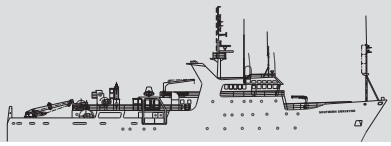


MARINE
NATIONAL FACILITY

2008 program

RV *Southern Surveyor*

CSIRO

voyage summary SS10/2008

SS10/2008

Biological oceanography of coastal cold-core eddies and of salps in the continental shelf waters off the Stockton Bight of eastern Australia.

Voyage period

10/10/2008 to 20/11/2008

Port of departure: Sydney, Australia

Port of return: Newcastle, Australia

RESPONSIBLE LABORATORY

School of Biological, Earth and Environmental Sciences, University of New South Wales
Sydney, NSW 2052 AUSTRALIA

CHIEF SCIENTIST(S)

Prof. Iain Suthers

Scientific Objectives

1) To investigate the biological oceanography of small (<50 km diameter, and possibly large) cyclonic eddies off the Stockton Bight in comparison to coastal waters, possibly in conjunction with an IMOS Slocum Glider in late 2008; and

2) To investigate the ecology and vertical distribution of salps in shelf waters. The spatial pattern of sampling will take into consideration the synoptic and forecast oceanographic conditions from BlueLink.

Voyage Objectives

1) To examine at least two (2) conspicuous eddies, south of the separation zone off Stockton Bight. To test whether a cyclonic eddy has greater zooplankton biomass or production and in larval fish growth in small cyclonic eddies (<50 km diameter, and if possible a large one ~100 km), in comparison to similar sampling in coastal waters.

2) To make at least two SeaSoar and ADCP transects across each eddy. During the day, standard CTD profiles with the rosette sampler will also be used to overlay longer and deeper SeaSoar profiles with nutrients (nitrate, nitrite, ammonia, TRP, Si), which will be particularly intensive near the separation area.

3) To examine the vertical diurnal distribution of salps and krill using EZ and neuston nets. Sampling will occur inside and outside the eddy field and in coastal water to a depth of 100 m. Sampling will take place over continuous 24 hour periods.

Below decks, the net sample will be quickly sorted and 10 individuals of abundant larval taxa will be transferred to NUNC vials and frozen in liquid nitrogen until RNA:DNA analysis; the remainder will be placed in buffered formalin and transferred to 95% ethanol within 4 weeks for otoliths and age determination.

Results – Summary of Achievements

We achieved all 3 target areas that we optimistically outlined in our voyage plan – an offshore eddy, a nearshore one and the Stockton Bight upwelling. Overall we encountered strong currents by the EAC (often around 5 knots) and remarkable abundances of gelatinous salps yet very few krill. While they are of course for just a 1 week period, the observations of a stronger East Australia Current and an increase in gelatinous zooplankton are consistent with projections of regional climate change impacts.

We had 3 significant outcomes: 1) the first sampling of light-nutrient-phytoplankton-zooplankton ecology within cyclonic eddies of SE Australia, and over day-night variation; 2) the observation of a ten-fold increase in salps abundance (gelatinous zooplankton) compared to identical sampling 70 years ago; and 3) identification of three synergistic processes in the Stockton Bight that underlie its renowned productivity and possible role for the South East Trawl fishery. One cruise objective we failed to meet was the simultaneous deployment of an IMOS Slocum glider due to the unavailability of the glider.

For the first time, we have comprehensive data on the structure and biological composition of two distinctive cyclonic (clockwise) cold-core eddies of the East Australian Current (EAC): a large, 120 km diameter offshore eddy, located north of Taupo Seamount, and a smaller, 40 km diameter coastal eddy situated 40 km east of Sydney. Both eddies were evident from remotely sensed currents and MODIS, as well as in the ADCP, CTD and Bunyip data from doming of the isotherms. The offshore eddy was formed as part of the retroflection behaviour of the EAC, and was present for many weeks (months?) before our voyage (i.e. an old eddy). The coastal eddy appeared to originate at the EAC separation zone, south of Smoky Cape in early October (i.e. 10 d before we sampled it). We found considerably more salps in the coastal eddy than the offshore one and many post-larval fish. We examined the response by natural planktonic assemblages to variable daily nutrient mild enrichment (10 µM; nitrate, ammonia, silicate, nutrient mixture) during 72h on-deck incubations. Influence on phytoplankton biomass, dominating group, primary productivity, photosynthetic health and response to light was measured.

