RESEARCH SUMMARY

CRUISE FR 2/93

Sailed Townsville	1800 hrs	Wednesday	10 February 1993
Arrived Townsville	0900 hrs	Friday	26 February 1993

Principal Investigators

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LARVAL FISH ASSOCIATED WITH FLOW DISTURBANCE ABOUT ISOLATED REEFS

March 1993

RESEARCH SUMMARY FR 2/93

1. ITINERARY

Sailed from Townsville 1800 hrs, Wednesday 10th February, 1993.
Arrived at Townsville 0900 hrs, Friday 26th February, 1993

2. SCIENTIFIC PROGRAM

The program was begun on Fr 8/92, in October of 1992, and both the aims of the program and a brief summary of those results are described here to put the scientific objective of this cruise in context.

The overall objectives were to examine the physical and biological oceanography around Cato Reef (23°S, 155°E) and Wreck Reef (22°S, 155°E). Curents in the region flow strongly past these steep sided reefs, creating a wake region in the lee of the reefs which brings nutrients into the euphotic zone and stimulates production of planktonic algae. This enhanced production is presumed to flow up the food chain to larval fish. The objectives were thus:

a) To undertake physical measurements delineating the flow pattern in the vicinity of the reefs in order to determine the structure and extent of the wakes. These measurements were to include ADCP (Acoustic Doppler Current Profiler) transects, CTD (Conductivity, Temperature and Depth) profiles and nutrient samples. In addition, current meters deployed in October on Fr 8/92 were to be retrieved from the crests of both Wreck and Cato Reefs.

b) To determine phytoplankton abundance and productivity of the total phytoplankton population, as well as that of the micro-, nano- and picoplankton. In addition experiments were also planned to investigate zooplankton grazing on heterotrophic and autotrophic organisms. The results from these experiments will be analysed in relation to the physical measurements.

c) To determine the horizontal and vertical distribution of chlorophyll, and zooplankton size and abundance with TUBSS (Towed Underwater Biological Sampling System).

d) To determine the distribution and abundance of larval fish within and outside the island wakes, and about the thermocline/nutricline.

3. PRINCIPAL INVESTIGATORS

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4. RESULTS

The proximity of Tropical Cyclone "Oliver" to the working region created some problems for the planned work. The first two days of the cruise were occupied undertaking tidal wake measurements around Derwent Island (21°S, 149°47E). By this stage "Oliver" had moved toward the Capricorn Channel and the *Franklin* then moved through Hydrographers Passage to avoid wind and swell. A day of TUBSS, EZ net and CTD casts allowed time for "Oliver" to dissipate before the ship was able to move southeast toward the work area. As a result of the loss of time,

it was thought best to concentrate the remaining time on studies around Cato Reef, which is smaller than Wreck, and therefore takes less time to survey for current circulation patterns.

The tidal wake work around Derwent Island consisted of ADCP work and simultaneous TUBSS and surface net tows. A well formed wake was observed on the southern side during the tidal flood cycle, with recirculating flows close to the Island, and a higher zooplankton size variability within the wake. The ebb cycle on the northern side was far less well defined physically and biologically, partly because of the slower ebb currents (the tidal system is non-linear in this area), and (perhaps) partly because of the shallower waters north of the Island creating some hydrodynamic "fairing".

Hydrographers Passage has strong tidal suction and nutrient uplift on the spring-flood-tide, as determined from earlier cruises (Fr 4/90 and Fr 9/90). The arrival of *Franklin* on this cruise coincided with a neap tide, so that less extreme effects were expected than on the 1990 cruises. TUBSS and the EZ nets were deployed on bathymetry-parallel transects 11, 13 and 16 nm offshore from White Tip Reef (at the outer entrance to Hydrographers Passage). These showed a high degree of variability in zooplankton size and number, and in larval fish catch (mostly 10-15 mm clupeids). A CTD line run inshore on the flooding tide showed the expected uplift of isotherms onto the outer shelf at 80 m depth, and subsequent mixing by the strong flow over topoography, although the effects were less pronounced than in 1990. During this transect samples were also collected to determine the contribution of macro-, nano- and picoplankton to total chlorophyll a concentration. Such information was not obtained during the 1990 cruise.

All moorings at Wreck and Cato Reefs were successfully retrieved without problem and the tapes will be read within a few weeks of the finish of the cruise. These will identify the variability of current patterns between October and February, and may also yield interesting information about the response to Tropical Cyclone "Oliver".

The results from work around Cato Reef on this cruise complement those found on Fr 8/92.

The flow incident to Cato Reef was noted as being from the South on the first ADCP survey. This flow seemed to persist for the major part of the cruise period, enabling biological and physical measurements to be undertaken with reasonable certainty of the state of the wake.

The EZ net performed beautifully in completing balanced sampling of the wake and the free-stream. Far higher abundances of larval reef-fish were found during this voyage compared to Fr 8/92 in October 1992, with a tendency for higher biomass within the wake. The TUBSS system resolved enhanced zooplankton abundance and variability in regions of horizontal shear within the wake.

The total phytoplankton population chlorophyll a concentration appeared to be greater, at least in some parts of the wake zone. Preliminary analyses of the data from the grazing experiments indicates that there is a great deal of small scale variability in grazing rates.

5. CRUISE NARRATIVE

All times and dates here are referenced to Australian Eastern Standard Time (EST), except where specific reference is made to UTC.

Wednesday 10th February. Sailed from Townsville at 1800, and headed south-east down the inside channel of the Great Barrier Reef. At this stage Tropical Cyclone "Oliver" was about 100 nm northwest of Wreck Reef, with a central pressure of 975 Hpa and wind speeds of 80 kts.

Thursday 11th February. Continued on down the Channel to the Cumberland Islands. We received weather reports indicating that Tropical Cyclone "Oliver" was still located close to our study area at Wreck and Cato Reefs, and decided that it would be prudent to undertake non-scheduled studies associated with wakes around smaller continental shelf islands until the cyclone danger had passed. At 2117, we began a survey of the flood tide wake behind Derwent Island (21 S, 149 47E) using both the Acoustic Doppler Current Profiler (ADCP) and the towed

Underwater Biological Sampling System (TUBSS). The wake was clearly evident in a number of ADCP cross-sections, and in the TUBSS data as a water mass with significantly higher variability in light attentuation.

Friday 12th February. Toward the conclusion of the flood tide (high tide being 5.0m at Mackay at 0235) six surface net tows were taken, both inside and outside the observed wake. At 0400 an ebb tide ADCP/TUBSS survey was begun, and completed at about 0800. After twelve additional surface net tows were undertaken in and out of the wake, a second flood tide survey was begun at 1016, leading up to the high tide at Mackay at 1454 (4.5m). This survey was completed at 1330. A second ebb tide survey was undertaken between 1540 and 1850. Finally a flood tide survey was made between 2130 and 0220 (Saturday), towing the TUBSS and surface nets at 3 kts across the wake in a time-series fashion with 32 successive plankton samples.

Saturday 13th February. On completion of the flood tide survey at Derwent Island at 0200, a final ebb tide survey was undertaken between 0240 and 0640, again with 35 surface net tows, and with TUBSS in a time series fashion. At 0800 it was decided to run a trial CTD (CTD Station 1), however, a hydraulics line burst while the CTD was deployed, and the CTD profile had to be cancelled without water samples. On the basis of the location and strength of TC "Oliver", which was approaching the coast at Gladstone, it was decided to transit to Hydrographers Passage in order to undertake research on Hydrographers Passage inflows and outflows as a follow up to earlier *Franklin* work, pending suitable weather for transit to Wreck and Cato Reefs.

We arrived just outside the outer entrance to Hydrographers Passage at 1530 and begun a TUBSS tow-yo survey in 90 m of water in a bathymetry-parallel direction 11 nm offshore from White Tip Reef. This survey line was denoted as survey line A. Relevant tides at Bugatti Reef for Saturday were high tide of 1.9 m at 1544, followed by a low tide of 0.9 m at 2110, and the next high at 0459 Sunday (2.4m). The TUBSS survey was taken for about 1 hour and was followed by the first EZ net survey until about 1900. The EZ net survey consisted of 3 coarse (1030 micron) nets sampling at depths between 15-25 m, 25-35 m and 35-50 m while the EZ net was going down, and at similar depths coming up with a fine mesh net (333 micron). Similar TUBSS and EZ net surveys were undertaken at line B in 150 m depth at about 13 nm offfshore, and at C in about 250 nm depth at about 16 nm offshore from White Tip Reef. Very high abundances of clupeid larvae (greater than one per cubic metre) were found at all depths (10-15 mm total length) at line C.

A CTD survey was then begun, running inshore with the incoming tide, with CTD Station 2 taken in about 270 m of water.

