RESEARCH SUMMARY

CRUISE FR 05/92

Depart Townsville:	2200	Monday	15-June-1992
Arrive Rabaul:	1500	Tuesday	30-June-1992
Depart Rabaul:	0600	Thursday	02-July-1992
Arrive Lae:	1200	Monday	13-July-1992

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INORGANIC AND ORGANIC CARBON CYCLES IN EQUATORIAL WATERS

JOINT GLOBAL OCEAN FLUX STUDY

ITINERARY

Leg 1			
Depart Townsville:	2200	Monday	15-June-1992
Arrive Rabaul:	1500	Tuesday	30-June-1992
Leg 2			
Depart Rabaul:	0600	Thursday	02-July-1992
Arrive Lae:	1200	Monday	13-July-1992

CRUISE NARRATIVE

Leg 1

After spending a hectic day setting up the HPLC equipment for pigment analyses as well as the pCO_2 equilibrator, the coulometer and the alkalinity titrator, we embarked from Townsville wharf at 2200 and immediately discovered that the Gyro compass was not working. We anchored off Magnetic Island and returned to Townsville at about 0900 on Tuesday 16th.

The system was checked out by a technician from Cairns. The verdict - the compass was on its last legs but would probably last until we reached Rabaul. Since we could not get a replacement at short notice, we decided to take our chances and left Townsville at 1500.

We generally had calm seas and favourable currents which allowed us to steam at 12-13 kt and, at one stage, we managed 14 kt. We arrived at the first station (10^0 S, 155^0 E) at about 0600 on Friday 19th. The individual casts were completed more rapidly than planned although the sampling time between casts occasionally took longer. This pattern persisted for the whole cruise and enabled us to rapidly make up the time lost due to the faulty Gyro-compass.

Early on the morning of Monday 22nd - just before the trace metal cast - the fan belts broke on the air conditioner for the clean container. We had no spares but the engineers managed to make two out of a larger belt. The first belt broke soon after the unit was switched on, the second broke after about 1 h. Finally, a temporary fan belt was made from spliced rope and this belt, although only partly successful, remained in use for the rest of Leg 1.

Temperatures in the GP laboratory (and the photographic room in particular) were as high as 35 ^{0}C and the HPLC and coulometer were not designed to operate at such a high temperature. The air conditioning could not cope with the heat produced by all the instruments. We took the air conditioning hose off the electronics rack in the operations room (under the PDR) and diverted it into the cable duct to the GP laboratory. This was only partly successful and, in the end, we were unable to use the coulometer and the alkalinity system during the cruise.

On Wednesday 24th, just before lunch, we moved into new territory as *Franklin* moved farther north than on any other cruise (the previous record was Truk). After completing the station at 10^0 N, 155^0 E we had gained enough time to add an extra station to the 147^0 E transect and so we steamed to 6^0 N, 147^0 E.

On Saturday 27th we checked on the Japanese buoy at 5^0 N, 147^0 E. We could not find it at the stated position but, as we proceeded to the next station, the buoy was located a few km away from the stated position. It was very difficult to find since it was disguised and looked like a 'floating coffin', but it seemed OK and we reported its exact location.

A few days prior to our expected arrival in Rabaul, one of the ship's officers developed shingles and, as we had continued to make good time, we arrived in Rabaul ahead of schedule so that he could seek medical attention.

Leg 2

We departed Rabaul dock at 0600, Thursday July 2nd, and after a short delay of about 3 hours in Rabaul Harbour to correct a steering problem, departed for the first time series site at 0^0 S, 155^0 E. Conditions were overcast and slightly bumpy, but improved overnight. We arrived at the time series site at 1730 Friday 3rd, in calm clear conditions. Following an initial CTD cast to the bottom, the free-floating sediment trap array was deployed. Although we had not previously deployed this array, the deployment went smoothly, and the ship had no difficulty tracking the array over the next three days.

The weather remained very kind, and we completed our scheduled sampling program at Site 1 in good time. We recovered the trap array at 1600, Monday 6th, at 0^0 02.82' S, 155^0 31.56' E. Recovery was made more difficult because the main surface buoy had collapsed, and the string of small surface floats designed to faciltate recovery had submerged. The crew improvised well and managed to lassoo the top float after several tries. After two further CTD stations, we departed for the second time series site at 2100 and arrived at 3^0 S, 155^0 E at 1230, Tuesday 7th.

