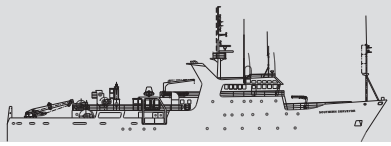


MARINE
NATIONAL FACILITY

RV *Southern Surveyor*

2009 program

CSIRO

voyage summary SS05/2009

SS05/2009

Salps, eddies and entrainment in the Stockton Bight

Voyage period
Start: 16/10/2009
End: 27/10/2009
Port of departure: Sydney, Australia
Port of return: Sydney, Australia

Responsible laboratory
School of BEES, University of New South Wales
Anzac Parade, Randwick NSW 2052 Australia

Chief Scientist(s)
Iain Suthers, Mark Baird

Scientific Objectives

The EAC is distinguished from other western boundary currents by the "mesoscale variability" – or eddies. Eddies of the East Australian Current entrain coastal water. Similar processes in the Kuroshio, California and Agulhas Currents are well documented for their importance to fisheries. We will compare ship-borne observations of species diversity and abundance; larval fish growth and zooplankton size frequency distributions within cold core eddies and compare these to the original coastal waters in the Stockton Bight. We will assess whether eddies are plankton incubators and provide cross-shelf transport to coastal nursery areas.

Last year (SS10/2008) we successfully investigated the biological oceanography of salps and coastal cold-core eddies in the Stockton Bight (33S, 152E), and we wish to establish the persistence of our findings. Salps are large, fast-growing gelatinous zooplankton that graze on diatoms, picoplankton and bacteria, and seem to displace the conventional crustacean zooplankton. Their dense blooms can significantly alter the food chain by removing phytoplankton but are also recorded in the guts of many fish. Described as the fastest growing animals on the planet, salps clearly have a major role in global carbon flux, but are essentially unstudied in the EAC since the work of Heron and others 20 years ago. By feeding on particles 1000 fold smaller than themselves, salps confound our biogeochemical models (Baird & Suthers 2007) and probably confound the biomass estimates of our optical plankton counter.

On SS05/2009 we will investigate eddies and entrainment processes off the central NSW coast, and thereby study the distributional ecology of salps. We will be conducting laboratory experiments with salps and krill in the Fish lab and the CT Room. We will retrieve an IMOS Slocum glider ("Nemo-3") deployed 2 weeks earlier and deploy a Sea Glider ("Dory-1") during the voyage and another Slocum ("Nemo-4) after the voyage. The gliders support a CTD and an 'Eco Puck' which records chlorophyll a, coloured dissolved organic matter (CDOM) and backscatter. We need to characterise the response of our own Eco-Puck to the local conditions on the *Southern Surveyor*'s CTD and to see if this response is consistent between years. This voyage is supported by ARC grants to Suthers & Baird to investigate salp ecology and to Suthers & Oke to investigate eddies of the East Australian Current (EAC).

Our scientific aims are :

a) the biological oceanography of small cyclonic eddies off the Stockton Bight in comparison to coastal waters, in conjunction with an IMOS Slocum Glider;

b) the process of entrainment of coastal plankton into the EAC and eddies between 31ºS (Smoky Cape) and 35 ºS (Jervis Bay);

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

d) To conduct laboratory experiments with live plankton in the Fish Lab and in the CT Room;

e) To retrieve a Slocum Glider (using the work boat) and to launch a Sea Glider; and to use the CTD and EZ or Rectangular Midwater Trawl (RMT) net samples to help interpret the glider's optical sensors.

Results

a) In late September (27th) we observed a small eddy ("a billow") form off Port Stephens which grew over the following week into a 100 km wide eddy, constrained by the EAC to the east and the shelf to the west. It appeared to be entraining productive shelf water from off Port Stephens. Before the voyage we deployed a Slocum glider upstream of the eddy (Crowdy Head), which was successfully inserted into the eddy. Our initial ADCP run across the eddy confirm its rotation with 1.5 m/s to the east, and a broad region of westerly 1m/s currents across the southern side. We sampled the eddy with the Sea Soar

b) We compared the plankton and abundance between the entrained eddy waters and the coastal waters in Stockton Bight and off Cape Hawke…..

c) We sampled salps with the usual N70 net and found approximately a tenth of the abundance last year, and likely to be similar to that found with the same net by Thompson (1942).

d) We found that the solitary stage of salps produced overnight less than 80 clones (aggregate stage) each as observed by Heron (1979), and the growth rates of the aggregates were measure and compared among water masses.

e) The Slocum glider completed one revolution of the cold core eddy off Port Stephens, before its retrieval 40 nautical miles off Newcastle. Valuable data was obtained before the eddy was over-run or "flooded" by EAC. Our own Eco-triplet, and identical to the optical sensor on tehglider was used extensively on the CTD and the Sea Soar transects.

f) The Sea Glider remained in the eddy off Port Stephens for a month, before moving SE over 100 nautical miles. It was navigated back into a new warm core that separated from the EAC off Port Stephens, and completed two complete revolutions before its retrieval on 6 January, 40 nautical miles NE of Sydney.

The N70 net rigged for vertical use

Methods and gear:

Description of gear (note: we did not deploy our usual 75 cm square neuston net this voyage).

1) modified N70 net (same as used in SS 10-2008 and SS Transit 01-2009). A 70 cm diameter ring net, with 53 cm long 4 mm mesh (formerly ¼" mesh), a 97 cm long 400 um mesh section (formerly silk, 70 mesh/inch), a 135 cm long 225 um mesh section (formerly silk, 200 mesh/inch, Kemp and Hardy 1929). Vertically hauled up from 50 m to the surface at ~1m/s using the alternate CTD wire (not ideal – a small electronic capstan winch is planned). We also used this net to collect live zooplankton.

2) EZ net. 1 m2 multiple opening and closing (MOCNESS) net as Oct. 2008, with 5 nets and using 500 um (0.5 mm) mesh nets (we used 375 um mesh in SS 10-2008). On board was a CTD, the Wetlabs Eco puck (see below) and a standard camera strobe (Canon 560 EXII in a Photosea 600 m housing) mounted on the front of the net to stun krill. Net was deployed to 500 m.

CTD. 14 * 10 L bottles, brand CTD (unit #21), WETLabs chlorophyll fluorometer, PAR sensor, a UNSW-UTS Eco-puck/Eco-triplet (for chlorophyll and CDOM fluorescence, backscatter at 650 nm), a WETLabs hyperspectral absorption-attenuation meter ac-s (on loan from CSIRO Marine and Atmospheric Research in Hobart) and on some CTDs the WETStar CDOM fluorometer (on loan from CSIRO Land and Water in Brisbane).

4) Sea Soar. Sea Bird CTD, wetlabs fluorometer, a Wetlabs Eco-triplet. Optical plankton counter mounted on the Sea Soar and EZ net (the OPC was flooded on the first deployment, despite a special trip back to Canada for service)

Voyage Narrative

All times reported below are local Eastern Daylight Saving Time (i.e. 11 h ahead of UTC).

Friday 16 October 2009

4:10 pm departed White Bay wharf (muster drill and vessel induction held prior to departure).
~4:30 pm cleared heads.
Steamed east to ~1,500 for CTD pressure test. Toolbox held prior to deployment.
WP1 was along 152º00'

A number of N70 vertical hauls were also made (using the capstan winch over the stern) to collect live salps and krill for experiments. Only a few aggregate (blue) stages were retrieved but they served to improve our methodology.

Steamed east to WP2 (crossing a distinctive eddy or shear),
turned NE and steamed across eddy to WP3.
WP2 34º00' 153º00'
WP3 32º40' 153º50'

Observed strong changes in underway SST, from 19, to 17.3, to 19 across eddy and 22 in EAC. Gusty southerly winds and moderate swell created significant rolls at times.

Saturday 17 October 2009 (cold core eddy)

Arrived WP3 on the NE side of the eddy at 9 am,
launched Sea Soar and returned to WP4

33°40′ 152 10′. Our initial deployment steamed NE to ensure well into the EAC,
before turning SW and returning along last night's track to WP4 33 40′, 153 10′

ADCP surface currents confirmed a significant but peanut
shaped eddy, approximately 60 nm from NE to SW.

Retrieved Sea Soar at 7:30 pm

Sea Soar had the Eco-triplet (chl-a and CDOM fluorescence, backscatter)
sensor attached which was downloaded after the track had ended.

4 pm began a 10 station CTD transect from SW to NE to 300 m depth (300, 150, 100,
75, 50, 25, 0). The Eco-triplet was attached to the CTD, together with the WETLabs ac-s.

CTD wire alarms scrapped #2 and 3.

By the 9th station we had not observed warming SST as expected on approach to EAC.

The 10th station (CTD15) was moved 6 nm to east
and 22 degree water was quickly found.

Other CTD problems scrapped #13 & 14.

Salps were retained from CTD15 (EAC) for rearing experiments

Pilot respiration experiments were undertaken with live krill captured using
an N70 net deployed to 100 m. Preliminary calculations and modelling
indicate daily ration could be as high as 25% body weight per day.

Report by Martina on phytoplankton and bio-optics:

Water from every second CTD (4, 6, 8, 10 and 12 (12?)) at 6 depths (5, 25, 50, 75, 100, 150 m) was processed for phytoplankton pigments (HPLC), stable isotopes (13C and 15N), picoplankton (0.2 – 2 um) and microplankton (> 10 um) enumeration, as well as the bio-optical parameters such as particulate and coloured dissolved organic matter (CDOM) absorption coefficients and on occasion, pulse amplitude modulated (PAM) fluorescence. Time was too limited between CTDs to filter enough particulate material for measures of total suspended matter.

Between each CTD, data from the Eco-triplet and acs
sensors was downloaded, and briefly QAQCed.

The photochemical efficiency of surface phytoplankton along the first
transect was relatively high (>0.55 out of a maximum of 0.6-0.7), and
there was no apparent relationship with dissolved nutrients.

Sunday 18 October 2009 (Cold core eddy)

CTD transects (at #15) finished by 2 pm.

