

# Sir Alister Hardy Foundation for Ocean Science

Monitoring the health of the oceans since 1931



2009 annual report

The Continuous Plankton Recorder survey Est. 1931



# annual report 2009

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## Director's review of the year

Welcome to our 2009 Annual Report in which we outline some of the activities of the past year. One of our major themes in the last 12 months has been the internationalisation of our work. While our

goals remain to continue to monitor and understand changes in the plankton communities of the North Atlantic, North Pacific and Southern Ocean, our Science Strategy (see [www.sahfos.ac.uk](http://www.sahfos.ac.uk) for details) dictates an increasingly international perspective. We embark on this to obtain the information needed for evidence-based policy for achieving sustainability of biological resources across broader stretches of our oceans and seas. To do this we are grateful to NERC, Defra, BAS, EU, Canada, France, Ireland, the Netherlands and the USA for continuing to fund our research.

During the year, we have extended our studies of the North Atlantic into the European Arctic with new routes now established between Mosjøen (Norway) & Reydarfjordur (Iceland) and between Bodo (Norway) and Longyearbyen (Svalbard). This is a significant step because it allows us to monitor the northward movement of Atlantic plankton across the Norwegian Sea. The first results that should be obtained during 2010 will be very exciting indeed. Similarly in the Pacific, a new step has been taken with Japan funding plankton analysis research in the western Pacific. We are delighted that Japan is able to take this important step which will ensure the western and eastern basins of the North Pacific are now studied.

The theme of internationalisation is also reflected in our publications. Although SAHFOS has rather a small number of research-active staff, they have authored 49 papers during the year, with 29 of these published in the peer-reviewed literature. Over 90% of the peer-reviewed papers involved international co-authorship, reflecting the growing collaborations in our work. One of our key papers of 2009 was a state-of-the-art review entitled Impacts of the Oceans on Climate Change. This

paper was lead by Prof. Chris Reid and co-authored with 32 other scientists from ten countries. It was published in *Advances in Marine Biology* (2009) 56: 1-150.

A further way SAHFOS continues to increase its international visibility is through data requests. During 2009, we received 53 requests for CPR survey data. Although by far the most numerous requests were from the UK (32), scientists in Canada (2), Denmark (2), Germany (3), Ireland (7), Italy (1), Norway (3), Spain (2) and Sweden (1) were also provided with data free of charge. We are keen to increase the use of our data further and SAHFOS would welcome enquiries particularly from scientists with whom we've not interacted before.

Our Associated Researcher scheme continues to run well and at the end of 2009 we made 11 new awards to scientists who wished to work with SAHFOS staff during 2010. The awards included scientists from Denmark, France, Germany, Greece, Ireland and USA as well as UK. Results from the 2009 awards are presented later in this report and demonstrate the wide variety of uses for CPR data.

During the year we welcomed Rob Camp, Astrid Fischer, Usha Jha and Gill Tanner to the staff and said good-bye to Julie Finlayson, Trevor Horne, Tony John and Alistair Lindley. Both Alistair and Tony were analysts of considerable skill and experience and they will be sadly missed by us. Fortunately Alistair and Tony have both indicated that they would like to be used in a consultancy basis in their retirement and Tony has already spent time in Brisbane and Hobart liaising with the Australian CPR Survey.

SAHFOS continues to play a significant role in the Plymouth Marine Sciences Partnership (PMSP). During the year I handed over chairmanship of the PMSP Board to the Director of the Marine Biological Association. With the economic downturn in 2009, funding for a new research centre to bring the research-active partners together disappeared. However PMSP will continue to recognise and harness the capabilities of the individual partners to deliver jointly conceived PMSP projects wherever possible.

A major future challenge for SAHFOS in 2010 is planning the next phase of "Going Global". This will involve setting up a regional CPR Survey in the South Atlantic centred in Cape Town. It will involve close collaboration with South African and Namibian marine scientists and collaborative monitoring of the Benguela upwelling system. This will involve many challenges for SAHFOS. We look forward to them.

In concluding the year's review, I would like to thank the Irish Marine Institute for hosting our autumn 2009 Council meeting in Galway.

Peter Burkill  
April 2010



## CPR survey Northern Hemisphere

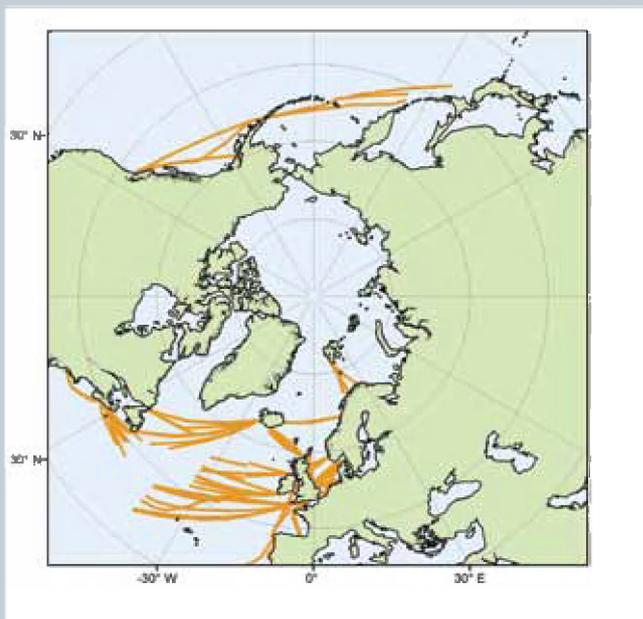


Fig.1. Continuous Plankton Recorder samples taken in the Northern Hemisphere during 2009. During 2009, the CPR survey expanded its operations into Arctic waters with tows from northern Norway to Svalbard.





# CPR survey operations



## Tow logistics and operations

Peter Pritchard, *Operations Manager*

The physical operation of the Continuous Plankton Recorder Survey over the past 78 years would not have been economically possible without the generous support of ships, owners, managers, charterers, port operatives and agents. The consistent monthly tows plus the assistance from the agents and port operatives in getting the recorders to and from the vessels are a fine testament to the shipping industry. The international marine, fisheries, meteorological and oceanographic communities are greatly indebted to them.

