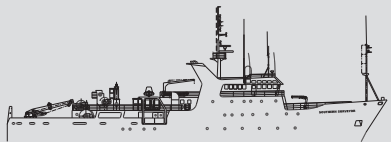

MARINE
NATIONAL FACILITY

2006 program

RV *Southern Surveyor*

CSIRO

voyage summary SS09/2006

SS09/2006

A comparison of nutrient supply processes and biological productivity in upwelling and frontal regions of the Lord Howe Ridge.

Itinerary

Depart Sydney 1030 Wednesday 27th September, 2006
Arrive Sydney 0730 Tuesday 11th October, 2006

Principal Investigators

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Scientific Objectives

The behaviour and significance of the East Australia Current (EAC) and its Tasman Front is the least understood when compared to the other four major western boundary currents of the world, yet its influence dominates Australia's phytoplankton and most likely the fisheries stocks of the region. Its role in the biogeography of tropical fauna, the early life history of the South East trawl fishes and the nutrient budgets is largely unknown. Past Franklin and *Southern Surveyor* voyages have revealed the mechanisms and significance of the EAC's separation zone off northern NSW. Farther offshore, we began investigating the Tasman Front in September 2004. Even farther east, the Tasman Front interacts with the Lord Howe Rise, and Middleton and Elizabeth reefs, with anecdotal evidence of 3 to 5°C temperature fluctuations and up to 3 to 5 knot currents, and sporadic chlorophyll concentrations. In this region, the nearshore and slope current circulations and their effects on biological productivity are unknown.

Our aims are:

1. To extend our physical and biological study of the Tasman Front to the Lord Howe Rise, a region recognised for its significant conservation value and unusual combination of temperate and tropical species;

2. to study the dynamics and significance of currents and upwelling around the Lord Howe Rise; and

3. to further assess our coupled oceanographic-zooplankton models of oligotrophic and eutrophic waters that occur in that region.

Voyage Objectives

The on-board observational program will utilise the following observational equipment:

(a) CTD casts at stations along transects of the Tasman Front and Lord Howe topography, using the full rosette sampler and fluorometer. We will take standard nutrients (nitrate, phosphate, silicate), salinity and oxygen at up to 8 depths at each station. Transects will have casts to 300 or 500 m depth.

(b) ADCP and SeaSoar profiles along transects at 8 knots. The SeaSoar will have the UNSW Optical Plankton Counter mounted.

(c) Neuston net samples simultaneously with Rectangular Midwater Trawl (RMT) plankton samples from the stern. Nearly all plankton sampling will take place at night, usually between 1900-0000, but where pilchard or gemfish larvae are particularly abundant we plan to sample them during the day as well. Plankton will be preserved in 5% formalin at an appropriate location on the back deck. The first and last tows of the 3 replicates will be iced and be pre-sorted for pilchard larvae for separate preservation in 95% alcohol.

(d) Recent SST and ocean colour satellite images will be downloaded throughout the voyage to ensure transects are related to current/topography areas of interest.

(e) Underway measurements of SST and fluorescence from automatic analysis of engine intake waters.

(f) A single mooring will be deployed at the saddle point between Lord Howe and Ball's Pyramid, for the period of a few days that the ship will be working in the region.

Operationally the decisions as to locations of transects can only be made with current knowledge of the position of temperature fronts and ocean colour. In general, we plan:

1) By day to make CTD casts at stations along 2 -3 cross-frontal transects of the Tasman Front, 4 -5 transects of the Lord Howe region and 4 -5 transects of the Elizabeth/Middleton Reef region, using the full rosette sampler and fluorometer. We anticipate there will be a total of 12 transects, each with 10 stations, with casts to 300 or 500 m deep, and each 10-15 nm long. Transects 1 to 3 will lie on the Tasman front, in deeper waters west of the Lord Howe Rise. Transects 3-12 will be 8-12 nm long and will lie in regions where steep topography in the 50m to 300m depth range is also associated with strong currents upstream or wakes downstream. The shallowest stations will be at the 30 m isobath.

2) By day: to separately undertake ADCP and SeaSoar (with optical plankton counter) profiles along these transects at 8 knots. We plan to conduct some ADCP and SeaSoar transects at slower speeds for finer spatial resolution, depending on the circumstances at the time.