An EZ net toobox was held at 3:30 pm. The overall sampling strategy was to sample 4 stations, with 2 tows per station down to 500 m deep (8 tows per region).

4 pm EZ net was deployed near CTD15.

EZ0 and EZ1 were commenced in the EAC water. The OPC software indicated anomalous readings and subsequent exploration revealed a tablespoon of water inside the right hand (pressure side) canister. Significant problems became apparent in the software and operation: false net trips, multiple net trips, flow readings.

We returned to EZ net sampling (EZ2 and EZ3), but problems continued to mount during the night. As a result of this 2 nets had to be discarded as we did not know at which depth they had opened.

During dusk (~18:45) and dawn the EK500 (38 and 120 kHz) revealed the daily rise and fall of zooplankton from 550 m depth to the surface. Some of the rising bands were vertically discrete and separate. Subsequent EZ net tows managed to target some of these bands and found them composed of either krill or zooplankton.

Kylie Pitt: *Salps were collected using the N70 net at 3:40pm (at location where gliders were deployed / retrieved) and approximately 5 salps were transferred to each of 5 2L aquaria filled with water collected at the same location. At 2:15am salps were transferred to individual containers using a scoop (to ensure salps were always submerged). Salps were observed closely and once the bud detached from the parent the chain of aggregates was divided into two and half was preserved in 5% formalin and the other half was returned to the tank. Aggregates were harvested at various intervals up to 6 hours later. This method was discontinued as it was decided that the size difference between the two ends of the chain was too large and would compromise the results.*

Monday 19 October 2009 (Glider recovery and deployment)

At 8 am the weather was perfect for the Sea glider deployment and Slocum retrieval. It was decided to steam west to the last surfacing; arrived at 12:24 pm (33 14' 152 43'). After some minor glider communications problems, the work boat was launched 1:30 pm and Sea Glider deployed 200 m away from the vessel with the same way point as the Slocum at the eddy centre (33°24'S, 153°15'E). The Slocum was successfully retrieved at 2 pm.

We made two CTD casts: one at the retrieval site and corresponding to the initial Sea Glider profiles (CTD16), and then one 10.8 km to SE to correspond with the final profiles by the Slocum Glider (CTD17).

CTD water was processed as for the first transect but there was no time to do filtrations for stable isotopes at CTD16 and only the first three depths (surface, 25, 45 m) were completed for this parameter at CTD17. Interestingly, the

sunny, calm weather resulted in a strong decline of photochemical efficiency in surface phytoplankton at CTD17 (0.12 – 0.32 compared to >0.57 at depth).

Salps were retrieved from CTD17 for rearing experiments (Kylie Pitt): The experimental protocol is as follows:

Approximately 100 actively swimming S2s were transferred to a ~70 l tank and held until 5am the following day (Thalia reportedly produces buds from ~5-7am). Water for experiments was collected at the same time as the salps. At 5am S2s that were asexually budding aggregates were gently removed using a scoop and transferred to individual 2L containers. Salps were closely observed and immediately following the release of the buds the S2 salps were preserved in 5% formalin (for subsequent analysis of size vs fecundity relationships) and the remaining chain of aggregates was haphazardly allocated to one of three time treatments: T0, T1, and T2. In the T0 treatment aggregates were harvested immediately after being released from the parent and preserved in 5% formalin. In the T1 and T2 treatments aggregates were harvested after 4 and 8 h respectively. Four replicates were assigned to each treatment for today's experiment.

We steamed inshore onto the shelf just off Gosford (WP 6 33 24' 151 50') to commence at 6pm, a 15 h, west to east Sea Soar transect of the eddy, and into the EAC WP7, 33 24' 154 20'. A new image revealed that the cold core eddy had been covered by 22 degrees. EAC water (to a depth of ~30 m), but still with clockwise currents. The Sea Soar performed very well (but with less cable out and only to 110 m deep).

Tuesday 20 October 2009 (return to the eddy)

~1 pm? the Sea Soar was recovered (33 24' 153 30') and we steamed 6 nm north to align with latitude of eddy centre (~33 18'), for EZ stations heading west back to eddy centre.

Due to the flooding of our eddy, we made two extra CTD casts – one in the EAC (CTD18) and one on Monday in the putative centre (CTD19), bracketing the EZ tows as well.

Martina comment on CTD samples from chlor max?

Water from CTD18 (25 m) and 19 (50 m) were processed for additional molecular analyses as well as the usual suite of phytoplankton and bio-optical parameters. As CTD18 was deployed in the late afternoon, there was a similar decline in photochemical efficiency of surface phytoplankton (0.18 – 0.29) compared to 0.52 – 0.60 at depths ≥ 25 m.

EZ net tows commenced 5 pm in the EAC waters (EZ4, 5). We then sampled in the eddy (EZ6, 7), then EZ8, 9, and at the putative centre (EZ10, 11), completing tows by 8 am Wednesday.

Wind was gusting to 29 knots around midnight, making sampling difficult.

Salps for rearing experiments were retrieved from CTD 18 in the EAC:

Kylie Pitt:

The experiment was successfully completed on 21st Oct. The identical experimental protocol from Oct 19th was used except that a minimum of six aggregates were assigned to each time treatment. Some salps were preserved in LN2 for subsequent rna:dna analyses (see Jason).

Ben Hollings (IMOS) reported the Sea Glider was performing: "Position at 08:24EDST was 33º21.569'S, 152º35.041'E; Glider due to surface again at 12:24EDST estimated position then is 33º13.6'S, 152º42.5'E"

Wednesday 21 October 2009 (Stockton Bight)

CTD19 was completed by 1 pm , and we then steamed back 4.5 hours west towards the shelf to commence the Stockton Bight CTD transect (#2) at ~5.30 pm . CTD stations (20 to 27) were 5 nm apart, with the transect being completed early on Thursday morning

Wind picked up in the evening again, but not as strong.

Similar to CTD18, surface phytoplankton at CTD19 were photoinhibited, with photochemical efficiencies <0.1 compared to >0.53 at depth. At CTD20, surface phytoplankton were only slightly photoinhibited, showing photochemical efficiencies of >0.54.

The same phytoplankton and bio-optical parameters were assessed on this CTD transect, although limited time between stations meant that particulate absorption samples were only taken at some stations and limited depths.

Salps for growth experiments were retrieved from CTD station (collected at 18:15). The experiment was successfully completed 22nd Oct. The identical experimental protocol from Oct 19th was used except that a minimum of eight aggregates were assigned to each time treatment. Some salps were preserved in LN2 for rna:dna work.

Thursday 22 October 2009, Stockton Bight

Weather superb.

CTD 27 was completed by approximately 3 am.

Returning back to deeper water along the CTD transect, we completed the 4 stations*2 tows each: EZ12, 13 (near CTD24); EZ14, 15 (near CTD22), EZ 16, 17 (near CTD20), and then a further 10 nm offshore (EZ18,19).

We made detailed observations on Diel Vertical Migration through the EK500. A deeper diffuse layer exists from 600-400 m however at dusk this layer migrates to the surface layer in 2 discrete bands, which matches an increase in the echo intensity at the surface and a decrease in intensity in the mixed layer. The migrating

bands were sampled directly during EZ18 and initial inspection shows that krill migrate to the surface in the first band and copepods migrate in the second band. Over 400 samples were sorted from the EZ net tows for stable isotope analysis, to investigate the trophic relationships across this layer. Overall the deep layer revealed by the sounder is dominated by krill, the 100-50 m layer is dominated by krill in the evenings, the 50-0 m layer is dominated by salps and larval krill.

EZ sampling was completed by 8 pm and we then steamed back into Stockton Bight to near CTD27 off Stockton Beach (~70m deep) to deploy the Sea Soar.

On the way back ~11 pm we stopped near CTD22 (33 06' 152 27') for only one (1) gentle EZ net tow as slow as possible to collect live krill from 400 m depth (EZ20). Also at this station, we made 2 vertical hauls with N70 net (no CTD needed, just the plankton net samples) for live salp experiments.

Salp protocol: Put 6 pregnant S2 into birthing tank.

Put a single S1 each into guppy tanks containing 1 um filtered, 18 fold concentrated and control (n=6 tanks/treatment).

Kylie Pitt: *Treatments were inspected periodically during Friday 23rd October. Salps in the control treatment appeared to be 'lazy' and remaining stationary or swimming slowly near the bottom of the tanks. Salps in the 1 um filtered and 18 fold concentration treatments remained fairly active with the exception of one salp that died in the 1 um filtered treatment. Initial observations indicate that the salps are unaffected by 18 fold concentrations. The 6 pregnant S2s in the birthing tank were not used for any experiments.*

Friday 23 October 2009

Deployed Sea Soar off Stockton Beach near CTD27 around 2 am, and steamed back along our CTD transect (45 nautical miles) and out to the eastern most EZ station (WP8, 33 18' 152 47' Leg03-Stockton Bight),

Weather superb.

8 am Arrived WP8 & still towing Sea Soar to WP9 off Broughton Island

Arrived 2 pm WP9 (near Broughton) 32 34' 152 27',
(Leg04- diagonal); and on to WP10 offshore.

Arrived 8 pm WP10 32 54' 153 15' (Leg05-Broughton
Is Leg), and onto WP 11, off Cape Hawke

No salps were caught today, therefore no growth experiments undertaken.

Saturday 24 October 2009

Arrived 2 am WP11 (near Cape Hawke __32 18' 152 38'__) (Leg06-diagonal)

Retrieved Sea Soar and commenced CTD transect #3, CTD28 commenced at 2.45 am and CTD36 finished at around 8 pm.

By the 3rd CTD station the alternate CTD winch we used for hauling the N70 net developed a tangle, entailing a 4.5 hour CTD station. Eventually the termination was removed and a line was wound onto the drum for the N70 net vertical haul.

