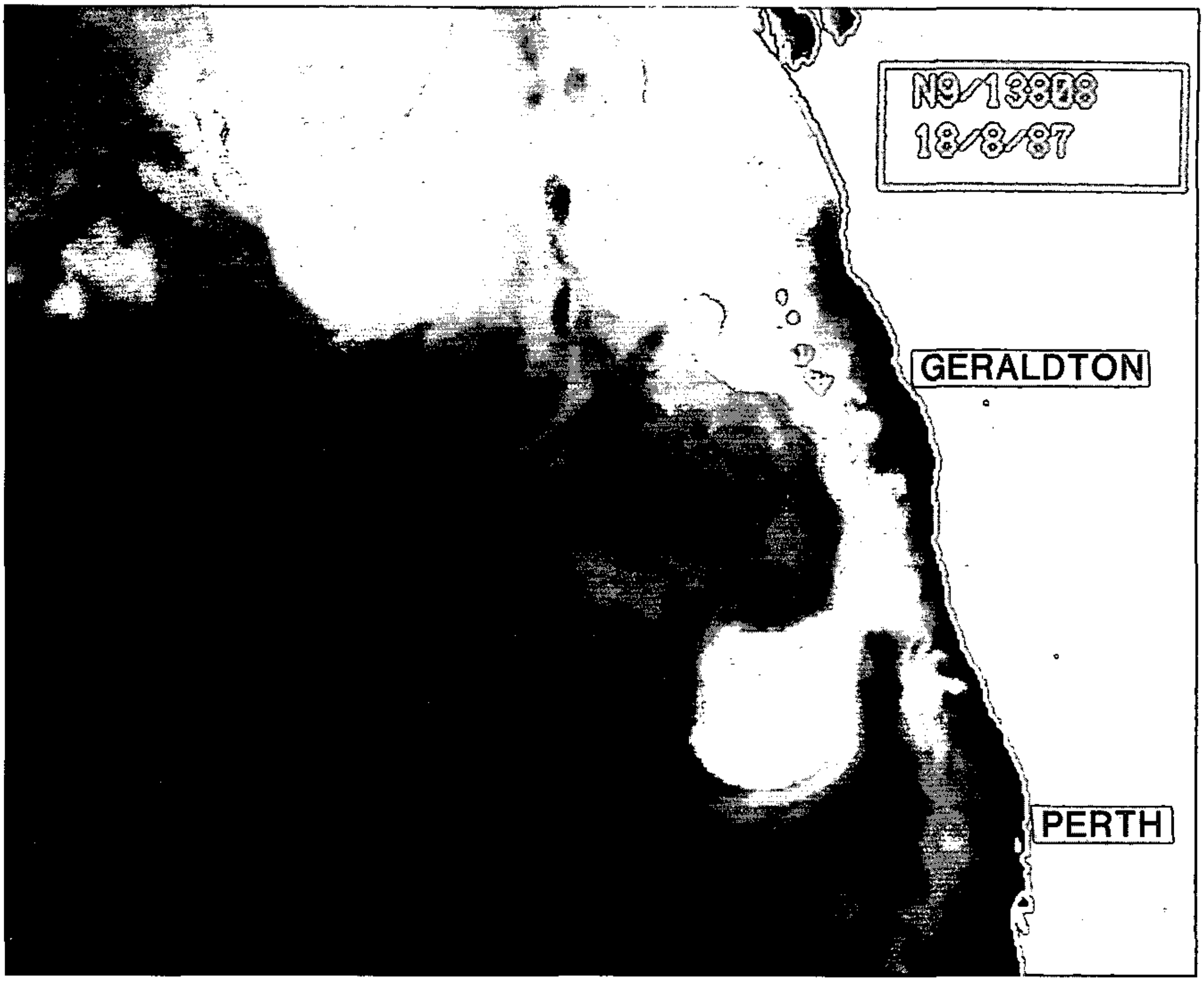

Figure 2 : NOAA/AVHRR infra-red image on 18 August 1987, showing mesoscale features of the Leeuwin Current between Shark Bay and Cape Leeuwin just prior to cruise Fr 8/87. The brightness temperature in band 4 (re-projected to a transverse Mercator grid) is illustrated.

there was a distinctive transition between the cool, low-salinity inshore water (T=19.5°, S<35.5), the warm, low-salinity water in the core of the Leeuwin Current (T>20.5°, S<35.5), and the cool, high-salinity offshore water (T<19.5°, S>35.7).