Sunday 14th February. The tidal flood CTD section was completed with CTD Stations 3-9, in progressively shallower water to 60 m depth. Nutrients and water samples for determination of micro-, nano- and picoplankton chlorophyll a were taken at 25 m intervals to 100 m depth, and at 50 m intervals thereafter. The CTD section was completed at 0518 (19 minutes after high tide at Bugatti Reef) with Station 9 near Ferris Shoal.

On the basis of weather reports it was decided to transit directly to Wreck Reef, and the ship began the transit at 0600. Through the day a watch was kept on the ADCP which showed a persistent south-eastward flowing current at 1-2 kts.

Monday 15th February. Arrived at Wreck Reef at 0800, and on the basis of wind and sea-state, decided not to proceed with current meter retrievals.
Instead, the *Franklin* tracked direct to Cato Reef, arriving at 1430. An ADCP survey was then undertaken, with Cato Reef being circumnavigated at a 10 nm radius, which identified a northward flowing current of about 0.3 m/s. A subsequent ADCP survey undertaken through the night showed a wake extending to about 40 nm north of Cato Reef. High variability and low average currents characterised the wake.

Tuesday 16th February. On completion of the Cato ADCP wake survey, the Franklin moved to a point 10 nm directly east of Cato Reef. Water samples were collected for the phytoplankton productivity and abundance studies, and zooplankton grazing studies (CTD Station 10). A standard CTD station (Station 11) to 500 m was also taken, with nutrient samples collected at

depths of; surface, 25, 50, 75, 100, 125, 150, 250 and 500 m. A TUBSS vertical deployment was also taken to calibrate the TUBSS sensors against the *Franklin's* CTD and fluorometer. The *Franklin* then repeated a 10 nm radius circle of Cato Reef in an anticlockwise direction, this time conducting CTD Stations 11- 18. These were completed by 2100.

Beginning at 2130, a sequence of TUBSS and EZ net tows were undertaken at sites E1, E2 (repeated) and E3, with each sequence consisting of a 30 minute TUBSS tow followed by a 60 minute EZ net to at 2.5 kt. During this tow TUBSS was undulated between depths of 5 and 120 m. Depths sampled with the EZ were 15-45 m, 45-75 m and 75-100 m, with the deepest depth interval containing the layer of maximum chlorophyll. Coarse mesh nets were used on the down tow as before, but even after 10 min (approximately 900 m^3 filtered), catch rates were low and the sample appeared damaged due to abrasion during the 50 min tow in 25^oC water. Furthermore the down tow was characterised by particularly high pitching of the net. Consequently the coarse mesh nets were removed from the EZ net and all later tows included a fine mesh, oblique down-tow for 10 min, and 3 depth stratified up-tows with fine mesh of only 12 min each.

The zooplankton biomass of this free stream transect appeared low though zooplankton maxima were measured with TUBSS at depths of 40-60 m. Larval fish were removed from the extra surface net tows taken during the EZ net tow. These surface samples were frozen in liquid nitrogen for later biochemical condition analyses, and some were preserved in alcohol for otolith analyses to determine if condition or recent growth was superior in the wake.

Wednesday 17th February. At the completion of the TUBSS and EZ net surveys, the ship moved to the location of CTD Station 12, where water samples were collected at about 0800 for the phytoplankton productivity and abundance studies, and zooplankton grazing rates. Following this the ship moved onto Cato Bank to the location of mooring B (deployed at 1011 on 9th October on Fr 8/92). A position marker float mooring was deployed at the estimated (by GPS) mooring position, and the Zodiac deployed for mooring retrieval. On arrival at the position marker float, the temporary surface marker float used in the deployment was seen about 20 m away. The acoustic release system was activated at 1011 and the release functioned immediately. The position marker float and mooring were retrieved, and brought aboard *Franklin* at 1019 without incident. The *Franklin* then went to the position of mooring A (deployed at 0723 on 9th October), and again the position marker float was deployed at the estimated mooring position. The Zodiac was deployed, and after locating the mooring through the acoustic pinger system, the mooring was released at 1135 at first call. All gear was retrieved and the Zodiac winched aboard.

A short CTD section comprising Stations 20 to 23 was then undertaken at 5 nm spacing, running directly north down the wake. At 2000 the TUBSS and EZ net survey was begun at stations N1, N2 and N3, these all being in the Cato Wake. Each station consisted of 30 minutes TUBSS tow-yoing between 5 and 120 m, and 60 minutes EZ net trawls.

Myctophid and exocetid fish and larvae were conspicuous in all surface and EZ nets, and a variety of myctophid, serranid, labrid and clupeid larvae were abundant in the EZ nets. Compared to October 1992, salps and eel leptocephali were conspicuously low in abundance.

Thursday 18th February. At 0500 the ship headed toward Wreck Reef.Water samples were collected at about 0800 for the phytoplankton productivity and abundance studies, and zooplankton grazing studies (CTD Station 24). The ship continued on toward Wreck Reef. On arrival at West Island (of Wreck Reef) at 1030 a position marker float was deployed at the expected site of mooring G (deployed at 0623 17th October 1992). The Zodiac was lowered, and after locating the mooring, the release was activated at 1111. After release the mooring was picked up and returned to the ship. A two hour transit to Bird Island on the eastern side of Wreck Reef followed, and the same procedure was followed for mooring retrieval for mooring F (deployed 0633 16th October). Unfortunately, this time the pinger system failed, however, the release system worked at call, and released so close to the position marker float that it actually became entangled. All gear was subsequently returned safely to *Franklin.* The ship then returned south toward Cato Reef, and began TUBSS and EZ net sampling at stations N3, N2 (twice) and site N1.

Friday 19th February. On completion of the TUBSS and EZ net surveys, the *Franklin* headed due west to begin a CTD section running west-east across the wake. Station 26 was taken at 0632, and was followed by Stations 27 and 28, comprising water samples for the determination of phytoplankton productivity and abundance, and zooplankton grazing rates and a standard CTD station 7 nm due east. The line of CTD Stations continued east at 7 nm spacing, finishing at CTD Station 34 at 156 E. The *Franklin* then steamed to site E3, where a sequence of TUBSS and EZ Net tows were undertaken throughout the night at sites E3, E1 and E2 (twice).

Saturday 20th February. On completion of the TUBSS and EZ net work, confirmation of the strength and direction of the incident current (and hence the wake) was needed, and the ship began a circumnavigation of Cato Reef at approximately 10 nm radius. At 0840 water samples were collected for the phytoplankton and zooplankton studies (CTD Station 35), and the ship continued on toward site E2, where TUBSS and EZ work was undertaken during daylight. These tows sampled the thermocline and chlorophyll maximum layers in detail, and we ignored the surface waters which are remarkably depauperate during the day. The depth bins were 170-130 m, 130-90 m and 90-50 m. The ship then positioned close to the southeast tip of Cato (Hutchinson Rock) where TUBSS was deployed and towed in an easterly direction towards E2 to examine zooplankton biomass close to the reef in the free stream. High abundances of particles were initially found, but these rapidly dwindled to a low, structureless pattern towards E2. At E2 a replicate EZ net tow was conducted at 1700. The ship then moved to site N1 where TUBSS and EZ net tow samples were taken, after which N2 was sampled twice and N3 once. This night sampling continued until 0400 Sunday.

Sunday 21st February. By 0600 the ship had repositioned due east of site N2, with the objective of undertaking a long TUBSS section from a point clearly in the free stream outside the wake due west to site N2. At 0730 the section was interrupted by water sampling to determine phytoplankton productivity and abundance, and zooplankton grazing rates. A TUBSS/CTD joint vertical deployment for TUBSS calibration followed at 0730. The section was resumed at 0830 and finally completed at 1153. Approximately 2-3 times the count rate was observed in the wake compared to the free stream. At N2 a deep EZ tow was conducted, similar to the previous day. No myctophid larvae were caught in the day tows but many reef-fish larvae were observed (approximately 10-100 per 800 m^3). The *Franklin* then repositioned over the northern side of Cato bank, and TUBSS was again deployed at 1430 for a section running north, down the steep northern side of Cato Bank and into deep water. TUBSS indicated a high degree of variability in zooplankton size and abundance at the shelf break. Particularly high abundances of particles were found at 60 m at the reef crest, with very little on the reef flat. At N2 a replicate EZ tow was made at 1730. The ship subsequently repositioned at E1 for an evening of TUBSS and EZ net sampling, finally occupying site E1 and E3 once each, and site E2 twice.

Monday 22nd February. At daybreak the ship had again repositioned at N1, and a CTD section was begun running south over Cato Bank and into deeper water on the upstream side. This comprised CTD stations 38 - 50, not including Station 41 which was allocated to phytoplankton sampling and zooplankton grazing experiments. These were completed at 1500 and the ship repositioned to begin a 15 hour ADCP survey. This continued through the evening and into the early hours of Tuesday.