Ships and companies participating during 2009 are shown in Appendix B, with photographs of the vessels inside the covers. During 2009 the 24 tow ships logged 126,165 nautical miles on 31 routes worldwide. There were 115,724 analysable nautical miles. The overall 92.3% sampling success rate in 2009 is a fine testament to the conscientious work of the CPR workshop team. Until 31 December 2009 a total of 5,703,497 nautical miles have been towed by the 290 ships since September 1931.

Seven changes of ships occurred in 2009: February - *Armorique* on the PR route. May - *Tor Hafnia* on the HE route. June - *BBC Reydarfjordur* on the new NI route. July - *Atlantic Companion* on the D route. September - *Stad Amsterdam* sailing clipper on the new FR (Falmouth to Rio de Janeiro) route. November - *Bretagne* on the PR route. December - *Perseus J* on the SB and IB routes.

The planned maintenance and safe working program continued across the fleet throughout 2009.

First sailing vessel to tow Continuous Plankton Recorders: Darwin Expedition re-enactment from Falmouth, UK to Rio de Janeiro, Brazil

On 31st August 2009 the large, 250 foot sailing clipper *Stad Amsterdam* was supplied with plankton recorders 177 and 180. The Bosun and crew were shown the deployment and recovery methods while the ship was anchored in Plymouth Sound. Katja Philippart of NIOZ, Texel was trained in unloading, servicing and reloading the filter cassettes. Katja imparted this knowledge to the 2nd Mate Arthur Hoogstad. NIOZ are coordinating this project with the Dutch television company VPRO chartering the clipper. The *Stad Amsterdam* completed 12 recorder tows between Falmouth, UK and Rio de Janeiro, Brazil from 3 September to 12 October 2010. The total distance towed was 4486 nautical miles. The recorder's impeller pitch had to be adjusted to allow for being towed from a sailing vessel instead of being in the propeller thrust wash of a motor ship. These tows are part of the 200th Anniversary of Charles Darwin's birth and the *Stad Amsterdam* is following in the tracks of HMS *Beagle's* Darwin Expedition around the world. The plankton recorders were returned from Rio de Janeiro to SAHFOS, Plymouth in October 2009. See page 26 for further details.

Antarctic: Falkland Islands to South Orkneys and South Georgia

In January and April 2009 the RRS *James Clark Ross* completed 2 tows between South Georgia and the Falklands. From 28 October to 31 December 2009, the *James Clark Ross*

During 2009 the CPR survey expanded its operations into the Arctic

## CPR operations



completed 5 tows between South Georgia, the Falklands and the South Orkneys. The spools were removed from the cassettes, had 4% formalin added, were sealed in tough polythene bags and placed in a black watertight case in temperature controlled storage until the ship returned to the UK. Dr Peter Ward of the British Antarctic Survey, Cambridge co-ordinates this ongoing project.

### Iceland and the North Atlantic

The Foundation is greatly indebted to the Hafrannsóknastofnunin (Marine Research Institute) of Reykjavik for the continuous logistical support to the survey. Teresa da Silva and her supervisor Dr Astthor Gislason organise the transfer of the Continuous Plankton Recorders to and from the Z route ship, *Reykjafoss* at Reykjavik. Eimskip Shipping Company of Reykjavik have steadfastly supported the CPR survey since 1933. They have allowed successive ships to tow CPRs from the east coast of the USA to Nova Scotia, Newfoundland and Iceland (E and Z) routes, (*Godafoss*, *Skogafoss*, etc.), and presently, the chartered *Reykjafoss*. They also allow the Foundation to tow CPRs on the Immingham to SE Iceland (V) route from the *Selfoss*.

The *Reykjafoss* of Reider Shipping BV, Netherlands towed the Z route from Newfoundland to Reykjavik each month during 2009. Their assistance is much appreciated. The ro-ro/containership *Atlantic Companion* covered the E route between New York, Halifax, Nova Scotia and south of Cape Race, Newfoundland throughout 2009. We are grateful to Atlantic Container Line of Sweden for their assistance. The *Jonni Ritscher* of Transeste Schiffahrt, Hamburg did the two D route tows from 33°W to 7°W in January and February 2009. The ship was replaced on charter by a Hapag Lloyd containership. Unfortunately Hapag Lloyd declined permission to use this ship. From June 2009 the *Atlantic Companion* took over the D route. The refrigerated cargo ship *Benguela Stream* towed the B route each month from 40°W to Portsmouth, UK. We are grateful to Seatrade NV, the managers, and the charterers Geest Bananas (UK) Ltd for their assistance.

### Arctic and North East Atlantic

From June to December 2009 the *Green Frost* of Green Reefers, Bergen completed six tows on the ST route between Svalbard and the North Cape of Norway. We are

indebted to Green Reefers A/S and the charterers Zahl Transport of Bodø, Norway for their assistance.

On 23 June 2009 the new NI route between Mosjøen, Norway and Reydarfjordur, Iceland was started. The chartered BBC *Reydarfjordur* towed the route each month in 2009. We are very grateful to the owners, Phoenix Reederei, managers EMS Conbulk and BBC of Leer, Germany plus Eimskip the charterers and Grieg Logistics Shipping Agency A/S for assisting the survey.