3) By night to take neuston net samples simultaneously with Rectangular Midwater Trawl (RMT) plankton samples from the stern, at 3 locations across each transect. At each location a CTD cast to 300 m may be made (minimal rosette sampling), before undertaking three replicate 10 minute plankton tows at ~3 knots at each location, and then steaming onto the next location. We anticipate that pilchard larvae and the plankton sizes will vary in size according to water mass and location relative to the front and topography.

   Notes on the RMT. It is 2 m wide and 75 cm deep, with a 7 m long net of 1.0 mm mesh. It has a top and bottom bar, with the bottom bar containing 100 kg lead, and supporting two lead rollers of 25 kg each. Within the triangle of the tow bridle there will be a small 20 cm diameter, 0.1 mm mesh plankton net with the cod end loosely attached to the RMT net, to prevent foul-ups. There are no electronics: it has a GO flow meter and a self contained time-temperature-depth recorder. We will bring two complete RMTs on board.

4) By night to conduct ADCP and SeaSoar profiles back along the transects at 8 knots (generally between 0000 and 0300. If time permits additional RMT tows will be made at the Front, before steaming north to the next transect of CTD stations starting around 0700. Plankton sampling may be more limited at some transects, depending on conditions.

Results

The Lord Howe Rise and Middleton/Elizabeth Reefs are part of a linear chain of volcanic islands and seamounts, caused by the relative motion of the continental crust over a volcanic hot spot. As a consequence the flanks of the island shelves and seamounts are extremely steep, approaching 450m in some places. The impact of the EAC extension on the region is thus interesting from both a physical and biological perspective.

The key achievements are best described by reference to the regions of observation. These were the Tasman Front, the Lord Howe Island region, and Middleton Reef. In each case our primary activities were CTD profiling, SeaSoar/ADCP surveys (the Seasoar was fitted with a particle counter) and net tows. The methodology was to determine the direction of prevailing currents, and undertake a Seasoar/ADCP survey to determine the general hydrographic structure of the water column and the general structure of current circulation. Based on this data, net tows were then undertaken to determine the biological productivity. In addition a set of CTD stations (with water samples) was undertaken to determine the nutrient, dissolved oxygen and vertical property fields. Logs of CTD stations are attached as Appendix 1, and net tows as Appendix 2.

At the time of the voyage the area was highly complex, with patches of EAC and temperate waters intermixed, and in continuous motion relative to each other. Thus there was no well-defined Tasman Front crossing to the Lord Howe area as we originally envisaged. Currents were however strong enough in the vicinity of topography to generate significant vertical and horizontal flow disturbances over the Taupo Seamount, the Lord Howe and Ball's Pyramid area and Middleton Reef. These features are described below.

The Tasman Front

This area includes the EAC directly offshore Sydney, and the Taupo Seamount. On transit east to Lord Howe the Taupo Seamount was observed using the SeaSoar/ADCP during a single east-west crossing. Spectacular variations of temperature, salinity, dissolved oxygen and fluorescence, occurring as a result of a current flowing from west to east over the Seamount, were noted. On return to Sydney the seamount was investigated far more extensively, with a SeaSoar/ADCP survey along east-west transects covering the majority of the seamount area, followed by net tows and a CTD survey. In addition, net tows were completed at four locations between Taupo Seamount and Sydney on the return leg, along what appeared to be a filament of the EAC flowing toward the north-east.

In general we found fewer larval fish at the eastern endmost regions of the EAC (154°E, 155°E) but increasing numbers were found towards the coast at 153°E and 152°E. Most remarkable of all was the opportunistic sampling of a cold core eddy, just to the east of Port Stephens at 33° 10'S, 152° 41'E, characterised by strong clockwise circulation, and a decrease in surface water temperature of nearly 2°C accompanying an increase in fluorescence. A CTD cast in the centre revealed a shallow sub-surface chlorophyll maximum. Rectangular midwater trawl tows revealed the greatest abundances of fishes and zooplankton on the voyage, including larval pilchards, 20mm juvenile blue mackerel, trevally, leatherjackets and a large assortment of lanternfish (Myctophids). Outside the eddy in the EAC waters we found relatively few Myctophids and some larval pilchards.