We deployed the sediment trap array at 1300 and commenced the time series stations soon after. Again the weather remained calm and (mostly) clear, and we completed the time series studies in good time. This site was more interesting in that the sediment trap array initially headed SW and seemed determined to beach itself on a string of atolls at 3^0 18' S, 154^0 44' E. However, it veered south as it approached the group, and we were able to leave it in the water for the planned three day period, recovering it at 1500, Friday 10th, at 3^0 18.69' S, 154^0 48.15' E. After completing the scheduled set of CTD casts, we departed for Lae at 0700, Saturday 11th. Wind and sea increased during this transit, and we initially made poor time against a strong current, but eventually arrived on schedule in Lae.

SCIENTIFIC PROGRAM

Sampling Strategy

Leg 1

The 24-bottle rosette was used for CTD casts from the surface to 2000 m at latitudes 10^0 S, 8^0 S, 5^0 S, 4^0 S, 3^0 S, 2^0 S, 1^0 S, 0^0, 1^0 N, 2^0 N, 3^0 N, 4^0 N, 5^0 N, 8^0 N and 10^0 N along 155^0 E, and at latitudes 6^0 N, 5^0 N, 4^0 N, 3^0 N, 2^0 N, 1^0 N, 0^0, 1^0 S an 1.5^0 S along 147^0 E. Additional casts to 200 m were made at about 11 stations to collect large volume samples for measurements of productivity, lipids and pigments.

For the 2000 m casts, samples were collected at depths of 0, 25, 25, 50, 50, 75, 75, 100, 100, 125, 125, 150, 150, 200, 300, 400, 600, 800, 1000, 1250, 1500, 1750 and 2000 m. For the shallow casts to 200 m, multiple bottles were tripped at 6-7 different depths including the depth of the deep chlorophyll maximum.

Samples were collected for the analysis of nutrients, salinity, oxygen, bacteria, cyanobacteria, pigments, lipids, alkalinity, DIC and, at selected stations, trace metals and copper complexing capacity. Underway measurements were made of pH and pCO_2.

Primary production was estimated at ten stations along 155^0 E (10^0, 8^0, 5^0, 3^0 and 1^{0}S, 0^0, 1^0, 3^0, 5^0 & 8^{0}N) and at 5 stations (5^0, 4^0, 2^0 N, 0^0 & 1.5^0 S) on 147^0 E. Seawater was sampled from 5 CTD depths, (generally 0, 50, 75 or the chlorophyll maximum, 100 & 125 m; however at sites with a deep chlorophyll maximum the regime was 0, 75, 110 or chlorophyll maximum, 125 & 150 m). P vs I (production versus intensity) curves were obtained by measuring ^{14}C uptake in samples from each depth, incubating 7 ml subsamples for 1 hour at 18 light intensities, and in the dark, in a modified photosynthetron.

Results have not yet been standardized to production per unit chlorophyll, but peak production in mg C fixed per hour was found at the surface at 1.5^0 S, 147^0 E and 3^0 S, 155^0 E. At the other 13 stations production peaks were associated with the chlorophyll maximum, which varied in depth between 60 and 115 m.

The PAR sensor was deployed at productivity stations during daylight hours, on a separate CTD cast as it is only pressure-rated to 300 m.

Water samples were filtered for nutrients (nitrate, nitrite, silicate, phosphate) at productivity depths at productivity stations only (75 samples). Filtered samples were analysed on board at the same time as the unfiltered OMS nutrients.

Particle size analysis, using a Hiac particle counter, was carried out at productivity stations at all OMS depths to 200 m. In order to determine optimum incubation time for bacterial production estimations using methyl ^{3}H-thymidine on Leg 2, a kinetics experiment was performed at 10^0 N, 155^0 S at 50, 115 (chlorophyll maximum) and 125 m. Replicate samples were incubated to determine DNA incorporation (on board) and incorporation into other macromolecules (in Hobart). Samples were also preserved for AODC counts to determine bacterial numbers and volumes.