Tuesday 23rd February. The ADCP survey was finished by 0700 and a phytoplankton CTD (CTD Station no 51) was taken at 0745. The ship returned to the south-western quadrant of Cato Bank to begin a bathymetric/ADCP survey designed to delineate the current structure and bathymetry at depths between 1000 m and 50 m depth. This continued through the day and into the evening.

Wednesday 24th February. The ADCP/bathymetric surveys were completed at 0600, and the ship repositioned to undertake the last CTD (CTD 52, a phytoplankton CTD) at 0730. Following this the ship moved to the shallower parts of the Bank where sampling for adult specimens of Lutjanids was facilitated by the crew. At 1100, *Franklin* departed the work area, crossing the East Australia Current and heading for the Capricorn Channel.

Thursday 25th February. The ship continued en-route to Townsville, up the Capricorn Channel

toward the Whitsunday Islands.

Friday 26th February. *Franklin* arrived outside the channel at 0800, and tied up at 0900 at Townsville harbour.

6. SUMMARY

On arrival at Cato Reef, and during the time the Franklin was in the region, a number of transects were made using the ADCP. Throughout the study, the incident current was toward the north, sometimes with a small component to the east or west. The incident current strength was mostly around 0.3 m/s, creating a wake of high variability to the north of Cato Bank. The demarcation between the eastern side of the wake and the free stream was clear, and this was utilised for some of the TUBSS work. By contrast the western edge of the wake was much more variable. Later in the cruise, a previously unknown seamount extending to within 400 m of the surface was located some 5 nm west of the western edge of Cato Bank. This appeared to have an additional effect, creating an additional wake of its own, no doubt contributing to the variability on the western edge. In all cases the wake proper was characterised by weak currents which were highly variable in direction.

Prior to arrival at Cato, two flood and two ebb tide ADCP surveys were carried out at Derwent Island, offshore from Mackay within the Great Barrier Reef. In these studies the flood tide wake was clearly identifiable, while the ebb tide wake was less well formed. The island appears to have significant shallower water on the ebb (north) side, and the resultant weaker wake structure may well be due to a streamlining effect. TUBBS tows were taken simultaneously.

Interspersed throughout the study were a number of CTD sections, these being as follows: the first was comprised of 8 stations circumnavigating Cato Island with a radius of 10 nm, the second section crossed the wake perpendicular to the incident flow at about 20 nm downstream, the third section ran down the axis of the wake, and the final section ran predominantly north-south from deeper water, over the Bank proper, and into deeper water again. On each of these sections nutrient, salinity and oxygen concentrations were obtained from Niskin bottle samples. The overall results of this component of the program will have to wait until the nutrient values are formally completed, and compared with the CTD data and ADCP data. In all, some 43 CTD stations were occupied for water column studies. Eight of these stations were taken in Hydrographers Passage, delineating the tidal suction and nutrient uplift on the flood tide.

Two current meters were deployed on each of Wreck and Cato Reefs in October 1992 on cruise Fr 8/92. All four moorings were recovered without incident. Overall data recovery appeared to be 100% for three of the meters, while the fourth appears to have provided only 75% of adata ossible. Results await reading of the tapes, as there was no tape reader aboard.

Replicated EZ net and surface samples were taken at night along transects in the wake of, and in the free stream adjacent to Cato Reef. High abundances of myctophid larvae and reef-fish larvae (Labridae, Clupidae, Serranidae) were found, sufficient to determine the biological significance of the island-mass effect. Larvae (and some zooplankton) from extra surface nets were frozen or preserved in alcohol for biochemical and otolith condition indices. Inspection of the samples showed a marked decrease in the abundance of eel larvae and salps since October 1992. During the day replicated EZ net tows were made about the chlorophyll maximum layer at stations E2 (free stream) and N2 (wake). These day samples were devoid of the usual myctophid fish and larvae, but each net contained between 10 and 50 reef-fish larvae. Surface net samples were taken during the island wake study about Derwent Island. These samples included a balanced ANOVA sampling design between the wake and the free stream, as well as time-series sampling in and out of the wake.

TUBSS was deployed before all EZ net tows, and during 2-4 hr dedicated tows. At 2.5 kt, TUBSS reached a maximum depth of 120 m, although only shallower depths are possible at 5 kt. TUBSS acquires data at 2 s intervals from a CTD, fluorometer and optical plankton counter which counts and sizes particles between 300μm and 2 cm. The highlight of the TUBSS data set includes transects across the Cato wake and perpendicular to the free stream adjacent to the island, and

transects through the Derwent Island wake. Both showed enhanced concentrations of particles, in the wake proper at Cato Reef and at the wake edge at Derwent Island.

Overall, the principal objectives of the program were met with activities including: 35 hours of TUBSS towing, 31 EZ net tows, more than 100 surface net tows, 52 CTD's, 450 samples were collected for phytoplanton primary production and chlorophyll a concentrations, and 9 grazing experiments. In addition, 4 moorings were successfully retrieved.

The total chlorophyll a concentration appeared in general to be higher in the wake zone than in the non-wake area. This was due to the subsurface chlorophyll a maxima extending over a greater depth range. In the wake zone chlorophyll a concentration began to increase at about 50 m, and extended to depths in excess of 100 m. By contrast the subsurface chlorophyll a maxima in the free stream was generally about 20 m thick and occurred at about 100 m. The contribution of the micro-, nano- and picoplankton to the total phytoplankton concentrations, both in and out of the wake, will be determined when the samples collected during the cruise have been analysed. Similarly, productivity and grazing data will be available when samples collected during the cruise have been counted in the laboratory at Monash University.

7(A) SCIENTIFIC PERSONNEL

Jason Middleton (University of New South Wales), Chief Scientist
Iain Suthers (University of New South Wales)
Greg Nippard (University of New South Wales)
David Rissik (University of New South Wales)
Peter Coutis (University of New South Wales)
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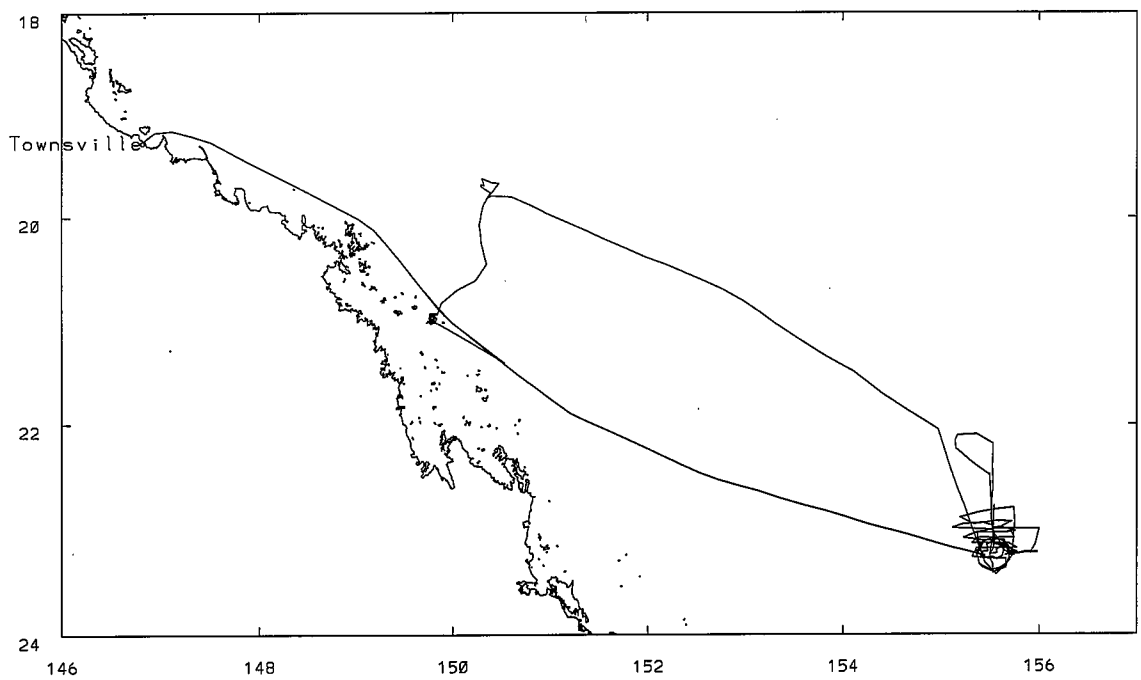
Rick Royle (Monash University)
Jeff Dunn (CSIRO), Cruise Manager
Eric Madsen (CSIRO)
Bob Griffiths (CSIRO)
Mark Lewis (CSIRO)

7(B) CREW

Neil Cheshire (Master)
Dick Dougal (First Mate)
Bryce Bathe (Second Mate)
John Scott (Chief Engineer)
Ian Hayward-Bryant (Second Engineer)
Don Roberts (Electrical Engineer)
Jeff Snell (Greaser)
Wayne Browning (Bosun)
Bluey Hughes (Able Seaman)
Kris Hallen (Able Seaman)
Paul Sanhueza (Abel Seaman)
Garry Hall (Chief Cook)
Bob Clayton (Second Cook)
Steve Corridon (Steward)

ACKNOWLEDGMENTS Thanks go to all for their professional approach and cheerful attitude. Ship's personnel contributed greatly, with many working longer than watch hours in order to get the job done. Particular thanks goes to Jeff Dunn for his persistent efforts at keeping the failing computer systems alive, to Eric Madsen for nursing the electronics, to Mark Lewis for keeping the EZ net firmly under control, and to Bob Griffiths for squeezing the last few nutrients from the oligotrophic waters. Thanks also go to Bob for his role as divemaster in developing the first (?) approved dive plan for Franklin.