### Pacific

The AT route between Tacoma, Washington and Anchorage, Alaska was resumed in March by the containership *Horizon Kodiak* of Horizon Lines LLC, USA. Fifteen individual tows were completed to September, with 5893 nm logged. CPR number 167 with cassettes 167/0, 167/1, 167/2 was used. The crew of the *Horizon Kodiak* performed all running repairs and servicing of the CPRs aboard the ship. Dr Robert Benda of Prince William Sound Community College, Valdez, Alaska with his son Scott Benda looked after the filter cassette unloading, servicing and reloading. The success rate of 96.9% was attributable to the care taken by the above people. The three towed filter cassettes were landed at Anchorage in watertight plastic Peli cases, care of Horizon Lines. Lori Galloway and Pam Moore of Horizon Lines, Anchorage organised their airfreight to Valdez. After reloading, Robert Benda returned them to Anchorage ready for placing back aboard the ship. The Horizon Lines, Tacoma container terminal shore gang handled the CPRs to and from the ship. Thanks are due to the Ship's Superintendent, Danny Ellis, and Horizon Lines' shore gang plus foremen, Ken Clinton and Vern Poulsen. The continued success of this route is a due to the excellent professional co-operation by all of the above.

The VJ route between Vancouver and Japan was towed for three tow sets over May, July, August and September by *Skaubryn* of Seaboard International Shipping Ltd. Each of the three westbound tow sets comprised seven 500 nm tows. At 3500 nm this is presently the longest annual route in the CPR survey. 9762 nm were logged over 21 tows. There were with 9657 analysable nm. This gave 98.9% success. The Brancker XR620 CTD + F unit was successfully run on the three sets of VJ route tows. The above success rate is attributable to the care taken by the Dr Sonia Batten, Doug Moore and the CPR team on Vancouver Island. We are indebted to Seaboard and the *Skaubryn* for their continued assistance.

### North Sea

The C, HE and LG routes have been consistently monitored each month by ships of the DFDS Tor Line fleet over many decades. The survey is greatly indebted for permission to tow CPRs from DFDS Tor Line's



headquarters in Copenhagen, and for the logistical help from their port offices at Immingham and Gothenburg. *Tor Dania*, chartered from Imperial Shipping Gothenburg, towed on the HE route to March 2009 and was replaced by *Tor Hafnia* of Norbulk Shipping, Glasgow. DFDS Tor Line's *Tor Ficara* and *Tor Petunia* towed on the C and LG routes.

*Maersk Flanders* has towed the R route between the Shipwash Bank and Hook of Holland since July 2000. The permission to tow from Norfolk Line, Netherlands and logistical help by Norfolk Line at Dooley Terminal, Felixstowe is much appreciated.

The M route, between Aberdeen and Tananger has been towed each month by the freight ro-ro *S. C. Aberdeen* of Sea Cargo A/S, Bergen. Sea Cargo of Bergen and Aberdeen have very kindly assisted the survey for many years.

The A route between Lerwick and Aberdeen has been towed each month by the freight ro-ro *Hascosay* of NorthLink Ferries Ltd. We are very grateful for their professional assistance to the survey.

#### Irish Sea

The 46°N in Biscay to 53°N (IB route) has been run each month to September by the *Velazquez*. The charterers are MacAndrews Ltd of London. The ship is managed and owned by Burger Bereederungs Contor, (BBC) of Germany. The *Perseus J* of Jüngerhans Maritime Services,

Haren Ems Germany resumed the SB and IB routes in December.

The *Norbay* of P&O Ferries Irish Sea Ltd, Larne, Northern Ireland consistently monitors the plankton each month between the Liverpool Bar light buoy and Dublin on the IN route. We are grateful to the ship and P&O Ferries at Gladstone Dock, Liverpool for their assistance.

#### Portuguese and NW Spanish coasts, Bay of Biscay and the Channel

*Velazquez*, the MacAndrews Ltd chartered containership, has towed each month on the SB route from January to September. This is from Cabo da Roca (38°50'N 9°53'W) to Leixoes (41°15'N, 8°58'W). The recorder bodies with the same filter cassette inside were then re launched off Leixoes and towed to 46°North in Biscay.

We are very grateful to P&O Ferries and the *Pride of Bilbao* which has towed monthly from Bilbao (43° 30'N, 3°10'W) around Ushant to off the Casquets (50°N, 2°20'W) since 2004. A comparison between the National Oceanography Centre's Ferrybox readings and a Brancker XR620 conductivity temperature and depth sensor fitted in the CPR tails is being made. Sea temperature data is also forwarded to the Meteorological Office, Exeter. Brittany Ferries' *Bretagne* and *Armorique* have towed each month on the Plymouth to (PR) route. We are much indebted to them for this facility.