Between CTD33 and CTD34 the northerly current of 1 knot changed to being dominated by the EAC, and by CTD35 was flowing over 2 m/s. Between CTD33 and 34 a large slick of green tinged water (an ephemeral filament?) was observed by the bridge, and the presence of some fishing boats. A spike in the ACS underway fluorometer was observed as well. We decided to investigate this area more on return along the transect with the Sea Soar, but no surface trace of it was seen. Lindsay's contour plot revealed a 20 nm wide patch of phytoplankton along this area at 40-50 m deep. The Sea Soar was deployed at 18:30 (Leg07) and we reached the coastal CTD28 by 1 am on Sunday morning.

No S2 salps were caught today and so no growth experiments were undertaken.

Sunday 25 October 2009

At 1 am the vessel turned SE and headed out to the 150 m contour, and to follow this contour along the shelf to Sydney (Leg 08 to 150 m depth, and then Leg09 to be completed off Broken Bay at 33 40').

2 pm arrived north of Sydney, retrieved Sea Soar off Broken Bay

5 pm commenced CTD#4 transect along 33 04' at the offshore end. The two nearshore CTD stations CTD43 and 44 were to correspond with the IMOS moorings SYD100 and SYD140.

These CTD samples were processed just as the previous transects, with CTD44 (PH100) being completed just after 1 am.

Collected salps at 3pm immediately following retrieval of Sea Soar (33°41.851, 151°44.845). Note that we have no CTD data for this location. The experiment was successfully conducted on Mon Oct 26th following the methods described earlier.

Note that no salps were caught in the N70 net during today's CTD transect.

Monday 26 October 2009

After setting up the EZ net and swapping over the Eco-triplet, we prepared to deploy the EZ net (EZ21). Unfortunately a southerly had picked up with gusts to 30 knots.

The net was successfully deployed and retrieved, although the retrieval conditions could be described as "marginal". Due to the pitching and surge, Net#3 was jammed open and the remainder failed to drop down.

After discussion it was decided to hove-to until 8 am.

Southerly had not abated by 8 am, nor at the next review at 4 pm. After discussion with Hobart, we decided to complete a swath-map transect along the Sydney shelf.

The vessel completed the transect off Newcastle by ~1 am and returned back to Sydney.

Tuesday 27 October 2009

8 am Met pilot off Sydney Heads

10 am docked in White Bay.

Summary

We were fortunate to observe the birth and development of a large cold core eddy off northern NSW, and into it deploy a Slocum glider for weeks and a Sea Glider for some months to come. This eddy is now nearly 4 weeks old, 100 km in diameter, in generally the same location, and is showing no sign of waning. It can be seen to entrain coastal waters from the western side, and to become encircled by EAC water and ultimately entrain that water as well. The eddy had the attributes of the Oct 2006 eddy where we found considerable numbers of larval fish in the centre, but not as much phytoplankton. Vertical profiles revealed upward doming of the isotherms on our first transect, before the eddy was flooded by EAC water to 30 m depth by our second transect, effectively obscuring it from satellite view. Subsequent Sea Soar profiles on the western (Stockton Beach) side and northern (Cape Hawke) side revealed the entrainment of shelf productivity.

We filtered over a metric tonne of water to analyse suspended particulate matter at multiple depths at 23 CTD stations for phytoplankton biomass, pigment composition, stable isotopes (13C and 15N), and occasionally, particulate absorption. The particle-free filtrate was stored for analysis of coloured dissolved organic matter. General observations show a consistent subsurface chl-a maximum

between 30 and 50 m, with greater phytoplankton biomass inshore compared to offshore. Real-time measurements of photochemical efficiency indicated that in situ fluorescence profiles were strongly impacted by diel light effects. As analyses are completed phytoplankton and bio-optical parameters will be assessed against fluorescence and backscatter profiles collected by the CTD, Seasoar and EZ net.

Our standardised N70 tows during this late October voyage, revealed far fewer salps (~10%) than early October 2008, and comparable to the abundances described by Thompson (1943).

We made detailed acoustic observations of zooplankton and diel vertical migration, coupled with discrete depth net samples. A deeper diffuse layer of zooplankton exists from 600-400 m which migrates to the surface at dusk in 2 discrete bands (which matches an increase in the echo intensity at the surface and a decrease in intensity in the mixed layer). Net samples show that krill migrate to the surface in the first band and copepods migrate in the second band. Over 400 samples were sorted from the EZ net tows for stable isotope analysis, to investigate the trophic relationships across this layer. Overall the deep layer revealed by the sounder is dominated by krill, the 100-50 m layer is dominated by krill in the evenings, and the upper 50 m layer is dominated by salps and larval krill.

Principal investigators

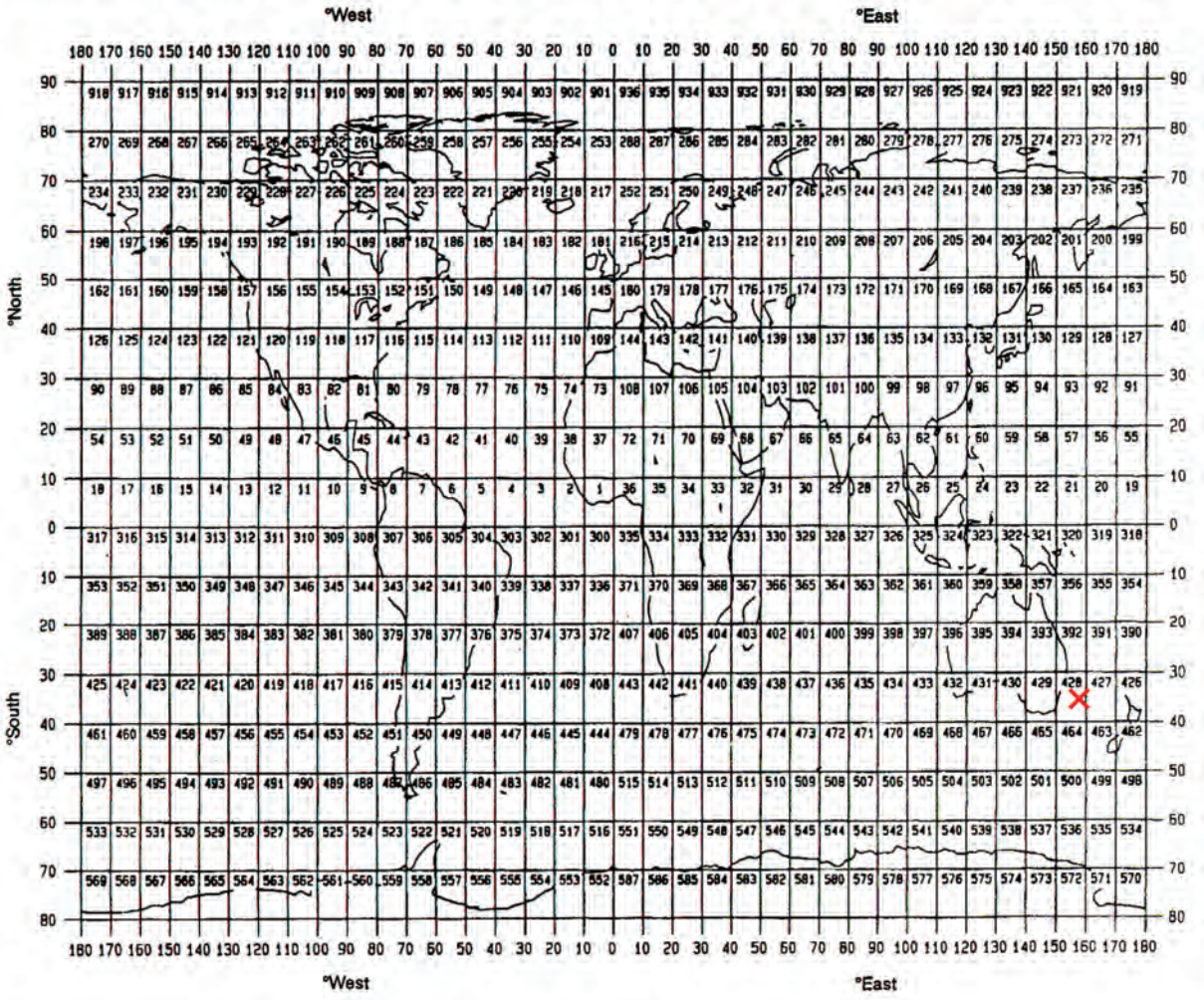
A. Iain Suthers (SIMS-UNSW), Mark Baird (UNSW), Jason Everett (UNSW), Matt Taylor (UNSW-SIMS)

B. Martina Doblin, Kadija Oubelkheir (SIMS-UTS)

C. Kylie Pitt (Griffith U.)

D. Lindsay Pender (CMAR), Rudy Kloser (CMAR, bio-acoustics)

GEOGRAPHIC COVERAGE - INSERT 'X' IN EACH SQUARE IN WHICH DATA WERE COLLECTED



MOORINGS, BOTTOM MOUNTED GEAR AND DRIFTING SYSTEMS									
Item No	**PI** See page above.	**APPROXIMATE POSITION**						**DATA TYPE** enter code(s) from list on last page.	**Description**
		LATITUDE			**LONGITUDE**				
		deg	min	N/S	deg	min	E/W		
1	A	33	14	S	152	43		D06	Slocum glider (IMOS)
2	A	33	14	S	152	43		D06	Sea glider (IMOS)

SUMMARY OF MEASUREMENTS AND SAMPLES TAKEN					
Item No.	**PI** see page above	**NO** see above	**UNITS** see above	**DATA TYPE** Enter code(s) from list on last page	**Description**
1	A,B	40	Casts	H10, P02, B08	CTDs
2	A	30	Tows	B09, B14	EZ Nets – Horizontal Haul @ depths 10, 30, 50, 70, 90 m
3	A,C	78	Tows	B09, B14	N70 vertical haul plankton net, 0.7 m diameter, 0.4-0.2 mm mesh; 50 m Vertical haul
4	A,B,D	9	Tows	H11	Sea Soar – Undulating horizontal tow
5	A	11	days	H71, H13, D71	Underway Instruments, ADCP
6	A,D	11	days	B28	Echo sounder, EK500 and EA500