Franklin Cruise 2/93



CTD LOG FR 02/93

CTD No	TIME (UTC)	TIME (EST)	LAT	LONG	DEPTH cast	DEPTH ocean
1	2204/12	0804/13	20 56.53	149 50.43	30	35
2	1330/13	2330/13	19 40.47	150 28.39	270	282
3	1433/13	0033/14	19 41.93	150 27.19	250	257
4	1533/13	0133/14	19 43.95	150 25.53	195	200
5	1624/13	0224/14	19 44.66	150 24.79	150	165
6	1718/13	0318/14	19 45.67	150 24.20	90	100
7	1807/13	0407/14	19 47.00	150 23.02	60	76
8	1846/13	0446/14	19 48.80	150 21.72	60	74
9	1918/13	0518/14	19 50.10	150 20.55	60	74
10P	2158/15	0758/16	23 14.85	155 43.28	500	1388
11	2305/15	0905/16	23 14.34	155 42.41	500	1140
12	0103/16	1103/16	23 07.90	155 40.14	500	1382
13	0222/16	1222/16	23 05.09	155 32.37	500	1100
14	0348/16	1348/16	23 07.81	155 25.01	500	1626
15	0533/16	1533/16	23 14.96	155 21.95	500	1586
16	0721/16	1721/16	23 22.08	155 25.01	500	1548
17	0843/16	1843/16	23 25.03	155 32.35	500	1565
18	1007/16	2007/16	23 22.11	155 39.87	500	1307
19P	2116/16	0716/17	23 07.97	155 39.71	500	1380
20	0326/17	1326/17	23 05.23	155 32.33	500	1100
21	0450/17	1450/17	23 00.19	155 32.44	500	1482
22	0601/17	1601/17	22 55.08	155 32.43	500	1672
23	0711/17	1711/17	22 50.13	155 32.49	500	1942
24	0819/17	1819/17	22 45.29	155 32.55	500	2307
25P	2101/17	0701/18	22 27.24	155 29.93	150	3090
26	2032/18	0632/19	22 59.53	155 07.75	500	3400
27P	2155/18	0755/19	22 59.99	155 14.86	150	2732
28	2304/18	0904/19	22 59.75	155 13.21	500	3200
29	0038/19	1038/19	23 00.12	155 22.63	500	1896
30	0156/19	1156/19	23.00.12	155 30.07	500	1500
31	0305/19	1305/19	23 00.03	155 37.87	500	1589
32	0440/19	1440/19	23 09.18	155 32.78	200	200
33	0606/19	1606/19	22 59.94	155 52.75	500	1625
34	0732/19	1732/19	22 59.99	155 59.98	500	1811
35P	2141/19	0741/20	23 18.50	155 23.83	150	2141
36P	2141/20	0741/21	23 01.36	155 40.96	150	1551
37	2248/20	0848/21	23 02.02	155 40.39	150	1543
38	1837/21	0437/22	23 07.73	155 32.65	500	635
39	1936/21	0536/22	23 08.99	155 32.91	500	515
40	2027/21	0627/22	23 09.18	155 32.78	200	200
41P	2207/21	0807/22	23 09.11	155 32.13	150	150
42	2207/21	0807/22	23 09.11	155 32.53	100	150
43	2234/21	0834/22	23 09.74	155 32.35	50	55
44	2329/21	0929/22	23 13.56	155 30.96	50	52
45	0005/22	1005/22	23 14.94	155 30.24	25	25
46	0032/22	1032/22	23 15.87	155 30.26	100	110
47	0124/22	1124/22	23 15.74	155 29.92	170	176
48	0209/22	1209/22	23 16.23	155 29.82	500	1526
49?	0321/22	1321/22	23 20.00	155 32.00	500	1200
50	1436/22	0436/22	23 14.91	155 32.00	500	1536
51P	2145/22	0745/22	23 01.99	155 22.34	150	1800
52P	2129/23	0729/23	23 15.04	155 24.95	150	540

Phytoplankton stations are designated by a P next to the station number.

FRANKLIN 02-93
TUBSS TOWS

FILE-NAME	DY	GMT HR	MN	SC	START LATITUDE (decimal)	START LONGITUDE (decimal)	START BOTTOM DEPTH (m)	LOCATION	COMMENT
FR029301.SUM	11	11	29	10	-20.9989	149.8119	43.6	DERWENT ISL	FLOOD; NIGHT
FR029302.SUM	11	12	1	1	-20.9953	149.7646	42.4	DERWENT ISL	FLOOD; NIGHT
FR029303.SUM	11	12	33	35	-21.0044	149.7818	41.2	DERWENT ISL	FLOOD; NIGHT
FR029304.SUM	11	13	4	6	-21.0140	149.8033	44.0	DERWENT ISL	FLOOD; NIGHT
FR029305.SUM	11	13	30	54	-21.0135	149.7688	42.4	DERWENT ISL	FLOOD; NIGHT
FR029306.SUM	11	13	58	30	-21.0175	149.7317	40.4	DERWENT ISL	FLOOD; NIGHT
FR029307.SUM	11	14	30	14	-21.0242	149.7770	42.8	DERWENT ISL	FLOOD; NIGHT
FR029308.SUM	11	15	1	41	-21.0227	149.8055	45.6	DERWENT ISL	FLOOD; NIGHT
FR029309.SUM	11	15	44	15	-21.0345	149.7856	44.0	DERWENT ISL	FLOOD; NIGHT
FR029310.SUM	12	0	3	14	-20.9844	149.7534	40.8	DERWENT ISL	EBB; NIGHT
FR029311.SUM	12	0	31	15	-21.0019	149.7841	38.0	DERWENT ISL	EBB; NIGHT
FR029312.SUM	12	0	59	36	-20.9996	149.8046	44.4	DERWENT ISL	EBB; NIGHT
FR029313.SUM	12	1	31	35	-20.9948	149.7589	42.8	DERWENT ISL	EBB; NIGHT
FR029314.SUM	12	11	27	48	-21.0090	149.8191	43.6	DERWENT ISL	FLOOD; NIGHT
FR029315.SUM	12	12	0	30	-21.0116	149.7881	42.4	DERWENT ISL	FLOOD; NIGHT
FR029316.SUM	12	12	36	16	-21.0181	149.7587	40.4	DERWENT ISL	FLOOD; NIGHT
FR029317.SUM	12	13	10	8	-21.0191	149.7849	42.0	DERWENT ISL	FLOOD; NIGHT
FR029318.SUM	12	14	1	42	-21.0099	149.8074	44.8	DERWENT ISL	FLOOD; NIGHT
FR029319.SUM	12	14	31	34	-21.0082	149.7782	42.8	DERWENT ISL	FLOOD; NIGHT
FR029320.SUM	12	14	59	13	-21.0088	149.7582	42.4	DERWENT ISL	FLOOD; NIGHT
FR029321.SUM	12	16	46	50	-20.9657	149.8112	45.6	DERWENT ISL	EBB; NIGHT
FR029322.SUM	12	17	25	24	-20.9667	149.7767	45.2	DERWENT ISL	EBB; NIGHT
FR029323.SUM	12	17	49	26	-20.9665	149.7595	43.6	DERWENT ISL	EBB; NIGHT
FR029324.SUM	12	18	44	2	-20.9642	149.8090	45.2	DERWENT ISL	EBB; NIGHT
FR029325.SUM	12	19	6	23	-20.9604	149.8214	45.2	DERWENT ISL	EBB; NIGHT
FR029326.SUM	12	19	40	11	-20.9566	149.7950	42.4	DERWENT ISL	EBB; NIGHT
FR029327.SUM	12	20	47	57	-20.9481	149.7713	44.0	DERWENT ISL	EBB; NIGHT
FR029328.SUM	12	21	17	8	-20.9462	149.8014	42.4	DERWENT ISL	EBB; NIGHT
FR029329.SUM	13	6	3	25	-19.7558	150.3863	96.8	HYDROG. PASS	LINE-A
FR029330.SUM	13	8	34	53	-19.6726	150.2733	158.0	HYDROG. PASS	LINE-B
FR029331.SUM	13	11	4	14	-19.6232	150.3072	250.0	HYDROG. PASS	LINE-C
FR029332.SUM	15	23	46	9	-23.2328	155.7018	1150.0	CATO REEF	ABORTED TUBSS/CSIRO CALIB.
FR029333.SUM	16	11	26	14	-23.2420	155.6787	1050.0	CATO REEF	STN E-1
FR029334.SUM	16	13	44	13	-23.2327	155.7475	1225.0	CATO REEF	STN E-2
FR029335.SUM	16	16	12	59	-23.2151	155.9016	1797.0	CATO REEF	STN E-3
FR029336.SUM	17	10	14	36	-23.0009	155.5331	1474.0	CATO REEF	STN N-2
FR029337.SUM	17	12	49	29	-23.1533	155.5479		CATO REEF	STN N-3
FR029338.SUM	17	14	58	53	-23.0371	155.5393	1457.0	CATO REEF	STN N-2 (repeat)
FR029339.SUM	17	17	15	45	-22.9020	155.5187	1710.0	CATO REEF	STN N-3
FR029340.SUM	18	9	31	24	-22.8601	155.5192	1831.2	CATO REEF	STN N-3
FR029341.SUM	18	11	45	22	-22.9977	155.5291	1461.2	CATO REEF	STN N-2
FR029342.SUM	18	14	10	30	-23.1518	155.5458	194.8	CATO REEF	STN N-1
FR029343.SUM	18	16	18	21	-23.0425	155.5305	1401.0	CATO REEF	STN N-2 (repeat)
FR029344.SUM	19	9	34	10	-23.2116	155.9374	1839.0	CATO REEF	STN E-3
FR029345.SUM	19	11	42	45	-23.2285	155.7982	1567.0	CATO REEF	STN E-2
FR029346.SUM	19	14	5	47	-23.2467	155.6755	1059.0	CATO REEF	STN E-1
FR029347.SUM	20	4	16	31	-23.2477	155.6419	675.0	CATO REEF	TRANSECT E-1 TO E-2
FR029348.SUM	20	4	47	1	-23.2444	155.6623	978.0	CATO REEF	TRANSECT E-1 TO E-2
FR029349.SUM	20	5	24	53	-23.2405	155.6872	1021.0	CATO REEF	TRANSECT E-1 TO E-2