Lord Howe Island

At Lord Howe Island a shallow water ADCP/SeaSoar current survey was undertaken across the wake downstream of Ball's Pyramid, a remarkable basaltic monolith rising 552m into the air from a base only slightly wider than its height, in a water depth of relatively constant 25-35m. The wake was easily observed in ADCP and fluorescence transects, and later will be compared with model predictions from ROMS (the Regional Ocean Modelling System).

Almost seven days of current meter time series data at 15s intervals was obtained from a current meter mooring located in 350m depth in the canyon between the Lord Howe and Ball's Pyramid shelves. While the data remains to be fully analysed, preliminary analysis indicates a flow from west to east through the canyon, modulated by internal tidal currents, with displacements of 50 to 60m vertically. Maximum currents observed were less than 1knt.

A CTD Survey was undertaken with 18 CTD stations located strategically around the entire Lord Howe and Ball's Pyramid area. While the nutrients remain to be analysed, the temperature and salinity data show episodic uplifts of colder (and presumably more nutrient rich) waters onto the shelf proper, from a surrounding ocean having horizontally varying properties.

A larger scale ADCP/SeaSoar Survey on the eastern and western flanks of the area confirmed this general result, with fluorescence maxima occurring near the shelf break areas, probably a result of internal variability in the offshore oceans along these continental margins.

Middleton Reef

This reef was chosen for investigation due to its conical shape, which arises steeply from ocean depths of over 2000m to the surface, and its steep sides. The horizontal extent of the reef proper at the surface is approximately 5nm.

The area was investigated primarily to determine the nature of flow disturbances, particularly upwelling and wake regions, and the biological influence. The combination of ADCP/SeaSoar transects upstream and downstream of Middleton Reef showed a typical wake, evident in temperature, salinity and fluorescence data, and confirmed by the horizontal current structure, flowing 2 to 3km downstream of the reef. Larger scale synoptic features of a warm core patch to the east of the reef served to confuse the issue farther downstream.

Net tows along Transect T2 located 2nm downstream of the reef showed fish species typical of tropical coral reefs within the wake, while outside the wake species were primarily pelagic. While not yet fully analysed. The CTD survey data also showed clear evidence of flow disturbance through vertical variations of hydrographic parameters upstream and downstream.

It is planned to later utilise the ROMS model to simulate the observed physical processes, and to elaborate on the responsible physical mechanisms.

Voyage Narrative

All times listed in this narrative are given in Eastern Standard Time (EST)

Wednesday 27th September

At 1030 RV *Southern Surveyor* departed from No 4 White Bay. We left Sydney Harbour Heads on a north-easterly heading to Lord Howe Island, undertaking CTD 1 in 150m depth at 1530 on the continental slope. We then collected 4 surface net tows, beginning at 33° 45'S, 151° 44'E from 1645 to 1730 (the SeaSoar and coring winch were not available for the RMT at that stage), then continued heading northeast towards Lord Howe Island.

Thursday 28th September

We dropped off a New Zealand owned satellite tracked buoy at 32° 50'S, 155° 30'E at time 1230. Heading to the southeast the SeaSoar was deployed heading toward the centre of an eddy deduced from satellite altimetry. At 1545 we undertook CTD 2 to1000m to test for bottle integrity at 33° 06.8'S, 155° 52.6'E, then undertook two

surface net (505, 506) and RMT tows (705, 706) from 1700 to 1730. Heading due east along 33° 05S, we undertook a SeaSoar and ADCP Transect across Taupo Seamount. Subsequent preliminary processing of the SeaSoar data by Lindsay Pender revealed a dramatic internal wave on the lee side of the seamount. On the eastern side of Taupo Seamount we conducted CTD3 at 2200 to 600m depth, then continued tracking toward Lord Howe Island.

Friday 29th September

The Surveyor arrived to the south east of Lord Howe at 1050, and we conducted CTD 4 in 2950m of water at 31° 50.03'S, 159° 00.1'E. The *Southern Surveyor* was then positioned to a point 1nm to the north of Ball's Pyramid to ascertain the current direction. Based on the current flowing from the north a set of ADCP and SeaSoar transects were undertaken from upstream to downstream of Ball's Pyramid. These were labelled T1 to T5. On completion of half of transect T5 the SeaSoar developed technical problems and the SeaSoar/ADCP transects were temporarily suspended.

