RV *Investigator* Voyage Plan

Voyage #:	IN2015_V03		
Voyage title:	Submesoscale processes – billows and eddies – along the productive shelf by the East Australian Current		
Mobilisation:	Brisbane, Tuesday, 2 June 2015		
Depart:	0800, Brisbane, Wednesday, 3 June 2015		
Arrive:	0800, Sydney, Thursday, 18 June 2015		
Demobilisation:	Sydney, Thursday, 18 June 2015		
Voyage Manager:	Max McGuire	**Contact details:**	max.mcguire@csiro.au
Chief Scientist:	Professor Iain Suthers		
Affiliation:	University of NSW	**Contact details:**	i.suthers@unsw.edu.au
Co-Principal Investigators:	A. Prof. Moninya Roughan, University of NSW A. Prof. Martina Doblin, University of Technology Sydney		

Scientific objectives

Frontal eddies or "billows" are ubiquitous, small cyclonic eddies <100 km in diameter, and regularly characterise the continental side of all ocean boundary currents. They occur approximately weekly, and last up to 3 weeks which is sufficient for the early life history of fish. The physics and biology of these ubiquitous eddies are not understood. They are not resolved by present-day surface altimetry, but are evident along the East Australian Current (EAC) in SST or in real-time surface currents from the Coffs Harbour HF Radar (30.5°S). We will determine if uplift within the eddy nurtures plankton in comparison to the inner shelf water; and in comparison to similar eddies offshore around the EAC retroflection. We expect entrainment of adjacent shelf water is pre-conditioned to sustain larval fish, compared to entrainment of Tasman Sea water. We expect the condition and size distribution (survival) of larval fish will be greater in frontal eddies than in source water on the shelf or in the EAC. Frontal eddies may be a general mechanism for recruitment to coastal fisheries, such as for the Kuroshio Current, Gulf Stream, Agulhas Current.

We will continue our long-term observations of phytoplankton, salps, krill, larval fish assemblages and eddy behaviour in this important region. We will investigate 2 to 3 frontal eddies on 2 separate occasions in the following possible locations:

- the EAC separation zone south of North Stradbroke Island (27.6°S); or
- south of Cape Byron (28.6°S);
- south of Smoky Cape (30.9°S),
- under the Coffs Harbour HF radar (30°S)
- south of Seal Rocks/Sugarloaf Point (32.4°S) and off Port Stephens (32.7°S) or Sydney (34°S).

Our scientific objectives are to:

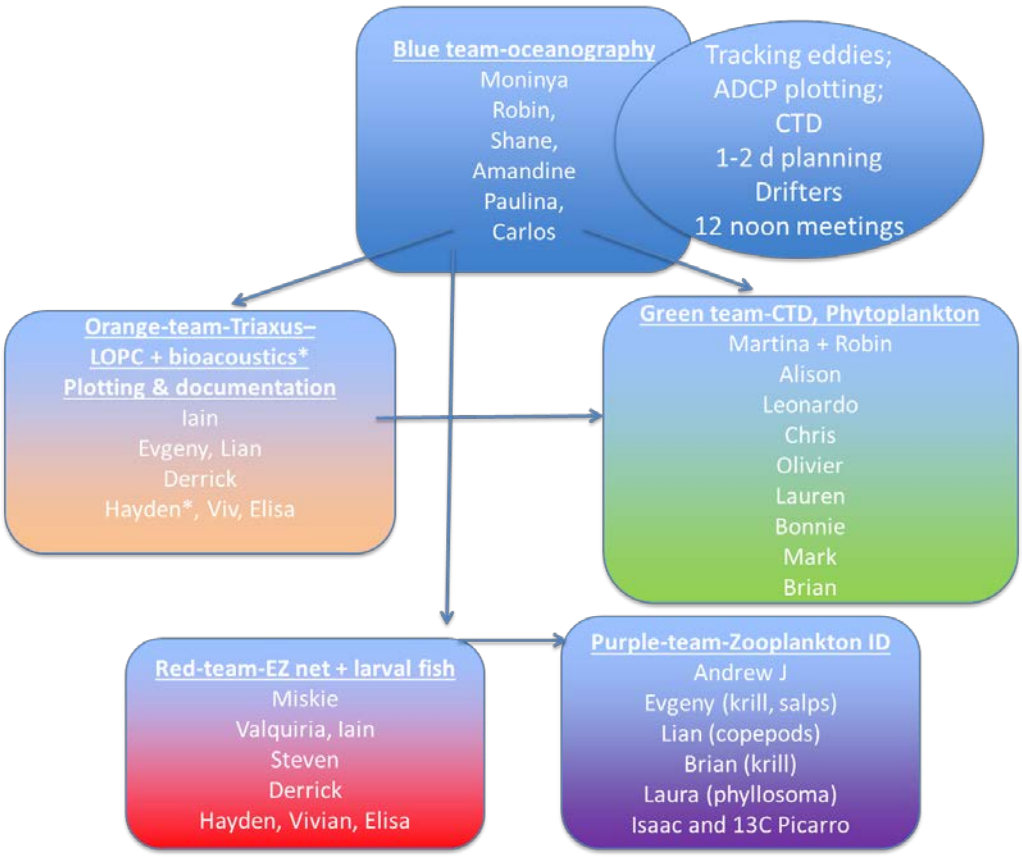
1. Examine the entrainment shelf water and the amount of eddy uplift driven in relation to the strength of the adjacent EAC, coastal wind, the coastal counter-current, and slope canyons; and to quantify oceanographic behaviour of frontal eddies including their movement;
2. Compare the zooplankton size structure and the bioacoustic biomass between coastal waters, frontal eddies and the adjacent EAC or Tasman Sea;
3. Similarly compare the phytoplankton (prokaryotic and eukaryotic) biomass, diversity of pigments and other molecular markers and biogeochemical functions across coastal, EAC and frontal eddy water masses,
4. Similarly compare the zooplankton size structure and species diversity, the larval fish size distribution and the bioacoustic biomass;
5. The abundance, condition and genetic traits of other zooplankton (lobster phyllosoma).