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	Electronic data streams held by CSIRO, OPC data held by FAMER lab at UNSW
5, 6	Electronic data streams held by CSIRO

Voyage track

GENERAL OCEAN AREA: Tasman Sea
SPECIFIC AREAS: Stockton Bight, Broughton Island, Cape Hawke, Sydney

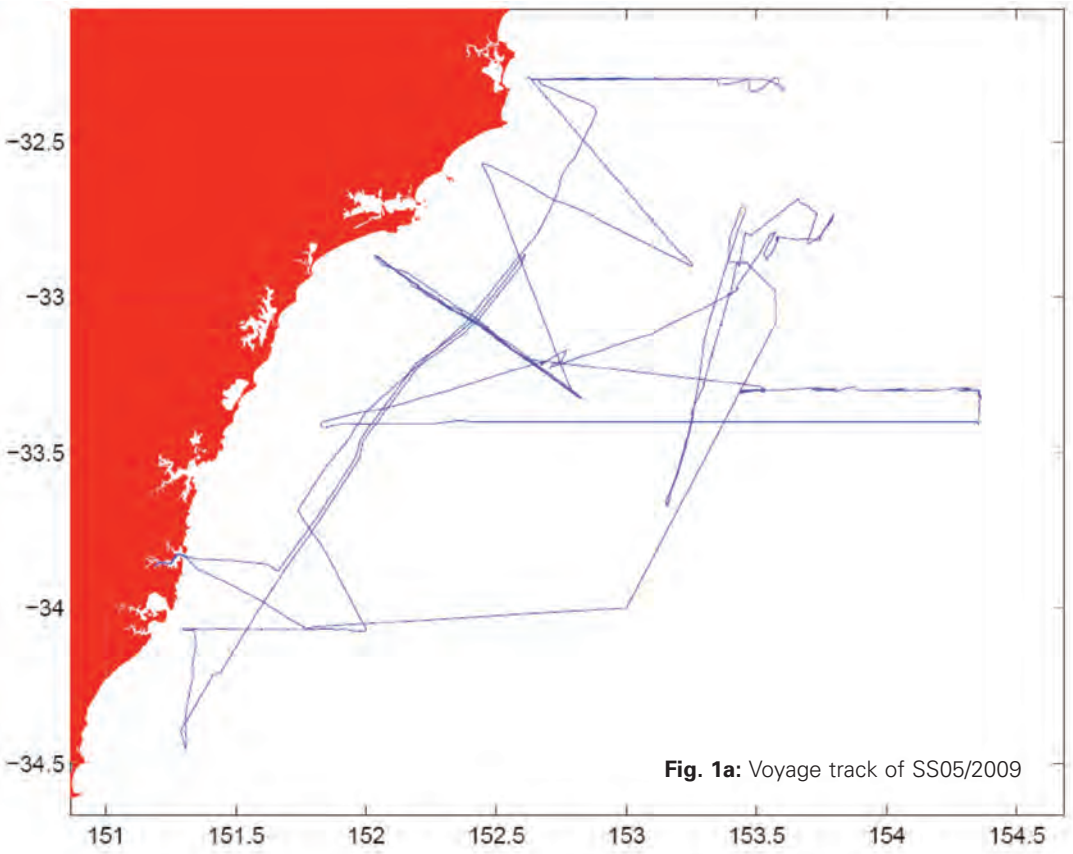


Fig. 1a: Voyage track of SS05/2009

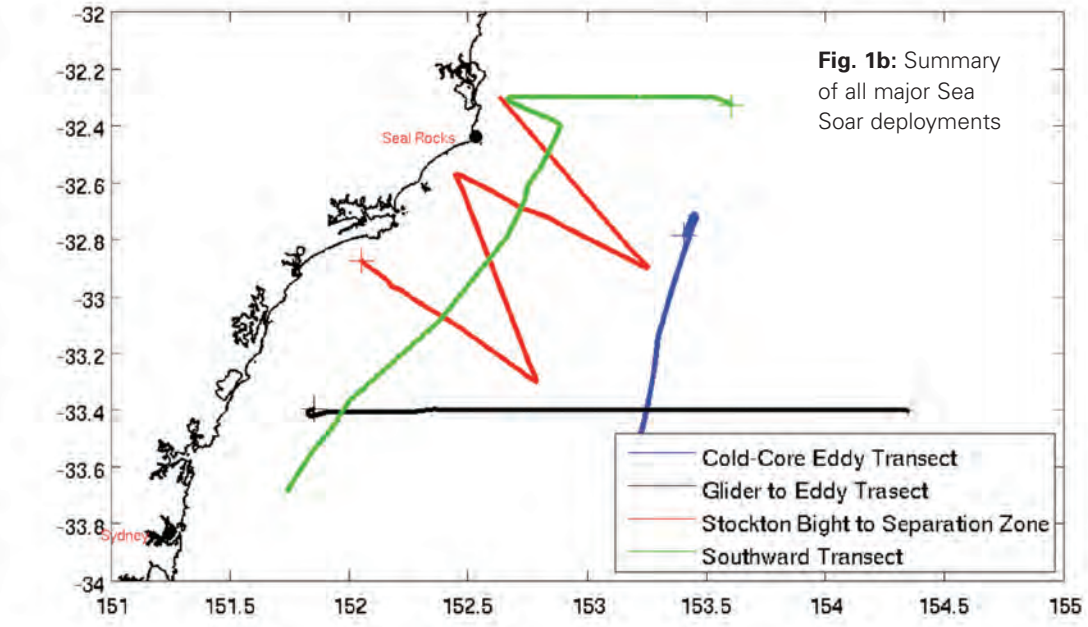


Fig. 1b: Summary of all major Sea Soar deployments

Scientific Participants

Name	Affiliation	Role
Lindsay Pender	CSIRO MNF	Electronics, voyage manager
Stephen Thomas	CSIRO MNF	Computing (2pm-2am)
Alicia Navidad	CSIRO MNF	Hydrochemistry
Iain Suthers	SIMS-UNSW	Chief Scientist
Mark Baird	UNSW	Alt-Chief Scientist (2am-2pm)
Jason Everett	UNSW	2am-2pm
Matthew Taylor	SIMS-UNSW	2pm-2am
Kylie Pitt	Griffith University	2am-2pm
Martina Doblin	SIMS-UTS	Phytoplankton
Kadija Oubelkheir	UTS	Bio-optics
Benjamin Harris	UNSW	2pm-2am
Natasha Henschke	UNSW	2am-2pm
Helen MacDonald	UNSW	2pm-2am
Adrian Ferguson	UNSW	2pm-2am
Tegan Sime	UNSW	2am-2pm

Marine Crew

Name	Role
MASTER	Ian Taylor
CHIEF OFFICER	John Barr
2nd OFFICER	Rob Ferries
CHIEF ENGINEER	John Morton
1ST ENGINEER	Dave Jonkers
2ND ENGINEER	Jamie Wheatcroft
BOSUN	John Howard
IR	Jeremy Blyth
IR	Jonathon Lumb
IR	Peter Mathiassen
IR	Ben McLucas
CHIEF STEWARD	Andrea Henderson
CHIEF COOK	Kyle Short
2ND COOK	Ken Rawson

ACKNOWLEDGEMENTS

We thank the captain of the RV *Southern Surveyor*, Ian Taylor, and his crew for their seamanship and enthusiasm, and also the dedication of the CSIRO Marine staff who made the science possible. We should note we had the crème de la crème of ships crew and the CSIRO support staff – their expertise, intuition and dedication is quite remarkable.

We acknowledge two ARC Discovery Grants to Iain Suthers, Mark Baird, Peter Oke, and the support of the University of New South Wales.