Near-surface currents from the ADCP show strong southwards flow (exceeding 0.5 m/s) along the thermohaline front associated with the Leeuwin Current beyond the shelf-break (Figure 5). Along the outer shelf region, the flow was less pronounced although generally towards the south, while the currents along the inner shelf were much weaker with a northwards or onshore tendency (confirmed by current estimates from ship-drifts). Surprisingly, currents towards the outer end of the central transect were directed strongly northwards towards the Leeuwin Current, possibly associated with an apparent northwards drift of cool (offshore) water evident through gaps in cloudy satellite images. This may also suggest, however, that there was some entrainment of offshore water into the Current, with consequent implications for larval transport.

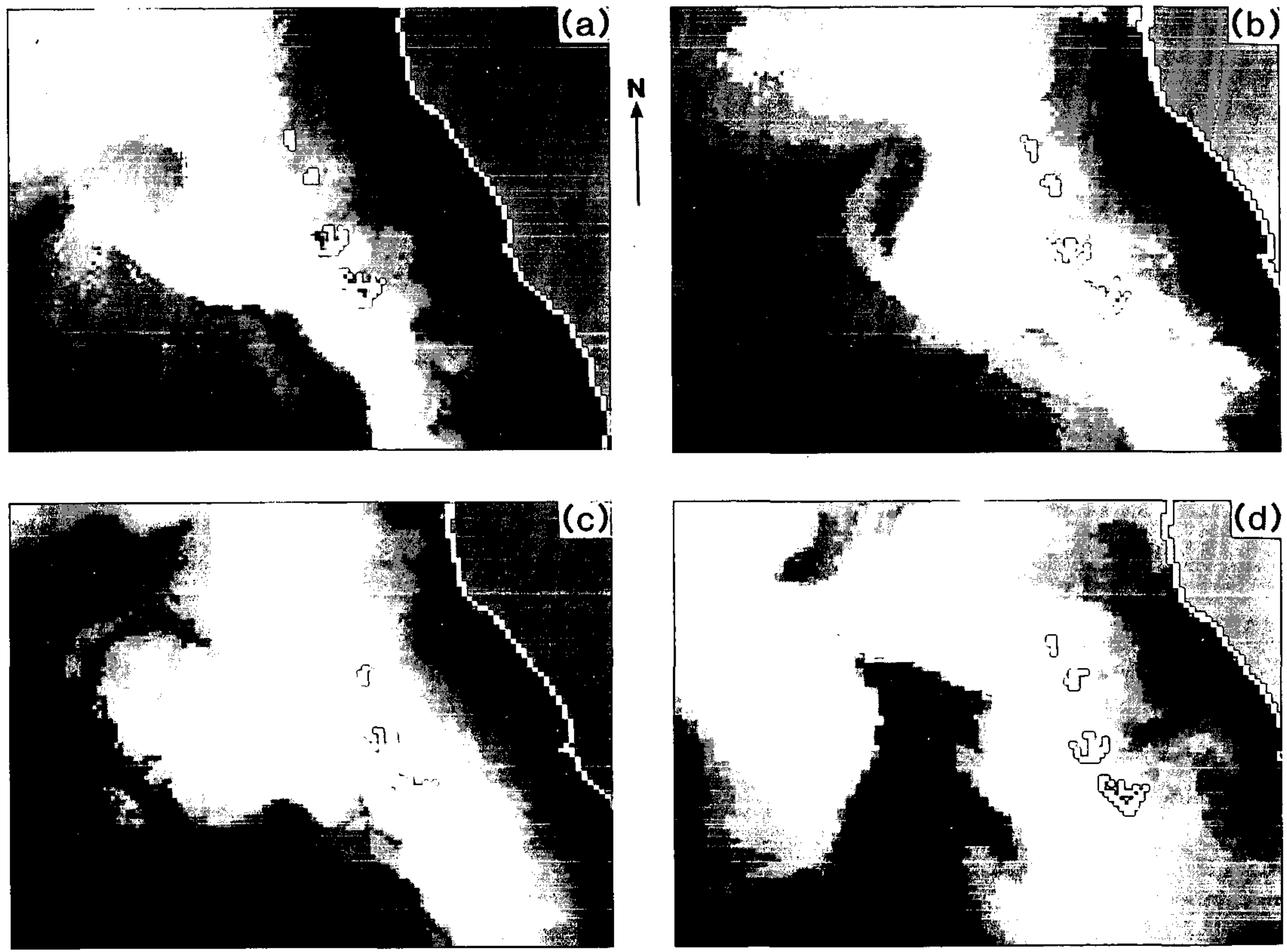

Figure 3 : Enlarged AVHRR images of the cruise area off the Houtman Abrolhos Islands, showing the development of the meander over the period (a) 18 August, (b) 19 August, (c) 28 August and (d) 8 September 1987.