Voyage objectives

Our 5 scientific aims rely on dynamical oceanography, which will rely on excellent communication with the internet for satellite imagery, forecasts and HF radar (e.g. http://oceancurrent.imos.org.au/Bris-Syd/latest.html.

We will only be able to specify the voyage track 24-48 hours in advance. The 28 scientists have been assigned to 5 teams:

1. Blue – oceanographic interpretation of satellite imagery, ADCP, CTD, Triaxus, plotting and daily forecasts. They will lead a planning meeting each day 12 noon, before the vessel meeting 2 pm (led by Moninya Roughan and Iain Suthers);
2. Orange – Triaxus deployments, Laser Optical Plankton counter calibration, plotting and interpretation (led by Iain, Evgeny);
3. Green – Phytoplankton abundance and diversity, biogeochemical functions (including N, C, S as important elements), from the CTD (led by Martina Doblin, Robin Robertson);
4. Red – EZ net deployments, larval fish diversity, and near real-time sorting for size distribution of specific species such as sardine (led by Tony Miskiewicz, Steven, Valquiria);
5. Purple – Zooplankton sorting and identification for larval lobster, larval octopus, salps and krill (led by Andrew Jeffs, Evgeny, Brian).



Summary of overall plan for the voyage is:

- Sample each eddy with 2-3 transects with the Triaxus and ADCP-underway at 8 knots;
- Conduct 5-7 CTD stations (~10 km spacing); and two (2) vertical hauls of a plankton net ("N70") while still on station; (meanwhile disconnect Triaxus and connect EZ net);
- Deploy drifters

- Conduct 4 EZ tows at 3 knots (2 stations with 2 replicate tows at each; preferably at night); after each EZ net we will do a CTD cast.
- A second CTD transect may be conducted.

Steam to the corresponding source waters on the shelf (or EAC):

- Conduct 4 EZ net tows (2 stations with 2 replicate tows at each);
- Before or after each EZ net we will do a CTD cast.
- Disconnect EZ and connect the Triaxus for a 3-4 h tow on the shelf;
- Proceed to next eddy or re-sample the previous.

In detail:

The 5 teams will address the voyage objectives in the following sequence for each frontal eddy:

1. To identify candidate frontal eddies and then sample them by steaming along 30-50 km transects at 8 knots with the Triaxus and all the underway sensors including the bioacoustic recording; at least 2-3 transects per eddy;
2. To sample each frontal eddy with a 6 to 8 station CTD transect, with water bottle sampling at 6-8 depths (See Figure 1). After each CTD cast, two (2) replicate vertical hauls from 50 m depth with a 70 cm diameter, 100 um mesh net ("N70 net") will also occur (via either the pot hauler or coring winch);
    a. CTD depths to fire bottles will be 500, 200, 150, 100, DCM, 50, 30, 15, 5 m.
    b. We will attempt on most days, around dawn, to have a "double-dip" of the CTD, with the first shallow cast simply to bring on board water for incubations.
3. To deploy 3 Lagrangian drifters into each frontal eddy during the transects (simply tossing them off the stern; we have 10 SVP drifters from the Global Drifter Program plus 12 of our own drifters); using their real-time location, we can return to the eddy 3-7 days later to examine maturation of the eddy community relative to the shelf.
4. To sample at two sites within each frontal eddy with the EZ net and CTD rosette sampler. The EZ net will be towed at night. The EZ net will have 5 nets of 500 um mesh; we plan to sample the upper mixed and lower mixed layers only which we expect (in early winter) to be 0-40 and 40-80 m depth, for a total tow time of 30-40 minutes.
    a. During the EZ net tow we wish to tow the 75 x 75 cm square surface ("neuston") net from the coring winch (2 replicates 5 minutes each). This will require some practice with the winch room; the neuston will be back on board and stowed before the EZ is retrieved.
    b. Before or after the EZ we will need to make a CTD cast.
    c. On some occasions at night, the RMT net (our back up for the EZ net) will also be towed as a large neuston net, at the surface.
5. We will identify and then similarly sample the source of entrained water on the shelf with the Triaxus; and 2 EZ net stations x two replicates with corresponding CTD cast. The order of EZ net or CTD does not matter; we will try to be consistent.
    a. Overall EZ-neuston sampling budget will be: 3 eddies + 3 shelf stations x 2 replicate sites x 2 tows x 4 nets (two upper, two lower mixed layer) = 24 EZ tows and 96 EZ net samples;

In the case of bad weather or gear malfunction, it is difficult to prioritise this list as they are mutually dependent. Additionally there may not appear candidate frontal eddies (we are now doing a visual census of OceanCurrent) for June/July for the final voyage plan). In this case we will examine the currents beneath the HF radar, and the effects of the nearby canyon; other mesoscale eddies and the EAC.

The absolute priority will be to sample a frontal eddy and the shelf, with the Triaxus; and to have the condition and length frequency distribution of larval fish. We will bring the RMT net (already on board), and surface neuston nets as back-up.

The phytoplankton characterisation of the frontal eddies will involve CTD transects where a few parameters will be measured (flow cytometrically derived cell abundance, HPLC pigment diversity as well as genetic diversity), as well as at CTD stations where water will be incubated for biogeochemical rate estimates. The latter type of phytoplankton characterisation will require large volumes of water. This is because we need to archive at least 4L of DNA/RNA for one assay from each depth, and each biogeochemical assay requires at least 16L of water (for a T0 and examination of one Nitrogen species – i.e., nitrate, ammonium, urea or nitrogen gas). Each assay requires 24 h incubation in the deckboard incubator and subsequent filtration in the rad van.

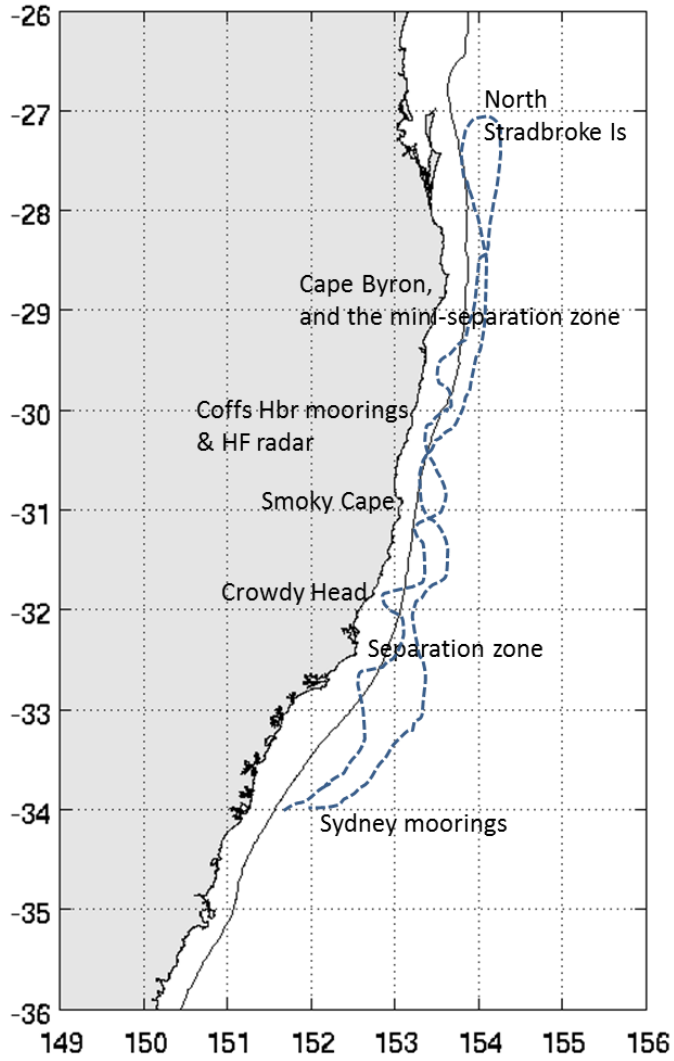
Overall activity plan including details for first 24 hours of voyage