We re-created Harold Thompson's N70 vertical haul net used for the 1938-1941 M. V. Warreen cruises, and deployed it at every CTD station. By estimating from our volumes of salps (primarily Thalia democratica), we believe our average abundance

was around 10 times greater than the maximum abundance Thompson observed off eastern Australia 70 years ago. We found roughly equal proportions of the sexual (blue) forms and asexual (brown) forms. We observed no dramatic evidence of vertical migration in the abundance of Thalia democratica over 24 hours in the EZ net. There were comparatively few krill in the EZ net, even at night and usually only in the bottom net (90 m). We found salps were easy to keep in bins of seawater. Despite low concentrations of small <5 um phytoplankton cells, salps seemed to be feeding as evident by their strands of faecal pellets after just 6 hours. Feeding history of salps was investigated by comparing respective stable isotopic signature and by on-board salp grazing experiments using asexual salps. Preferential feeding of salps will be investigated using flow cytometry and HPLC pigments composition.

Strong upwelling was evident in the Stockton Bight and around Broughton Island in response to the strong offshore current. A conspicuous filament of green water was evident near 200 m isobath, off Stockton Beach, which was entrained from off Sugarloaf Pt. This filament was approximately 30 m deep, and similar to one sampled on SS Transit 3-2008 in August. At least 3 separate oceanographic processes led to the evident productivity of the Stockton Bight and around Broughton Island (topographic-separation dynamics, a strong EAC, and entrainment from Smoky Cape). This region, which we refer to as the "Myall-Stockton Shore" (as it is largely adjacent to the Myall Lakes system), includes the continental shelf area southwest of Sugarloaf Point (Seal Rocks), the entrance to Port Stephens and the Stockton Bight. We hope to use autonomous gliders and future research cruises to undertake further investigations of the Myall-Stockton Shore and its interaction with the EAC separation and coastal eddy formation.

Voyage Narrative

All times listed in this narrative are given in Eastern Daylight Savings Time (EDST, UTC = EDST-9). Narrative by Dr Hassler concern the phytoplankton ecology is included in italics.

Friday 10 October 2008

At 1500 hrs RV Southern Surveyor departed from No 4 White Bay in light winds and low swell. We left Sydney Harbour Heads 1600 and turned northeast, undertaking a test CTD-2 in 150m depth at 1630 on the continental slope. We also did the first vertical haul 50 m to surface of an N70 net, originally used by Dr Harold Thompson from the Warreen in 1938-1941. (In fact he sampled with an N70 net at a nearby station (32 50'30", 152 44) on 27 Sept. 1938 and found 7 salps). We made two replicate vertical hauls, finding ~dozen salps in one, and a litre (many thousands of individuals) in the other. (See Appendix for full description of gear, including the simultaneous vertical haul of a 20 cm diameter 100 um mesh net).

After the CTD-2 we proceeded 40 nm along the 200 m isobath to WP2, in search of a small cold core eddy expected near the shelf break and off Newcastle. However the partial MODIS image for Thursday showed it to be closing up like a filament and

as the SeaSoar was not quite ready, we steamed for 20 h to WP 3 (north of Taupo Seamount) for a large and conspicuous cold core eddy. This large eddy seeded with oceanic water should provide a dramatic contrast with the coastal eddy).

The next day's image proved that the possible filament was a classic coastal cold core eddy, and that we actually passed right over it as we turned out into the Tasman and onto WP3. Very strong currents up to 5 knots southward were observed as we entered the EAC. The bridge at 0500 hrs reported change in ocean colour and they paused to dip net at few salps (32 53 153 01).

Some salps from the N70 were trialled in some large bag experiments, and they seemed to live very well.

WP1 33 30, 152 00
WP2 33 00, 152 30
WP3 32 20 155 15

Finished unpacking and setting up.

Practicum of collection and processing of water sample from trial CTD 2. Check of all equipment.

Saturday 11 October

The Bluelink OceanMaps forecasts indicated that the EAC formed a classic (retrograde) U-turn northwards off Jervis Bay. The meander began forming a large warm core eddy at 34 S 154 E, and further downsteam, circled our target cold core eddy. By heading eastwards we crossed the southward and thence northward EAC on our eastward steam, arriving WP 3 at 1700. We experienced slight NW currents, consistent with being located in the bottom SW corner of a clockwise eddy.

We completed the CTD-3 at WP3, ~32 20 155 15 (CTD 3) mainly to collect water for Christel Hassler's primary productivity experiments (to complement those at CTD12).

We then made our first deployment of the SeaSoar-1 along 155 15 northwards, for 40 nm and aiming for 31 40. Slight but persistent NW currents were observed suggesting we were still on the westward side of the eddy. At around 31 51 and just before we entered the strong eastward currents (at the top of the CC eddy), the SeaSoar was prematurely retrieved after experiencing some abnormal pitch oscillations.

We collected water from the centre of the oceanic cold core eddy at CTD 3 to measure depth profile of photosynthetic health and response to light, stable isotopic signature, Chl a, pigments composition, characterisation of planktonic community by microscopic and flow cytometry analysis. With water collected from 25 m depth, we did additional work including primary productivity measurement using 14-C incubations and study the response of phytoplankton to nutrient enrichment (called experiment Nut 1, started at 2230 hrs) during 72h on-deck incubation.

