# FRANKLIN

National Facility
Oceanographic Research Vessel

**Continental Shelf Processes and their Effects on Plankton Condition and Size Structure.**

## CRUISE SUMMARY

## RV FRANKLIN

## FR 01/99

Depart Brisbane 1130hrs, Wednesday 20 January 1999
Arrive Brisbane 0900hrs, Thursday 4 February 1999

**Principal Investigators**

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## Project Description

This cruise is the second of two, the first being FR 14/98, undertaken from 14 to 27 November, 1998.

The overall program aims to determine and model upwelling processes of the East Australia Current (EAC) off Northern NSW, and to determine the effect of the nutrient supply on the growth, condition and size structure of zooplankton and red-tide forming biota. The area from Urunga to Port Stephens (30S to 33S), and from the

coast to the 500m isobath, is the prime area of interest. This area includes the region north of the usual separation point, where the EAC hugs the coast causing strong (3 – 4 kn) currents, to the area beyond the separation point where the interaction of the EAC and the sloping continental shelf forms a very strong thermal and velocity front at the outer continental shelf. With the cruise originating in Brisbane, we will also take the opportunity to observe the shelf-sea response to the EAC in the region of North Solitary Island.

In summary, objectives are:

- to observe the baroclinic structure of the coastal currents at a range of latitudes off the Northern NSW shelf, and, together with data acquired by current meters to be retrieved from this cruise, identify the key processes responsible for upwelling,
- to sample the phytoplankton and zooplankton communities at each of these sections, as well as the larval fish condition, and hence
- to finally draw conclusions concerning the overall effects of the physical environment on the production of nutrients, and the subsequent development of the food chain to the stage of larval fish.

**Results**

The cruise track is shown in Figure 1, with offshore lines generally indicating sections where CTD and biological sampling were implemented. The oceanographic structure was observed through satellite images, and CTD transects undertaken both north and south of the separation point.

Key features north of the separation point are shown for Smoky Cape in Figure 2, which has both the temperature structure (as found from the CTD), and velocity structure (as found from the ADCP). The East Australia Current is evident from the deeper ocean all the way to the coast, with surface temperatures exceeding 27C over the entire section, and the colder subsurface waters being absent from the continental shelf. Velocity contours are everywhere southward, and exceeding 1 m/s in surface waters everywhere, and with a localised sub-surface maximum coinciding with the strongest horizontal thermal gradients as would be expected from a thermal wind balance. A steady current over a continental shelf which is uniform alongshore will have a geostrophic balance throughout the main part of the water column, and according to Macready and Rhines (Journal of Physical Oceanography, 1993, vol 23, p5-22) a bottom boundary layer which eventually shuts down, becoming inviscid, and leaving a thermal wind balance throughout the entire water column. This appears to be the case northward of the separation point at Urunga (30 30S).

At Smoky Cape (31 00S) the continental shelf narrows, providing a constriction to that part of the EAC which lies over the continental shelf and slope. As a consequence, the currents accelerate past this point, and the bottom boundary layer activates, driving colder (and more nutrient-rich) waters up the slope and onto the continental shelf proper. As the EAC flows southward, productivity may then occur in the phytoplankton which now have source of both nutrients and light. Downstream at Crowdy Head (32 00S) sections of temperature (Figure 3) show the colder water over the inner part of the shelf, and weaker currents inshore. Associated with the colder

nearshore waters, CTD casts showed a higher concentration of fluorescence indicative of the presence of phytoplankton.

Farther downstream, and after the surface warm waters of the EAC had separated from the coast, the nearshore waters were observed to be progressively cooler and saltier, and had a larger biomass.

Our overall biological aim for both cruises was to investigate the influence of nutrient intrusions on plankton distribution and condition, in comparison with the anthropogenic nutrient discharge off Sydney. We conducted replicated sampling at two stations around the 50 m and 100 m isobath, at seven locations between the Urunga and Point Stephens transects. Our findings concern the size frequency distribution of zooplankton, and the spatial distribution and condition of larval fish (specifically the late stages of yellowtail (*Trachurus novazealandie*), and anchovy (*Engraulis australis*), and of *Noctiluca scintillans*, an important red-tide dinoflagellate.

Inspection of the samples suggests a greater biomass of zooplankton (and phytoplankton), as well as larval fish abundance at the 50 m station compared to the 100 m station. The size distribution of zooplankton was consistently greatest at 354 um (the OPC's lowest resolution), and exponentially declined with size. The slope of the logged size distribution was often lower for the 100 m station, suggesting lower productivity, consistent with our observations of lower biomass. Synoptic sampling with the surface neuston net will permit verification of the OPC results. The biomass of zooplankton caught at the northern transects seemed markedly lower than at southern transects, consistent with the appearance of green phytoplankton adhering to the nets south of Diamond Head.

Larval yellowtail were abundant in the northern, low nutrient waters, and were surprisingly sparse in the southern productive water. Nevertheless we obtained sufficient numbers to compare their protein growth (RNA/DNA levels) and otolith growth rates in response to the upwelling, and to compare these rates with those found off Sydney (in November). These same larvae will be used to compare carbon and nitrogen stable isotope ratios, which may indicate the predominant nutrient sources. Larval anchovy, and an unidentified flatfish may also be used to compare condition.

*Noctiluca* was absent from samples collected at Urunga, Smoky Cape and Point Plomer, where the EAC flowed close to the coast. However, at the Diamond Head section, south of the EAC separation point, *Noctiluca* cells became conspicuous. There appeared to be a strong gradient in abundance across the shelf with greater abundances occurring at the inshore stations, particularly at the 25m and 50m isobaths. A significant finding from this study was that *Noctiluca* was virtually absent in the offshore EAC waters. Niskin casts at various depths determined the vertical distribution patterns of *Noctiluca*. At the 25m and 50m stations, *Noctiluca* was present throughout the entire water column, but greater densities were found at the surface. In contrast, there were a greater number of cells in the upper 50m of the water column at the 100m station. These cross shelf and vertical distribution patterns persisted further south off Cape Hawke, Port Stephens and Stockton Bight, although the density of *Noctiluca* appeared to gradually increase the further south we traveled. These findings were supported by underway samples which were collected once per hour since the

beginning of the cruise. The same pattern was also evident in the previous cruise in November. Night sampling, at the 50m and 100m isobath at each section, provided samples for determination of the nutritional and reproductive status of *Noctiluca*.

**Cruise Narrative**

All times given in this narrative are in Eastern Standard Time (EST = UTC+10), except where explicitly stated as UTC.

Wednesday 20 January Left Keppel-Cairnscross Shipyard at 1130, heading down the Brisbane River, out across Moreton Bay and south toward our study site.