Iain Suthers
Chief Scientist

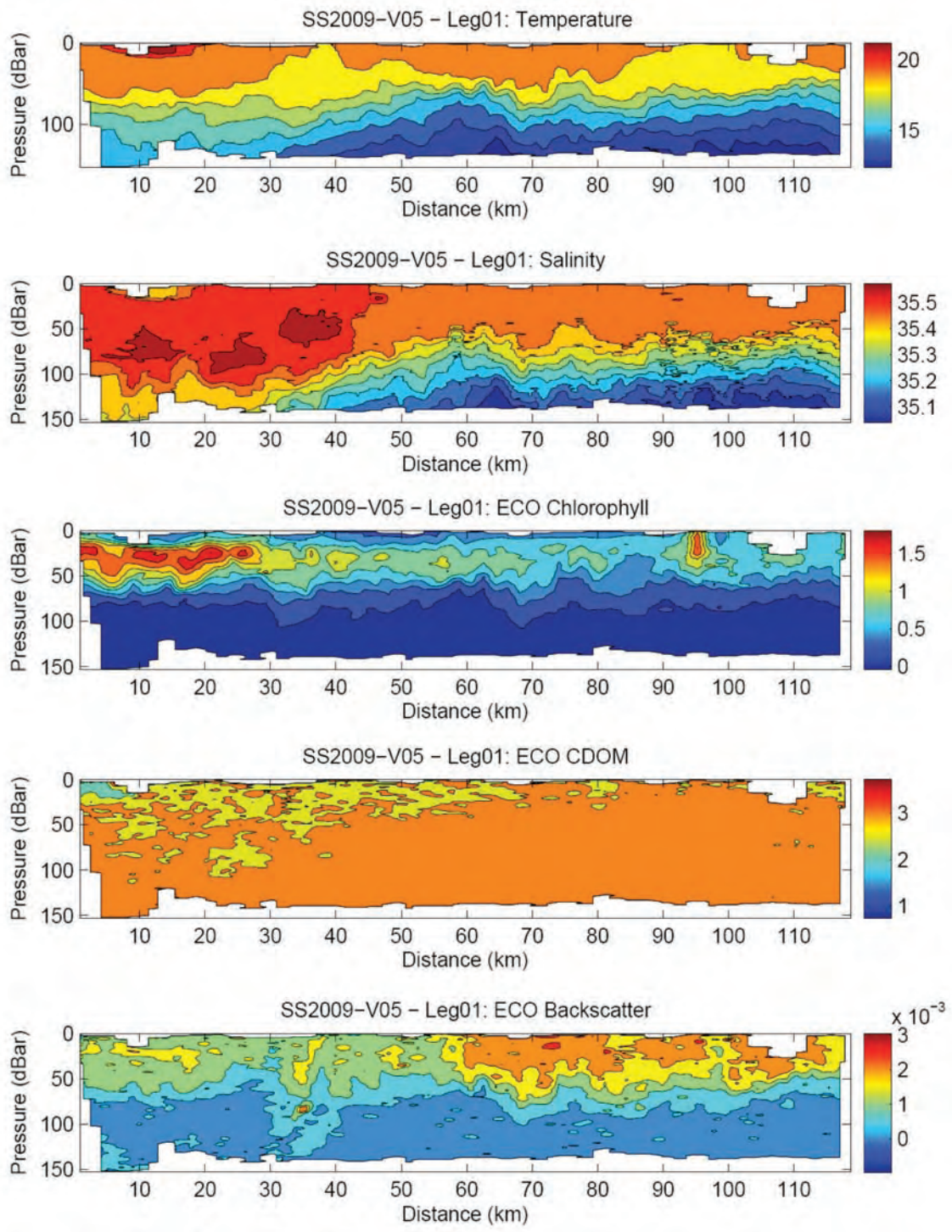


Fig. 2: Initial Sea Soar transect across the eddy, just out of Sydney, from south to north, followed by a CTD transect.

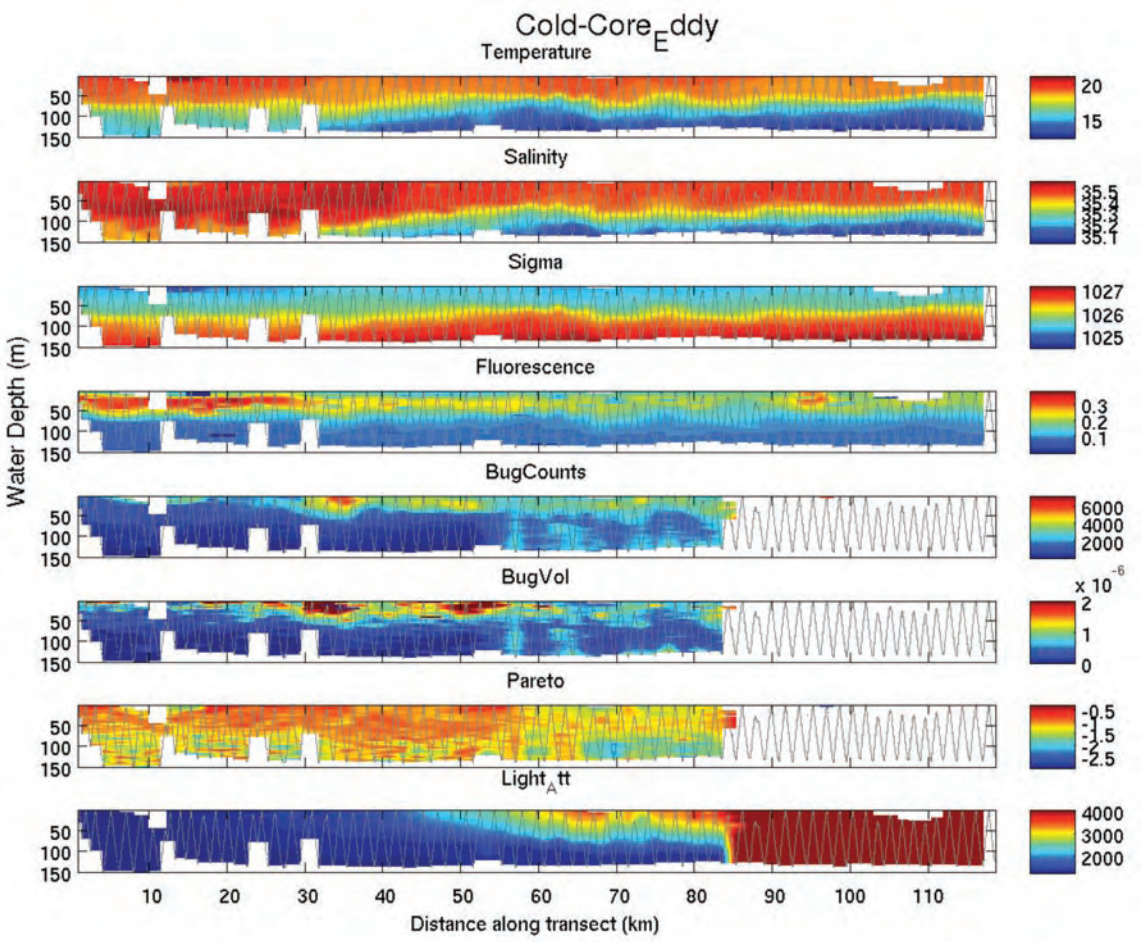


Fig. 3: Corresponding image of Leg01 (Fig. 2) but including the OPC data of particle ("bug") counts, total particle biovolume, the pareto statistic (numerically equivalent to the slope of the normalised biomass size spectrum) and the light attenuance signal (the latter showing the demise of the instrument due to a minute leak).

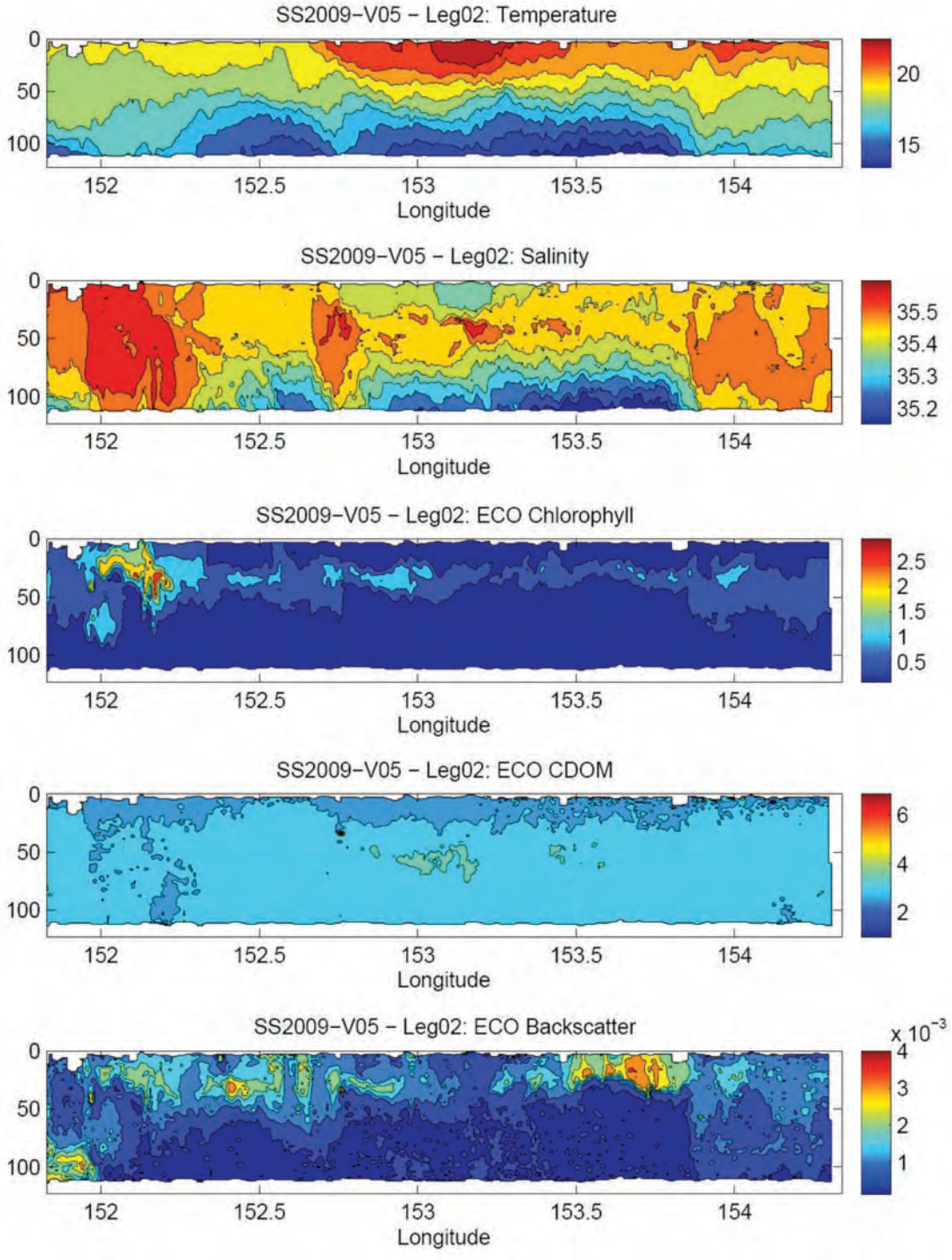


Fig. 4: East to West transect of the cold core eddy (after retrieval of Slocum and deployment of Sea glider) showing flooding of the eddy by EAC water.