FRANKLIN 02-93
TUBSS TOWS

FILE-NAME	GMT DY	HR	MN	SC	START LATITUDE (decimal)	START LONGITUDE (decimal)	START BOTTOM DEPTH (m)	LOCATION	COMMENT
FR029350.SUM	20	5	49	2	-23.2384	155.7048	1227.0	CATO REEF	TRANSECT E-1 TO E-2
FR029351.SUM	20	6	29	49	-23.2335	155.7380	1260.0	CATO REEF	TRANSECT E-1 TO E-2
FR029352.SUM	20	7	8	30	-23.2518	155.7822	1472.0	CATO REEF	TRANSECT E-1 TO E-2
FR029353.SUM	20	9	52	7	-23.1516	155.5512	394.8	CATO REEF	STN N-1
FR029354.SUM	20	11	59	31	-23.0468	155.5340	1410.4	CATO REEF	STN N-2
FR029355.SUM	20	14	22	0	-22.9081	155.5190	1692.0	CATO REEF	STN N-3
FR029356.SUM	20	19	57	29	-23.0209	155.7618	1524.0	CATO REEF	E/W TRANS. TO N-2
FR029357.SUM	20	20	35	26	-23.0200	155.7320	1540.4	CATO REEF	E/W TRANS. TO N-2
FR029358.SUM	20	21	4	52	-23.0218	155.7089	1533.2	CATO REEF	E/W TRANS. TO N-2
FR029359.SUM	20	22	57	10	-23.0367	155.6732	1543.0	CATO REEF	TUBSS/CSIRO CALIB.
FR029360.SUM	20	23	30	45	-23.0355	155.6653	1522.4	CATO REEF	E/W TRANS. TO N-2
FR029361.SUM	21	0	10	42	-23.0341	155.6319	1548.8	CATO REEF	E/W TRANS. TO N-2
FR029362.SUM	21	0	31	27	-23.0330	155.6149	1535.2	CATO REEF	E/W TRANS. TO N-2
FR029363.SUM	21	1	27	25	-23.0297	155.5665	1451.2	CATO REEF	E/W TRANS. TO N-2
FR029364.SUM	21	1	54	19	-23.0257	155.5437	1470.4	CATO REEF	E/W TRANS. TO N-2
FR029365.SUM	21	4	27	51	-23.1679	155.5476	54.0	CATO REEF	N-TRANS. FROM CATO FLATS
FR029366.SUM	21	5	11	18	-23.1434	155.5514	575.6	CATO REEF	N-TRANS. FROM CATO FLATS
FR029367.SUM	21	9	25	6	-23.2473	155.6776	1061.6	CATO REEF	STN E-1
FR029368.SUM	21	11	14	47	-23.2319	155.7674	1473.6	CATO REEF	STN E-2
FR029369.SUM	21	13	21	18	-23.2197	155.8943	1794.0	CATO REEF	STN E-3

EZ NET AND TUBSS TOW LOCATIONS

Cato Reef

E1	23 14.8	155 42.0
E2	23 14.0	155 46.0
E3	23 13.0	155 55.0
N1	23 07.8	155 33.0
N2	23 01.2	155 32.0
N3	22 52.9	155 31.0

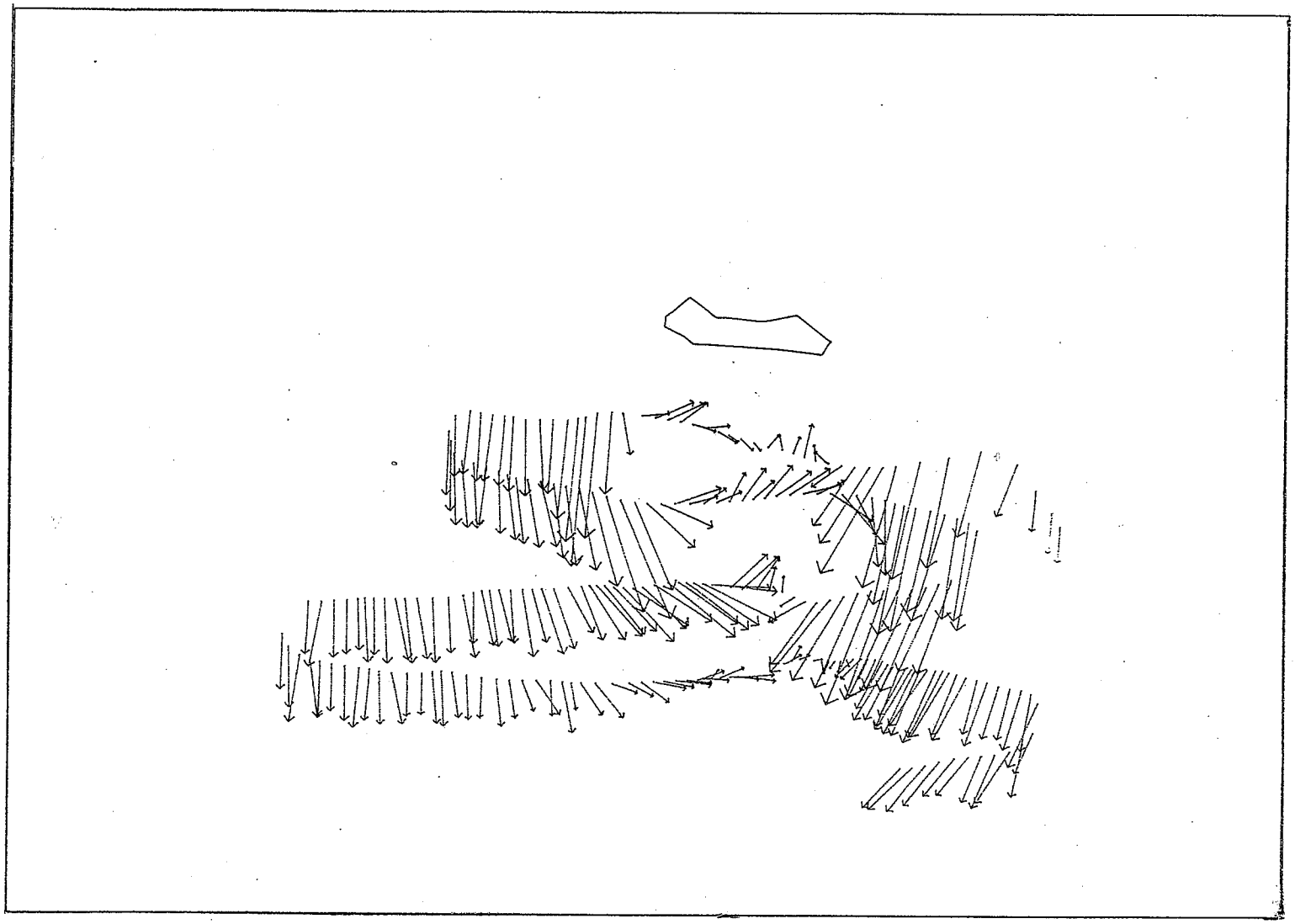


Figure 1 Showing the wake behind Derwent Island beginning 1115 11 Feb., 1993 UTC [2315 11 Feb., 1993 EST]