Sunday 12 October – the offshore eddy

We then proceeded to the end of the proposed transect but also moved further westward to begin a southward transect, back across the eddy, composed of 8 stations,6 nm apart, sampling between the surface and 300 m; CTD4-CTD11. The eastward shift of this transect was successful, in moving from the strong EAC easterly current into a trivial current by the middle of the transect. Some westward current was apparent by CTD 10, 11.

At every CTD we made two vertical hauls of the N70 net plus a 20 cm diameter 100 µm mesh net, from 50 m depth to the surface (using the spare CTD trawl winch).

The weather was perfect (slightly overcast which precluded a good MODIS image).

The SeaSoar was disconnected and the EZ net attached to the tow cable.

At 1600 we had an EZ net toolbox.

At 1630 we then commenced EZ and simultaneous neuston net (via the hydro A frame) near the eddy centre at 32 20 155 30 for 22 hours, finishing at 1530 on Monday 13th. Tows were made every 2 hours at 1630, 1830 etc. 5 nets were used to sample 5 depths around 90 m, 70 m, 50 m, 30 m, 10 m, plus the initial net on the way down (oblique tow) and two replicate neuston tows. The EZ net performed very well, but occasionally tripping two bars at once (which we accounted for in the samples).

The initial oblique sample from the surface to 100 m was preserved in 95% ethanol after sample # EZ-9. Occasional neuston samples were preserved similarly. Otherwise all other samples were fixed in 7% formaldehyde solution and buffered with a teaspoon of soda ash (NaCO3).

Up to 10 salps from every neuston and EZ net were frozen in liquid nitrogen.

We sampled the CTD 11 at the centre of the eddy again to measure profile (25, 50, 75m and depth of Chl max) of Chl a, pigments, stable isotopic phytoplankton signature, photosynthetic health and response to light), and planktonic community characterisation. For all further stations, stable isotopic signature of the phytoplankton will be compared to subsequent vertical net taw (50 m to surface).

In the evening (2015 hrs), the nutrient experiment (Nut 1) was sampled for photosynthetic heath measurement and nutrient re-enrichment.

Monday 13 October – back to the coast

The final EZ tow was completed at approximately 1530 hrs.

The EZ was disconnected from the tow cable and the SeaSoar re-connected for a tow out of the eddy back to the coast.

We then proceeded to a CTD station, but the cable had uncoiled off the drum and had jammed down to the axel.

At 1730 hrs we cancelled the CTD and SeaSoar tow to proceed back to the coast and sample a coastal cold eddy that we initially passed over on Friday night.

In the evening (1750hrs), the Nut 1 experiment was sampled for photosynthetic health and nutrient re-enrichment.

Tuesday 14 October – the eddy transects

At 0200 we completed CTD-12 station to a depth of 300 m for Christel Hassler, to compare with her earlier productivity study in the eddy centre.

We steamed all night and arrived at WP4 at 0830 and deployed the SeaSoar-2 into the EAC. Currents of up to 4 knots and to the SW were observed, with water temperature around 22.3oC. A slight drizzle began. We changed course slightly in response to discussions with colleagues in Hobart and the latest MODIS images. At 33 45′ and ~152 30′, we made a turn in towards Sydney at approximately 1530, towards WP6 just off Broken Bay (130 m bathymetry).

Sea-Soar-3. After 2 hours towing across the EAC the strong 1.5 m/s SW currents suddenly dropped (around 152 00), the temperature also dropped by 2oC to 20oC, and bottom water less salty as we entered the small coastal eddy (previously observed at the start of the cruise, near WP2 last Friday night). The scale range for the SeaSoar fluorometer had to be doubled and then trebled as we approached the eddy core. The biovolume for our optical plankton counter had to be increased by an order of magnitude. The SeaSoar-3 was retrieved at 20:00 hrs and we steamed towards WP6 on the southern side of the eddy (~30 nm off Sydney Heads). The SeaSoar-4 was to be re-deployed at WP6 at 2330. A 20-25 knot southerly had picked up, making for a bouncy ride.

WP4 33 00 S, 153 00 E
WP533 00 S, 153 00
WP6 33 45 S, 151 45

In early morning, we sampled CTD 12 in between two Sea Soar deployments on the outside of the oceanic cold core eddy and did similar tasks as for CTD 3, to compare phytoplankton parameters inside and outside this cyclonic eddy. We started nutrient enrichment experiment 2(Nut 2, 0330hrs).

In the evening (1845 hrs), experiment of nutrient enrichment 1 was collected for Chl a analysis, pigment composition, nutrient dissolved concentration (including NH3), photosynthetic health and response to high light, and primary productivity.