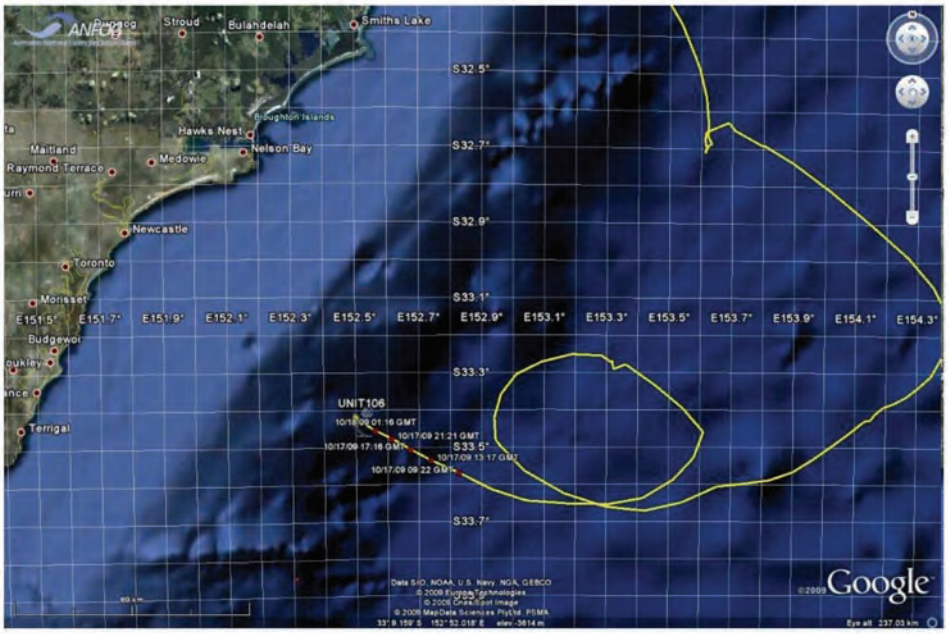


Fig. 5a: Glider track of Slocum Unit 109 "Nemo-3" retrieved off Gosford by *Southern Surveyor*.

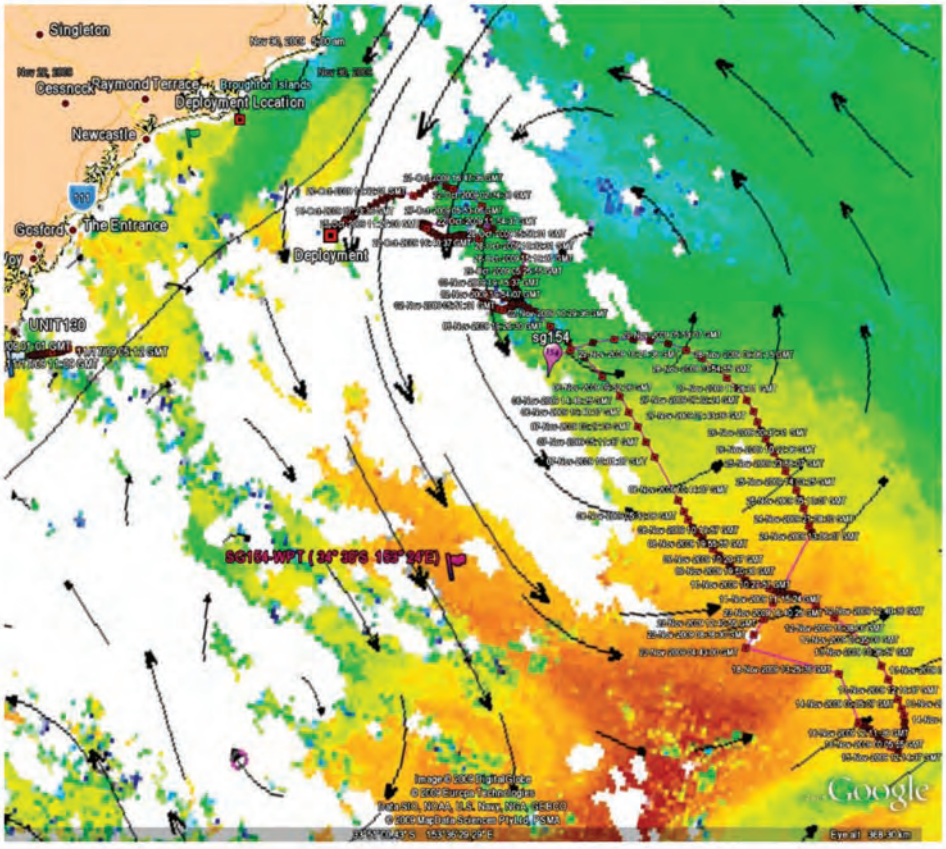
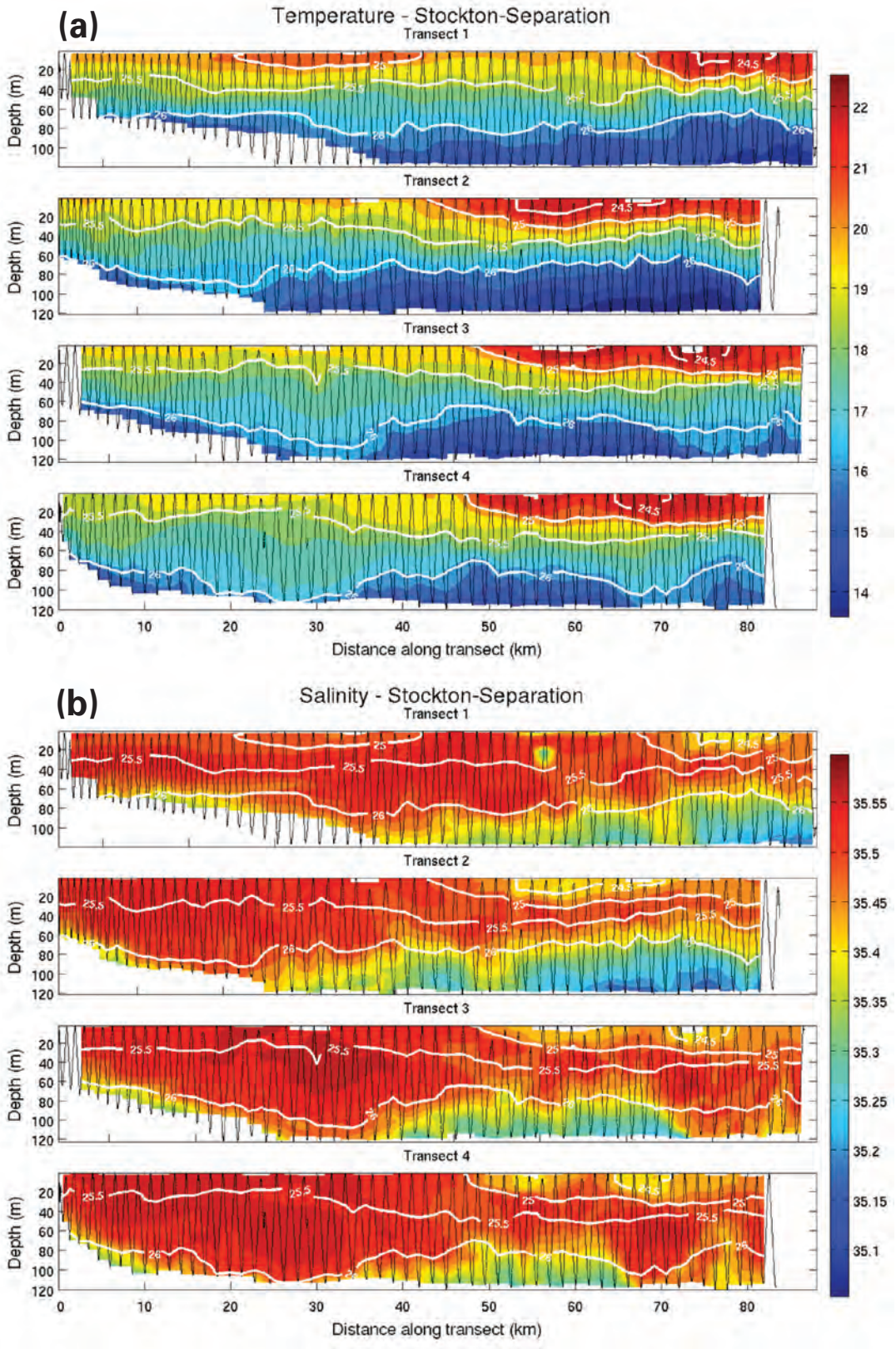


Fig. 5b: Glider track of Sea Glider 154 by late November, released from *Southern Surveyor* 05-2009 in mid October (Slocum Glider 130 "Nemo-4" is also shown in yellow on the shelf off Newcastle). The sea glider completed two revolutions of the warm core eddy off Sydney and was retrieved on 11 Jan. 2010.


(a)
Temperature - Stockton-Separation
Transect 1
Transect 2
Transect 3
Transect 4
Depth (m)
Distance along transect (km)
(b)
Salinity - Stockton-Separation
Transect 1
Transect 2
Transect 3
Transect 4
Depth (m)
Distance along transect (km)