Thursday 21 January Continued south, hugging the 200m contour to optimise our following East Australia Current. At 0830 we conducted a practice CTD cast (CTD 1) to 100m at 30.00 S, and problems were detected with the rosette. We then headed to the Urunga CTD section, arriving at 1550, and a further test (CTD2) was conducted. Further problems were identified, and Erik Madsen continued with repairs. The ship conducted an ADCP transect inshore from about 1650 to 1820. The ship remained at the inner end of the Urunga section until the CTD was finally operational. At the Urunga 50m station CTD3 was deployed, with water samples collected for *Noctiluca* distribution studies. A drop net cast to 40m was made with a 50cm diameter, 30um mesh. The surface neuston net (75cm square, 500um mesh with a 20cm, 100um mesh insert) was towed for 2 replicate tows, while the EZ net (500um mesh) was deployed over 3 depth bins, 40-30, 30-20 and 20-10m. A third neuston tow was conducted for sorting and freezing for later biological analyses. Ten to twenty pelagic juvenile flatfish were found, but few carangids or engraulids as seen the previous November cruise were evident. This sampling effort was repeated at the 100m station with CTD4, and again at the 50m station with CTD6. CTD5 was a dud. In all nets we found an abundance of late stage crab larvae and a few slipper lobster larvae. The fourth EZ net was used at the 50m station at 10-20m, and caught 20-30 carangids for biochemical analyses. The repeat 100m station was cancelled due to the onset of dawn, and we steamed inshore to begin the CTD transect

Friday 22 January At the completion of the biosampling, the Urunga CTD section was begun at 0540 with CTD7 in 30m, extending to CTD8 (50m), CTD9 (75m), CTD10 (100m), CTD11 (150m), CTD12 (200m), CTD 13 (300m), CTD14 (500m) and finishing with CTD 15 (1000m) at 1400. During the CTD transect, water was filtered from Niskin bottles through 100um mesh for the presence of *Noctiluca*, while a drop net was also deployed at 75m, 100m and 200m. The ship then tracked along the 100m contour, undertaking CTD16 at 1000m depth half way between the Urunga and Smoky Cape Sections, and then CTD17 at 1000m depth off the Smoky Cape section. At four stations (75m, 100m, 200m, 1000m) a drop net to 100m was conducted. At this stage it was dusk, and the ship headed for the 100m contour at 31 00S, to begin night biosampling. An ADCP transect was recorded on the way inshore from 1907 to 2025. Biosampling consisted of the same methods as were undertaken the previous evening. At 2000 we tracked to the 100m station, but sampled to the south of the transect at 31 00S due to topography and the presence of our moorings. CTD18 (100m depth), CTD19 (50m), CTD20 (100m) and CTD21 (50m) were undertaken and each was followed by an EZ net tow and neuston tows. On the last 2

stations the 4th EZ net was used to collect larvae for later biochemical analyses. The main specis frozen in liquid nitrogen were the larvae of a local carangid (*Trachurus*) and an unidentified late stage flatfish. Fewer fish and zooplankton were found at the 100m station compared to the 50m station.

Saturday 23 January *Franklin* was repositioned at the inner end of the Smoky Cape Section and the CTD section was begun with CTD22 (30m), CTD23 (50m), CTD24 (75m), CTD25 (100m), CTD26 (150m), CTD27 (200m), CTD28 (300m), CTD 29 (500m) and CTD30 (1000m). At the completion of the section the ship tracked directly for Smoky Cape, conducting an ADCP section between 1224 and 1330. We then headed southeast to find the 1000m contour midway between the Smoky and Point Plomer sections. CTD31 was taken here in 1000m depth, and the ship headed further south along the 1000m contour to the offshore end of the Point Plomer section when CTD32 was taken. The ship then proceeded inshore along the Point Plomer section to obtain a clean ADCP section, beginning about 1800 And ending about 2000. Biosampling (EZ net and neuston tows) then followed at CTD33 (50m), CTD34 (100m), CTD35 (50m) and CTD36 (100m). No *Noctiluca* were found on this transect.

Sunday 24 January The Point Plomer CTD section was begun with CTD37 (30m), followed by CTD38 (50m), CTD39 (75m), CTD40 (100m), CTD41 (150m), CTD42 (200m), CTD43 (300m), CTD44 (500m) and finally at CTD 45 (100m) where a bottle test was undertaken at 1000m depth. The ship then tracked directly to the offshore end of the Diamond Head section where CTD46 was taken in 500m. The ship then began an ADCP transect in toward shore, crossing the front, with temperatures dropping from 27.3 to 23.6 C in about 4nm from the 100m to the 50m contour. Concurrently surface ADCP currents changed from 3.6kn toward 188T, to 0.1kn toward 045T. The underway Wetlab fluorometer was checked , revealing little apparent fouling of the sensor, although "zero" with filtered seawater still –0.12 umol/litre.

Just before 2100 we began the 50m biosampling station, where the fluorescence was very high (2.3 umol/l, and the zooplankton biomass seemed to have greater concentrations in all samples. In particular the top EZ net was coated with green slime after the tow. We subsequently completed the 100m, 50m, and 100m stations with CTD, EZ net and neuston nets taken at CTD48 (100m), CTD49 (50m) and CTD50 (100m).

Monday 25 January The Diamond Head section was begun at 0600 with a more detailed CTD section than usual to delineate the frontal structure. Stations undertaken were CTD51 (25m), CTD52 (50m), CTD53 (65m), CTD54 (75m), CTD55 (85m), CTD56 (100m), CTD57 (120m), CTD58 (150m) and CTD9 (20m). *Franklin* then returned to the 150m contour, and the first Diamond Head mooring was released. On retrieval at1450 it was found that the mooring had failed at the lower end of the FSI current meter spindle, losing the current meter and the top floats. The remainder of the mooring was in good shape.

The ship then repositioned to the 95m mooring, the 50m mooring and the 30m mooring. All releases responded to all call signals, but none to selective calling. Due

to lack of light, it was decided to continue with biosampling and to return to the moorings at day break.

*Franklin* then tracked south to the 50m contour at latitude 31 10 S, where 4 successive CTD, EZ and neuston stations were undertaken offshore Cape Hawke, well into the predicted upwelling region. We conducted EZ net tows and surface neuston tows at the 100m, 50m, 100m, and 50m sites, the latter being conducted at sunrise. Only a few *Trachurus* were caught here, despite an abundance of zooplankton.

Tuesday 26 January On return north to the Diamond Head section, moorings were released at 95m depth (time 0920), 50m depth (time 1010) and 30m depth (time1045). All came up intact, but it was found that in each case the ship had to have the propeller declutched to reduce ambient noise in order that the acoustic transponder system would function properly. On completion of the Diamond Head mooring retrieval the ship headed north toward Smoky Cape around 1700, and the mid depth (100m) mooring was recovered around 1800. Mooring recovery was suspended for the night

A light trap was deployed off Smoky Cape, before proceeding with EZ and surface net tows at the 50m and 100m stations. We then deployed the MiniBat which malfunctioned, and so undertook an ADCP transect. At 0130 we conducted further EZ surface net tows at the 100m and 50m stations. At dawn we attempted to retrieve the light trap, but it could not be found.

Wednesday 27 January The ship repositioned at the 150m mooring location off Smoky Cape and the mooring released. It came aboard at 0800 without the top half, failure in the mooring occurring in the FSI current meter spindle rod, in exactly the same position as the failure in the Diamond Head mooring. The latter half of this mooring was recovered by a fisherman at Bateman's Bay in December!

The ship then headed inshore and retrieved the last remaining mooring at 0945 in 50m. Thus all seven moorings deployed were retrieved, with the top sections of the two 150m depth moorings separating because of mechanical failure of the FSI spindle. A CTD section was then begun at Smoky Cape, beginning with CTD61 (25m), and ending with CTD70 (300m). Unfortunately the drop net rope snapped and the net was lost at CTD70. At 1605 an ADCP transect was begun from the Smoky Cape 300m station to Point Korogoro (31 03S). The ship then travelled southward along the coastline between 50 and 60m depth, to the Crowdy Head section (31 50S). Temperatures dropped from over 27C to 25C off Diamond Head, and we proceeded south to Crowdy Head where the temperature was 22.8C. The MiniBat was repaired (CPU chip seating needed cleaning) and deployed at 2000 between 50 and 80m depth across the front. We then conducted a 50m CTD/EZ station (CTD71), a 100m station (CTD72) and a 50m station (CTD73), finishing at 0445. Fish larvae were surprisingly sparse in these samples, but there was an abundance of zooplankton.