Zooplankton samples were collected at each productivity station by hauling a ring net (mouth area 0.25 m^2, mesh diameter 200 μm) from 100 m to the surface. Samples were preserved in 4% formaldehyde for subsequent determination of biomass and dominant taxa.

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Along 155^0 E, additional casts were made to the bottom at 5^0 S, 0^0 and 5^0 N for the determination of trace metals. Replicate samples were collected using the teflon-coated Niskin bottles and the new Helmond-Byrne bottles. The TM bottles took about 4 h to sample mainly due to the logistics of shuffling 24 bottles. At the equator we experienced more problems with the Helmond - Byrne bottles since they did not fit on the 12-bottle rosette or the racks in the wet laboratory and we had to store the trace metal bottles (full of seawater) all over the place.

Both sets of bottles were used on the casts. The nine TM niskins were placed at 0, 100, 200, 400, 600, 800, 1000, 2000 and 3000 metres at 5^0 S with the fifteen HB bottles at the same depths plus 300, 500, 700, 900, 1500 and 2500 metres. At the equator, the depth was only

2500 m, therefore no samples were taken at 3000 and the bottom depth of 2500 was sampled using the TM niskin. At 5^0 N the sampling was the same as at 5^0 S except that there was no duplicate sample at 1000 metres due to the handle falling off TM niskin #80.

The protocol for sampling was:

1. Take the CTD to the burst depth then hold for 30 seconds.

2. Descend from the burst depth at 10 m/min

3. Fire off the first bottle after 30 seconds.

4. Immediately fire off the second bottle.

For 5^0 S, and the 2000 m depth at the equator, the duplicate bottle was raised again to the burst depth and sampled as for the 1st bottle.

A total of 69 TM and CuCC samples were taken along the 155^0 E transect. The TM and CuCC samples were sampled in the clean container. They were sampled under gravity and not under pressure as filtered samples were not required.

The CuCC samples were spiked with 25 µl of 0.8 mM $CuSO_4$ in the chemistry lab at the end of each sampling.

Due to the timing of the TM sampling, either at night or the early hours of the morning, no blank samples were taken away from the ship on the Zodiac.

Leg 2

Leg 2 was used to conduct JGOFS time series studies to complement the transect data collected on Leg 1. These studies addressed physical, chemical and biological processes and their variation on time scales of hours to days, and space scales of tens of kilometres, at each of two sites.

The transect data from Leg 1 along 155^0 E showed a strong surface salinity front between 2^0 and 3^0 S, and a strong subsurface salinity front between 2^0 and 3^0 N. These data also indicated a general deepening of the chlorophyll maximum from south to north, and relatively high production at 3^0 S. The time series sites were therefore chosen to be 0^0 S, 155^0 E and 3^0 S, 155^0 E. It would have been desirable to conduct a third station at 3^0 N, 155^0 E but this was not possible in the cruise time allocated.

The water column structure at each site on Leg 2 was established by an initial CTD cast to the bottom. A free-floating sediment trap was then deployed, and followed for about 72 hours. During this period, an intensive study was made of processes related to production and carbon flux in the top 300 m. Repeat CTD casts were made to 300 m, providing continuous profiles of T, S, DO, PAR (in daylight hours) and chlorophyll fluorescence. Water samples from 0, 25, 50, 75, 100, 125, 150, 200, 250 and 300 m were analysed for standard hydrology (salinity, DO) and inorganic nutrients (nitrate, nitrite, silicate, phosphate). The depth closest to the chlorophyll maximum (typically 75 m) was shifted to sample the chlorophyll maximum. Standard nutrient samples were unfiltered, but filtered nutrients were measured at 0, 50, 75, 100 and 125 m for comparison. Filtered samples from 4 stations at each site were collected and frozen for total dissolved nitrogen (TDN) analysis on shore.

The repeat CTD stations were divided into two categories on the basis of the primary production studies. One day was devoted to a study of diel variation in photosynthetic parameters. Stations were conducted at 0200, 0800, 1400 and 2000, and ^{14}C incubations carried out at each of 5 depths (0, 25, 50, 75, 100 m) at each station. For each depth, P vs I curves were measured by incubating small subsamples (7 ml) for 1 hour at each of 18 light intensities (plus triplicate darks), using a modified photosynthetron.