- 2 June15 (mobilise day). 1 hour tutorial and workshop with the CTD procedures for calibration and nutrients, before the at-sea tutorial on 3 June;
    - 1 hour tutorial with EZ net; plus the simultaneous deployment of the 75 cm2 surface (neuston) net from the Coring boom.
- 3 June. Steam to east of North Stradbroke Island (EAC). Complete safety drills on the way. Sample EAC for full phytoplankton characterisation (this represents an end point to our analyses). We would like to do a double CTD cast; the first (quick) cast, to sample surface water which will be rapidly drained from the CTD; re-set the CTD and the normal second cast, to sample water from multiple depths.
    - Off the shelf deploy CTD + N70 vertical haul (2 to 3 attempts, including at sea tutorials); followed by two (2) EZ nets (preferably in daylight for the initial deployment (?); but normally EZ tows will be at night).
    - Instigate the laboratory phytoplankton, zooplankton and larval fish procedures.
    - Slowly steam to adjacent shelf (~100 m isobath) and re-deploy 2* CTD + N70; followed by 2 EZ net tows (this is the other endpoint of our analyses).
    - We anticipate these may be “only” practice tows – but there may be an eddy present.
- 4 June. If no further frontal eddies off North Stradbroke, then steam to Cape Byron or to Coffs Harbour HF Radar; conduct ADCP transects under HF Radar.
    - A-line extends 30km offshore along -29 Deg, 50’
    - B-Line extends 26km offshore along -30 deg 3’
    - Coffs Harbour-Line extends 28 km offshore along -30 deg 18’
- 5-6 June. Conduct Triaxus, CTD transect and EZ sampling in Freddy1 .
    - Deploy drifters (in triplets) in eddy;

  - Sample shelf 4 x EZ net, 4 CTDs, to sample source water.
  - Triaxus tows on shelf

- 7-8 June. Continue to steam south to Port Macquarie, and conduct Triaxus, CTD and EZ sampling. Deploy drifters (in pairs) in Freddy2 and on shelf.
- 9 June. Conduct Triaxus, CTD and EZ sampling (EZ9, EZ10) in EAC and/or mesoscale eddy (or Tasman Sea) for comparison with both freddies.
  - Surface neuston net tows with RMT net at night for lobster phyllosoma and salps.
- 10-11 June. Return to Coffs or south of Cape Byron, to re-sample Freddy1. Examine influence of North Solitary Canyon (30 degr S) on eddy formation using Triaxus and CTD with LADCP.
- 12-13 June. Re-sample Freddy2, and/or chase after Freddy3. Double CTD cast needed to characterise phytoplankton alongside EZ nets.
- 14-15 June. Re-sample Freddy2, and/or chase after Freddy3. Double CTD cast needed to characterise phytoplankton alongside EZ nets.
- 16-17 June. Intensive sampling with Triaxus and EZ net along the Tasman Front, off Port Macquarie to Seal Rocks, or off Port Stephens. Discover entrainment and Freddy4, or return to Freddy1. Need sufficient EAC and coastal water mass samples for comparison.
  - Surface neuston net tows with RMT net at night for lobster phyllosoma and salps.
  - Conduct Triaxus, and surface neuston net tows with RMT in EAC and/or Tasman Sea for comparison with both freddies, complete by midnight to steam back to Sydney by 8 am 18 June.

Voyage Track



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Time Estimates

See above.

Piggy-back projects (if any)

None

Investigator Equipment

Towed gear

1. EZ net with 5 x 500 um mesh nets fitted, with soft cod ends of <500 um mesh with spares; calibrated CTD; calibrated flow meters outside and through nets; MNF support and software interface.
2. Triaxus towed body and towed body winch, with Laser Optical plankton counter, with new GO flow meter.

3. Bongo net for back-up.

Underway Equipment and Support

1. Multibeam/Multifrequency bio-acoustic system;
2. Underway echosounder with bottom detection and real-time display;
3. Underway thermosalinograph and fluorometer and real-time display;
4. Drop keel for thermosalinograph and ADCP (150 & 75 kHz) data gathering with real-time display;
5. Meteorological instruments including ISAR SST radiometer, Met data – wind speed and direction, air temperature, humidity;
6. Ops room displays mirrored in the data processing lab further forward, and position + thermosalinograph + UTC displayed in the wet labs.
7. Two network connections (one for phone, one for computer backup) for UTS container laboratory, with 6 h data transfer and backup onto ship's server.