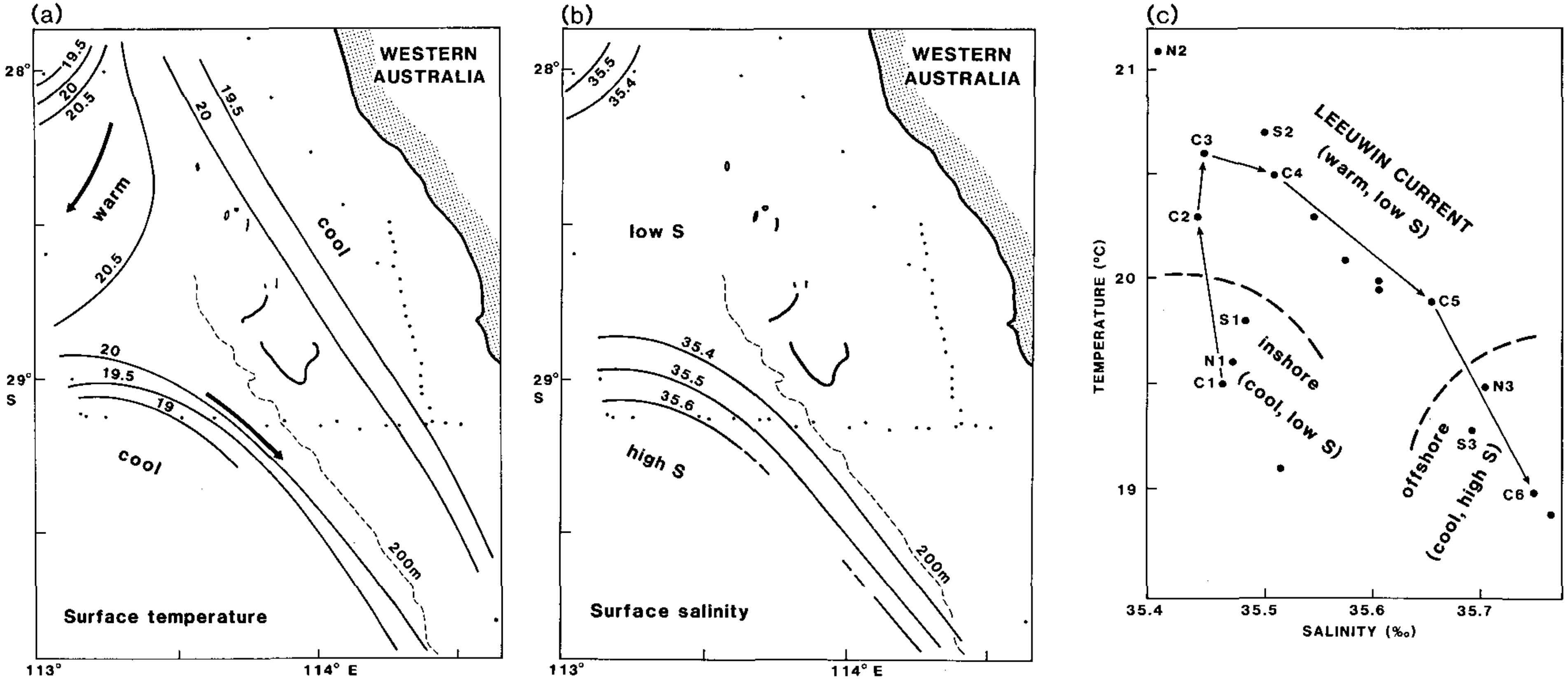

Figure 4 : (a) Surface temperature and (b) salinity for cruise Fr 8/87, from thermosalinograph records. The dots show the positions of net trawls, covering a wider area than the CTD stations. (c) is a surface temperature-salinity (T-S) plot showing the water masses in the upper layer across the transects from CTD station data. Stations N1 to N3 represent the northern CTD transect, C1 to C6 the central transect (points connected by arrows to show the progression across the shelf), and S1 to S3 the southern transect (see Figure 1 for the station positions).