Wednesday 15 October – off Sydney, at a coastal cold core eddy?

The SeaSoar-4 was towed for 6 hours north to WP7, slicing through what we estimated was the core of the eddy. MODIS images were poor from Monday and unavailable (cloud) on Tuesday. We estimated the eddy was 20 nautical miles (36 km in diameter) travelling at 0.25 degree of latitude southwards per day (0.31 m/s), just seaward of the 200 m isobath. Subsequent vertical profiles revealed doming of the isotherms through the eddy of around 30 m.

WP7 33 30′ 152 06′
WP8 34 00′ 152 25′

We then steamed SE to the estimated side of the eddy and began a CTD transect at WP8 for CTD13 to CTD22 (off Sydney Heads, Fig. 4). Winds were brisk for most of the day but had calmed by evening. There was an

hour or so delay when the UPS power supply failed and the operations room computer's shutdown. This transect was completed by around midnight.

It was on this transect (an all subsequent ones) that we took the initiative to take an extra 10 L bottle sample at our CTD depths, and count the number of small salps retained on a 200 um mesh screen.

In early morning (0030 hrs) we sampled the Nut 2 experiment for photosynthetic health and nutrient re-enrichment.

Three stations were sampled from the transect through the coastal eddy (in the EAC (CTD13), in the core of the coastal eddy (CTD 18) and in coastal water off Sydney Heads, CTD 22). We took sample for Chl a, pigments, NH3 dissolved concentration, stable isotope, photosynthetic heal and response to high light, microscopic and planktonic community characterisation at depths of 25, 50, 75 m and Chl max.

Thursday 16 October – EZ nets within the Sydney cold core eddy

The weather returned to very calm.

We steamed back to station CTD-20 and deployed the EZ net in the same way as before, followed by CTD-18, repeated over the next 24 hours (the first few stations did not sample alternately at these two stations). The abundance of salps at both stations was sometimes overwhelming. For example, sometimes the surface neuston net was dropped into the water for only 15 seconds, before it was filled with salps to more than one litre. The EZ net tows were shortened to 5 min per net and the cod ends were often full to the brim (2 litres) and beyond. We measured the total volume and retained 500 mL. The salps seemed to be all Thalia democratica, with the blue-gut (sexual) form and the slightly larger and more robust brown-gut (asexual) form observed in roughly equal proportions. The salps were most abundant in the top 30 or 40 m including the neuston and were relatively sparse at the 90 m depth. We retained some blue form from the neuston and 10 m EZ net in liquid N2 for RNA:DNA ratios. Occasionally we kept separate blue and brown salps from the neuston in LN2, and kept blue ones from the 90, 50, 10 and neuston nets. Large larval fish were frequently observed amongst the salps.

Water temperatures remained around 19.5-19.7°C. Currents were generally to the NE at the inner station (CTD20) and from NW at the outer station (CTD-18), suggesting that the top of this cyclonic eddy was passing directly through our transect.

The only problem was a minor overlap of the EZ net trawl wire late in the evening.

Around midnight the last EZ net was completed and CTD-25 was made between the two stations (formerly CTD-19).

In early morning, from CTD 22 with water from 25 m depth, we did additional work including primary productivity measurement using 14-C incubations and study the response of phytoplankton to nutrient enrichment (called Nut 3, started at 0415) during 72h on-deck incubation.

We sampled the Nut 2 experiment (0500) for photosynthetic health and nutrient re-enrichment.

In the evening (2120), water from the nutrient enrichment 2 was collected for Chl a analysis, pigment composition, nutrient dissolved concentration (including NH3), photosynthetic health and response to high light, and primary productivity.

Friday 17 October – The Broken Bay transect 33 30' (the control incl. SeaSoar-5)

We pulled in EZ net and steamed 3 hours north to off Broken Bay and began another 10 station CTD transect (#26-33) along 33 30', spaced every 5 degr. Longitude (4 nm). Our objective was to compare conditions to the previous eddy transect. As we steamed north, the ADCP confirmed our impression of the eddy, with NE currents of 1 knot for approximately 20 nautical miles (before becoming SW about 10 miles before the first CTD). We removed the extra 20 cm diameter, 100 um mesh from the N70 net (we tried mounting it inside the net but the jar floated out).

Weather was perfect. We completed CTD 26-32 (Fig. 5), but the SST was still 19.5 and with < 1 knot SW current. In the interests of time, we skipped the next scheduled CTD station and steamed on the next 4 nm and temperatures rose to 19.79. Just before 33 30' 152 20' the SST dropped to 19.2 and then climbed back up to 21.4. We plan to SeaSoar-4 this region tomorrow (Ford Water? – in fact we believe this to be a filament of coastal water entrained off Sugarloaf Point).