CTD Equipment and Support

1. minimum 24-bottle CTD-rosette with 10L Niskin bottles and O_2, PAR, fluorometer, and transmissometer sensors mounted (Tranmissometer will provide output in m-1 not %; needs proper calibration and calculation of output).
2. CTD voltage inputs calibrated to correctly log sensor inputs.
3. MNF supplied hydrochemist to carry out oxygen sensor calibrations on land and analyses at sea (priority), as well as salinity and nutrient analyses. Nutrient analyses to include dissolved nitrite/nitrate, phosphate, silicate, ammonium. Lowered ADCP (LADCP) RDI 300 kHz mounted on rosette with battery pack.
4. Deck incubators
5. All three deckboard incubators are required;
6. Plus dry lab incubators in the forward dry lab.
7. Rad-van, co-located with UTS container lab

We will be generating large volumes of 15N waste – greater than 1000L of water and have organised suitable handling of filtrate to work within the MNF isotope protocols.

Application to use isotopes has been submitted and commented on by the Radiation Safety Officer (RSO) at CSIRO.

User Equipment

- UTS flow cytometry container laboratory – on same deck as rad van, ideally
- Nets (UNSW):
    - Rectangular midwater trawl (1.5 x 0.75 m, with 1 mm mesh)
    - Neuston nets (75 x 75 cm, with 500 um mesh)
    - N70 vertical haul net
- 10 SVP drifters to be deployed

- UBC Laser Optical Plankton Counter may be brought aboard for the EZ net.
- BRUVS units x 3

Special Requests

- Power including comms and water to UTS lab van
- Round the clock operation for phytoplankton team depending on the timing of CTDs and experiments. This may mean someone is working in the van alone at night.

Aft lab (wet and dirty),

- Preservation of EZ and N70 samples in the fume hood;
- Scientific preparation for on-deck activities (wet weather gear);
- Temporary storage of neuston nets, N70 net
- If middle lab too full, sorting may occur here in aft lab.

Middle lab Red and Purple teams

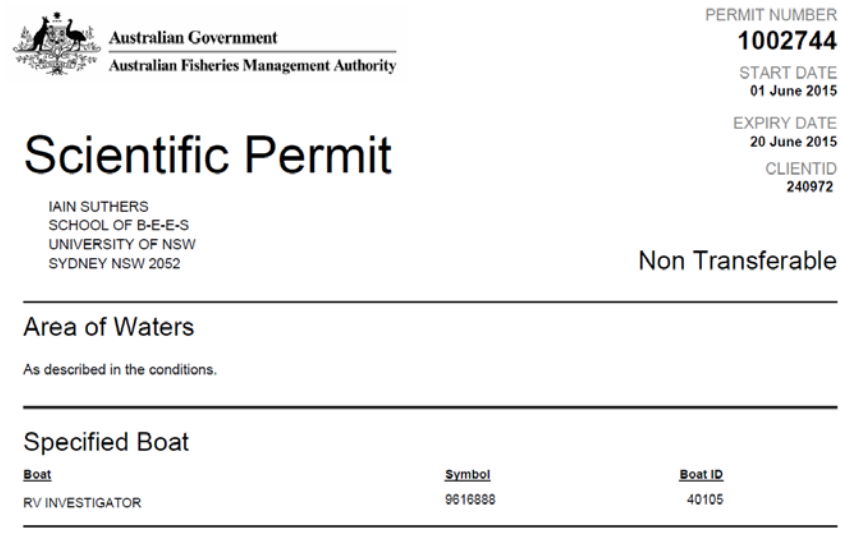
- Microscopes with video recording capability (UNSW) lap-top to record larval fish lengths; [3m bench space].
- Sorting the EZ and RMT zooplankton samples on a bed of ice to reduce decomposition, identifying under lamps with and magnifying lamps [6m bench space];
- 13C Picarro [4m bench space]
- A constant flow of clean seawater (at least 3 L per minute)
- The ability to dispose that seawater back into the ocean
- Stable power (enough to keep an average fridge on)
- About 4 metres of dry bench space near the seawater source (underway lab is too small for this).

Forward Lab – Green team

- Gas chromatograph with Bonnie UTS [1m bench space]
- Peristaltic pump [1m bench space]
- Filtration of phytoplankton samples (or in middle lab)
- Access to laboratory incubators

Permits

Permit from AFMA for plankton - **1002744**



Australian Government
Australian Fisheries Management Authority

PERMIT NUMBER
1002744
START DATE
01 June 2015
EXPIRY DATE
20 June 2015
CLIENTID
240972

Scientific Permit

IAIN SUTHERS
SCHOOL OF B-E-E-S
UNIVERSITY OF NSW
SYDNEY NSW 2052

Non Transferable

Area of Waters

As described in the conditions.

Specified Boat

Boat	Symbol	Boat ID
RV INVESTIGATOR	9616888	40105

No Foreign clearances are required.