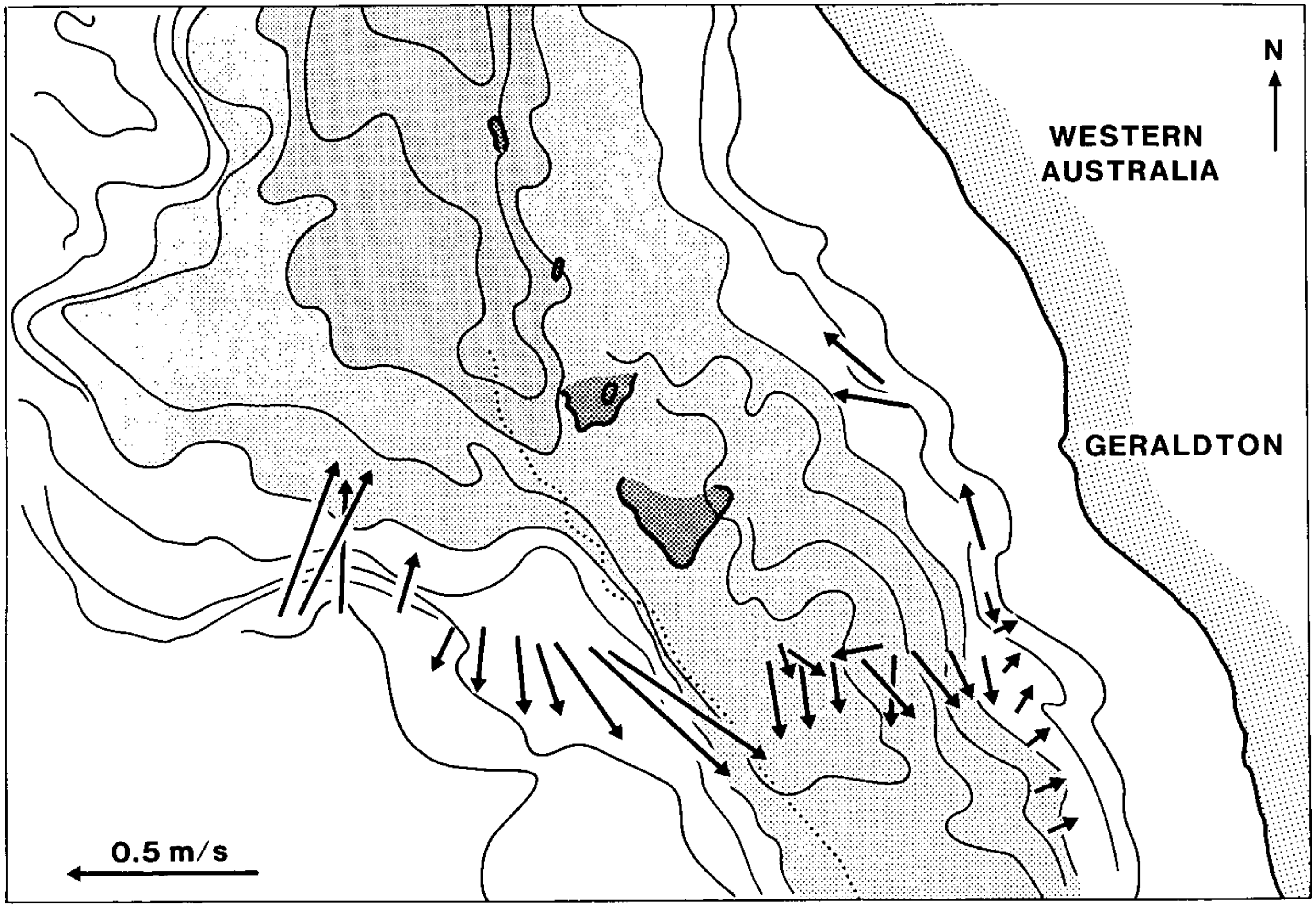

Figure 5 : Near-surface currents from the Doppler acoustic profiler for the period 27 to 29 August, superimposed over a line sketch of the satellite image for the 28th (from Figure 3c). The arrow-tails are at the measuring positions, and the velocity scale is indicated. The dotted line represents the shelfbreak.

Subsurface structure

The central transect along 29°7'S demonstrates the main features of the subsurface water properties down to 500 m (the other two transects were similar). Figure 6(a,b) shows the relatively strong thermohaline front just beyond the shelfbreak, marking the offshore boundary of the warm, low-salinity Leeuwin Current, as well as the cooler water near the coast.

Conditions on the shelf were well-mixed with very little variation in either temperature or salinity between the surface and the bottom, and to almost 100 m at the shelfbreak. The contours sloping downwards from offshore towards the continental shelf reflect the southwards flow in the Leeuwin Current, and there was perhaps some suggestion of a northward undercurrent below about 350 m (Thompson 1984). There was a subsurface core of higher-salinity water (probably South Indian Central Water; Rochford 1969) between 100 and 150 m (Figure 6b).

Nutrients were uniformly low in the surface layer (both on and off the shelf: Figure 6 c,d,e). The nitrate and phosphate concentrations were about 0.2 µM, and that of silicate about 3 µM. Below 200 m, the nutrient concentrations increased appreciably with depth, particularly in the case of nitrate. The relative uniformity in nutrient concentrations in the surface waters, from nearshore to offshore, does not preclude the possibility of water masses of different origins being present. Indian Ocean surface waters are characteristically of low productivity, low in nitrate and phosphate, and reasonably uniform in silicate (Wyrtki et al. 1988). Further, upwelling events are not known off Western Australia (Rochford 1980), and shelf waters have similar nutrient concentrations to the ocean values, except for nitrate in the immediate vicinity of the coast during winter (Pearce et al. 1985; CSIRO Marine Laboratories Marmion unpublished data). Hence, the inability to distinguish between offshore waters, Leeuwin Current water, and shelf waters using nutrient levels is not surprising.