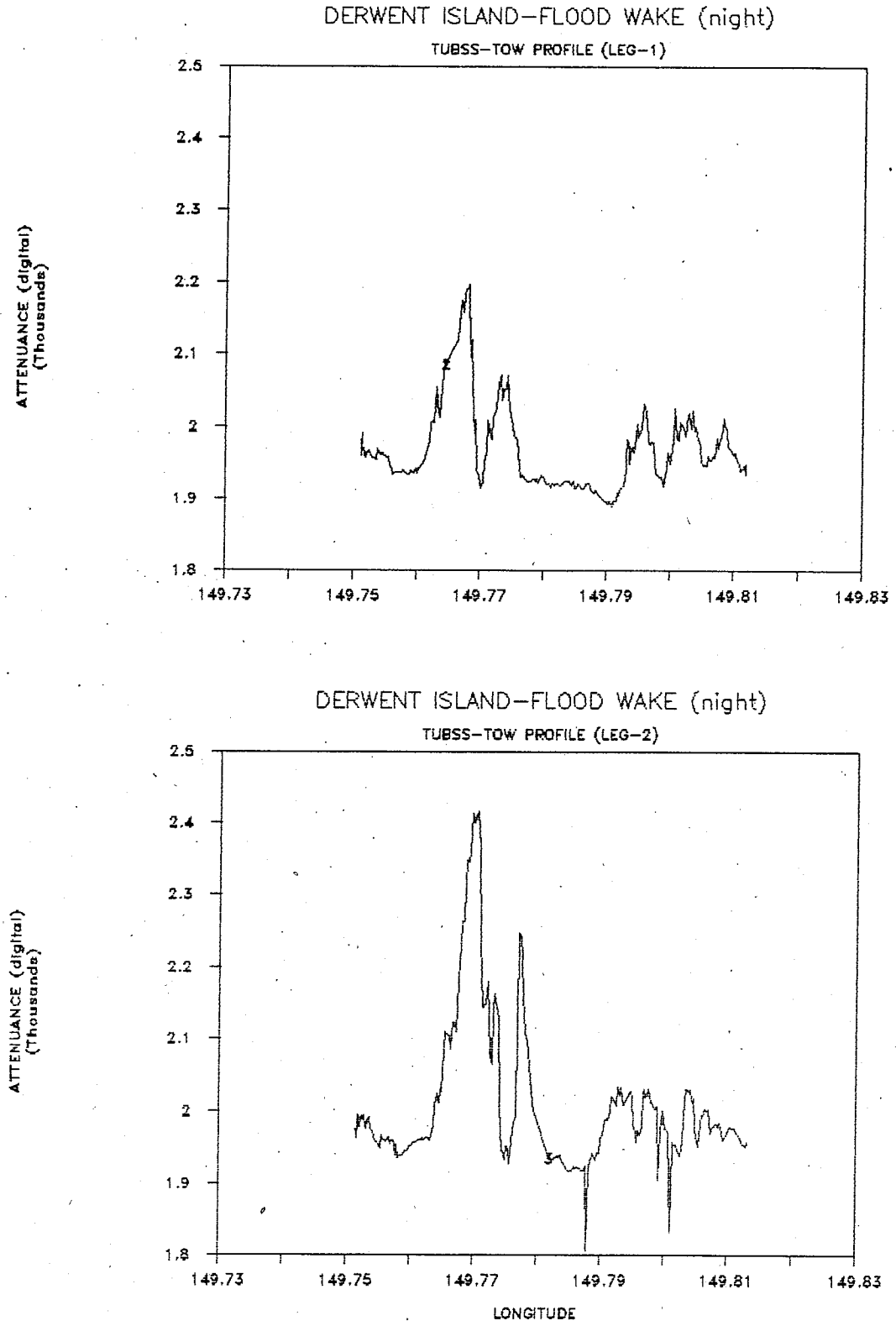


Figure 2(a) TUBSS transect at a constant depth (11 m) across the flood tide wake of Derwent Island during the night of 11-12 February 1993, from the free-stream region, across the wake and back into the free-stream. Figure shows changes in attenuance (i.e. water colour and particles < 250 μm, in digital units) recorded by the optical plankton counter (OPC) with respect to longitude; (i) approximately 1 nm downstream and (ii) 2 nm downstream (souths). Sudden changes in attenuance correspond to edges of eddy shown in ADCP plots.

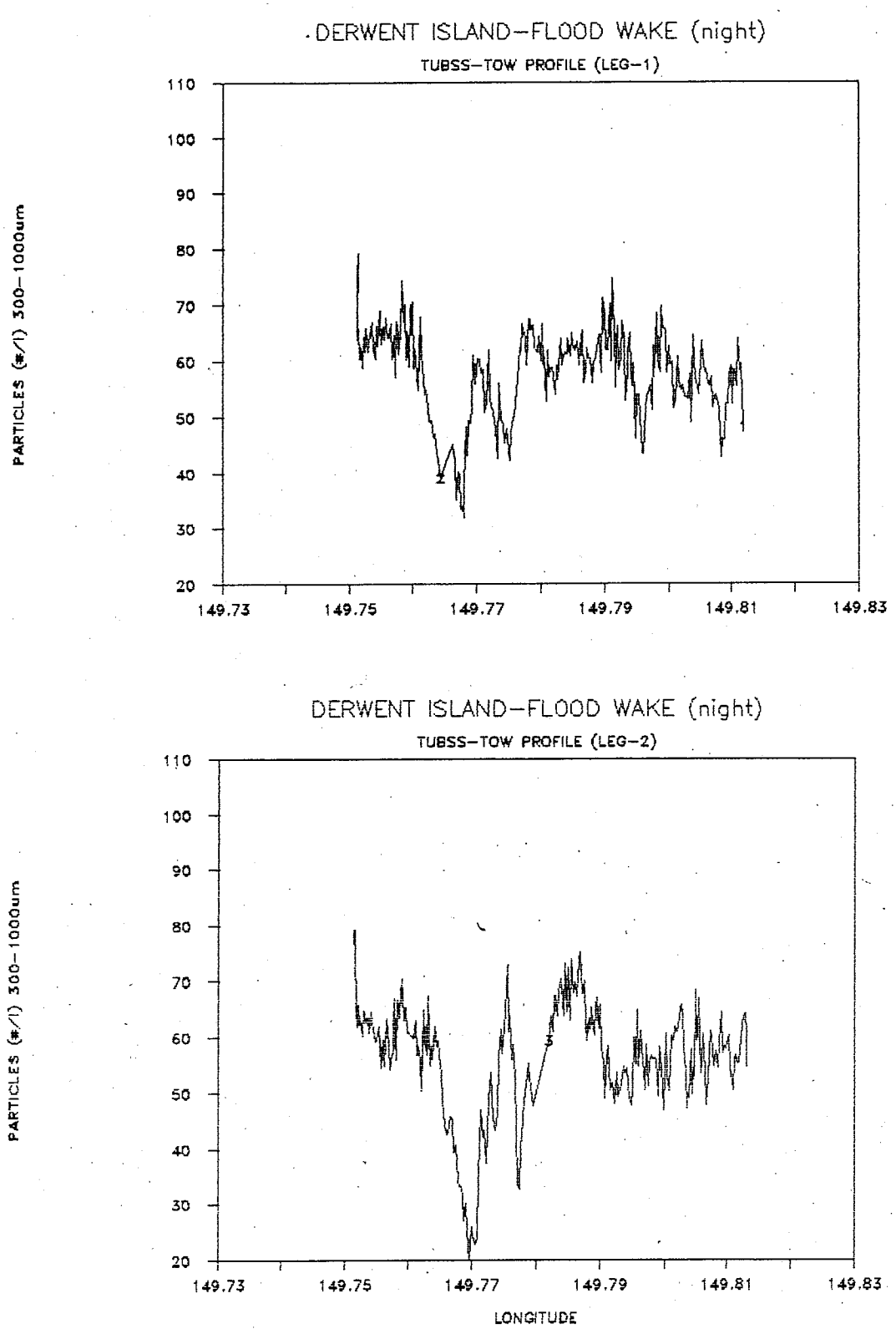


Figure 2(b) As in Figure 1(a), showing horizontal distribution of small (300-1000 μm) particle concentration as recorded by OPC (numbers per litre).