Animal care and ethics (larval fish):

Provisional approval from UNSW 5 May 2015

Radioactivity:

UTS has a permit to use radioactivity and this has been sighted by the CSIRO RSO.

Personnel List

Name	Role on vessel	Organisation
Iain Suthers	Chief Scientist	UNSW
Hayden Schilling	PhD, LOPC, bioacoustics	UNSW
Vivian Yeung	Honours-LOPC	UNSW
Valquíria Garcia	larval fish -Brazil	UNSW
Elisa Holgate	Honours-LOPC	UNSW
Tony Miskiewicz	larval fish ID	Adjunct-UNSW
Derrick Cruz	PhD, Visiting Fellow	UNSW
Lian Kwong	MSc – zooplankton size	Univ. British Columbia
Evgeny Pakhomov	krill, copepods, salps	Univ. British Columbia
Andrew Jeffs	phyllosoma, larval fish	Univ. Auckland
Laura Woodings	PhD - phyllosoma genetics	La Trobe U.
Steven Hawes	PhD – larval fish models	U. Sydney
Shane Keating	submesoscale maths	UNSW
Moninya Roughan	HF radar, drifters	UNSW
Amandine Schaeffer	HF radar, drifters	UNSW
Carlos Rocha	PhD-BGC	UNSW
Robin Robertson	CTD-LADCP	UNSW
Paulina Cetina Hedia	Modelling drifters,	UNSW
Isaac Santos	13C Picarro-BGC	SCU

Name	Role on vessel	Organisation
Martina Doblin	Alternate Chief Scientist	UTS
Alison McInnes	Flow - Imagery	UTS
Chris Brownlee	Flow cytometer	UNSW
Leonardo Laiolo	PhD - pigments	UTS
Olivier Lackza	microbial genetics	UTS
Lauren Messer	microbial genetics	UTS
Bonnie Laverock	microbial genetics	UTS
Mark Brown	microbial genetics	UNSW
Brian Griffiths	Phytoplankton, krill	UNSW
Max McGuire	Voyage Manager	CSIRO MNF
Don McKenzie	Deputy Voyage Manager	CSIRO MNF
Hugh Barker	IT/Data Support	CSIRO MNF
Stewart Wilde	IT/Data Support	CSIRO MNF
Brett Muir	Electronics Support	CSIRO MNF
Aaron Tyndall	Electronics Support	CSIRO MNF
Dave Watts	Acoustics Support	CSIRO MNF
Matt Boyd	Acoustics Support	CSIRO MNF
Mark Rayner	Hydrochemistry Support	CSIRO MNF
Cassie Schwanger	Hydrochemistry Support	CSIRO MNF
Christine Rees	Hydrochemistry Support	CSIRO MNF
Mark Lewis	Gear Specialist	CSIRO MNF