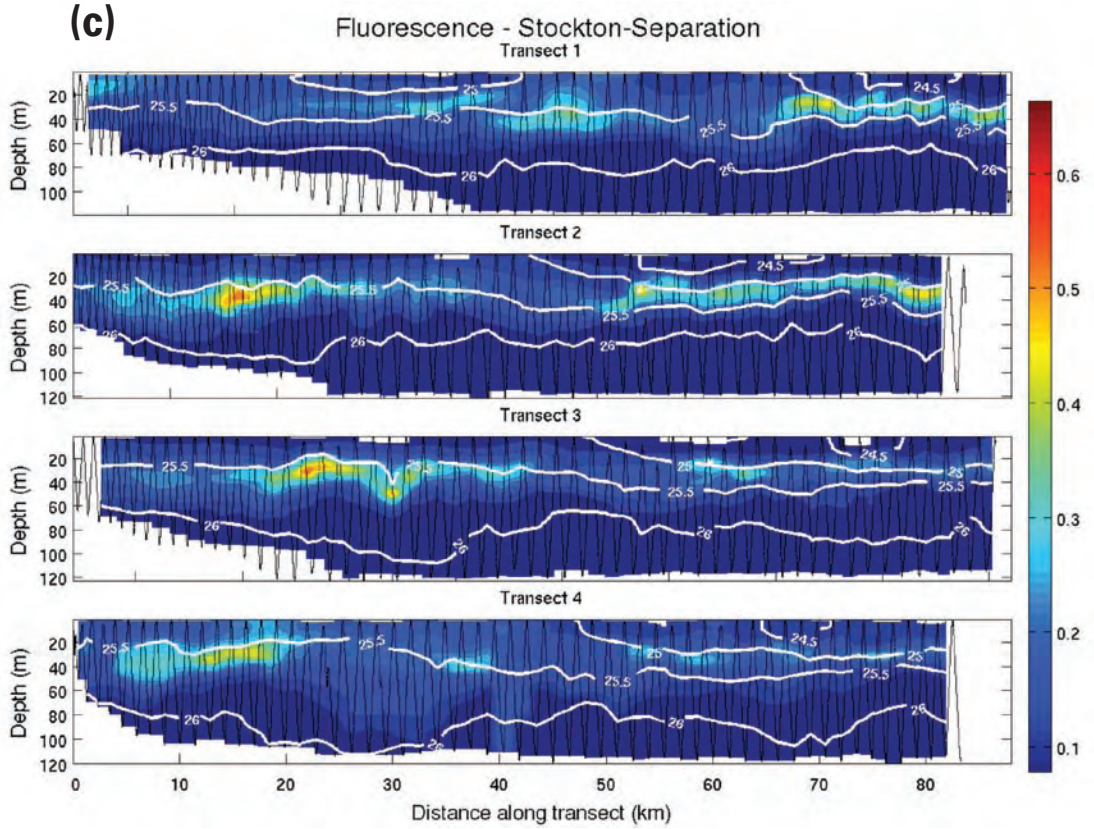


Fig. 6: Sea Soar transects through the EAC separation zone (see Fig. 1b for locations) a) temperature; b) salinity; c) fluoresence

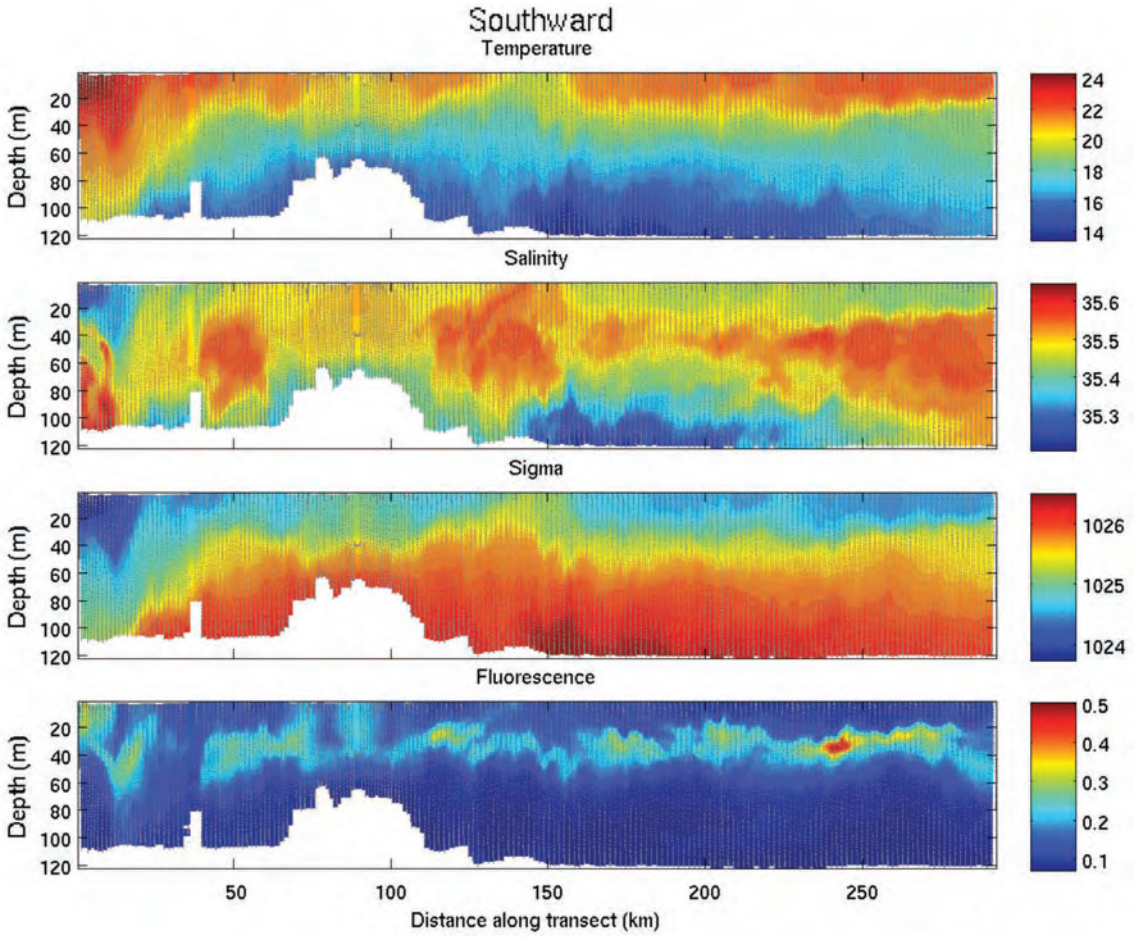


Fig. 7: Sea Soar summary of a 300 km deployment along the continental shelf, north to south, from off Cape Hawke to off Broken Bay.

Appendix 1
Table of all CTD stations and associate N70 vertical hauls.

CTD	Date	UTC	Local	Location	Lat	Long	Bathym	N70	Notes
1 (test)		8:34	19:34				1185		
2	Sun 18/10/2009			miss-fire					
3	Sun 18/10/2009			miss-fire					
4	Sun 18/10/2009	10:06	21:06	Big Ed	33 40'	153 10'	4816	1,2	southern end of eddy, 12 nm to next
5	Sun 18/10/2009	11:52	22:52	Big Ed	33 28'	153 14'	4830	3,4	6 nm to next
6	Sun 18/10/2009	13:40	0:40	Big Ed	33 23'	153 16'	4845	5,6	6 nm to next
7	Sun 18/10/2009	15:25	2:25	Big Ed	33 17'	153 18'	4847	7,8	6 nm to next
8	Sun 18/10/2009	16:58	3:58	Big Ed	33 11'	153 20'	4850	9,10	6 nm to next
9	Sun 18/10/2009	18:48	4:48	Big Ed	33 05'	153 22'	4849	11,12	6 nm to next
10	Sun 18/10/2009	20:37	7:37	Big Ed	32 59'	153 24'	4850	13,14	6 nm to next
11	Sun 18/10/2009	22:11	9:11	Big Ed	32 53'	153 26'	4823	15,16	6 nm to next
12	Sun 18/10/2009	23:43	10:43	Big Ed	32 48'	153 29'	4710	17,18	6 nm to next
13	Sun 18/10/2009			miss-fire					
14	Sun 18/10/2009			miss-fire					
15	Sun 18/10/2009	2:35	13:35	Big Ed	32 40'	153 40	4808	19,20	NE off line to find 21deg and EAC
16	Mon 19/10	3:55	14:55	glider deployment	3328	21,22	to correspond with initial Sea Glider profiles		
17	Mon 19/10	5:25	16:25	glider pickup	2483	23,24	to correspond with final Slocum Glider profiles		
18	Tues 20/10	4:35	15:35	EAC-EZ start	4413	23,24	nb – duplicate mislabel on N70, should have a few pillies in it		
19	Wed 21/10	1:35	12:35	eddy centre			4797	25,26	
20	Wed 21/10	6:37	17:37	Stockton Bight	33 12′	152 37′	1689	27,28	Martina chlorophyll, EZ16,17
21	Wed 21/10	7:56	18:56	Stockton Bight	33 09′	152 32′	1099	29,30	
22	Wed 21/10	9:05	20:05	Stockton Bight	33 06′	152 27′	521	31,32	Martina chlorophyll, EZ14,15
23	Wed 21/10	10:32	21:32	Stockton Bight	33 03′	152 22′	146	33,34	
24	Wed 21/10	11:34	22:34	Stockton Bight	33 01′	152 17′	139	35,36	Martina chlorophyll, EZ12,13
25	Wed 21/10	12:38	23:38	Stockton Bight	32 58′	152 12′	131	37,38	
26	Wed 21/10	13:47	0:47	Stockton Bight	32 55′	152 07′	122	39,40	Martina chlorophyll
27	Wed 21/10	14:59	1:59	Stockton Bight	32 52′	152 02′	69	41,42	N70 re-labelled OK;went to only 40 m as shallow
28	Sat 24/10	15:38	2:28	Cape Hawke	32 18′	152 38′	87	43,44	
29	Sat 24/10	16:41	3:41	Cape Hawke	32 18′	152 45′		45,46	
30	Sat 24/10	18:54	4:54	Cape Hawke	32 18′	152 52′	117	47,48	
31	Sat 24/10	20:30	11:30	Cape Hawke	32 18′	153 00′	359	49,50	
32	Sat 24/10	0:57	11:57	Cape Hawke	32 18′	153 07′	2000	51,52	snafu sorted out with N70 winch
33	Sat 24/10	2:22	13:22	Cape Hawke	32 18′	153 14′		53,54	
34	Sat 24/10	3:39	14:39	Cape Hawke	32 18′	153 21′	3305	55,56	
35	Sat 24/10	5:04		Cape Hawke	32 18′	153 28′	4193	57,58	
36	Sat 24/10	6:38		Cape Hawke	32 18′	153 35′	4505	59,60	
37	Sun 25/10	6:21		Sydney	34 04	152 00	2171	61,62	Chlorophylls
38	Sun 25/10			Sydney	34 04	151 54'		63,64	
39	Sun 25/10			Sydney	34 04	151 48			Chlorophylls
40	Sun 25/10			Sydney	34 04	151 42			
41	Sun 25/10			Sydney	34 04	151 36			Chlorophylls
42	Sun 25/10			Sydney	34 04	151 30			
43	Sun 25/10			Sydney	34 04	151 24'			Chlorophylls, S of SYD140
44	Sun 25/10			Sydney	34 04	151 18'			Chlorophylls, S of SYD100