On the other two days at each site, a reduced set of ^{14}C incubations was carried out to investigate day-to-day and local spatial variability. Stations were conducted at 0800, 1400 and 2000, and samples from 3 depths (0, 50 and 75 m) were incubated at 9 light intensities (plus triplicate darks), chosen to give estimates of the initial slope and maximum value of the P vs I curve. One station at each site was used to compare photosynthetic parameters under blue light and white light illumination. All other incubations were carried out under blue light.

At the first site, one station at 0800 was used to conduct time series incubations in vials and in 2 l polycarbonate bottles. Samples from the surface and the chlorophyll maximum were incubated on deck under neutral density mesh screens and blue film at light intensities corresponding to 1.7, 4 and 17 % of incident solar irradiance. Subsamples were harvested and filtered at 1, 2, 4, 8, 12 and 24 hours.

Bacterial production was measured using the tritiated thymidine method. Samples were incubated from each of 3 depths (0, 50 and 75 m) at 2 productivity stations (1400 and 2000) at each site.

A prototype CCD-based spectroradiometer was used, together with a commercial 8-band radiometer, to obtain vertical profiles of downwelling spectral irradiance $E_d(\lambda)$, upwelling spectral irradiance $E_u(\lambda)$, and upwelling spectral radiance $L_u(\lambda)$, at 0900 and 1300 h each day. The profiles were conducted on the sunny side of the ship, and the HIAB crane was used to allow profiles to be made about 8 m clear of the ship's side.

Zooplankton samples were obtained at each station by hauling a 0.25 m^2 ring net (200 μm mesh) from 200 m to the surface. Samples were preserved in formalin.

Large volumes of seawater (approximately 60 l at each of 4 depths) were collected and filtered for lipid analysis at 2 stations on each site.

Forty litre samples from each of 6 depths were collected and filtered, and both filtrate and filters processed and retained for D. Smith, University of Melbourne. The samples will be analysed for Pb/Th isotopes to provide alternative estimates of particle flux.

The sediment trap arrays were modelled on the Knauer design. Each array consisted of 8 individual cylindrical traps fixed to a welded aluminium cross-frame. Two arrays were deployed at 200 and 700 m depths on a single mooring attached to a surface buoy array fitted with flashing light and radio beacon. After recovery, trap contents were filtered through 47 mm precombusted GF/C filters, and frozen desiccated. One filter from each depth was analysed immediately for HPLC pigments.

The PAR sensor was deployed at productivity stations during daylight hours, on a separate CTD cast as it is only pressure-rated to 300 m.

Water samples were filtered for nutrients (nitrate, nitrite, silicate, phosphate) at productivity depths at productivity stations only (75 samples). Filtered samples were analysed on board at the same time as the unfiltered OMS nutrients.

Zooplankton samples were collected at each productivity station by hauling a ring net (mouth area 0.25 m^2, mesh diameter 200 μm) from 100 m to the surface. Samples were preserved in 4% formaldehyde for subsequent determination of biomass and dominant taxa.

At the Equatorial site, the sediment trap drifted slowly ESE, covering ca. 30 nautical miles in 3 days. The (uncalibrated) ADCP data indicate SE flow at ca. 0.5 m s^{-1} above 150 m, and ENE currents at ca. 0.5 m s^{-1} at 200 m. There was relatively little evidence of diel or day-to-day variation in the physical or chemical structure in the water column. A strong pycnocline extended from ca. 60 to 120 m, with a very pronounced subsurface chlorophyll maximum at ca. 75 m. There was considerable diel variation in photosynthetic parameters. The sediment traps at both 200 and 700 m collected a significant amount of material, as judged by colour on the filters, and shorter deployments may be possible in future.

After deployment at 3^0 S, the sediment trap array drifted SW, and appeared to become entrained in the circulation around an atoll group at 3^0 18' S, 154^0 44' E, eventually travelling south just to the east of the islands. The physical structure was characterised by a shallow mixed layer to ca. 40 m, and a series of strong stepped pycnoclines to ca. 250. The chlorophyll maximum at about 50 m was very pronounced, and production was higher than at the Equator. The amount of material collected in sediment traps was again large.