The concentration of particulate organic material (POM; <1 mm in size) in the Leeuwin Current is low, and it increases towards the coast (Figure 6f). This cross-shelf gradient is consistent in particulate type and concentration values with results from coastal studies out to 20 km off Seven Mile Beach, Dongara (CSIRO Marine Laboratories Marmion unpublished data). Particle size fractionation at stations C1 to C4 showed that the POM comprised particles smaller than 84 µm; the POM biomass was equally distributed between the 84-10 µm and the <10 µm fractions.

Generally, phytoplankton are an insignificant component of POM in the coastal and midshelf waters off Dongara and near Perth. The high POM concentrations on the shelf are undoubtedly derived from coastal processes, in which organic detritus is advected out onto the shelf from the extensive benthic communities of seagrasses and macroalgae occurring nearshore. A similar gradient was found for inorganic matter, presumably of nearshore origin.

The POM values of the cross-sectional profiles are indicative of three water masses across the study area, namely

(i) temperate coastal Western Australian, with very high POM (particulate organic carbon, or POC, of 500 to 2000 µg dry weight per litre),

(ii) tropical-subtropical Indian Ocean waters of the Leeuwin Current

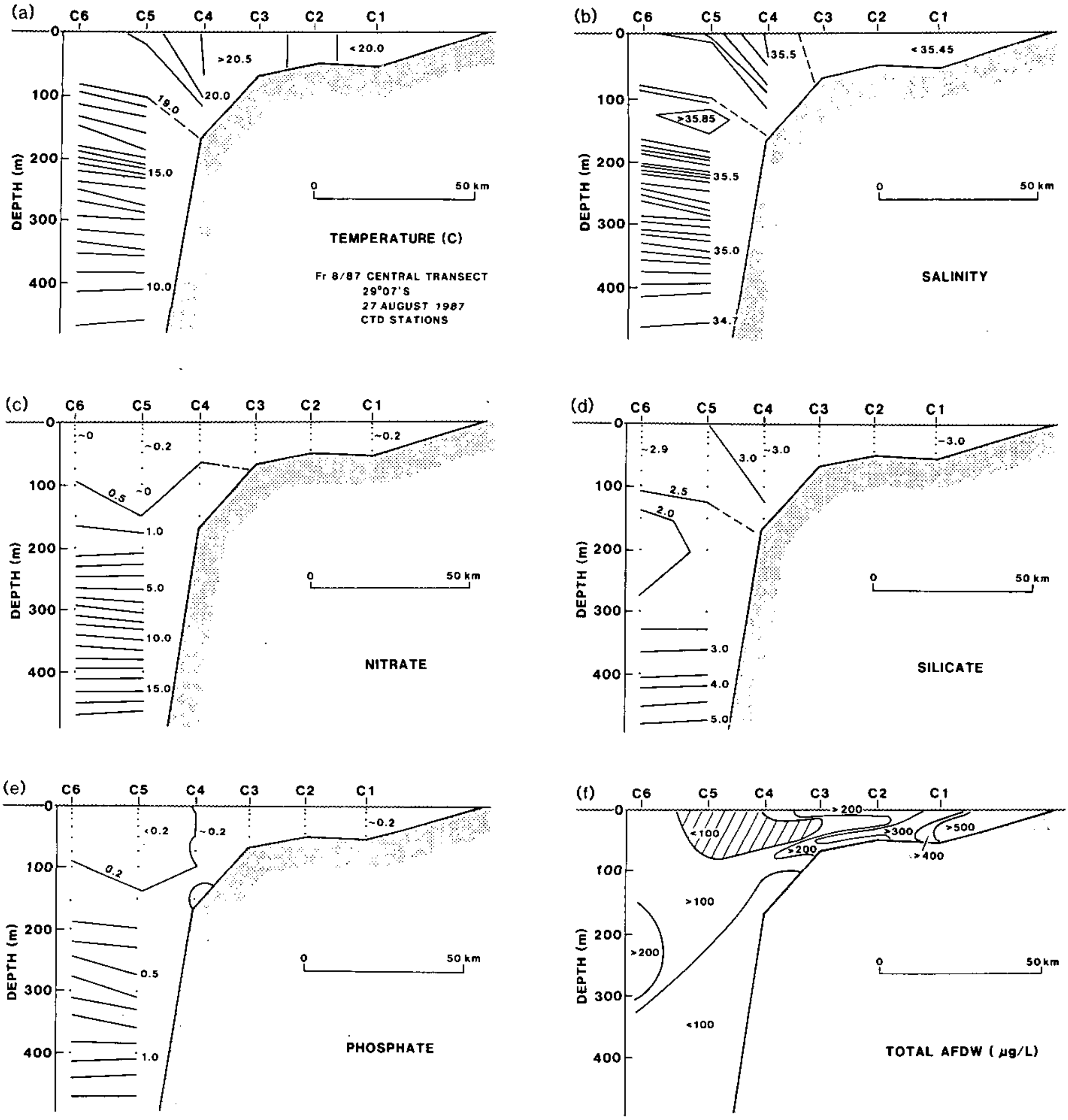

Figure 6 : Vertical CTD sections across the central transect: (a) temperature (°C), (b) salinity (ppt), (c) nitrate (µM), (d) silicate (µM), (e) phosphate (µM), and (f) ash-free dry-weight organic particulates (<1 mm, in µg/l). C1 to C6 are the station positions, and the dots indicate sample depths.

(characterised by POC of <20 µg carbon per litre), and

(iii) subtropical temperate water (characterised by POC of 50-250 µg carbon per litre) (Crossland et al., submitted).

The distribution of particulate materials across the shelf suggests that the Leeuwin Current may act as a partial "barrier" separating inshore (coastal) and offshore (open ocean) waters (Figure 6f). The interleaving tongues of inshore and Leeuwin Current water masses on the shelf indicate that there may well be some exchange of water between the coastal waters and the Leeuwin Current, but the Current would effectively block any further offshore interchange of water properties. The exchange of nutrients