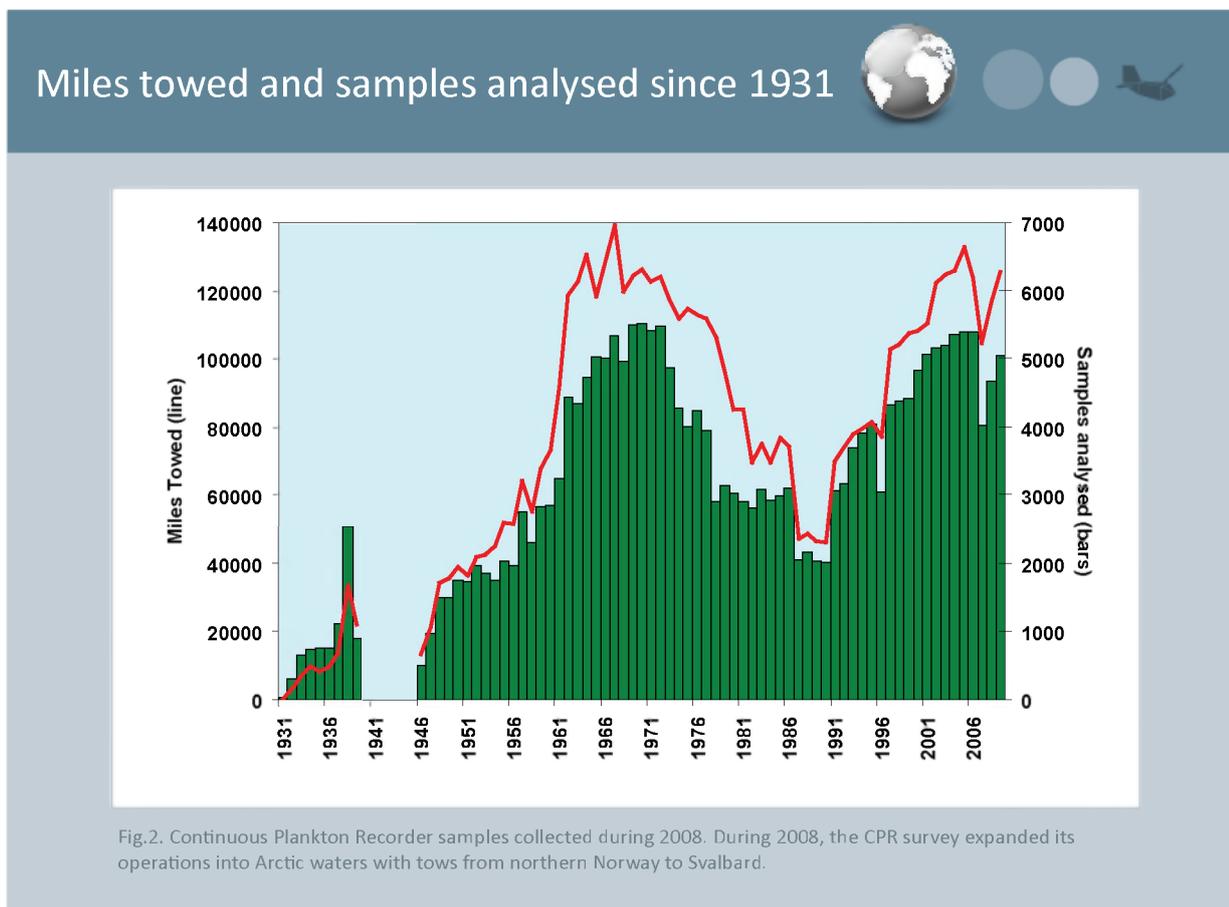


Fig.2. Continuous Plankton Recorder samples collected during 2008. During 2008, the CPR survey expanded its operations into Arctic waters with tows from northern Norway to Svalbard.

## Taxonomic analysis and database management

Tanya Jonas, *Senior Analyst*

2009 has seen a big change in the Analysis Team, with three leaving and three joining us. Alistair Lindley started with the survey in 1967, when it was still at Edinburgh, and he was joined in 1969 by Anthony John. Alistair has analysed 13,357 samples, his two years' head start allowing him to beat (just) Anthony's 13,242. Between them, they analysed 11% of all the samples ever collected in the survey's 78 years. We have not entirely lost the benefits of their knowledge and dedication, however, as both have found time to offer their help in retirement. Julie Finlayson has also left the survey after 14 years, during which she made an enormous contribution to the analysis effort.

Our three newcomers are Astrid Fischer, Robert Camp and Usha Jha. All three have completed their training and are now analysing North Atlantic and North Sea samples.

### Analyst training

As well as the three new Plymouth analysts, we have trained four plankton biologists for our sister surveys: Anita Slotwinski, David McLeod and Claire Davies, all from the Australian Survey, and Sanae Chiba for the Pacific Survey (working from Japan). Dr. Abigail McQuatters-Gollop trained as an analyst but her research demands have made it impossible for her to take up regular analysis. Alice Jones, a CASE PhD student was trained over one week in general plankton identification.

We ran several in-house practical training sessions for analysts, covering Ceratiaceae, Rhizosoleniaceae, copepods, cysts and other resting stages of plankton. Dr Claudia Castellani and Marianne Wootton visited the Natural History Museum to learn taxonomic drawing techniques. Janet Bradford-Grieve led a two-day workshop on copepods, and most of the analysts attended the jointly hosted SAHFOS/MBA Phytoplankton Workshop.

### Sample analysis

In 2009 the CPR Survey towed more miles and generated more samples than it did in 2008. Up to 12 March 2010, 4,897 samples were allocated for analysis.

During the year, we entered our data on the new CPR Console as well as on the existing paper system, to ensure continuity of reliable figures. This extra work, together with the staff changeover, made for a very testing year. From 2010 onwards, the Console will be the sole data recording method.

### North Atlantic survey

During 2009, 126,165 miles of CPR tows yielded 4479 samples for analysis (Figure 2, Appendix B). Two new routes started in the early summer: NI (Mosjøen, Norway to Iceland) and ST (Svalbard to Northern Norway). All the other routes for the area were regularly sampled with only the D, DA and IB having fewer than 10 tows during the year.

### Pacific survey

The two Pacific routes sampled 15,819 nm in 2009 yielding 388 samples for analysis at Plymouth and Vancouver Island. The AT route runs from Anchorage, Alaska, to Tacoma, Washington, and was towed in March, April, May, June and August. The VJ, the longest regular CPR route, runs from Vancouver to Japan, and was towed in April/May, June/July and August/September. Everything west of the 180° meridian is analysed by JAMSTEC in Japan. In addition to the standard analysis procedures followed by the sister laboratories, some developmental stages of copepods are identified in Pacific samples.

### South Atlantic survey

During the austral summer of 2008/9, the British Antarctic Survey (BAS) carried out six tows (13 to 18SF), in the Scotia Sea. A small, experienced analyst team looked at 84 samples from 13, 15 and 18SF. They used standard procedures and recorded the developmental stages of most of the 'eye count' copepods; some euphausiids were identified to genera or species. Quality-controlled data from these tows were passed to BAS in early March 2010. In late 2009 BAS carried out five more tows in the Scotia Sea; these samples will be returned to Plymouth in summer 2010.



### Special CPR tows in 2009

*Stad Amsterdam* followed the route of Charles Darwin's HMS *Beagle* voyage. They have made twelve tows between Plymouth and Rio de Janeiro, sampling for 4,373 miles. Only four silks have been returned to Plymouth so far, but we are eagerly awaiting our chance to analyse the samples from this, our longest route.