As on Leg 1, approximately 6 to 9 l of water from the top 7 depths were filtered for HPLC analysis of pigments on board. Samples were also collected from all depths for HIAC particle size analysis. Cyanobacteria samples were collected from all depths and frozen for later analysis. Phytoplankton samples were collected on filters for SEM analysis from 0, 25, 50, 75 and 100 m on one station at each site. A detailed profile of similar samples at 10 m intervals through the subsurface chlorophyll maximum was also obtained on one station at the second site.

PRELIMINARY RESULTS

Objectives

1) To measure vertical and horizontal profiles of pH, carbon dioxide and fluorescence in waters of the western equatorial Pacific Ocean.

The new pH sensor from Titron did not arrive in time for the cruise and we were unable to run the underway fluorometer since the seawater supply was inadequate. The lack of underway fluorescence was not a great liability since the surface Chl *a* concentrations were very low and previous experience indicated that surface fluorescence was not well correlated with measurements of Chl *a* integrated through the water column.

Underway measurements were made of pCO_2 and pH and, although changes of about 10 - 15 µatm were commonly observed over distances of about 60 km, the surface waters were approximately in equilibrium with the atmosphere. The pCO_2 results are still being worked up but they are in general agreement with pCO_2 values calculated from pH measurements. However there are large variations in pCO_2 as can be seen from Figure 1. The data is similar to that obtained during FR08/90 although there was less variability in 1990.