Thursday 28 January At dawn a CTD section was begun at Crowdy Head, beginning with CTD74 (30m), and comprising CTD75 (50m), CTD76 (65m), CTD77 (75m), CTD78 (85m), CTD79 (100m) and CTD80 (120m). The ship then returned along 31 40S toward the coast, conducting an ADCP transect *Franklin* then headed south along the 50m contour to 32S near the town of Old Bar, and undertook a short

CTD section with CTD81 (50m), CTD82 (75m), CTD83 (100m) and CTD84 (150m). A strong front was again observed with large temperature gradients and high fluorescence concentrations. Some engraulid or clupeid larvae were found, but no carangids. *Noctiluca* were abundant in the nearshore waters.

We then steamed to the 100 m station off Cape Hawke again, but winds gusting to 30 knots (easterly) prevented deploying the EZ net, and we completed a CTD and neuston tow only at the 100 m station. *Noctiluca* were again abundant in nearshore waters (in contrast to the northern waters). Some anchovy or herring larvae were found, but no yellowtail larvae.

Friday 29 January At latitude 32 10S (directly offshore from Forster – Tuncurry, a CTD section was undertaken, comprising CTD91 (30m), CTD92 (50m), CTD93 (65m), CTD94 (75m), CTD95 (85m), CTD96 (100m). At the completion of the 75 m CTD cast we encountered an algal bloom of *Trichodesmium* (a buoyant blue-green alga) at 32 09S, 152.40E, approximately 0900. The ship's course was altered to take a sample. Surface slicks of *Trichodesmium* were again encountered at the 500 m station, well within the EAC at approximately 1550.

The optical plankton counter was re-mounted on the miniBAT to improve its hydrodynamics on the upcast, and was deployed from 16:30-18:00 in EAC (27C) water. After initial problems, the instrument towed well, especially at 4 knots but we did not have time to enter the frontal region. At 1900 we steamed to the 100 and 50 m stations off Broughton Island (along the 32 33S latitude), arriving at around 2030. The moon was nearly full (setting at 0300) and the night was very calm. We completed the 100 m, 50 m, 100 m, 50 m, (and repeat 50 m station) by 0430. The CTD fluoresence peaks at 50 m were not as dramatic as at the 100 m station, the deeper nets at the 50 m station came up coated with green slime. Many *Trachurus* larvae were found in the surface nets at 50 m, which were frozen in liquid nitrogen for biochemical analysis or were preserved in alcohol for otolith analysis. On the final surface net tow, we collected a large quantity of purple jellyfish, which had attracted a school of larger *Trachurus* (10-25 mm).

Saturday 30 January A long CTD section was undertaken at 32 33S, offshore from Broughton Island, comprising CTD107 (30m), CTd108 (50m), CTD109 (75m), CTD110 (85m), CTD111 (100m), CTD112 (110m), CTD113 (120m), CTD114 (130m), CTD115 (150m), CTD116 (200m), CTD117 (300m), CTD118 (500m) and CTD119 (1000m).

The CTD transect off Broughton Is. was completed by 1700, and we began a 3 hour steam into the Stockton Bight area to sample along the 33 50S latitude (100 m, 50 m, 100 m and 50 m stations with the CTD and EZ/surface nets, finishing at dawn). This transect (32 53S) was a few miles south of Sunday's CTD transect off Pt. Stephens, because the bathymetry was not as steep. Some of the highest fluorescence readings of the trip were recorded around 15 m depth, and there appeared to be a corresponding increase in zooplankton biomass. Few *Trachurus* were caught here, but many engraulid larvae were obtained.

Sunday 31 January Moving 5nm farther north, the final CTD section was begun off Port Stephens, with CTD124 (50m), CTD125 (75m), CTD126 (100m),

CTD127 (120m), CTD128 (150m), CTD129 (200m) and CTD130 (300m). Again the EAC front was observed on the surface at CTD128, with temperatures increasing from 23 to 27C as we tracked offshore.

After completing the CTD transect at Point Stephens, we steamed back north, pausing off Crowdy Head before midnight for a 90 min. miniBAT tow at 4 knots from the 50 to 80 m isobath. The tow commenced in cooler (SST 23.9C), high fluoresence water, and completed in EAC water (26C), where there was still a 2-3 kn current (Figure 3). At 1600, the ship headed north to North Solitary Island.

Monday 1 February At 1200 the ship arrived at North Solitary for 24 hours work studying the wake in the lee of the island. No current was evident, so a CTD section was begun, with CTD stations 131 to 140. The EAC was much further offshore than on the original southward leg at the beginning of the cruise. The ship then headed further north arriving at the Clarence River mouth at Yamba at 0600.

Tuesday 2 February Arriving at the mouth of the Clarence River at 0600, a thermosalinograph survey was undertaken, 3 nm offshore and 4nm north and south of the mouth. Lowest observed salinities were 32. A CTD section was run at high tide (0931, 1.8m) with CTD141 to CTD149 at 25m depth, 1 nm offshore from the coast, a Minibat survey was run, a second T/S survey was undertaken and 5 last CTDs were done (CTD150 to 154) shortly after low tide (1559, 0.3m).

The miniBAT was towed at 4 knots from the southern most station off Angourie Pt. to one mile south of Woody Head (6 nm). Over 60 "to-yos" were completed, showing that the lower salinity plume had been advected further to the north from its position during the morning. A greater biomass of zooplankton occurred at the northern and southern extremity of the transect, but there was little apparent relationship with the salinity minimum. At 1800 we departed the Yamba area for Caloundra. At 2300 the other CTD unit was deployed and tested at a 1000m station

Wednesday 3 February This day was spent in transit to Caloundra; a fine day with 20kn southeast winds.

Thursday 4 February At 0400 the Pilot was taken aboard at Caloundra, and after a pleasant trip across Moreton Bay and up the Brisbane River, we tied up at 0900.

**Personnel**

Scientists

| | | |
|---|---|---|
| Professor Jason Middleton | University of New South Wales | Chief Scientist |
| Dr Iain Suthers | University of New South Wales | Co-investigator |
| Jocelyn Delacruz | University of New South Wales | |
| Greg Nippard | University of New South Wales | |
| Richard Piola | University of New South Wales | |
| Moninya Roughan | University of New South Wales | |
| Augy Syahailatua | University of New South Wales | |
| Ann-Marie Wong | University of New South Wales | |
| Bob Beattie | CMR | Cruise Manager / Computing |
| Erik Madsen | CMR | Electronics |
| Mark Rayner | CMR | Hydrochemistry |
| Mark Underwood | CMR | Electronics |

Crew

| | |
|---|---|
| Neil Cheshire | Master |
| Arther Staron | First mate |
| Ian Moodie | Second Mate |
| Gordon Gore | Chief Engineer |
| Dave Jonker | First Engineer |
| Andrew Mclagan | Electrical Engineer |
| Phil French | Greaser |
| Bill Hughes | Bosun |
| Travis Broadhurst | AB |
| Peter Rischin | AB |
| Simon Smeaton | AB |
| Gary Hall | Chief Cook |
| Walter Edwards | First Cook |
| Ron Culliney | Steward |

**Acknowledgments**

We would like to express our gratitude to the ships company of the Research Vessel *Franklin*, for again providing us with enthusiastic and capable support, often over long hours and in marginal conditions. It was a pleasure to again sail with former shipmates Bob Beattie, Erik Madsen and Mark Rayner, and with the new CSIRO electronics engineer Mark Underwood, who all provided technical support of excellent quality and with cheerful good humour.

Greg and Richard again provided excellent scientific support, with Greg achieving a 7 from 7 record in mooring retrievals. Augy was his usual cool self, while Ann-Marie deserves thanks for enduring a cruise as volunteer. Jocelyn, Augy and Moninya were the powerhouse team, doing the majority of CTD's in their early morning watch, and working like trojans in support of their PhD data.

Thanks to all for a field project well accomplished.