The ship relocated north to deploy a mooring on the saddle between the island shelves at 400m depth at 31° 39.9'S, 159° 13.04'E. This mooring was deployed at 1934.

The vessel then returned to begin net tows beginning at T1. Three replicate 10 minute tows at 20m depth were taken on each transect T1 (2nm upstream), T2 (2nm downstream), T4, T7 and T8, finishing with samples 521, 721, 921. These were undertaken through the night finishing at 0215. Considerable plankton biomass (mostly salps) was evident in the nets at T2 and T8.

Saturday 30th September

On completion of the net tows, a set of 19 CTD's began with CTD 5. The objective of this set of CTDs was to determine the general hydrography of the oceans surrounding the Lord Howe Island area. The set was begun with CTD5 at 0503 and these continued through the day, ending at CTD 24, when unfortunately a technical problem resulted in the CTD system being lost. The location and seabed characteristics were noted with a view to later retrieval attempts. A weak cold front passed through the area about 0330, with the wind changing from northwest to southwest and increasing in speed to about 25knts. Seas rose slightly, and the Surveyor began the transit north to Middleton Reef.

Sunday 1st October

On arrival at Middleton Reef, a set of SeaSoar/ADCP transects was started. These were undertaken assuming the current was flowing toward the southeast, which seemed evident from ADCP measurements made north-west of the reef. Transect T1 was upstream of Middleton Reef, while transect T2 was across current (direction 0600M) and 2nm downstream of the reef at the closest point. Transects T3, T4 and T5 were parallel to T2 and progressively further downstream of the Reef. In the middle of T5, the *Southern Surveyor* turned north to head directly up the axis of a current shear, and the SeaSoar was brought aboard at 0030.

A time series of 13 RMT tows (no surface net) was subsequently run along Transect T2, beginning in the north-east and ending at the southwest, from 0140 to 0530 (sunrise). The transect nicely encompassed 0.25m/s currents to the south at either end, and confused (wake) currents in the middle.

Monday 2nd October

The net tows at transect T2 were completed at 0530, and the SeaSoar reconnected. The *Southern Surveyor* then began a clockwise repeat of T1, and on arrival at the downstream region, began a new Transect (T1.5) at closer spacing the reef (closest point 1nm). This transect was completed along 2400m. Subsequently transects T2, T3, T4 and T5 were repeated and the SeaSoar/ ADCP work completed about 1830. These parallel transects were 3nm apart.

The ship returned to the north-eastern end of T2 transect (ie 2nm downstream of the island) and nightly RMT tows began at 1825. We completed 12 tows along T2 (or M2, identical to the previous night), then repositioned 2nm further downstream and began a parallel transect M2.5 beginning at the south-western end at 2200. After 10 RMT tows we then moved to a 3rd transect, a further 2nm downstream (M3.5) beginning at 0114. The ADCP currents began to reveal the presence of a warm core eddy at the north-eastern end of the transects, with stronger westerly and southwesterly currents. A total of 9 RMT tows were made along M3.5, and 5 were made along M4.5 (2nm further downstream) but only half of this transect – to the middle – was completed before sunrise. In total, 36 RMT tows with the associated fine mesh net were made (#735-770). Transects M2 and M2.5 had weak currents of 0.1-0.2 m/s, but flow disturbance downstream of the reef were evident in the middle. Remarkably what appeared to be the wake regions had high concentrations of larval fish, while the free stream tows were dominated by distinctively black, 1-3cm long juvenile myctophids (Diaphus?). At M3.4 and M4.5 the currents were more diffuse.

Tuesday 3rd October

During the previous 48 hrs the CMAR team had been busily building the standby CTD system, and it was ready for deployment. On completion of net tows at 0545, the ship began a CTD survey beginning at CTD 26 and running through the day and evening. CTDs 26 to 33 were taken upstream of Middleton Reef, while CTDs 34 to 37 were undertaken along Transect 2, CTDs 38 to 40 along Transect 3 and CTDs 41 to 43 along Transect 4. The survey was completed with CTD 43.