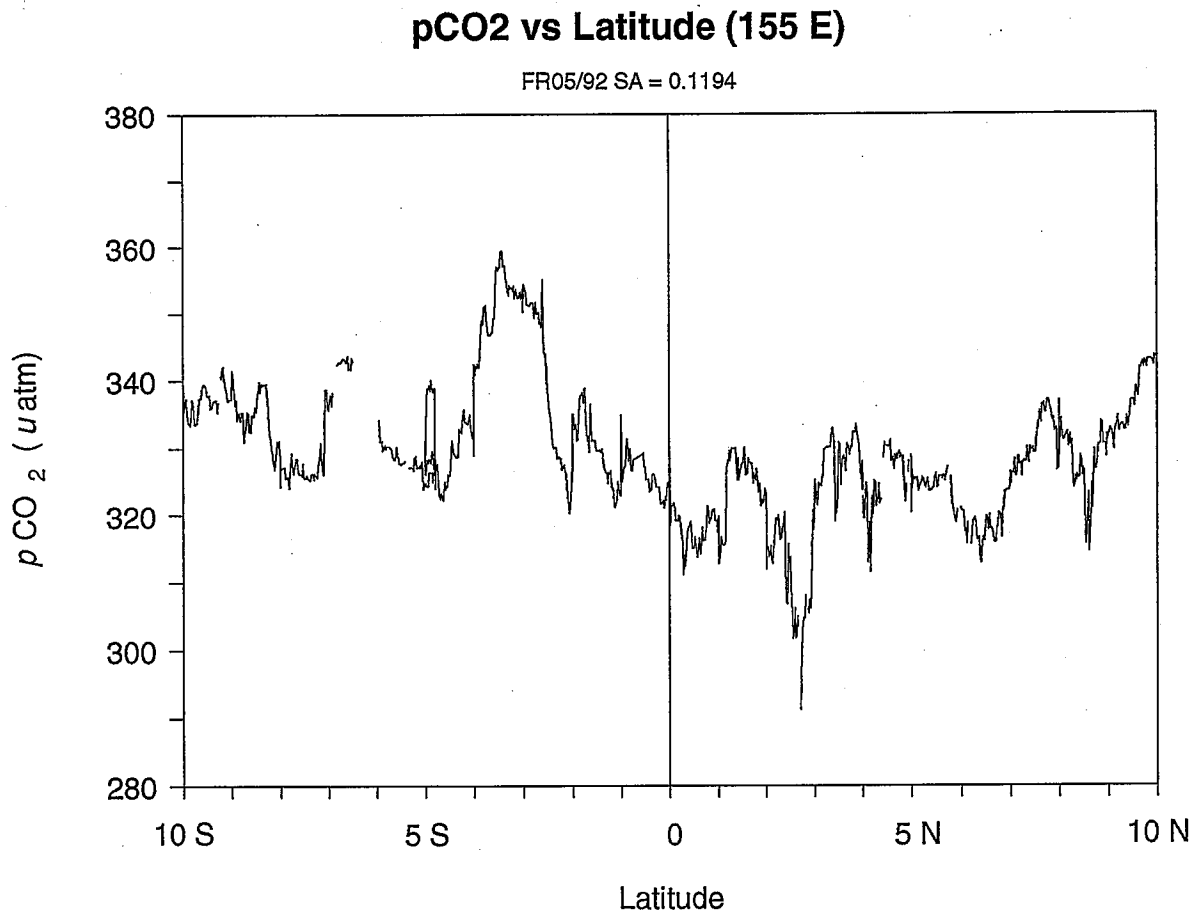

Figure 1

The air conditioning in the GP laboratory could not cope with the heat produced by the instruments and we were unable to analyse samples for DIC and alkalinity during the cruise. Samples were collected for analysis back in Hobart.

2) *To study the primary and secondary productivity of these waters.*

Results have not yet been standardized to production per unit chlorophyll, but peak production in mg C fixed per hour was found at the surface at 1.5° S, 147° E and 3° S, 155° E. At the other 13 stations production peaks were associated with the chlorophyll maximum, which varied in depth between 60 and 115 m.

3) *To study the physical, chemical and biological processes that determine the vertical fluxes of carbon across the air-sea interface and within the water column.*

The SeaTech fluorometer was invaluable to the cruise in that it enabled us to collect samples from the deep chlorophyll maximum. The fluorometer was calibrated with Chl *a* measurements determined on board by HPLC. The correlation between fluorescence and Chl *a* was given by the equation:

$$\text{Chl } a = 0.0124 * \text{SeaTech} + 0.027 \ (r^2 = 0.698)$$

Compared to the calibration obtained during FR08/90, the correlation coefficient was lower and the slope of the calibration was lower by about 20%. Concentrations of Chl *a* were generally about 0.1 $\mu g\ l^{-1}$ rising to about 0.4 $\mu g\ l^{-1}$ at 50 - 100 metres. The depth of the chlorophyll maximum increased from south to north along 155° E (Figure 2).