and POM across the shelf would be inhibited by such a barrier, which would also ensure that planktonic larvae of low-motility organisms could be constrained either on the shelf or seaward of the Leeuwin Current (as suggested by Cresswell and Golding 1980). An active swimming mode would consequently be required for such organisms to traverse (either through or beneath) the Current.

Surface faunal distributions

The distribution of fauna in the surface net samples suggests a strong dependence on the water masses associated with the Leeuwin Current and adjacent waters (Figure 7).

Panulirus larvae were found exclusively off the shelf i.e. in the outer region of the Current, and were all stage VI to IX larvae (Figure 7b). The final stage larvae (stage IX) were all concentrated at the stations along the shelfbreak just inshore of the Leeuwin Current front, and were presumably about to contribute to the settlement of puerulus along the coast. It is noteworthy that no *Panulirus* phyllosomata or pueruli were found in the inshore samples, which conforms with results of all previous studies. The implication of this is that the metamorphosis to the puerulus stage occurs beyond the shelf (and perhaps the Leeuwin Current) and that the movement towards the coast by the pueruli is subsurface.

Scyllarid (slipper lobster) phyllosomata were found both on the shelf and offshore. Those nearest the coast (Figure 7d) were early-stage larvae (stages I to IV) of *Scyllarus bicuspidatus*, hence recently hatched. The *Scyllarus bicuspidatus* larvae found offshore or within the Current were late-stage (stages VII to IX). (It would appear that the time-scale of the scyllarid life history differs from that of *P. cygnus*.) It is significant that almost all of the scyllarid larvae within the Leeuwin Current (Figure 7c) were late stages (VII to IX) of the unknown *Scyllarides* sp. *a* described by Phillips et al. (1981). This suggests that these larvae may have been transported to this area from the north.

The main biomass concentration of the nekton occurred in the Leeuwin Current, particularly along the outer edge (Figure 7e). The other faunal components also displayed specific distribution patterns (Figure 7f). Krill and salps were found in the outer regions of the Current beyond the shelf break, whereas fish larvae were closer inshore.