Appendix 2. Table of all EZ net stations

Sample (EZ&net)	Lat	long	Region	Correlating CTD	Team	Success	Date UTC	Date local	Time UTC	Time local	depth (m)	Notes
0.1	32 43.658	153 43.231	Off Shore Eddy	15	B	Yes	18/10/09	18/10/09	504	1607	500-340	
0.2						Yes					340-200	
0.3						Yes					200-100	
0.4						Yes					100-50	
0.5 ≈50m						Yes					50-0	Had to pay out of wire; net haul from 50m-100m
1.1	32 45.483	153 47.122	Off Shore Eddy	15/9	B	Yes	18/10/09	18/10/09	831	1932	500-320	
1.2						Yes					320-200	
1.3						Yes					200-100	
1.4						Yes					100-50	
1.5						Yes					50-0	
2.1	32 48.85	153 34.59	Off Shore Eddy	12 and/ or 15	B	Yes	18/10/09	19/10/09	1353	1253	500-300	
2.2						Yes					300-100	
2.3						Yes					100-0	
2.4						No					*	
2.5						No					*	
3.1	32 51.40	153 31.84	Off Shore Eddy	12	A	Yes	18/10/09	19/10/09	1629	330	500-400	Check Nets at SIMS!! Do we have the surface net?
3.2						Yes					400-300	
3.3						No					300-100	
3.4						No					100-50	
3.5						Yes					50-0	
4.1	33 18.22	154 21.46	Off Shore Eddy	18	B	Yes	20/10/09	20/10/09	554	1640	500-350	
4.2						Yes					350-200	
4.3						Yes					200-100	
4.4						Yes					100-50	
4.5						No					50-0	Cod end lost. Wind problems, net was towed in prop wash for 20min, samples very degraded
5.1	33 17.55	154 19.30	Off Shore Eddy	19/18	B	Yes	20/10/09	20/10/09	814	1914	500-350	400 for 23m3
5.2						Yes					350-200	200 for 25m3
5.3						Yes					200-100	haul 100m for 30m3
5.4						Yes					100-50	net 4 may have sampled 100-om depth
5.5						No					50-0	Didn't drop
6.1	33 18.01	154 03.65	Off Shore Eddy	In between 18/19		Yes	20/10/09	20/10/09	1051	2151	500-400	
6.2				but not close proximity		Yes					400-200	
6.3						Yes					200-100	
6.4						Yes					100-50	

Sample (EZ&net)	Lat	long	Region	Correlating CTD	Team	Success	Date UTC	Date local	Time UTC	Time local	depth (m)	Notes
6.5						Yes					50-0	Kept 1/4 of sample. 8 pillies kept from 3/4 disposed. (work out volumes)
7.1	33 17.72	154 03.95	Off Shore Eddy	In between 18/19	B	Yes	20/10/09	20/10/09	1234	2335	500-400	
7.2				but not close proximity		Yes					400-200	
7.3						Yes					200-100	
7.4						Yes					100-50	
7.5						Yes					50-0	
8.1	33 17.82		Off Shore Eddy	In between 18/19	A	Yes	20/10/09	21/10/09	1532	232	500-400	
8.2				but not close proximity		Yes					400-200	
8.3						Yes					200-100	
8.4						Yes					100-50	2L subsampled to 1.1L
8.5						Yes					50-0	
9.1	33 17.80	153 48.80	Off Shore Eddy	In between 18/19	B	Yes	20/10/09	21/10/09	1811	511	500-400	
9.2				but not close proximity			Yes					400-200
9.3						Yes					200-100	Migration occurring, most likely affectinh net 3
9.4						Yes					100-50	Plume (migration?) past net 4 by the time net dropped
9.5						Yes					50-0	
10.1	33 18.00	153 31.9	Off Shore Eddy	19	B	Yes	20/10/09	21/10/09	2056	755	500-400	Vertical migration finished. Log file was not activated, no data obtained.
10.2						Yes					400-200	
10.3						Yes					200-100	
10.4						Yes					100-50	
10.5						Yes					50-0	
11.1	33 18.17	153 31.83	Off Shore Eddy	19	B	Yes	20/10/09	21/10/09	2309	1009	500-400	
11.2						Yes					400-200	
11.3						Yes					200-100	
11.4						Yes					100-50	
11.5						Yes					50-0	Iain took ≈30 assorted larval fish, stored in EtOH
12.1	33 01.16	152 17.37	Stockton bight	23/24	A	Yes	21/10/09	22/10/09	1720	420	125-100	first net was opened at 134m (EZ was in shallow shelf water)
12.2						Yes					100-75	
12.3						Yes					75-50	
12.4						Yes					50-25	
12.5						Yes					25-0	

Sample (EZ&net)	Lat	long	Region	Correlating CTD	Team	Success	Date UTC	Date local	Time UTC	Time local	depth (m)	Notes
13.1	33 00.881	152 17.237	Stockton bight	23/24	A	Yes	21/10/09	22/10/09	1849	549	125-100	
13.2						Yes					100-75	
13.3						Yes					75-50	
13.4						Yes					50-25	
13.5						Yes					25-0	
14.1	33 05.848	152 27.012	Stockton bight	21/22	A	Yes	21/10/09	22/10/09	2115	815	500-400	On continental slope, echoes from deeper depths than on the abyssal plains
14.2						Yes					400-200	
14.3						Yes					200-100	
14.4						Yes					100-50	
14.5						Yes					50-0	
15.1	33 05.160	152 27.219	Stockton bight	21/22	A	Yes	21/10/09	22/10/09	2309	1009	500-400	
15.2						Yes					400-200	problems with net openning, net tripped after 100m3 so volume was reset
15.3						Yes					200-100	
15.4						Yes					100-50	1.1L subsample from 2.2L
15.5						Yes					50-0	
16.1	33 12.112	152 37.062	Stockton bight	17/20	B	Yes	22/10/09	22/10/09	147	1247	500-400	
16.2						Yes					400-200	
16.3						Yes					200-100	
16.4						Yes					100-50	
16.5						Yes					50-0	
17.1	33 12.055	152 37.13	Stockton bight	17/20	B	Yes	22/10/09	22/10/09	359	1459	500-400	Began to do EZ trawls at less than 2kn
17.2						Yes					400-200	
17.3						Check					200-100	
17.4						Check					100-50	
17.5						Yes					50-0	
18.1	33 17.94	152 46.89	Stockton bight	16/17	B	Check	22/10/09	22/10/09	632	1732	500-400	
18.2						Yes					400-200	
18.3						Check					200-100	
18.4						Check					100-50	
18.5						Check					50-0	
19.1	33 17.98	152 46.96	Stockton bight	16/17	B	Yes	22/10/09	22/10/09	827	1927	500-400	Problem with this final EZ, net order was different, watch for anything abnormal
19.2						Yes					400-200	
19.3						No					200-100	Will tell us what was traveling up at dusk
19.4						Yes					100-50	
19.5						Yes					50-0	

CSR/ROSCOP PARAMETER CODES

	METEOROLOGY
M01	Upper air observations
M02	Incident radiation
M05	Occasional standard measurements
M06	Routine standard measurements
M71	Atmospheric chemistry
M90	Other meteorological measurements

	PHYSICAL OCEANOGRAPHY
H71	Surface measurements underway (T,S)
H13	Bathythermograph
H09	Water bottle stations
H10	CTD stations
H11	Subsurface measurements underway (T,S)
H72	Thermistor chain
H16	Transparency (eg transmissometer)
H17	Optics (eg underwater light levels)
H73	Geochemical tracers (eg freons)
D01	Current meters
D71	Current profiler (eg ADCP)
D03	Currents measured from ship drift
D04	GEK
D05	Surface drifters/drifting buoys
D06	Neutrally buoyant floats
D09	Sea level (incl. Bottom pressure & inverted echosounder)
D72	Instrumented wave measurements
D90	Other physical oceanographic measurements

	CHEMICAL OCEANOGRAPHY
H21	Oxygen
H74	Carbon dioxide
H33	Other dissolved gases
H22	Phosphate
H23	Total – P
H24	Nitrate
H25	Nitrite
H75	Total – N
H76	Ammonia
H26	Silicate
H27	Alkalinity
H28	PH
H30	Trace elements
H31	Radioactivity
H32	Isotopes
H90	Other chemical oceanographic measurements

	MARINE CONTAMINANTS/POLLUTION
P01	Suspended matter
P02	Trace metals
P03	Petroleum residues
P04	Chlorinated hydrocarbons
P05	Other dissolved substances
P12	Bottom deposits
P13	Contaminants in organisms
P90	Other contaminant measurements

	MARINE BIOLOGY/FISHERIES
B01	Primary productivity
B02	Phytoplankton pigments (eg chlorophyll, fluorescence)
B71	Particulate organic matter (inc POC, PON)
B06	Dissolved organic matter (inc DOC)
B72	Biochemical measurements (eg lipids, amino acids)
B73	Sediment traps
B08	Phytoplankton
B09	Zooplankton
B03	Seston
B10	Neuston
B11	Nekton
B13	Eggs & larvae
B07	Pelagic bacteria/micro-organisms
B16	Benthic bacteria/micro-organisms
B17	Phytobenthos
B18	Zoobenthos
B25	Birds
B26	Mammals & reptiles
B14	Pelagic fish
B19	Demersal fish
B20	Molluscs
B21	Crustaceans
B28	Acoustic reflection on marine organisms
B37	Taggings
B64	Gear research
B65	Exploratory fishing

	MARINE GEOLOGY/GEOPHYSICS
G01	Dredge
G02	Grab
G03	Core – rock
G04	Core – soft bottom
G08	Bottom photography
G71	In-situ seafloor measurement/sampling
G72	Geophysical measurements made at depth
G73	Single-beam echosounding
G74	Multi-beam echosounding
G24	Long/short range side scan sonar
G75	Single channel seismic reflection
G76	Multichannel seismic reflection
G26	Seismic refraction
G27	Gravity measurements
G28	Magnetic measurements
G90	Other geological/geophysical measurements