## Appendix 1. CTD Log

| | | UNSW CTD Log FR01/99 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Cast | Transect Name | Depth | Date | Time (UTC) | | Latitude | Longitude | |
| # | | (m) | (UTC) | start | stop | | | |
| 1 | Test | | | | | | | |
| 2 | Urunga | 500 | 21 1 99 | 5:54 | 6:20 | 30 34.95 | 153 22.83 | |
| 3 | Urunga (night) | 50 | 21 1 99 | 11:25 | 11:43 | 30 31.04 | 153 10.06 | |
| 4 | Urunga (night) | 100 | 21 1 99 | 13:50 | 14:12 | 30 32.51 | 153 15.46 | |
| 5 | Urunga (night) | 50 | 21 1 99 | | | | | |
| 6 | Urunga (night) | 50 | 21 1 99 | 16:53 | 17:12 | 30 30.71 | 153 09.09 | |
| 7 | Urunga | 30 | 21 1 99 | 19:41 | 19:54 | 30 30.37 | 153 04.17 | |
| 8 | Urunga | 50 | 21 1 99 | 20:28 | 20:42 | 30 31.40 | 153 09.18 | |
| 9 | Urunga | 75 | 21 1 99 | 21:10 | 21:31 | 30 32.46 | 153 13.29 | |
| 10 | Urunga | 100 | 21 1 99 | 22:10 | 22:38 | 30 32.52 | 153 15.56 | |
| 11 | Urunga | 150 | 21 1 99 | 23:38 | 0:01 | 30 33.70 | 153 19.42 | |
| 12 | Urunga | 200 | 22 1 99 | 0:29 | 0:52 | 30 33.98 | 153 20.33 | |
| 13 | Urunga | 300 | 22 1 99 | 1:39 | 2:09 | 30 34.72 | 153 22.19 | |
| 14 | Urunga | 500 | 22 1 99 | 22:52 | 3:03 | 30 34.47 | 153 23.55 | |
| 15 | Urunga | 1000 | 22 1 99 | 3:57 | 4:44 | 30 35.20 | 153 24.95 | |
| 16 | Urunga N/S | 1000 | 22 1 99 | 6:08 | 6:55 | 30 46.33 | 153 21.36 | |
| 17 | Urunga N/S | 1000 | 22 1 99 | 8:16 | 9:03 | 30 59.06 | 153 22.22 | |
| 18 | Smoky Cape (n) | 100 | 22 1 99 | 10:25 | 10:30 | 30 59.97 | 153 09.90 | |
| 19 | Smoky Cape (n) | 50 | 22 1 99 | 12:21 | 12:48 | 31 00.19 | 153 05.68 | |
| 20 | Smoky Cape (n) | 100 | 22 1 99 | 14:16 | 14:20 | 31 00.18 | 153 09.80 | |
| 21 | Smoky Cape (n) | 50 | 22 1 99 | 16:25 | 16:42 | 30 59.96 | 153 05.90 | |
| 22 | Smoky Cape | 25 | 22 1 99 | 19:06 | 19:16 | 30 55.20 | 153 06.19 | |
| 23 | Smoky Cape | 50 | 22 1 99 | 19:26 | 19:40 | 30 55.63 | 153 06.75 | |
| 24 | Smoky Cape | 75 | 22 1 99 | 19:59 | 20:14 | 30 56.39 | 153 07.89 | |
| 25 | Smoky Cape | 100 | 22 1 99 | 20:39 | 20:57 | 30 56.69 | 153 09.52 | |
| 26 | Smoky Cape | 150 | 22 1 99 | 21:36 | 21:54 | 30 57.62 | 153 14.21 | |
| 27 | Smoky Cape | 200 | 22 1 99 | 22:21 | 22:45 | 30 57.27 | 153 15.58 | |
| 28 | Smoky Cape | 300 | 22 1 99 | 23:11 | 23:38 | 30 57.60 | 153 17.01 | |
| 29 | Smoky Cape | 500 | 23 1 99 | 0:15 | 0:43 | 30 58.52 | 153 19.69 | |
| 30 | Smoky Cape | 1000 | 23 1 99 | 1:21 | 2:03 | 30 58.91 | 153 22.35 | |
| 31 | Smoky Cape N/S | 1000 | 23 1 99 | 5:54 | 6:42 | 31 11.372 | 153 23.490 | |
| 32 | Smoky Cape N/S | 1000 | 23 1 99 | 7:48 | 8:28 | 31 22.74 | 153 20.15 | |
| 33 | Pt Plomer (n) | 50 | 23 1 99 | 10:35 | 10:50 | 31 19.58 | 153 01.37 | |
| 34 | Pt Plomer (n) | 100 | 23 1 99 | 12:25 | 12:44 | 31 20.10 | 153 05.79 | |
| 35 | Pt Plomer (n) | 50 | 23 1 99 | 14:17 | 14:35 | 31 19.73 | 153 01.45 | |
| 36 | Pt Plomer (n) | 100 | 23 1 99 | 16:38 | 16:59 | 31 20.19 | 153 05.68 | |
| 37 | Pt Plomer | 25 | 23 1 99 | 19:07 | 19:18 | 31 19.30 | 152 59.64 | |
| 38 | Pt Plomer | 50 | 23 1 99 | 19:45 | 19:57 | 31 19.60 | 153 03.88 | |
| 39 | Pt Plomer | 75 | 23 1 99 | 20:26 | 20:43 | 31 20.07 | 153 03.88 | |
| 40 | Pt Plomer | 100 | 23 1 99 | 21:26 | 21:46 | 31 20.13 | 153 05.67 | |
| 41 | Pt Plomer | 150 | 23 1 99 | 22:42 | 23:04 | 31 21.25 | 153 10.13 | |
| 42 | Pt Plomer | 200 | 23 1 99 | 23:38 | 0:03 | 31 21.24 | 153 11.54 | |
| 43 | Pt Plomer | 300 | 24 1 99 | 0:54 | 1:21 | 31 22.04 | 153 14.86 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 44 | Pt Plomer | 500 | 24 1 99 | 2:20 | 2:47 | 31 22.11 | 153 17.57 | |
| 45 | Pt Plomer | 1000 | 24 1 99 | 3:35 | 4:17 | 31 22.51 | 153 20.49 | |
| 46 | Diamond Head | 500 | 24 1 99 | 6:47 | 7:13 | 31 47.59 | 153 14.04 | |
| 47 | Diamond Head n | 50 | 24 1 99 | 10:27 | 10:46 | 31 47.21 | 152 57.71 | |
| 48 | Diamond Head n | 100 | 24 1 99 | 12:27 | 12:47 | 31 48.23 | 152 59.21 | |
| 49 | Diamond Head n | 50 | 24 1 99 | 14:27 | 14:44 | 31 47.07 | 152 51.76 | |
| 50 | Diamond Head n | 100 | 24 1 99 | 17:07 | 17:28 | 31 49.94 | 152 58.94 | |
| 51 | Diamond Head | 25 | 24 1 99 | 20:03 | 20:16 | 31 43.63 | 152 49.31 | |