5 May 2015

Figures

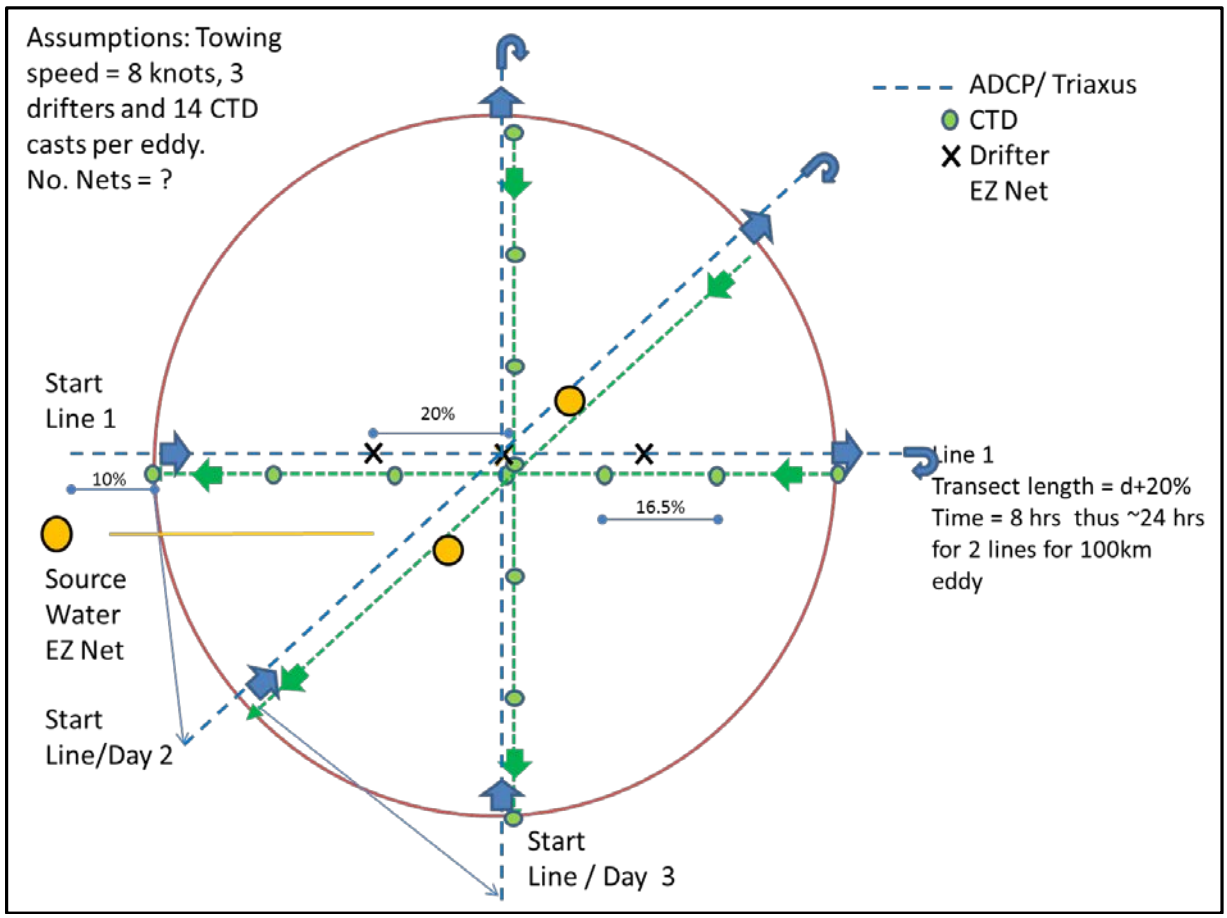


Figure 2. Plan for Triaxus-ADCP transects, with CTD transect

Table 2. Estimates of travel time for different sized eddies totalling 2 to 2.5 days. Assuming towing speed = 8 knots, 3 drifters and 14 CTD casts per eddy (12 h of EZ nets and CTDs)

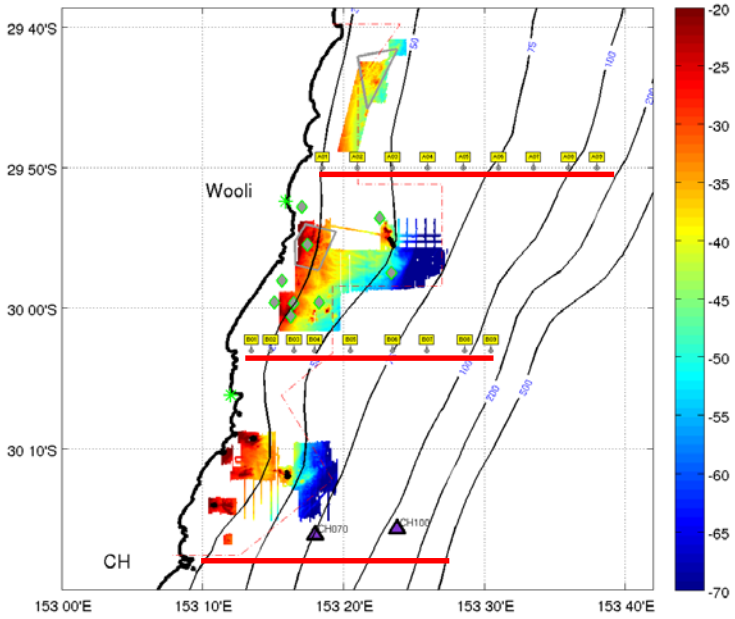
Eddy Diameter (km)	Transect length (diam + 20%)	time for transect (h)	Arc Length (s=r*theta) in rads]	Time to relocate (h)	Total Time for 1 line	Time for 1 CTD line	Time for EZ Nets	no. of full lines	No. Triaxus only lines	Total Time in the Eddy (h)
100	120	8	39	2	10	11	4*2	2	1	64
80	96	6	31	2	8	11	4*2	2	1	58
60	72	5	24	1	6	11	4*2	2	1	52
40	48	3	16	1	4	11	4*2	2	1	46