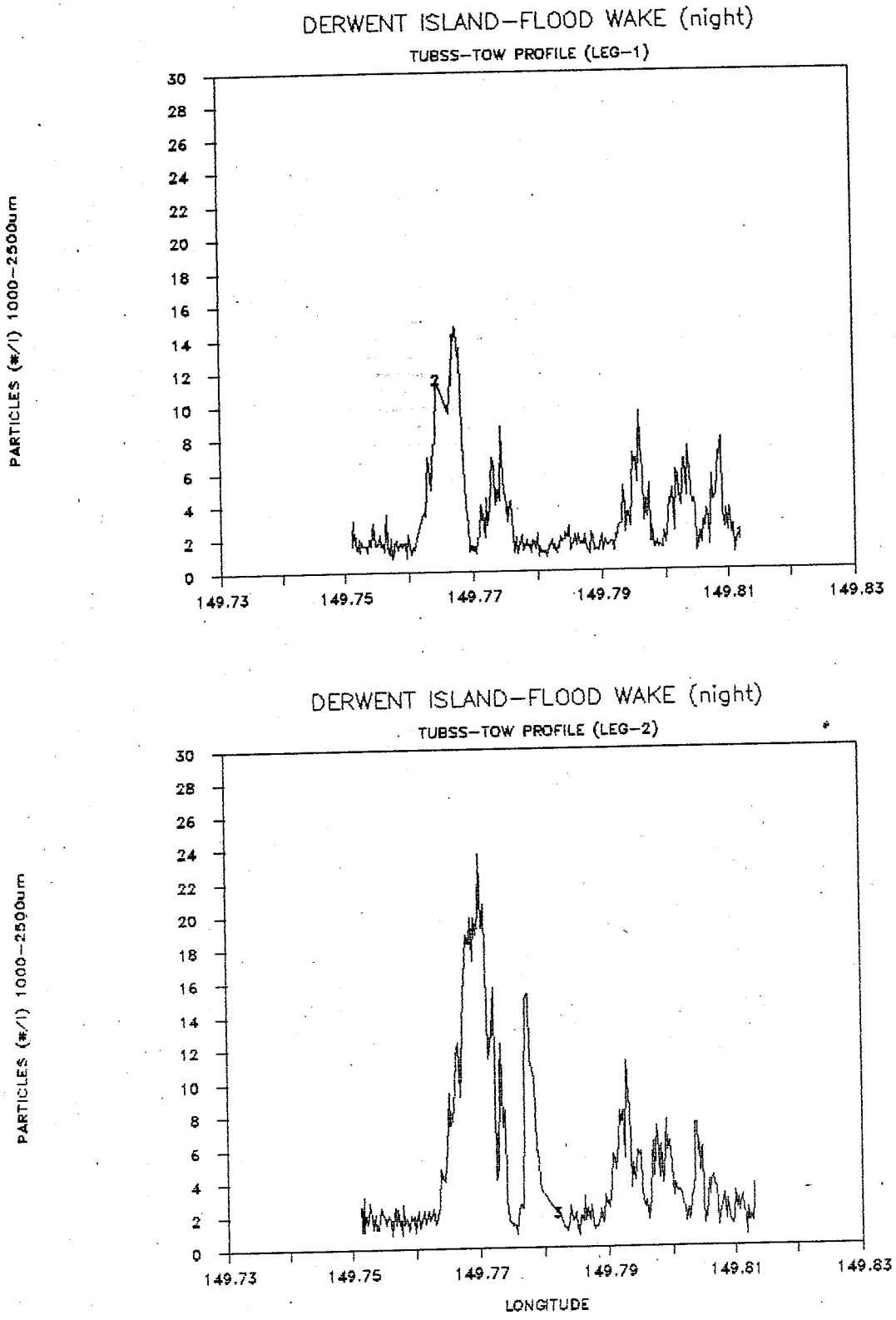


Figure 2(c) As in Figure 1(a), showing horizontal distribution of medium (1,000-2,500 μm) particle concentration as recorded by OPC (numbers per litre). Note how small and medium particle sizes appear to be negatively correlated, but correspond to the eddy edge.

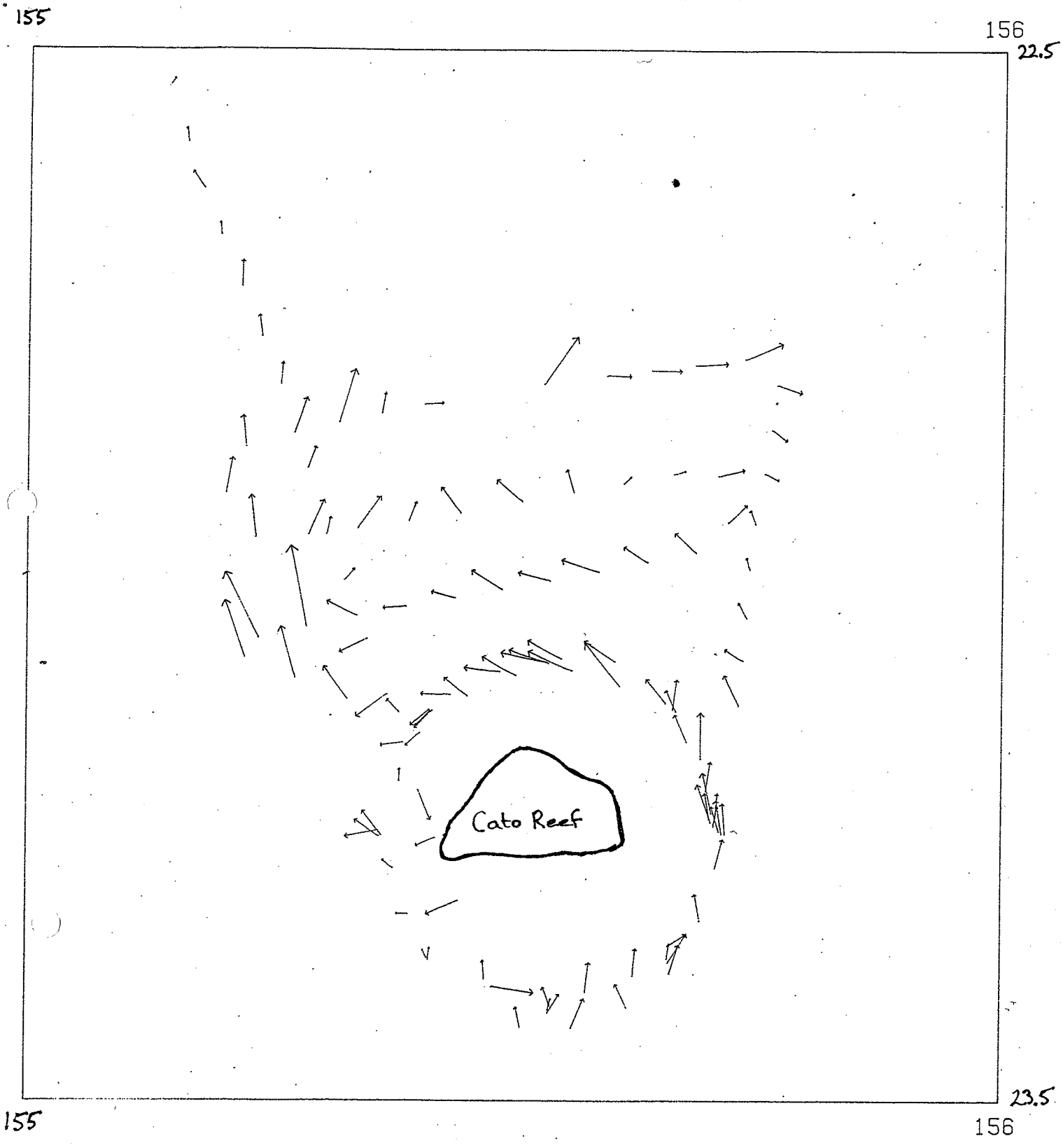


Figure 3 Showing the wake behind Cato Reef, observed by the ADCP between 0030 15 Feb., 1993 and 1100 16 Feb., 1993 [UTC].