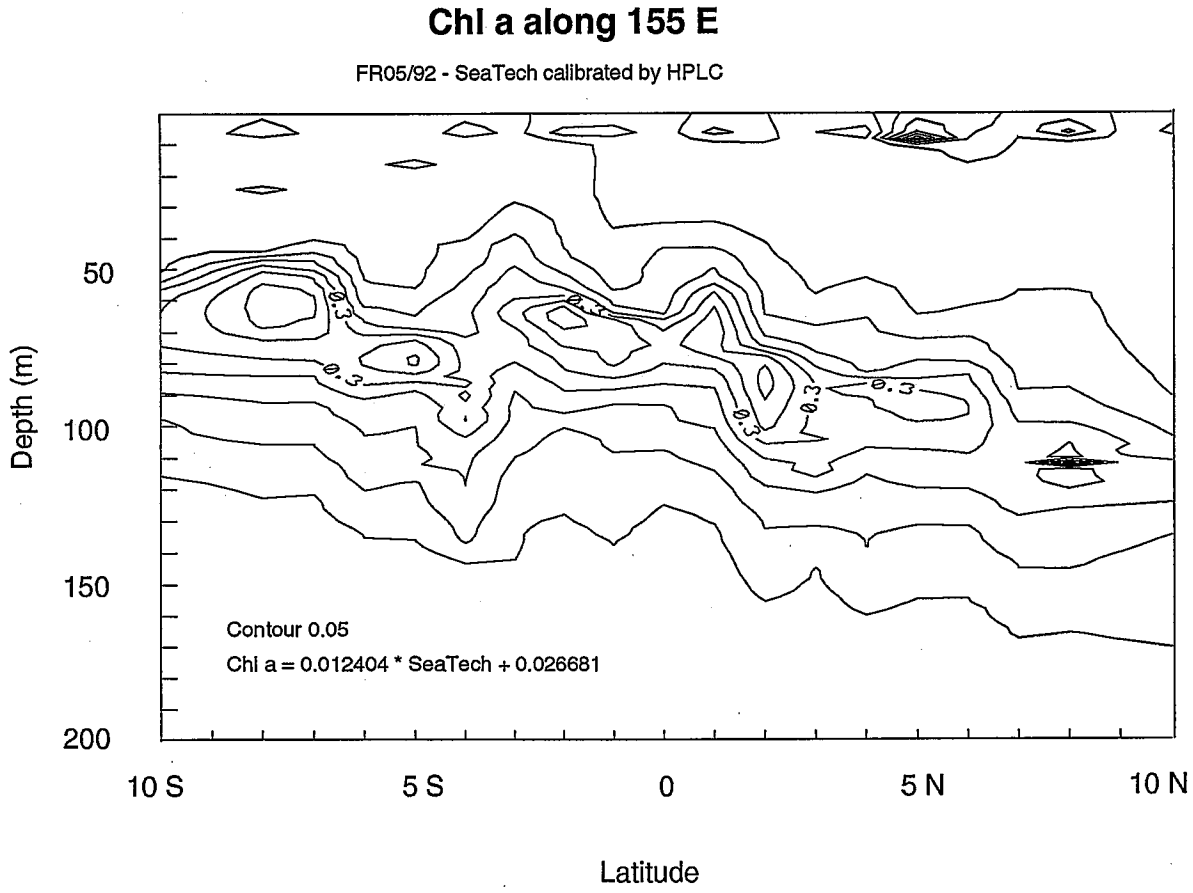

Figure 2

Samples were collected for later analysis of lipids, pigments, bacteria, cyanobacteria, trace metals, copper complexing capacity, DIC and alkalinity. The preliminary fluorescence and hydrology data were used to determine the protocols for Leg 2.

4) *To study the chemical and physical processes leading to increased biomass along the equator at the western boundary of the Pacific Ocean.*

The data on productivity, light, salinity, temperature and nutrients will be used to study the processes controlling the biota in this region. Extended measurements were made during Leg 2. We also attempted to get information on the particulate fluxes out of the euphotic zone by deploying floating sediment traps and by collecting samples for estimating these fluxes from measurements of the disequilibrium between the naturally occurring radionucleides $^{210}Pb/^{226}Ra$ and $^{210}Po/^{210}Pb$.

5) *To use chemical methods, particularly lipid and pigment analyses, for characterisation of the phytoplankton community structure within different water masses.*

Samples were collected and analysed on board for chlorophylls and carotenoids. The data has been processed to provide quantitative information on chlorophyll *a* concentrations for calibrating the SeaTech fluorometer. The pigment analyses showed high proportions of zeaxanthin and α-carotene highlighting the importance of prokaryotic organisms (cyanobacteria and prochlorophytes). Chlorophyll *b* from green algae was also significant at some stations. The major carotenoids were butanoylfucoxanthin and hexanoylfucoxanthin from prymneseophytes. The processing of the data for the other chlorophylls and the carotenoids will be done back in Hobart. Samples will also be analysed in Hobart for lipids.

PERSONNEL

Ship's Crew		**Scientific Staff**
Master	Neil Cheshire	Denis Mackey (Chief Scientist - Leg 1)
Mate	Dick Dougal	John Parslow (Chief Scientist - Leg 2)
2nd Mate	Bryce Bathe	Bob Beattie (Cruise Manager - Leg 2)
Chief Eng.	John Scott	Bronte Tilbrook (Leg 1)
2nd Eng	Peter Harding	John Volkman (Leg 2)
Elec. Eng.	John Browne	Harry Higgins
Bosun	Jannick Hansen	Val Latham
AB	Bluey Hughes	Jeanette O'Sullivan (Leg 1)
AB	Kris Hallen	Ros Watson (Leg 2)
AB	Wayne Browning	Erik Madsen (Leg 1)
Greaser	Jeff Snell	Phil Adams (Leg 2)
Steward	Dave Ramsay	Dave Terhell
Ch. Cook	Gary Hall	Danny Holdsworth (Leg 1)
2nd Cook	Bob Clayton	Don McKenzie (Leg 2)
		Pru Bonham
		Teresa O'Leary
		Mark Pretty (Leg 1)
		Brian Griffiths (Leg 2)

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