| 52 | Diamond Head | 50 | 24 1 99 | 20:41 | 20:56 | 31 44.43 | 152 52.96 | |
| 53 | Diamond Head | 65 | 24 1 99 | 21:10 | 21:28 | 31 44.54 | 152 54.46 | |
| 54 | Diamond Head | 75 | 24 1 99 | 21:38 | 21:57 | 31 44.86 | 152 55.01 | |
| 55 | Diamond Head | 85 | 24 1 99 | 22:21 | 22:45 | 31 45.21 | 152 56.57 | |
| 56 | Diamond Head | 100 | 24 1 99 | 23:23 | 23:50 | 31 46.77 | 152 59.90 | |
| 57 | Diamond Head | 120 | 25 1 99 | 0:56 | 1:20 | 31 47.93 | 153 04.17 | |
| 58 | Diamond Head | 150 | 25 1 99 | 1:42 | 2:05 | 31 49.41 | 153 04.50 | |
| 59 | Diamond Head | 200 | 25 1 99 | 2:33 | 2:58 | 31 49.87 | 153 06.36 | |
| 60 | Cape Hawke (n) | 50 | 25 1 99 | 11:11 | 11:26 | 31 10.06 | 152 36.88 | |
| 61 | Cape Hawke (n) | 100 | 25 1 99 | 13:12 | 13:30 | 32 10.10 | 152 46.77 | |
| 62 | Cape Hawke (n) | 50 | 25 1 99 | 15:53 | 16:09 | 32 10.19 | 152 36.57 | |
| 63 | Cape Hawke (n) | 100 | 25 1 99 | 18:26 | 18:50 | 32 09.75 | 152 46.44 | |
| 64 | Smoky Cape | 25 | 27 1 99 | 0:50 | 1:03 | 30 55.16 | 153 06.13 | |
| 65 | Smoky Cape | 50 | 27 1 99 | 1:17 | | 30 55.34 | 153 06.73 | |
| 66 | Smoky Cape | 75 | 27 1 99 | 1:47 | 2:05 | 30 55.59 | 153 08.09 | |
| 67 | Smoky Cape | 100 | 27 1 99 | 2:51 | 3:09 | 30 56.15 | 153 10.05 | |
| 68 | Smoky Cape | 150 | 27 1 99 | 3:51 | 4:09 | 30 56.66 | 153 14.20 | |
| 69 | Smoky Cape | 200 | 27 1 99 | 4:37 | 4:55 | 30 56.84 | 153 15.52 | |
| 70 | Smoky Cape | 300 | 27 1 99 | 5:23 | 5:43 | 30 57.12 | 153 16.97 | |
| 71 | Crowdy Head n | 50 | 27 1 99 | 13:05 | 13:25 | 30 50.96 | 152 48.37 | |
| 72 | Crowdy Head n | 100 | 27 1 99 | 15:24 | 15:42 | 31 52.48 | 152 57.06 | |
| 73 | Crowdy Head n | 50 | 27 1 99 | 17:55 | 18:11 | 31 51.05 | 152 48.28 | |
| 74 | Crowdy Head | 25 | 27 1 99 | 19:42 | 19:53 | 31 50.92 | 152 46.46 | |
| 75 | Crowdy Head | 50 | 27 1 99 | 20:10 | 20:29 | 31 51.03 | 152 48.20 | |
| 76 | Crowdy Head | 65 | 27 1 99 | 20:44 | 20:54 | 31 51.30 | 152 49.42 | |
| 77 | Crowdy Head | 75 | 27 1 99 | 21:08 | 21:11 | 31 51.47 | 152 50.31 | |
| 78 | Crowdy Head | 85 | 27 1 99 | 21:51 | 22:11 | 31 58.83 | 152 51.95 | |
| 79 | Crowdy Head | 100 | 27 1 99 | 22:55 | 23:21 | 31 52.57 | 152 57.20 | |
| 80 | Crowdy Head | 150 | 28 1 99 | 0:31 | 0:50 | 31 53.38 | 153 03.84 | |
| 81 | Sth Crowdy | 50 | 28 1 99 | 3:31 | 3:49 | 31 00.08 | 152 42.71 | |
| 82 | Sth Crowdy | 75 | 28 1 99 | 4:18 | 4:36 | 31 59.98 | 152 45.02 | |
| 83 | Sth Crowdy | 100 | 28 1 99 | 5:37 | 5:55 | 32 00.12 | 152 20.29 | |
| 84 | Sth Crowdy | 140 | 28 1 99 | 7:39 | 8:09 | 32 00.05 | 153 02.32 | |
| 85 | Cape Hawke (n) | 100 | 28 1 99 | 9:39 | 9:57 | 32 10.11 | 152 46.64 | |
| 86 | Cape Hawke (n) | 50 | 28 1 99 | 11:33 | 11:49 | 32 07.84 | 152 38.05 | |
| 87 | Cape Hawke (n) | 100 | 28 1 99 | 14:13 | 14:24 | 32 10.18 | 152 46.26 | |
| 88 | Cape Hawke (n) | 50 | 28 1 99 | 15:50 | 16:08 | 32 09.97 | 152 36.76 | |
| 89 | Cape Hawke (n) | 100 | 28 1 99 | 17:52 | 18:16 | 32 10.05 | 152 46.24 | |
| 90 | Cape Hawke (n) | 50 | 28 1 99 | 19:46 | 20:02 | 32 07.07 | 152 38.00 | |
| 91 | Cape Hawke | 25 | 28 1 99 | 21:01 | 21:12 | 32 09.98 | 152 32.91 | |
| 92 | Cape Hawke | 50 | 28 1 99 | 21:35 | 21:50 | 32 09.99 | 152 36.45 | |
| 93 | Cape Hawke | 75 | 28 1 99 | 22:21 | 22:38 | 32 09.79 | 152 40.48 | |
| 94 | Cape Hawke | 85 | 28 1 99 | 23:18 | 23:37 | 32 10.06 | 152 42.60 | |
| 95 | Cape Hawke | 100 | 29 1 99 | 0:05 | 0:24 | 32 10.19 | 152 46.63 | |
| 96 | Cape Hawke | 110 | 29 1 99 | 0:41 | 0:55 | 32 10.26 | 152 48.15 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 97 | Cape Hawke | 120 | 29 1 99 | 1:35 | 1:52 | 32 10.18 | 152 53.31 | |
| 98 | Cape Hawke | 150 | 29 1 99 | 2:46 | 3:02 | 32 10.11 | 152 58.84 | |
| 99 | Cape Hawke | 200 | 29 1 99 | 3:32 | 3:52 | 32 10.12 | 153 00.47 | |
| 100 | Cape Hawke | 300 | 29 1 99 | 4:21 | 4:45 | 32 09.94 | 153 02.44 | |
| 101 | Cape Hawke | 500 | 29 1 99 | 5:21 | | 32 10.11 | 153 04.11 | |
| 102 | Broughton Is. | 100 | 29 1 99 | 9:56 | 10:15 | 32 33.14 | 152 32.97 | |
| 103 | Broughton Is. | 50 | 29 1 99 | 11:45 | 12:02 | 32 32.93 | 152 26.37 | |