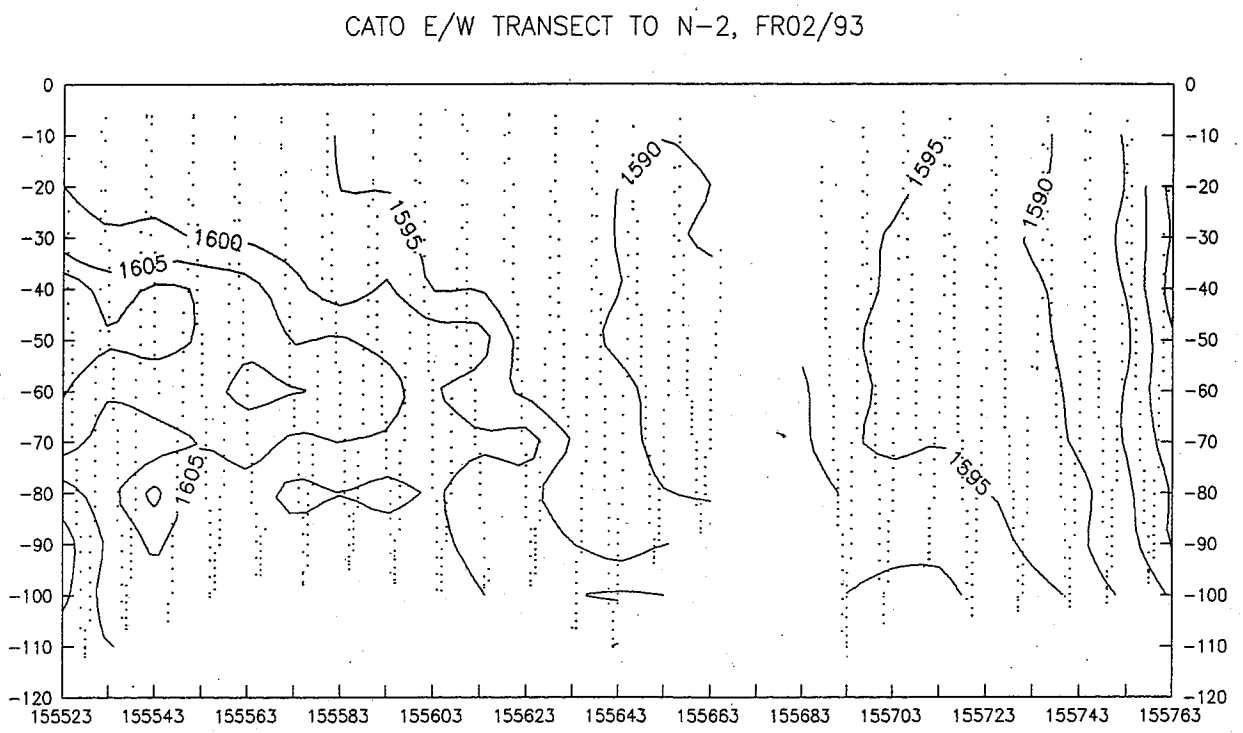


Figure 4(a) Vertical profile of attenuance, as a function of longitude, over approximately 8 nm from east to west across the Cato Island wake, along latitude 23°01'S (approximately 5 nm north (downstream) of the reef's 200 m isobath). Dots show the "tow-yo" path of TUBSS starting in the eastern free-stream, pausing for a CTD station, and continuing into the wake region.

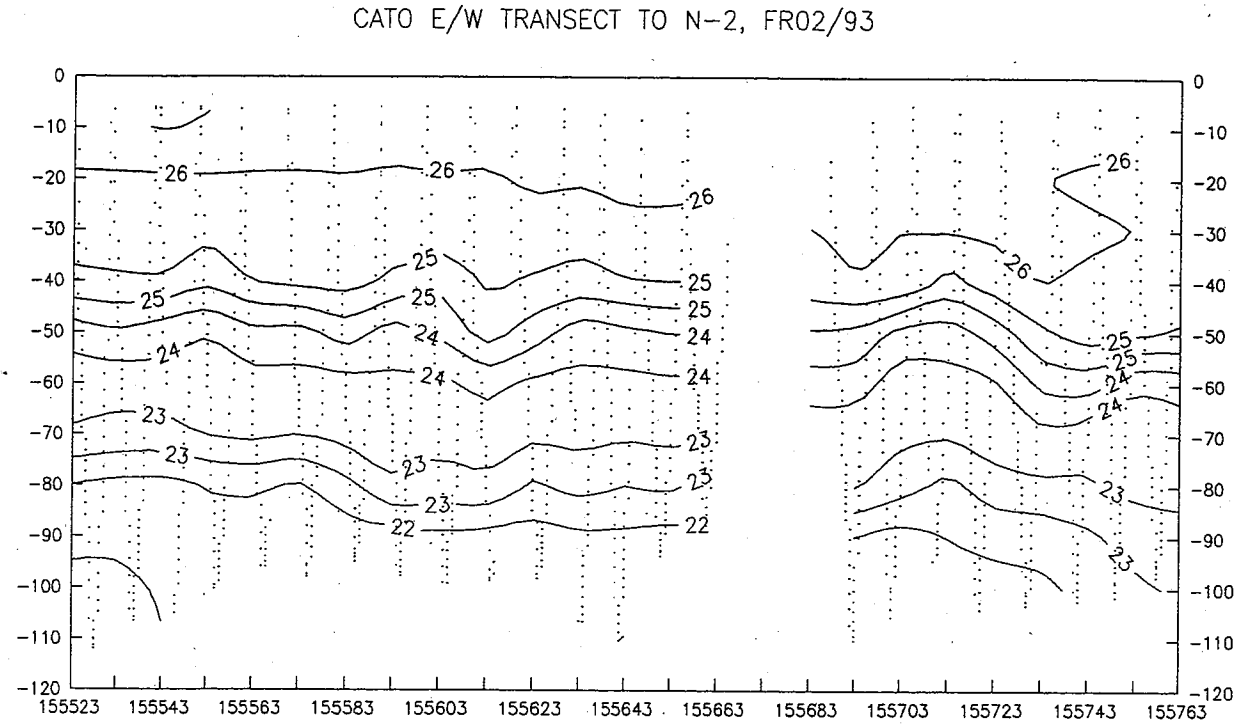


Figure 4(b) Vertical profile of temperature, as in 2(a)).

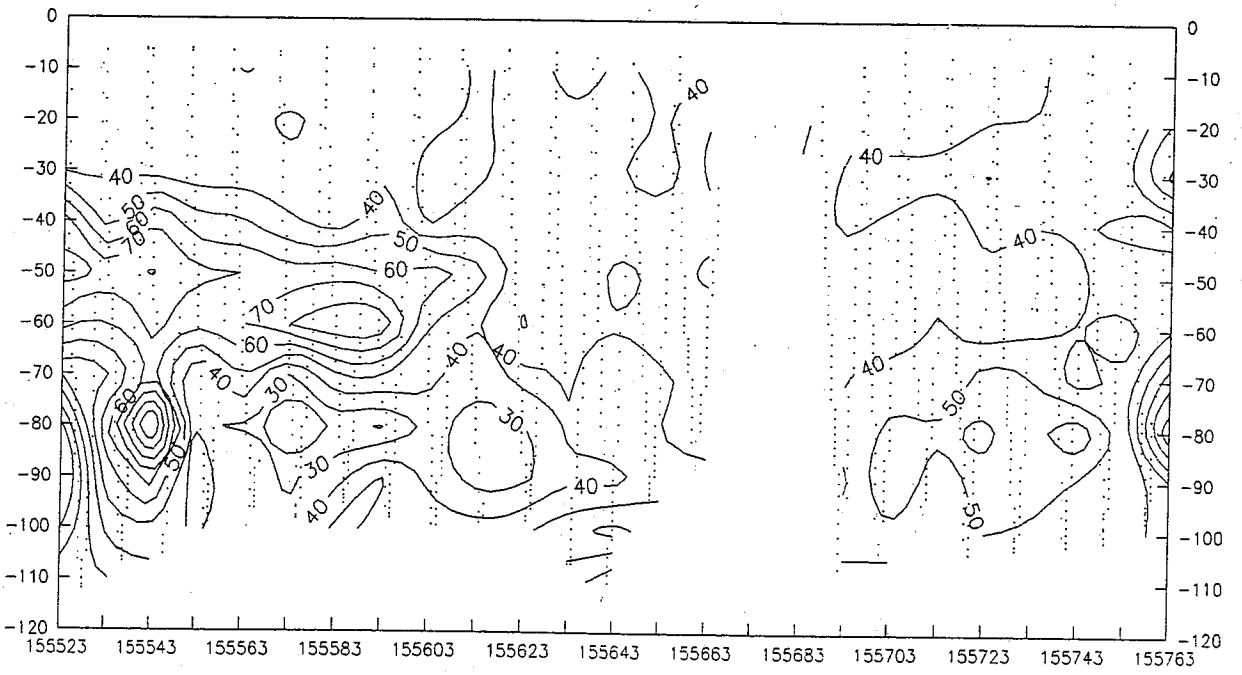


Figure 4(c) Vertical profile of small (300-1,000 μm) particle concentration (no. per litre), as in 2(a)).