The CTD transect was interrupted for 30 min while the SeaSoar cable was streamed out to remove a cable over-lap.

Salp experiment 1. A salp experiment was set up in the back of the Fish Lab the previous night with two treatments: 150 um and 5 um filtered water versus salps or no-salps (n=2 tanks per treatment, 8 tanks in total).

We collected the salps for the pilot grazing experiment with a gentle tow of the N70 net from 10 m. It was determined previously that in both the filtered and unfiltered water there was very little natural chlorophyll, and most of the particles were <5 um in size. Nevertheless we persevered and released 7 brown asexual salps into the 4 tanks at 15:00. We harvested 25 of the 28 salps at 21:00 (after 6 hours) and transferred to individual vials in liquid nitrogen. Most seemed healthy, often trailing long faecal pellet strings. We speculate that the iridescent commensal copepod, Sapharina, may graze these pellet strings (as surmised by Dakin and Heron). Some had produced a string of clones.

We then steamed back to CTD-30 (33 30' 152 00') and CTD-32 (33 30' 152 10') and at 1530 began a series of EZ and neuston tows. There seemed to be as many or possibly more salps here than in the eddy!

The OPC stopped working on EZ 32, but Drew was able to open the instrument and re-align the mirrors for the final tow. However the EZ net bars jammed so we then steamed back to the coast to deploy the SeaSoar-5 along the transect to the EAC during the remainder of the night.

The SeaSoar cable had a twist to it so it was brought back on board, delaying the start by about an hour. The transect was completed around 8 am Saturday, and we steamed to the beginning of the Stockton Bight transect.

In the early morning we sampled Nut 3 experiment (0330) for photosynthetic health and nutrient re-enrichment.

In the afternoon (1510) we started a first 6h salp grazing experiment. In vivo fluorescence and Chl a was follow through time (see stations file). Initial and final water sample were sampled for pigments analysis. Based on in vivo and Chl a on board analysis, no grazing was seen. Salps collected at the end of the incubation were healthy and fecal pellets were seen, attesting that grazing indeed occurred.

We sampled the northern transect (Broken Bay) in the EAC (CTD 26) and coastal zone (CTD 33) for Chl a, pigments, NH3 dissolved concentration, stable isotope, photosynthetic health and response to high light, microscopic and planktonic community characterisation at depths of 25, 50, 75 m and Chl max.

Saturday 18 October – the Stockton Bight

A CTD transect of 7 stations was surveyed from the EAC to Stockton Beach (CTD-34 to CTD-40), commencing at around 1000 hrs . The EAC was strong offshore at 3 knots, but on approach to the 200 m isobath the current and water temperature began to decline, and fluorescence quadrupled from back ground levels. A subsequent MODIS image revealed that our CTD-36 probably went through the centre of a filament of enriched coastal water derived from off Sugarloaf Point. The N70 vertical haul net came up green with algae (Thalisiosira?), and while salps still dominated the sample there were more zooplankton for once. As we continued across the shelf, the fluorescence fell to around double back round levels and 19.5oC. Due to the abundance of filamentous green algae we decided to return offshore for the EZ net tows. Such abundances can frequently damage the net (and in fact we did blow out two EZ nets the next day).

12 h EZ net tows commenced at 12 midnight between CTD stations 36 and 35

Salp Experiment 2. We repeated Expt. 1, except that we starved the salps in 1 micron filtered water from 1 pm to 7 pm (6 hours). Another 10 salps were further starved until 1 am, frozen in LN2 for RNA/DNA. 16 salps were then allocated to the 4 +salp bags and harvested at 1 am, 4 individually frozen in LN2 for Christel and in groups of 4 or 6 for RNA:DNA.

In the early morning, we sampled Nut 3 experiment (2:30 am) for photosynthetic health and nutrient re-enrichment.

In the evening (7 pm), we started a second 6h salp grazing experiments. Initial and final sample were taken for Chl a, in vivo fluorescence, pigments, plankton community microscopic and flow cytometric characterisation. Water was also sampled for Chl a analysis following 3h incubation. Again, salps were healthy, visible fecal pellets but no grazing could be seen using Chl a or in-vivo fluorescence. Analysis of salp's fecal pellets demonstrated a strong fluorescence signal using both in-vivo and extractive measurements, most likely explaining why no grazing could be seen using these techniques. Hopefully, HPLC will be sensitive enough to differentiate Chl a from fecal pellets. In addition, flow cytometric analysis should tell us about the occurrence of bacterioplankton grazing.

In the evening (10:45 pm), we collected the water from the nutrient enrichment 3 for Chl a analysis, pigment composition, nutrient dissolved concentration (including NH3), photosynthetic health and response to high light, and primary productivity.