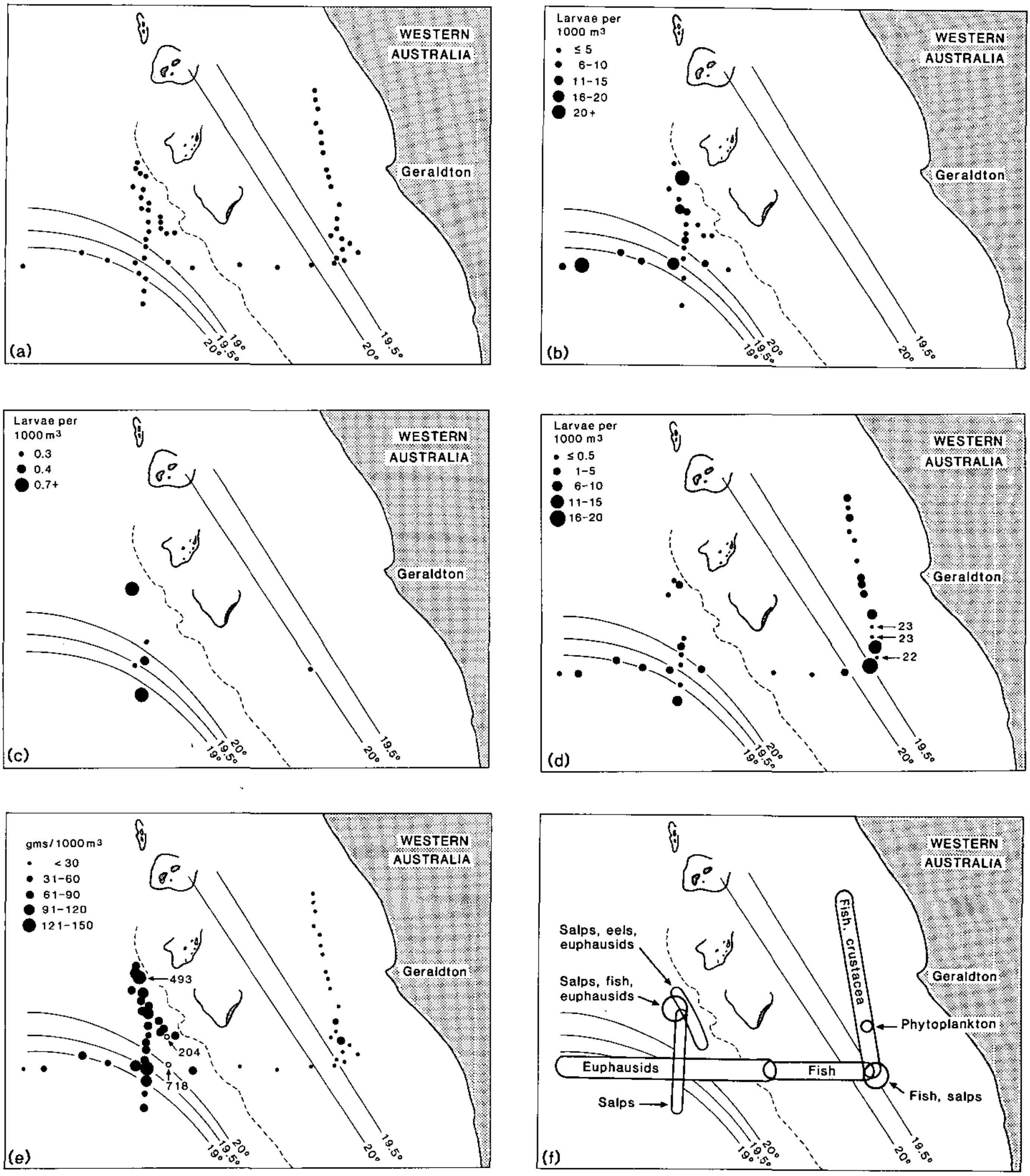

Figure 7 : (a) Positions of surface net stations during cruise Fr 8/87; distributions of (b) *Panulirus*, (c) *scyllarides* and (d) *scyllarus* phyllosomata in numbers of larvae per 1000 cubic metres of water filtered; (e) is the biomass of the samples in grams per 1000 cubic metres of water filtered; (f) shows the dominant faunal components in the plankton samples. The numbers in (d) and (e) are individual values beyond the upper limits of the ranges used. The surface isotherms from Figure 4a are shown to indicate the position of the Leeuwin Current.

Conclusions

Unfortunately, the limited data obtained from this cruise (because of the sampling problems) are inadequate for anything but tentative conclusions to be drawn. For example, the apparent concentration of stage IX phyllosomata along the shelfbreak just inshore of the Leeuwin Current boundary may indicate that this is the area of major phyllosoma/puerulus metamorphosis (possibly stimulated by the Current) or it may represent nothing more than a transition occurring from offshore to onshelf conditions. Only additional sampling using the subsurface sampler will provide the quantitative data necessary to test this hypothesis.

A cruise of the FRV *Southern Surveyor* is planned for September 1991 to continue this work, including use of the vital subsurface multiple opening-closing net.

Acknowledgements

The satellite images were obtained by courtesy of Curtin University and CSIRO Division of Exploration Geoscience. We express our appreciation to the Master, crew and all aboard the RV *Franklin* for assisting in the program. Bernadette Heaney, Carol Bowron, Simon Braine, Ian Cook, Jeff Dunn, Bob Griffiths and Angela Way assisted with data processing. Useful (and welcome) comments on the manuscript were contributed by George Cresswell, Rhys Brown, Chris Chubb and Nick Caputi.