## Technological development: the Water and Microplankton Sampler (WaMs)

Anthony Walne, *Instrumentation*

Discussions started between SAHFOS, CEFAS and Defra towards the end of 2008 concerning the production of a water and microplankton sampler that could be carried on a CPR. This was seen as potentially contributing to Defra and the UK's requirements under the EU Marine Strategy Framework Directive and also complimentary to the molecular analysis already currently being done at SAHFOS. The main objective of the water and microplankton sampler is to enable the CPR survey to monitor the full size range of plankton in the oceans from the larger plankton (which the CPR already samples) to the nano and pico plankton size ranges. The water and microplankton sampler is also aimed at monitoring the smaller Harmful Algal Bloom (HAB) species.

In September 2008 the electronics workshop at CEFAS laboratory, Lowestoft, produced outline plans for two designs for the instrument. One design used a series of spring-loaded syringes for sample storage and the second design used a peristaltic pump which directed

the sample via a valve block into one of several plastic bags of the type used for medical purposes. We opted for the latter design and after discussion it was considered feasible to produce an instrument capable of taking and storing up to 12 samples of about 100 ml each.

A prototype instrument was produced in March 2009 and was towed mounted in a CPR by the *Plymouth Quest* to Station E1 on 28th April. This instrument was capable of taking 4 samples at pre-set intervals. During this 20 mile tow the sampler collected 4 samples which were later preserved with Lugol's iodine. Note that samples 1, 2 and 4 were set for 100% fill and sample 3 was set for 50%.

On 10th June the instrument was towed on the standard CPR route between Roscoff and Plymouth (PR route) by the Brittany Ferries vessel *Armorique* at speeds up to 21 knots. The depth of the CPR was 4-5 m for most of the tow with a period of 6-7 m. The





# Global CPR Network

## SCAR Southern Ocean CPR survey

Graham Hosie, *Director of the SCAR SO-CPR survey, Australian Antarctic Division (AAD)*

The Southern Ocean CPR Survey (SO-CPR) had a relatively quiet sampling season in 2008/09, following the extremely busy 2007/08 season for the Census of Antarctic Marine Life (CAML) during the International Polar Year (IPY). Forty-four tows were completed from five vessels compared with nearly double that number the previous season. The bulk of the tows were completed by Australia (26), followed by Japan (8), New Zealand (7), Brazil (3) and one trial tow by Chile, covering approximately 13,075 nautical miles and providing 2615 samples. The year 2009 was also marked with a number of important milestones.

Traditionally we have relied on research vessels operating in the Antarctic or supply vessels travelling to Antarctic stations. In 2008/09 seven successful tows were conducted between New Zealand and the Ross Sea from a commercial fishing vessel. This will continue each Antarctic summer for the foreseeable future, greatly improving the monitoring of plankton in the western Pacific region. This work is supported by the New Zealand Ministry of Fisheries and the National Institute of Water and Atmospheric Research (NIWA), in cooperation with the vessel's operating company. Following these tows in 2008/09 the CAML sponsored a training workshop for Ms Karen Robinson (NZ plankton analyst) to learn processing techniques from the SO-CPR and plankton team at the Australian Antarctic Division.

The South American CAML (LA-CAML) consortium of Brazil, Uruguay, Argentina, Chile, Peru, Ecuador and Venezuela officially joined the SO-CPR Survey in 2008/09 with tows across Drake Passage from the Brazilian vessel *Ary Rongel* and a trial tow on the Chilean vessel *Galvarino*. This is an important region in relation to the Antarctic krill fishery and also the proximity of the rapidly warming western Antarctic Peninsula. We will be conducting tows annually. Dr Lucia Campos (Brazil), coordinator of LA-CAML, and Dr Manuela Basso (Brazil) SO-CPR coordinator in South America hosted an extensive CPR workshop at the Federal University of Rio de Janeiro (UFRJ) in November 2009, to train 14 people from Brazil, Argentina, Chile, Peru, Ecuador and

## Global CPR Network

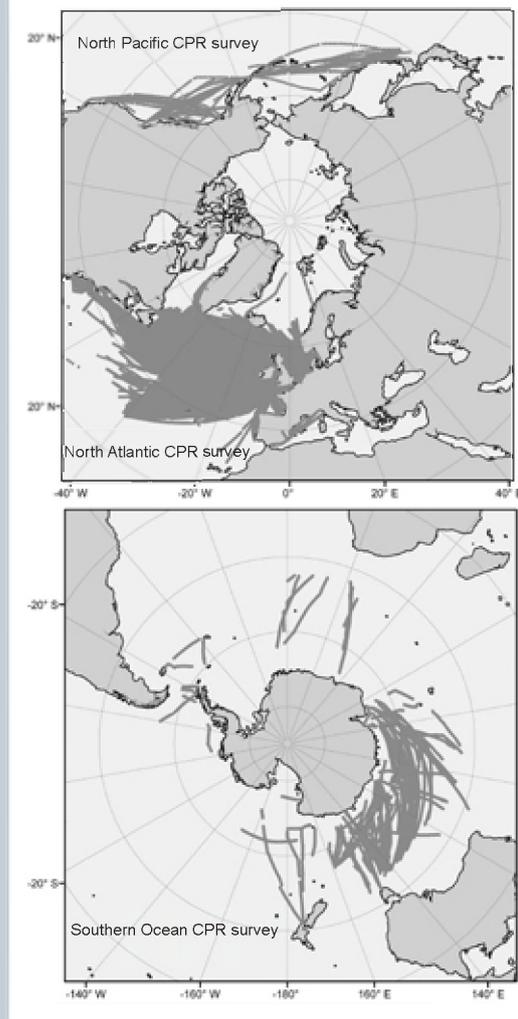


Fig. 4. Continuous Plankton Recorder sampling in the Northern and Southern Hemispheres. Efforts are under way to build a global CPR database combining all CPR data from the world's oceans into a centralised form.