Sunday 19 October; SeaSoar-6 and CTDs to Broughton Is.

EZ net tows were completed at 12:30 pm, and we steamed 2 hours to launch the SeaSoar-6 towards Broughton Island. After an hour the SeaSoar was brought in to replace a lost flow propeller. After 2 hours it suffered a series of power failures. Drew suspected a problem with the cable, and planned SeaSoar transects in Stockton Bight abandoned.

We commenced a series of 6 CTD stations (CTD42-CTD47) along this transect in towards Broughton Island, which was completed by 0200. This concluded the scientific activities for SS10/08.

We finish collecting and treating water from nut 3 experiment until 5 am and then start packing our equipment.

Monday 20 October

Met the pilot boat at 8 am outside Newcastle and docked at 9 am.

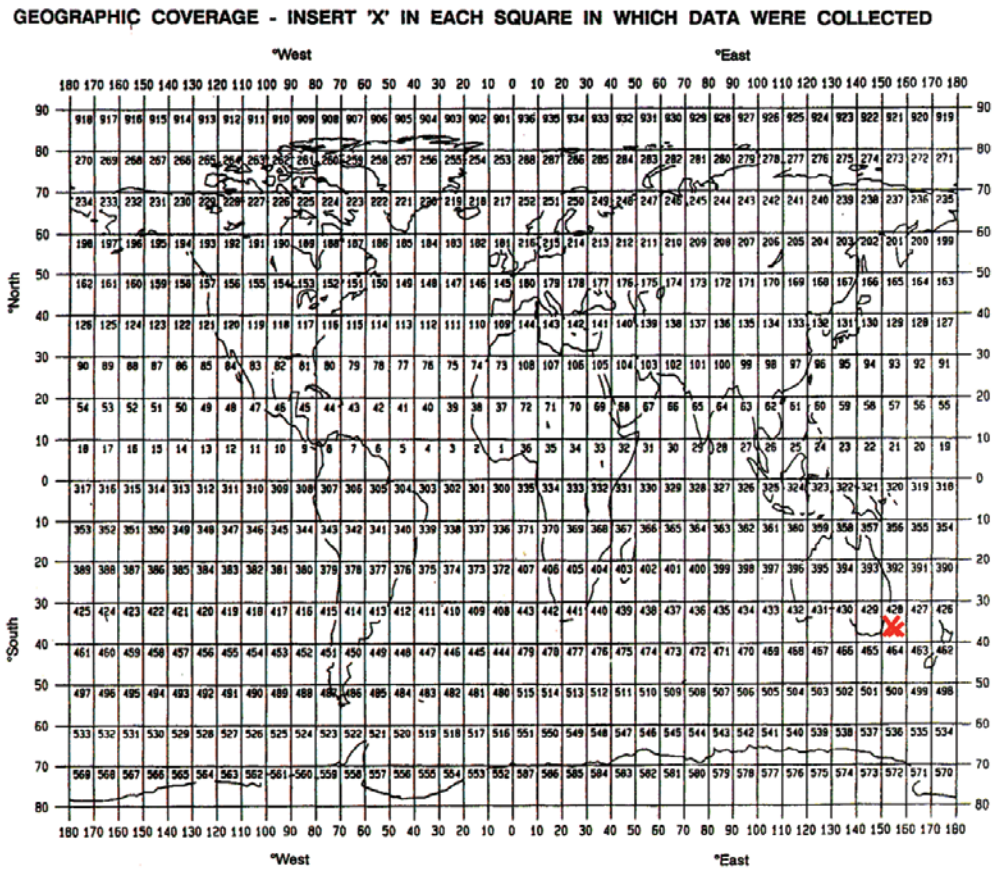
Summary

The SS10/08 voyage was an extremely successful cruise. For the first time, we have comprehensive data on the structure and biological composition of two distinctive cyclonic (clockwise) cold-core eddies of the East Australian Current (EAC): a large, 120 km diameter offshore eddy, located north of Taupo Seamount, and a smaller, 40 km diameter coastal eddy situated 40 km east of Sydney. We found considerably more salps in the coastal eddy than the offshore one and many post-larval fish. We built and deployed a replica plankton net from the 1938-1941 Wareen cruises to allow direct comparison of zooplankton (especially salp) abundances. From this sampling we observed up to a 10 fold increase in salp abundance compared to 70 years ago. Strong upwelling was also evident in the Stockton Bight and around Broughton Island in response to the strong offshore current. A conspicuous filament of green water was evident near 200 m isobath, off Stockton Beach, which was entrained from off Sugarloaf Pt. This filament was approximately 30 m deep, and similar to one sampled on SS Transit 3-2008 in August. At least 3 separate oceanographic processes led to the evident productivity of the Stockton Bight and around Broughton Island (topographic-separation dynamics, a strong EAC, and entrainment from Smoky Cape).