Wednesday 4th October

The CTD survey was completed at 0400, and the ship immediately headed south, returning toward Lord Howe. At 1530, the Surveyor arrived at the northern most slope of the Lord Howe shelf, and CTD 44 was undertaken.

On completion the vessel began a SeaSoar/ADCP survey running SSE-NNW along the eastern edge of the rise. This survey was aimed at determining the oceanic structure along the eastern margin. The survey proceeded into the evening, and into the following morning. Survey lines were:

- Transect 1 from (31° 22'S, 159° 04E') to (31° 50', 159° 22'E) (SeaSoar -25m depth)
- Transect 2 from (31° 50'S, 159° 24E') to (31° 22', 159° 06'E)
- Transect 3 from (31° 22'S, 159° 08E') to (31° 50', 159° 26'E)

Thursday 5th October

On completion of the SeaSoar/ADCP survey, the vessel relocated to the site of the lost CTD, where recovery operations were begun. Trawling was undertaken for 2 hours but the grapnels got snagged and came up empty and bent! The *Southern Surveyor* then moved south to the current meter mooring site, where mooring release was attempted without success. Into the evening, SeaSoar/ADCP transects were undertaken on the western side of Lord Howe Island, running in NNW-SSE directions. Transect T1 was undertaken on the continental shelf running NNW. Transect T2 was located 1nm to the east of T1 running SSE, and T3 in deepest water 1nm to the west of T2, heading NNE. On the retrieval of the SeaSoar, it was kept at 10 m depth while a fine mesh neuston net was deployed for calibration (#971, 972 – but large quantities of salps precluded keeping a quantitative sample).

Friday 6th October

At the completion of Lord Howe Island west Transect T3 the ship repeated T1, heading SSE and then returned to the current meter mooring site, arriving at daybreak. The work boat was deployed at 0600, and the mooring was successfully released and retrieved into the workboat, which was subsequently recovered aboard *Southern Surveyor* at about 0730.

The Surveyor then moved again to the site of the lost CTD where grapnel operations began at 0915 to retrieve the CTD. These operations proceeded throughout the day, but the seabed is evidently very rocky and the grapnels got hooked up many times. Finally the grapnel operations were completed around 1900 (unfortunately without success), and the Surveyor headed off to Taupo Seamount.

Saturday 7th October

On arrival at Taupo Seamount, we began a survey to determine the nature of flow disturbance and its effects on physical structure, currents, nutrient uplift and the biological response to the overall flow disturbance.

The first component in the study was a SeaSoar survey running east-west across the seamount. Transect T1 of the Taupo SeaSoar survey began at 0915 on the eastern side at latitude 32° 57.7'S, travelling west. Transect T2 began on the west side at latitude 33° 04.6'S and headed east, and Transect 3 began about 2000 at 33° 10.0'S.

Sunday 8th October

Transect T4 (at 33° 15.0'S) was completed about 0400, and the ship steamed north to the intersection of T2 at 33° 05'S, 156° 23.3'E. An attempt was made to tow the Sea Soar and OPC at 4 knots, during a surface net tow with a fish mesh net for comparison (two samples, #973, 974 but SeaSoar was not logging. A line of CTD's began with CTD 45, heading west to cross the seamount and determine the hydrographic and nutrient structure. The first four stations in over 1000m of water east of the seamount showed little difference, while more structure was seen over the seamount proper. The CTD section was completed with CTD 57 at 1900.

The RMT net was subsequently deployed, working along the 30° 05'S parallel west to east, taking tows throughout the night in blustery conditions with a strong wind and swell rising from the south. The aim was to take samples in free-stream current (ie away from any influence of the seamount), on top of the seamount, and at an intermediate distance between these two extremes. This was done on both the western and eastern sides. The transect began west of Taupo Seamount, 33° 05'S 155° 56'E (net sample starting #775, finishing with #792), and 3 tows were taken at each of six stations along the transect, making a total of 18 RMT samples taken (and 18 fine mesh plankton samples). No surface tows were undertaken here because of the windy conditions.

Monday 9th October

At 0400, the last SeaSoar deployment was begun, with the *Southern Surveyor* heading north to obtain an east-west transect at the northern end of the Taupo Seamount. The SeaSoar was recovered at 1000. During recovery the SeaSoar was towed at 10m depth at 4knt during two 10min surface tows with the fine mesh net for comparison with the OPC (#993, 994). The ship repositioned to begin the last CTD (CTD 58), this being the continuation of the section along 30° 05'S that was begun the previous day.