Venezuela who are likely to prepare and use the CPR in the Southern Ocean. I provided instruction in the history and basic theory of the CPR, its advantages and limitations, followed by maintenance and preparation of the CPR, use of CPR at sea including deployment and recovery, changing cassettes and safety issues such as the use of formalin. All participants practiced loading and re-loading silk on the cassettes, and all are now ready for future CPR deployments. The workshop was supported by the Brazilian National Science and Technology Institute on Antarctic Environmental Research (Instituto Nacional de Ciência e Tecnologia de Pesquisas Ambientais e Antártica, INCT-APA), the South American Network on Antarctic Marine Biodiversity (BioMantar), the Brazilian Science and Technology Council (CNPq), the Chilean Antarctic Institute (Instituto

Antártico Chileno, INACH) and LA-CAML. The enthusiasm and support offered by South America augurs well for future expansion of CPR tows around South America.

Another notable milestone in 2009 was the completion of the first zooplankton atlas of the Southern Ocean using the CPR data gathered from 1991 up to the end of 2007/08 Antarctic season, which was also the first season of the IPY. The atlas was presented at the 10th SCAR Biology Symposium in Sapporo, Japan, July 2009 and will be published in the symposium's special issue of *Polar Science* later in 2010 (McLeod et al., in press). The atlas comprises distribution maps of the 50 most abundant species/taxa and focuses on the region south and west of Australia where there is the highest density of CPR tows.



Fig. 5. Participants at the Southern Ocean CPR Training Course at the Federal University of Rio de Janeiro (Rio de Janeiro, Brazil) 9 to 11 November 2009. Copyright Dr Manuela Basso (UFRJ).

Another CPR presentation at Sapporo was given by Dr Kunio Takahashi, National Institute of Polar Research (NIPR), who looked at long term results from the Southern Ocean CPR tows conducted from Japanese vessels. These showed a substantial increase in pelagic foraminiferan numbers in the 2004/05 season when they represented between 50 to 75% of total zooplankton numbers in much of the Indian Ocean sector instead of the pre-2004/05 levels of ~5%. Numbers now seem to be decreasing to earlier levels.

I noted in the 2008 SAHFOS Annual Report that 2007/08 was an important sampling season in providing a circum-Antarctic synoptic assessment of the current spatial patterns of plankton diversity around Antarctic as a contribution to CAML and the IPY. The Antarctic Circumpolar Current (ACC) is a unique current that

flows uninterrupted around Antarctica. The 2007/08 sampling also provided the opportunity to determine if species composition was consistent in the various bands of the ACC by comparing transects collected at approximately the same point in time. Following the April 2009 SAHFOS Council meeting I conducted a small data analysis workshop with colleagues Drs Kunio Takahashi and Brian Hunt, University of British Columbia. The week long workshop was supported by CAML and hosted by SAHFOS. Analyses of the data showed that while latitudinal (north-south) zonation was clearly evident, no real longitudinal (east-west) zonation could be found within the ACC. This indicates that the species composition is relatively consistent within the current, or in other words there appears to be just one community travelling on the ACC conveyor belt. Preliminary results of this work were presented at the CAML Symposium in Genoa May 2009 and also at the 10th SCAR Biology Symposium in Sapporo.

Finally, one of the significant highlights of the year was the exchange visit of Tony John, recently retired senior analyst of SAHFOS, to the AAD in Hobart and the CSIRO Cleveland laboratories near Brisbane, supported by the AusCPR and SAHFOS. The primary purpose of the visit was to compare the zooplankton processing methods used by SAHFOS, SO-CPR and AusCPR. Part of the SAHFOS method involves counting a portion of the zooplankton on silk in a series of traverses, whereas SO-CPR and AusCPR count all of the zooplankton after washing off the silk. The latter method was adopted to meet specific objectives in the Antarctic and Australian programmes. As expected there were differences in the counts between the two methods, however we are now working on developing a data analysis procedure that will allow reliable intercomparison and merger of our respective datasets. The secondary purpose of Tony's visit was to ensure that the SAHFOS phytoplankton counting and colour indexing methods employed by the SO-CPR and AusCPR teams are being correctly applied. In turn the visit provided the opportunity for Tony to check his identifications of the Antarctic plankton with the AAD taxonomic expert, notably with the SO-CPR senior analyst John Kitchener. The exchange was extremely valuable and we look forward to more exchanges in staff between our laboratories as the CPR programme becomes more global.

## The United States West Atlantic (US-CPR) CPR survey

Jack Jossi, U.S. Dept. of Commerce, NOAA Narragansett Laboratory, USA

This, the longest running sister survey, which started in the mid 1970s, uses the same design of CPR as SAHFOS and has three routes currently in operation. Sampling between Boston and Nova Scotia (route C0) began in 1961 when it was conducted by the CPR staff of the Oceanographic Laboratory, Edinburgh. The US assumed its operation in 1977. The second route (B0) extends over the shelf and slope from New York City toward Bermuda, and has been in existence since 1976. A third route (N0) covering Narragansett and Mount Hope Bays, and Rhode Island Sound includes

monthly sampling using a CPR internal mechanism in an Acrobat undulating towed vehicle. This route has been conducted since 1998, and includes concurrent measurements of temperature, salinity, oxygen, nitrate, photosynthetically active radiation, fast repetitive rate fluorometry, chlorophyll fluorometry, and optical plankton counting. Plankton samples from all routes are analysed at the Polish Sorting Centre, Gdynia, Poland. SAS databases and QC'd ASCII files are maintained at Narragansett. During 2009 the CPR sampled transects totaling 5012 nm, resulting in 483 ten mile blocks, and four 5 mile blocks. We are very grateful to the officers and crews of the containerships Reykjafoss (Eimskipafelag, Reykjavik, Iceland), and Oleander (Bermuda Container Lines Ltd., Hamilton, Bermuda), without whose generous support this important ocean monitoring programme would not be possible.