Principal investigators

A) Professor Iain Suthers (School of BEES, University of NSW)
B) Dr Mark Baird (School of Mathematics and Statistics, University of NSW)
C) Dr Jason Everett (School of BEES, University of NSW)

Marsden squares



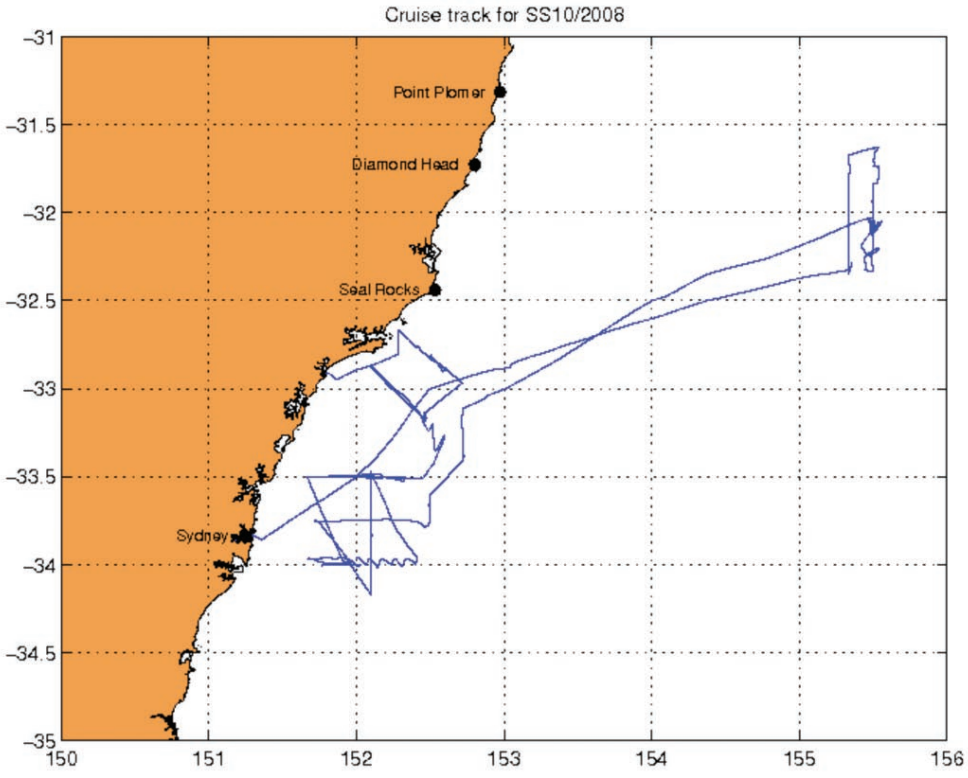
Summary of measurements and samples taken

Item No.	PI	NO	UNITS	DATA TYPE	DESCRIPTION
1	B	47	Casts	H10, P02, B08	CTDs
2	A	38	Tows	B09, B14	EZ Nets – Horizontal Haul @ depths 10, 30, 50, 70, 90 m
3	A	85	Tows	B09, B14	Neuston Nets – Horizontal surface tow, simultaneously with EZ Nets
4	C	81	Tows	B09, B14	N70 Nets – 50 m Vertical haul
5	C	6	Tows		Sea Soar – Undulating horizontal tow
6	B				Underway Instruments

Curation report

Item No.	DESCRIPTION
1	CSIRO
2	Electronic data streams held by CSIRO, Samples held by FAMER lab at UNSW for >10 years
3	Samples held by FAMER lab at UNSW for >10 years
4	Samples held by FAMER lab at UNSW for >10 years
5	Electronic data streams held by CSIRO, OPC data held by FAMER lab at UNSW
6	Electronic data streams held by CSIRO

Voyage track



Sampling took place off eastern NSW – Exact locations were based upon oceanographic conditions

Personnel list

Scientific Participants

Name	Affiliation	Role
Iain Suthers	UNSW	Chief Scientist
Mark Baird	UNSW	Oceanography/Salp Biology
Jason Everett	UNSW	Salp Biology
Anthony Richardson	CSIRO/UQ	Zooplankton
Christel Hassler	CSIRO	Chemical Oceanography
Will Figueira	UTS	Larval Fish
Matthew Taylor	UNSW	Krill Biology
Adrienne Gatt	UNSW	Zooplankton (Honours)
Ben Harris	UNSW	Krill (Honours)
Natasha Henschke	UNSW	Salp Biology (Honours)
Justine Djajadikarta	UTS	Chemical Oceanography
Pamela Brodie	CMAR	Electronics Support
Drew Mills	CMAR	Electronics Support
Alicia Navidad	CMAR	Electronics Support