| 104 | Broughton Is. | 100 | 29 1 99 | 13:16 | 13:33 | 32 33.18 | 152 32.73 | |
| 105 | Broughton Is. | 50 | 29 1 99 | 15:23 | 15:39 | 32 32.99 | 152 23.60 | |
| 106 | Broughton Is. | 50 | 29 1 99 | 17:21 | 17:42 | 32 32.88 | 152 26.47 | |
| 107 | Broughton Is. | 30 | 29 1 99 | 19:40 | 19:51 | 32 32.99 | 152 21.62 | |
| 108 | Broughton Is. | 50 | 29 1 99 | 20:21 | 20:35 | 32 33.01 | 152 26.01 | |
| 109 | Broughton Is. | 75 | 29 1 99 | 20:55 | 21:12 | 32 33.04 | 152 28.45 | |
| 110 | Broughton Is. | 85 | 29 1 99 | 21:24 | 21:41 | 32 33.12 | 152 29.32 | |
| 111 | Broughton Is. | 100 | 29 1 99 | 22:04 | 22:22 | 32 33.10 | 152 32.77 | |
| 112 | Broughton Is. | 110 | 29 1 99 | 22:32 | 22:51 | 32 33.15 | 152 33.32 | |
| 113 | Broughton Is. | 120 | 29 1 99 | 23:44 | 0:07 | 32 33.50 | 152 41.16 | |
| 114 | Broughton Is. | 130 | 30 1 99 | 0:52 | 1:03 | 32 33.17 | 152 45.74 | |
| 115 | Broughton Is. | 150 | 30 1 99 | 1:36 | 1:55 | 32 33.19 | 152 49.23 | |
| 116 | Broughton Is. | 200 | 30 1 99 | 2:30 | 2:49 | 32 33.19 | 152 50.39 | |
| 117 | Broughton Is. | 300 | 30 1 99 | 3:20 | 3:44 | 32 33.08 | 152 51.75 | |
| 118 | Broughton Is. | 500 | 30 1 99 | 4:24 | 4:56 | 32 33.06 | 152 53.73 | |
| 119 | Broughton Is. | 1000 | 30 1 99 | 5:47 | 6:32 | 32 33.11 | 152 56.78 | |
| 120 | Stockton Bight N | 100 | 30 1 99 | 10:29 | 10:47 | 32 49.91 | 152 11.54 | |
| 121 | Stockton Bight N | 50 | 30 1 99 | 12:30 | 12:45 | 32 49.95 | 152 05.17 | |
| 122 | Stockton Bight N | 100 | 30 1 99 | 14:19 | 14:37 | 32 49.99 | 152 11.52 | |
| 123 | Stockton Bight N | 50 | 30 1 99 | 16:57 | 17:16 | 32 49.87 | 152 05.19 | |
| 124 | Port Stephens | 50 | 30 1 99 | 19:28 | 19:42 | 32 44.99 | 152 14.09 | |
| 125 | Port Stephens | 75 | 30 1 99 | 20:00 | 20:14 | 32 44.72 | 152 14.51 | |
| 126 | Port Stephens | 100 | 30 1 99 | 20:44 | 21:04 | 32 44.99 | 152 16.85 | |
| 127 | Port Stephens | 120 | 30 1 99 | 21:58 | 22:15 | 32 45.09 | 152 24.51 | |
| 128 | Port Stephens | 140 | 30 1 99 | 23:03 | 23:23 | 32 45.82 | 152 31.27 | |
| 129 | Port Stephens | 150 | 31 1 99 | 1:01 | 1:18 | 32 45.06 | 152 40.75 | |
| 130 | Port Stephens | 200 | 31 1 99 | 1:48 | 2:07 | 32 45.38 | 152 42.53 | |
| 131 | Nth Solitary | 50 | 01 2 99 | 3:28 | 3:34 | 29 57.95 | 153 23.26 | |
| 132 | Nth Solitary | 75 | 01 2 99 | 4:20 | 4:26 | 29 57.93 | 153 26.39 | |
| 133 | Nth Solitary | 90 | 01 2 99 | 5:22 | 5:30 | 29 57.94 | 153 30.47 | |
| 134 | Nth Solitary | 100 | 01 2 99 | 6:52 | 6:58 | 29 57.97 | 153 33.77 | |
| 135 | Nth Solitary | 200 | 01 2 99 | 7:47 | 7:57 | 29 57.92 | 153 35.86 | |
| 136 | Nth Solitary | 300 | 01 2 99 | 8:23 | 8:36 | 29 58.07 | 153 37.83 | |
| 137 | Nth Solitary | 500 | 01 2 99 | 8:58 | 9:19 | 29 58.14 | 153 39.75 | |
| 138 | Nth Solitary | 1000 | 01 2 99 | 9:41 | 10:27 | 29 58.00 | 153 41.54 | |
| 139 | Nth Solitary | 1500 | 01 2 99 | 11:29 | 12:49 | 29 58.18 | 153 47.64 | |
| 140 | Nth Solitary | 2000 | 01 2 99 | 13:11 | 13:54 | 30 00.40 | 153 50.04 | |
| 141 | Clarence River | 25 | 01 2 99 | 23:40 | 23:43 | 29 21.94 | 153 23.44 | |
| 142 | dud | 25 | 01 2 99 | | | | | |
| 143 | Clarence River | 25 | 02 2 99 | 0:07 | 0:11 | 29 23.00 | 153 23.36 | |
| 144 | Clarence River | 25 | 02 2 99 | 0:25 | 0:30 | 29 24.02 | 153 23.46 | |
| 145 | Clarence River | 25 | 02 2 99 | 0:45 | 0:50 | 29 24.99 | 153 23.46 | |
| 146 | Clarence River | 25 | 02 2 99 | 1:04 | 1:09 | 29 25.98 | 153 23.48 | |
| 147 | Clarence River | 25 | 02 2 99 | 1:25 | 1:30 | 29 27.02 | 153 23.42 | |
| 148 | Clarence River | 25 | 02 2 99 | 1:44 | 1:48 | 29 27.98 | 153 23.44 | |
| 149 | Clarence River | 25 | 02 2 99 | 2:02 | 2:06 | 29 29.02 | 153 23.48 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 150 | Clarence River | 25 | 02 2 99 | 6:05 | 6:09 | 29 21.92 | 153 24.42 | |
| 151 | Clarence River | 25 | 02 2 99 | 6:29 | 6:30 | 29 22.97 | 153 22.97 | |
| 152 | Clarence River | 25 | 02 2 99 | 6:53 | 6:53 | 29 23.97 | 153 23.42 | |
| 153 | Clarence River | 25 | 02 2 99 | 7:08 | 7:09 | 29 24.99 | 153 23.46 | |
| 154 | Clarence River | 25 | 02 2 99 | 7:26 | 7:29 | 29 26.00 | 153 23.55 | |
| | | | | | | | | |