## The Australian Continuous Plankton Recorder (AusCPR) survey

Anthony J. Richardson & Graham Hosie

AusCPR is a joint project of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Antarctic Division (AAD) to monitor plankton communities as a guide to the health of Australia's oceans. AusCPR was initiated in 2008 and forms part of the Integrated Marine Observing System (IMOS), an initiative of the Australian Government.

Currently, AusCPR has two areas of operation. The first is on the east coast extending from Brisbane (27°S) to Melbourne (38°S). Unlike most other CPR routes around the world, we have specifically targeted an oceanographic feature, the East Australia Current, a southward-flowing, warm-water western boundary current. This current has intensified over the last 60 years, with a poleward advance of ~350 km, and in the south is warming at a rate of 2.28 °C/century; global climate models suggest that this current will continue to strengthen. A CPR towing point was installed aboard the ANL Windarra in March 2009 and our first tow was completed in June with monthly tows since. The second area of operation is in the Southern Ocean, south of Australia in collaboration with the SCAR Southern Ocean CPR Survey based at the AAD (see the Southern Ocean CPR report). Some good news for AusCPR in 2009 was the securing of increased funding until mid-2013. This will not only guarantee the continuation of the existing

routes, but will also increase the number of routes in the survey. There will be two new routes across the Tasman to New Zealand (one annually and the other seasonal) in conjunction with hydro-acoustic surveys for mid-trophic level fish and squid. Another new route will



Fig. 6. Phytoplankton Colour Index recorded on the Brisbane to Melbourne route in July 2009.

be along the Great Barrier Reef lagoon, in conjunction with a ship of opportunity fitted with a pCO<sub>2</sub> sensor. This will enable us to understand how changes in pH could be affecting calcifying organisms collected in the CPR (e.g., coccolithophores, echinoderm and mussel larvae, forams, pteropods). We will also extend our Brisbane to Melbourne route through to Adelaide; this passes through the Bonney Upwelling centre the largest upwelling cell in Australia.

We would like to take this opportunity here to thank the staff at SAHFOS for their continued support over the past year. Starting and running a new CPR survey has not been easy, and would not have been possible without the support of SAHFOS. In particular, Tony John has

visited the AusCPR survey (in both Brisbane and Hobart) to train staff in phytoplankton identification. Finally, we would also like to thank the AusCPR team – Frank Coman, Claire Davies, David McLeod and Anita Slotwinski – without their dedication the Survey would not be a reality.

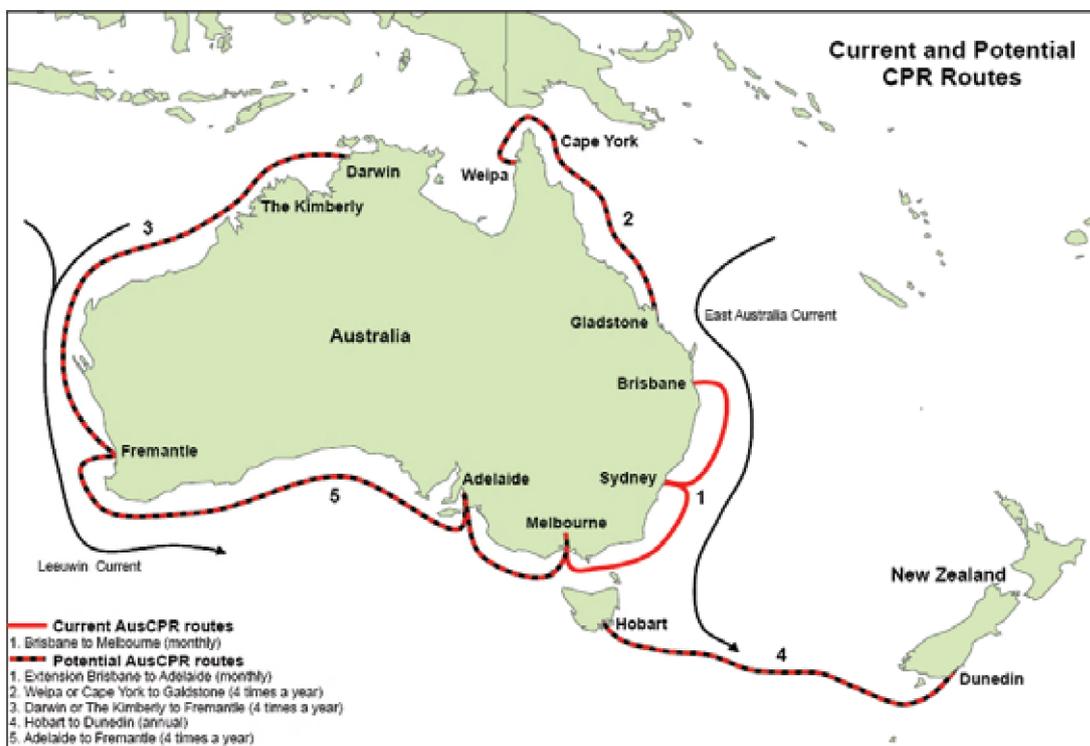


Fig.7. Map of existing (solid) and future (dashed) AusCPR routes.

### Integrated marine observing systems

The SAHFOS CPR survey is an integral part of the United Kingdom Marine Monitoring and Assessment Strategy (UKMMAS); the CPR routes in the western North Atlantic form part of the Canadian Atlantic Zone Monitoring Program (AZMP); new CPR routes in South Africa and Namibia will contribute to the Benguela Current Commission (BCC) State of the Environment Information System; and routes in Australia form part of the Australian Integrated Marine Observing System (IMOS).