On completion of the Taupo work the *Southern Surveyor* began its return to Sydney, accomplishing RMT plankton net tows enroute at 4 regions along the East Australian Current at approximately 1 degree longitude intervals. An initial station of 3 tows was made during sunset (#795-797), but sampling began in earnest after dark at 2100, Region 1 (33° 00 S, 155° 00 E) with two stations of three tows each (#798-803), and 0300 on Tuesday 10th with 2 stations of 3 tows each (33° 30'S, 154° 00'E, #804809).

Tuesday 10th October

Region 3 (1530 00'E) was sampled with the RMT at 1000 (#810-816). On completion of net tows at 33° 40'S, 153° 10'E a SeaSoar tow was made into the centre of a cold core eddy located at 33° 20'S, 152° 50'E (based on an image of 7th October). The SeaSoar was brought on board with mechanical problems and we continued to steam towards the cold core eddy. The ADCP revealed strong clockwise currents around the eddy, diminishing at the core. At the core the temperature was nearly 2°C cooler than in the EAC, and had higher fluorescence. A final CTD was made (CTD 59) with nutrient and water samples taken at 500m and at the surface. Two groups of 3 RMT tows were made (#817-822) where we caught the highest abundances of larval and juvenile fish of the voyage including blue mackerel, pilchards, trevally, leatherjacket and many Myctophids.

Wednesday 11th October

The final scientific observations were comprised of net tows at Region 4 (33° 30'S, 152° 00'E), where we found very little zooplankton (RMT #823-828). Following these tows the *Southern Surveyor* headed for Sydney Heads to meet the Pilot at 0630.Following net tows in the early hours just offshore Sydney, the Surveyor entered Sydney Harbour at 0700 and tied up at no 3 White Bay at 0730.

Summary

We are pleased to report that we met all voyage objectives, and in addition were able to opportunistically examine flow over the Taupo Seamount, and characteristics of an itinerant cold core eddy which was located south-east of Foster toward the end of the Voyage.

In particular we were able to confirm our original assumptions that the influence of the extended East Australia Current on the topographic features of the Lord Howe Ridge does indeed induce nutrient supply and biological productivity. Further the variability of the EAC and the Tasman Front is also confirmed as a region of productivity, with cold-core eddies which are associated with clockwise gyres and thin surface mixed layers also being observed as regions of high biological productivity.

Personnel

Scientific Participants			Marine Crew	
Jason Middleton	(UNSW)	Chief Scientist	Ian Taylor	Master
			Samantha Durnian	First Mate
Iain Suthers	(UNSW)		Brent Middleton	Second Mate
Mark Baird	(UNSW)		John Morton	Chief Engineer
Moninya Roughan	(UNSW)		Dave Jonker	First Engineer
Philippe Estrade	(UNSW)		Seamus Elder	Second Engineer
Debbie Cox	(UNSW)		Russell Williams	Boatswain
Scott Rowe	(UNSW)		John Howard	IR
Greg Nippard	(UNSW)		George Cook	IR
Tom Mullaney	(UNSW)		Gerry O'Doherty	IR
Ash Fowler	(UNSW)		Vince Wesley	IR
Jason Everett	(UNSW)		Alan Sessions	Chief Cook
Lindsay Pender	(CMAR)	Voyage Manager	Terry Reid	Second Cook
			Charmayne Aylett	Steward
Drew Mills	(CMAR)			
Karl Forcey	(CMAR)			

Acknowledgements

We would like to express our heartfelt thanks and appreciation to those most directly involved in ensuring the success of our Voyage, being the supporting scientists from CMAR and the Ships' crew of the *Southern Surveyor*. At all times, with some adversity, the CMAR staff led by Lindsay Pender provided capable and professional support, in a friendly and helpful fashion. Ships' crew were similarly obliging, responding to our adaptive sampling strategy with helpful suggestions, and capable articulation of the vessel and its equipment. Though faced with a variety of operations, and following job hazard analyses, all tasks were performed safely with never a risk to personnel.

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Jason Middleton
Chief Scientist
October, 2006