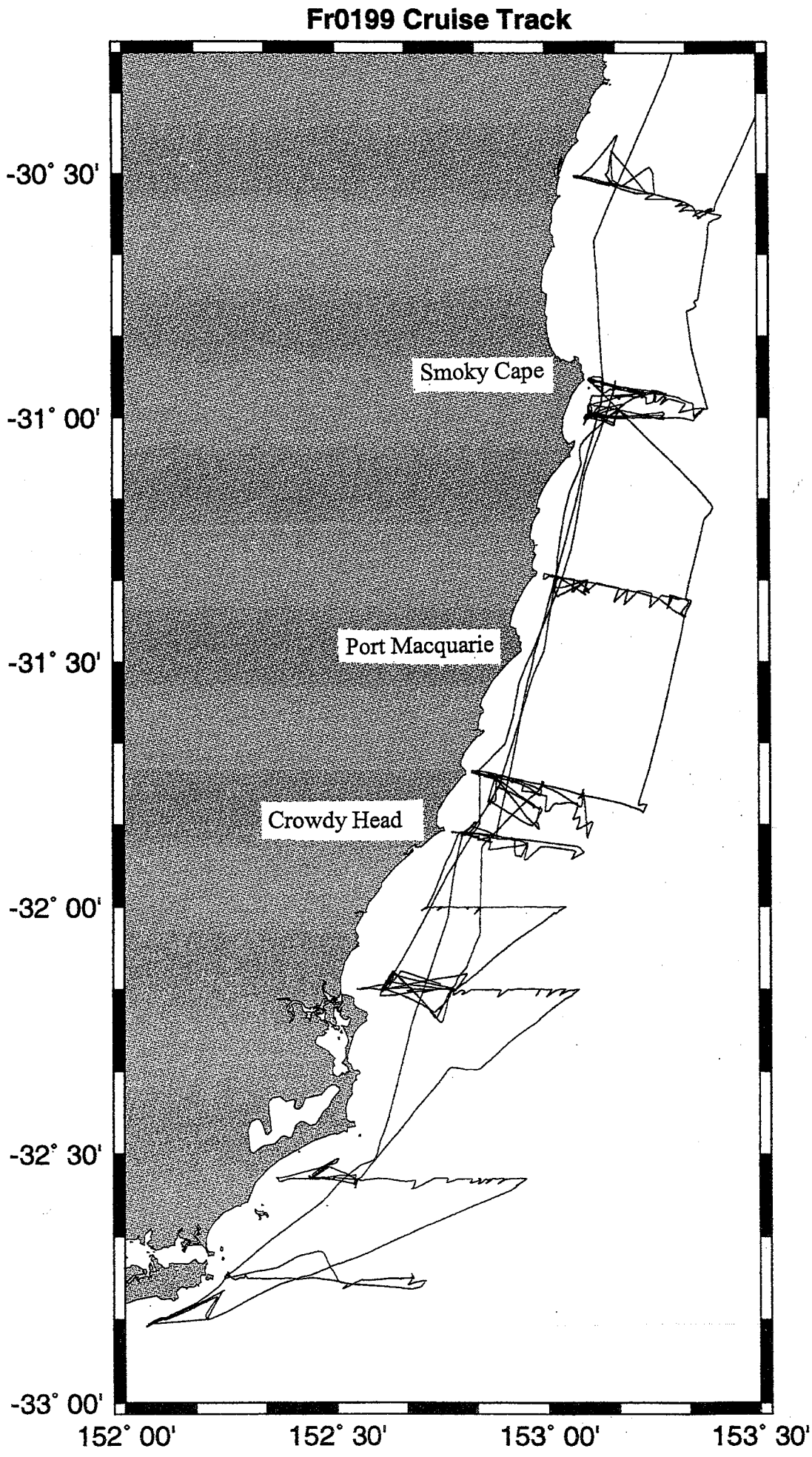
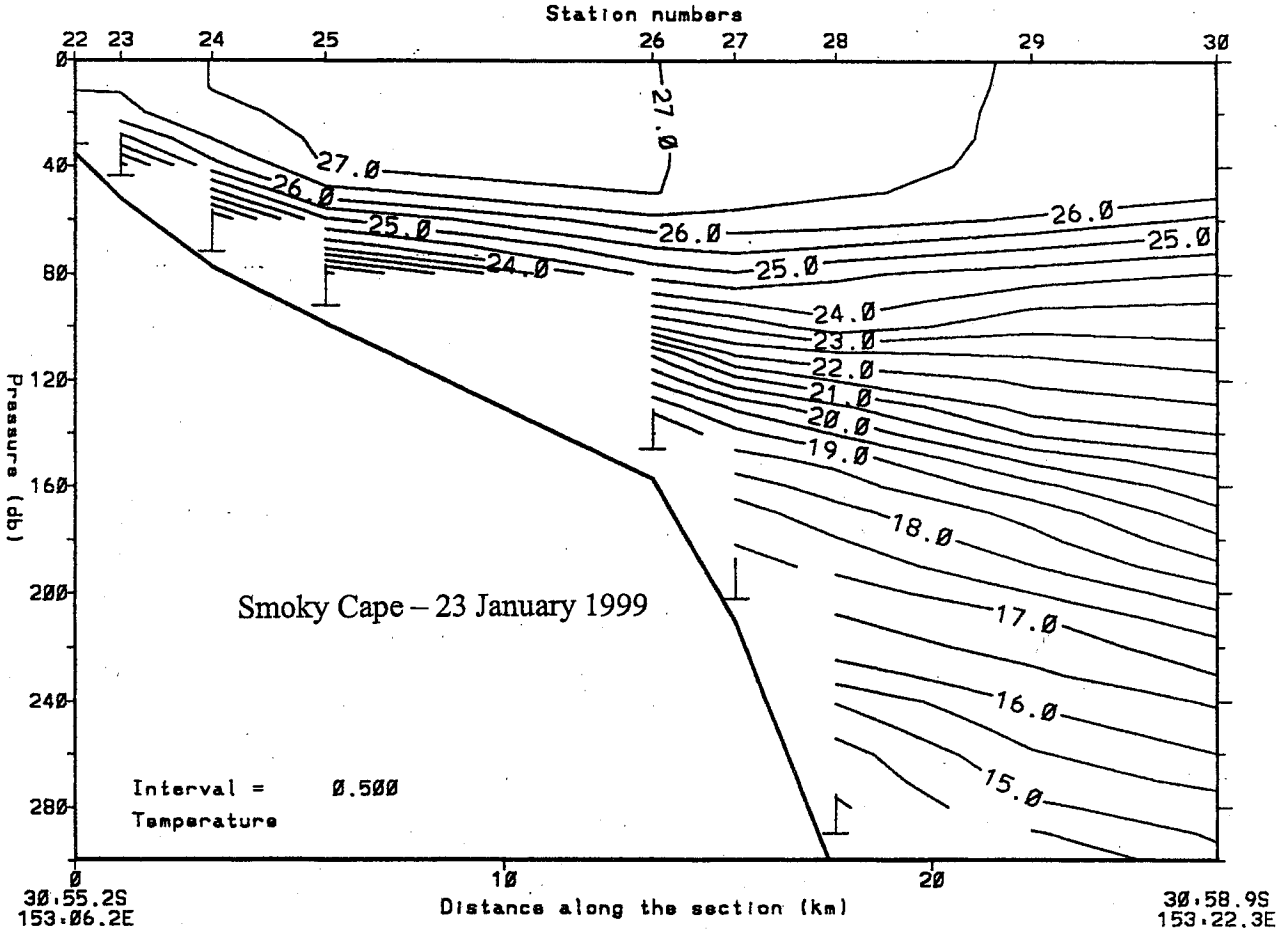