Marine Crew

Name	Role
Ian Moodie	Master
John Boyes	Chief Officer
.Naomi Petersen	Second Mate
John Morton	Chief Engineer
Dave Jonker	First Engineer
Seamus Elder	Second Engineer
Tony Hearne	Boatswain
Matt Barrett	IR
Paul O'Neill	IR
Gareth Gunn	IR
David Persson	IR
Ged Hogg	Chief Cook
Dayal Patel	Second Cook
Darcy Chalker	Chief Steward

Acknowledgements

We thank the officers and crew of the National Research Facility, RV Southern Surveyor for their enthusiasm, expertise and professionalism for the duration of the trip. To Dr Peter Oke (CSIRO) who prepared and emailed MODIS images each day of the voyage.

Chief Scientist

Professor Iain Suthers

Figures and captions

Fig. 1. Satellite derived altimetry and inferred currents and SST derived from a composite of single images over a 3-day period. Our two targeted eddies are circled.

Fig. 2. MODIS images of SST (degrees C) and of surface chlorophyll concentration (mg m-3) for 7 and 10 October 2008 showing the nearshore eddy of approximate 40 km diameter. MODIS of 7 Oct. showed the eddy off Seal Rocks, and indicated it was formed from water been upwelled off Point Plomer-Diamond Head around 3 October 2008. By the time we sampled 15-16 October it was approximately 2 weeks old had moved to 34oS (about 0.25o d-1).

Fig 3. Transect 1 of the voyage, north to south along 155 30 across a cold core eddy, with Depth and Latitude. Note the doming of the isotherms of 50 to 100 m around 32.1oS.

Fig. 4. Raw CTD output for the cross-eddy transect, off Sydney at 34oS. Note doming of the isotherms. Strong ADCP current vectors 3 knots southward offshore (east, right hand side) and slight 1 knot currents northward landward side.

Fig. 5. Raw CTD output for north of the cross-eddy transect, off Broken Bay at 33.5oS where no feature was evident other than the strong EAC offshore

Fig. 6. Raw CTD output for the Stockton Bight (and similar to the final CTD transect off Broughton Island). There was a dramatic filament evident in the MODIS image (Fig. 7) trailing south from Sugarloaf Pt., showing a slug of ocean colour was only 30 m deep.

Fig. 7. MODIS image for Friday 17 October 2008, showing surface chlorophyll concentration. (mg chlorophyll m-3). We fortuitously made a CTD transect through the distinctive filament flowing off Sugarloaf Point on Saturday and second CTD on Sunday evening off Broughton Island (to the north).

Appendix 1 – Science Report

Voyage SS10/2008

Biological oceanography of coastal cold-core eddies and of salps in the continental shelf waters off the Stockton Bight of eastern Australia.

Professor Iain Suthers (Chief Scientist)

Itinerary

Departed Sydney, Australia 10th October 2008 at 15:00 hrs
Arrived Newcastle, Australia 20th October 2008 at 09:00 hrs

Contribution to Australia's national benefit:

More than 50% of Australians live beside the East Australian Current and are largely unaware of its influence on our climate, fisheries and marine tourism. The Current is accelerating, warming Tasmanian waters by more than 2 degrees in less than a century – the fastest rate of increase in the world. The Current is characterised by forming eddies – more than any other comparable current –causing variability in ocean forecasts especially off south eastern Australia. Until now there has been no study of the clockwise, coastal eddies off eastern Australia (biologically important) in comparison to the ~50 studies of large, anticlockwise oceanic eddies (which are climatically important).

During our voyage we observed stronger currents and more jelly-like zooplankton – consistent with climate change predictions. We found significantly increased abundance of salps, when compared to similar surveys 70 years ago. Salps are the fastest growing multicellular animals on the planet with rapidly sinking faeces and a comparatively large size, which play a major role in the ocean's carbon flux. Salps feed on marine bacteria, short-circuiting classic ecological models of feeding. We estimate the average abundance was up to 10 fold more than observed with an identical net during 1938-1942. This increased abundance is being seen worldwide where gelatinous zooplankton, such as salps and jellyfish, are beginning to displace other more nutritious zooplankton species such as copepods and krill.

We compared a nearshore and offshore eddy to assess the significance of the source waters. The nearshore water had entrained coastal water from just south of the major upwelling zone of NSW. It appeared to be enriched compared to the offshore eddy, which forms the basis of two on-going ARC funded projects. Our samples will indicate the level of enhanced production from these eddies and their influence on eastern fisheries. It is likely that with climate change the occurrence of such eddies will increase, with benefits to the fishing industry.

Our research contributes to Australia's national benefit by increasing our understanding of

sustainable use of Australia's biodiversity (Goal 5) and understanding of how components of the Australian marine ecosystem will respond to climate change (Goal 7).