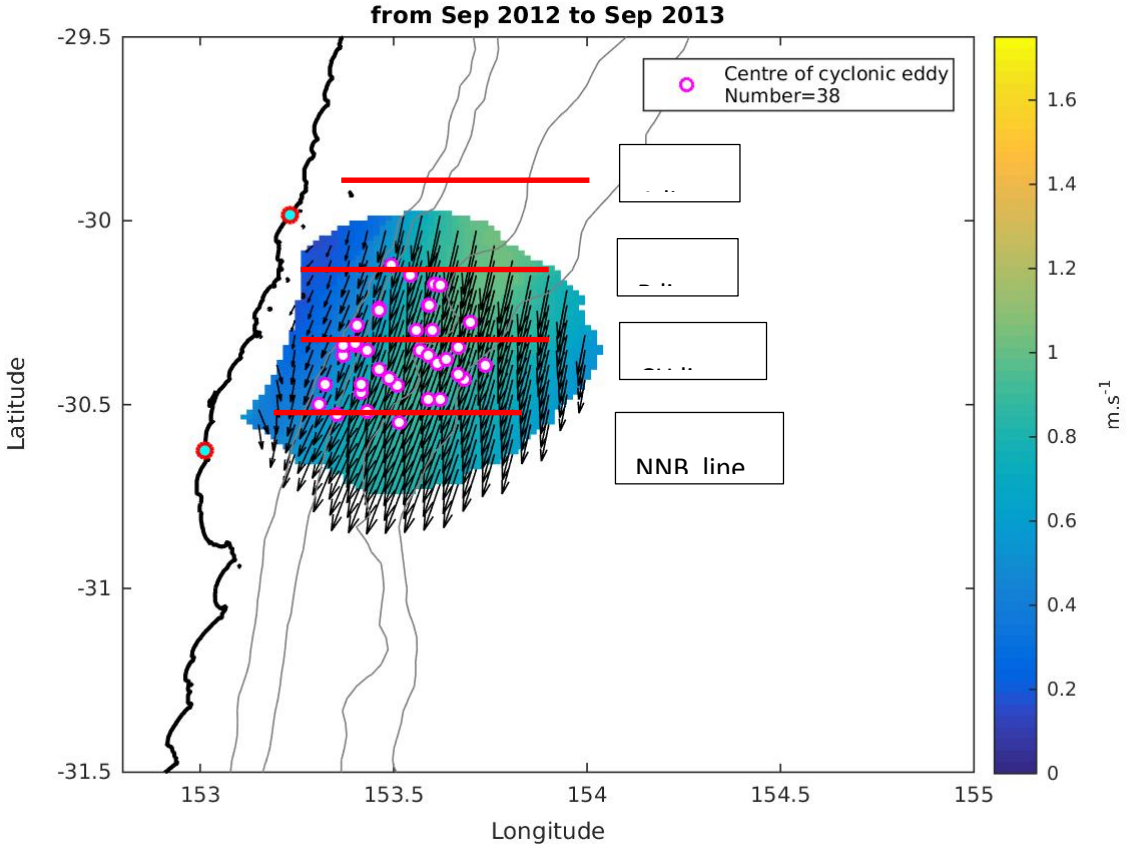
HF Radar Sampling Lines
A line -29deg 50'S
A01,-29,50.000,153,18.500
A03,-29,50.000,153,23.500
A05,-29,50.000,153,28.500
A07,-29,50.000,153,33.500
A09,-29,50.000,153,38.000

B line -30deg 10'S
B01,-30, 3.000,153,13.500
B03,-30, 3.000,153,16.500
B05,-30, 3.000,153,20.500
B07,-30, 3.000,153,25.900
B09,-30, 3.000,153,30.500

Coffs Harbour Moorings to avoid
CH070 -30 17 153 17.91
CH100 30 16.07, 153 23.80

CH line shore normal along 30deg 18'





Nominal lines under the radar footprint. Fig Credit A Gramoule, unpublished data.

Lobster Collector sites CH 30.3S, Forster 32.2 S Sydney 34 S and Ulladulla 35.3S

Appendices

SVP drifter details

Eddy_1: SVP 139657,139658 and 139659

Eddy_2: SVP 139660,139661 and 139662 “Backup” drifter: SVP 139666

Eddy_3: SVP 139663,139664 and 139665

1. Before deployment, remove only the plastic shrink-wrap.
2. Do not remove the paper tape securing the drogue and/or tether. Likewise, do not remove the cardboard surrounding the float.
3. WARNING: Do not remove the paper tape securing the tether and drogue. If you do, the drogue and/or tether can unfurl during deployment and may cause injury!
4. Record the ID number listed on the drifter. This number can be found on the shipping container, the plastic shrink-wrap, or the protective cardboard box. It is also listed on the surface float itself.
5. Deploy the buoy from the stern, at lowest possible deck (preferably less than 10 meters, including heave), into the sea. The ship may be travelling between 1 and 20 knots. The tether and drogue are secured with paper tape that will dissolve in the water.
6. Record the date, time (GMT), coordinates at deployment, and deployment details.

SVP drifter release strategy (3 per eddy)