Figure 1 Cruise Track for Voyage FR 1/99



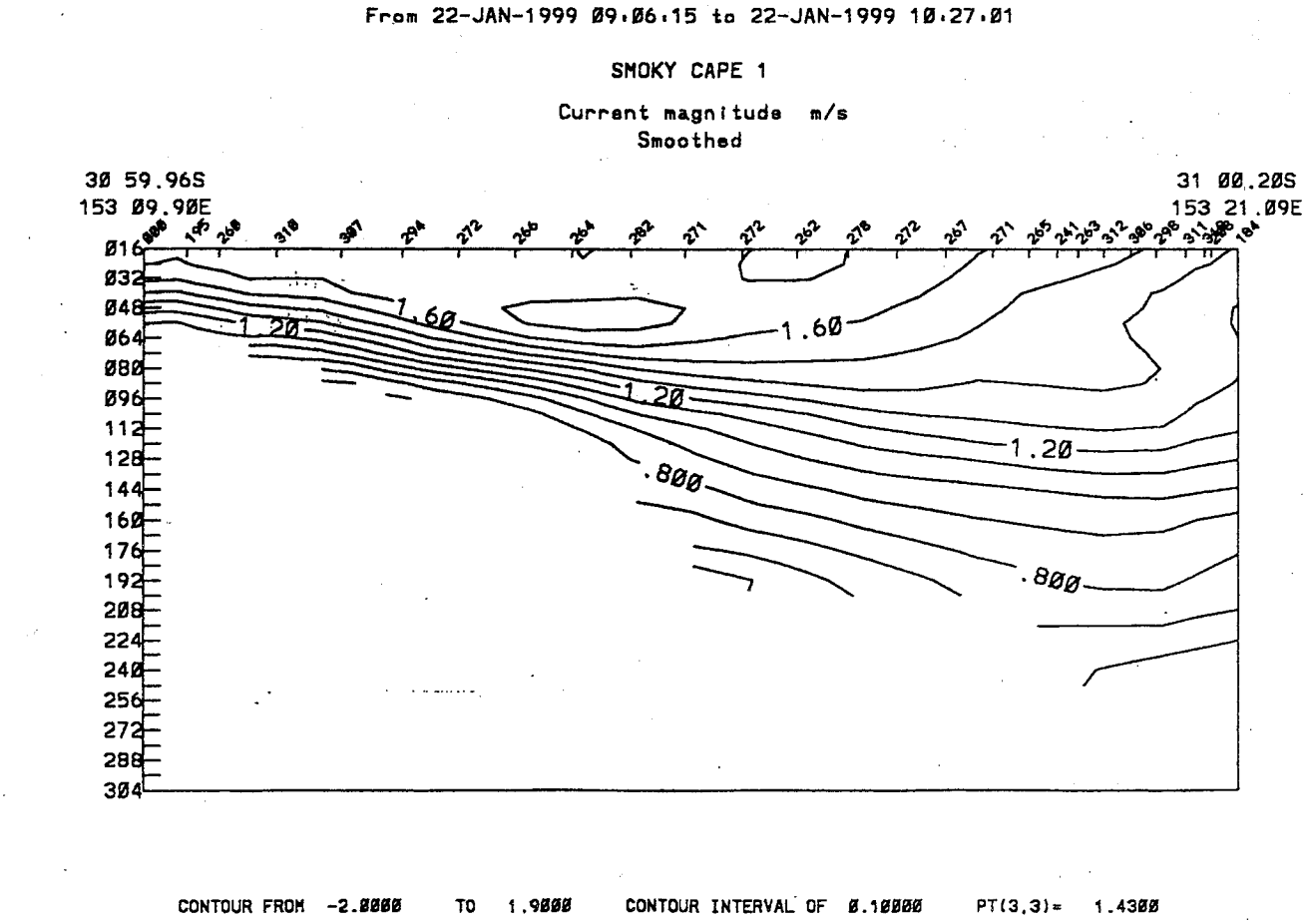
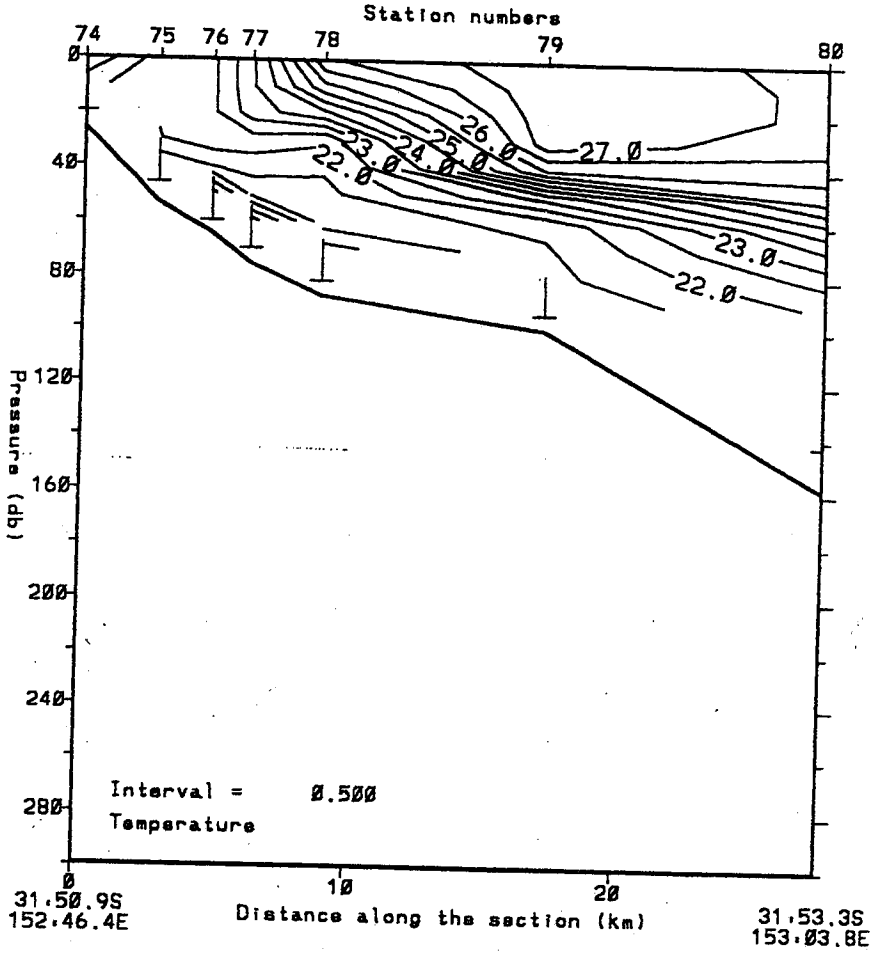



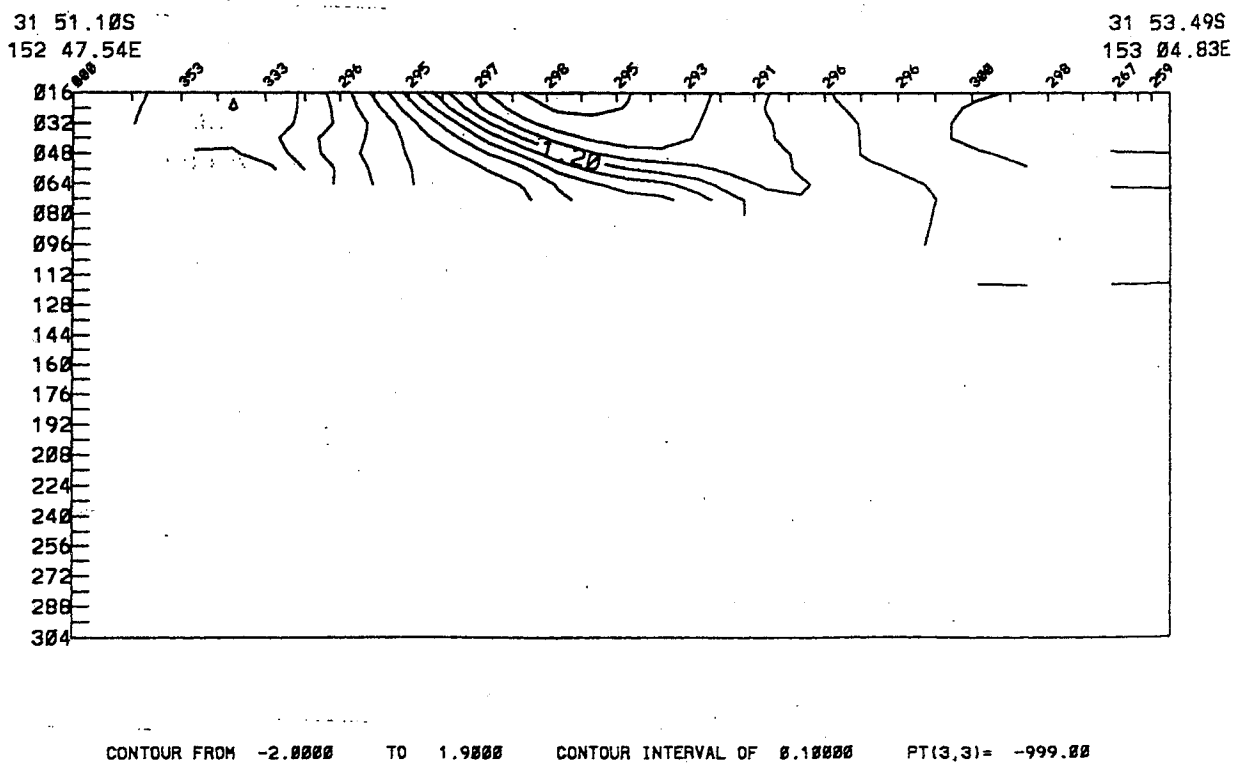

Figure 2 Temperature and Longshore Current sections for Smoky Cape




From 28-JAN-1999 01:04:00 to 28-JAN-1999 02:37:01

CROWDY HEAD

Across component (Dashed = in to page)
Smoothed




CONTOUR FROM -2.0000 TO 1.9000 CONTOUR INTERVAL OF 0.10000 PT(3,3)= -999.00

Figure 3 Temperature and Longshore Current sections for Crowdy Head