References

Barton, I.J. and Cechet, R.P (1989). Comparison and optimization of AVHRR sea surface temperature algorithms. *Journal of Atmospheric and Oceanic Technology*, **6**, 1083-1089.

Church, J.A., Cresswell, G.R. and Godfrey, J.S. (1989). The Leeuwin Current. In: Poleward flows along eastern ocean boundaries, ed. S.J. Neshyba, C.N.K. Mooers, R.L. Smith and R.T. Barber, Springer-Verlag, New York, 230-252.

Cresswell, G.R. and Golding, T.J. (1980). Observations of a south-flowing current in the southeastern Indian Ocean. *Australian Journal of Marine and Freshwater Research* **27A**, 449-466.

Crossland, C.J., Pearce, A.F. and McLay, L.D. (submitted). Nutrient supply to the North West Shelf, Australia; the role of particulate and dissolved organic matter. (submitted to *Australian Journal of Marine and Freshwater Research*).

Pearce, A.F., Johannes, R.E., Manning, C.R., Rimmer, D.W. and Smith, D.F. (1985). Hydrology and nutrient data off Marmion, Perth, 1979-1982. CSIRO Australia Marine Laboratories Report 167, 45 pp.

Pearce, A.F. and Phillips, B.F. (1988). ENSO events, the Leeuwin Current, and larval recruitment of the western rock lobster. *Journal du Conseil*, **45**, 13-21.

Phillips, B.F. (1981). The circulation of the southeastern Indian Ocean and the planktonic cycle of the western rock lobster. *Oceanography and Marine Biology Annual Reviews*, **19**, 11-39.

Phillips, B.F., Brown P.A., Rimmer, D.W. and Braine, S.J. (1981). Description, distribution and abundance of late larval stages of the Scyllaridae (slipper lobsters) in the South-eastern Indian Ocean. *Australian Journal of Marine and Freshwater Research* **32**, 417-437.

Rochford, D.J.(1969). Seasonal variations in the Indian Ocean along 110 °E. 1. Hydrological structure of the upper 500m. *Australian Journal of Marine and Freshwater Research* **20**, 1-50.

Rochford, D.J. (1980). Nutrient status of the oceans around Australia. CSIRO Australia Division of Fisheries and Oceanography Annual Report 1977-79, 9-20.

Thompson, R.O.R.Y. (1984). Observations of the Leeuwin Current off Western Australia. *Journal of Physical Oceanography*, **14**, 624-628.

Wyrtki, K., Bennett, E.B. and Rochford, D.J. (1988). Oceanographic atlas of the International Indian Ocean Expedition. National Science Foundation, 531 pp., reprinted Amerind Publishing Company, New Delhi.

Appendix : RV *Franklin* Cruise FR8/87 : CTD Station List

Stn. No.	Time WAST	Date	Latitude	Longitude	Bottom Depth	Cast Depth
1	0924	27-AUG-87	29:28.87S	113:41.42E	1265	998
2	2059	27-AUG-87	29:07.09S	114:28.00E	52	44
3	2239	27-AUG-87	29:06.24S	114:16.08E	49	42
4	0019	28-AUG-87	29:06.66S	114:05.04E	67	56
5	0204	28-AUG-87	29:07.18S	113:54.01E	166	146
6	0402	28-AUG-87	29:07.06S	113:43.19E	913	498
7	0625	28-AUG-87	29:07.35S	113:30.13E	1748	498
8	1334	28-AUG-87	29:45.73S	114:11.05E	747	498
9	1538	28-AUG-87	29:45.11S	114:24.23E	103	96
10	1733	28-AUG-87	29:44.41S	114:41.03E	55	46
11	0423	29-AUG-87	28:00.65S	113:38.88E	55	48
12	0650	29-AUG-87	28:00.15S	113:16.14E	182	168
13	0848	29-AUG-87	28:01.43S	113:00.15E	721	698
14	1225	3-SEP-87	29:05.26S	113:36.39E	1134	798
15	1839	3-SEP-87	29:07.23S	113:38.68E	1163	498
16	1815	4-SEP-87	28:55.39S	113:38.78E	710	498
17	0542	5-SEP-87	29:05.30S	113:45.95E	747	498
18	1810	5-SEP-87	29:07.30S	114:30.90E	50	42

CSIRO Marine Laboratories

Division of Fisheries
Division of Oceanography

Headquarters
Castray Esplanade, Hobart, Tasmania
GPO Box 1538, Hobart, Tasmania 7001, Australia

Queensland Laboratory
133 Middle Street, Cleveland, Queensland 4163

Western Australia Laboratory
Leach Street, Marmion, WA
PO Box 20, North Beach, WA 6020

CSIRO
AUSTRALIA

ISBN 0 643 05260 7.
ISSN 0725–4598