# CPR research highlights

## Macroscale ecophysiology of *Calanus finmarchicus* in the North Atlantic Ocean

Pierre Helaouët, SAHFOS

The concept of the Hutchinson's n-dimensional hypervolume, representing the ecological niche of species, constitutes an essential tool in macroecology that can be used to help understand the way a species experiences its environment. Here, the realised niche was evaluated by projecting the spatial distribution of the species in an Euclidean space as a function of a few key environmental parameters. Sea surface temperature, and to a lesser extent its correlates oxygen and nutrients, appeared to be the most conspicuous factors driving the spatial distribution of *C. finmarchicus* in the North Atlantic Ocean at both annual and monthly scales. While the choice to select SST as the first dimension to assess the realised niche was therefore straightforward, the selection of the second dimension was more complicated. Many studies have reported that the species is a major grazer of diatoms. Therefore, we chose to characterise the realised niche by using SST and an index reflecting the concentration of diatoms in the field.

The niches were characterised by a well-defined optimum separated from the rest of the niche by a pronounced gradient between 8°C and 12°C within which abundance and the potential egg production rate decreased rapidly to a level inferior to 5% of the total abundance of the species (see Fig. 8 a-b). A high local biological variance has been found in areas characterised by annual SST ranging from 9°C to 12°C with a peak of variability between 9°C and 10°C. It is worth noting that the boundary observed by these authors on the basis of the examination of three trophic levels, coincided with that of *C. finmarchicus* the macroecological level (i.e. abundance).

In the subarctic gyre, climate change and its effect on SST will have only a limited

impact on *C. finmarchicus* (Fig. 8a and 9a). The modest variations in both abundance of *C. finmarchicus* between a cold and a warm year suggest that the species will not be affected by climate until the end of this century when some degree of physiological stress may be evident (Fig. 9a). As an important component of the trophodynamics, it is therefore unlikely that the North Atlantic Drift Province (including the Subarctic Gyre) will be severely affected this century. The position of *C. finmarchicus* at the optimum of its ecological niche may temper the effect of variation in SST on the trophodynamics of the ecosystem (Fig. 9b). In recent decades, the North Sea experienced substantial changes in ecosystem state. One of the major changes that has been documented has been a pronounced decline in the abundance of *C. finmarchicus*. In 1962, the species represented 80% of the total *Calanus* whereas it represented only 20% of the genus by the beginning of the 2000s. Our approach explains well the pattern of change (Fig. 8b) and indicates that the phenomenon is unlikely to reverse in the next few decades (Fig. 9b). The pattern of change might, in contrast, be reinforced. At the end of the century, *C. finmarchicus* could be outside its thermal preferendum for 8 months in a warm year and 5 months during a cold year (Fig. 9b). The physiological stress induced by rising temperature is expected to affect consecutively: reproduction, growth, feeding and ultimately the survival of the individuals.

Consequences of rising temperature extend from phenological to biogeographical changes to modifications in dominance of key-structural species. Changes in the abundance of *C. finmarchicus* may affect ecosystems, altering the diet of exploited fish (e.g. the Atlantic Cod), modifying the flow of energy in ecosystems and the strength of the biological carbon pump. Our approach based on the Hutchinson concept of the ecological niche has enabled patterns of changes observed for this key-structural species to be better understood and may allow future changes to be more accurately anticipated.



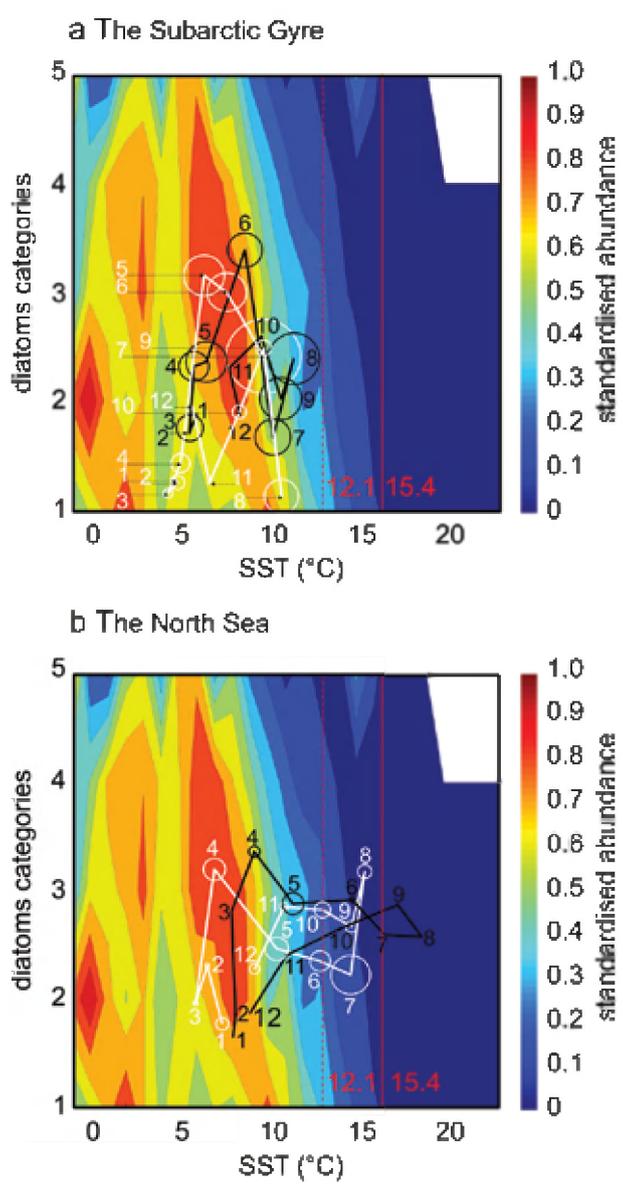


Fig. 8. The realised niche is defined by the abundance of *Calanus finmarchicus* (standardised between 0 and 1) as a function of both categorised abundances of diatoms and SST for the whole North Atlantic Ocean. (a-b; circles) abundances of the species for the coldest (in white; 1973 for the Subarctic Gyre and 1964 for the North Sea) and the warmest year (in black; 2002 for the Subarctic Gyre and 2001 for the North Sea) of the whole time period (1960-2002) are represented as functions of SST and abundance of diatoms. Thermal limits of the realised niche corresponding to the 95th (dashed red line) and 99th (red line) percentiles calculated on the cumulated abundance.

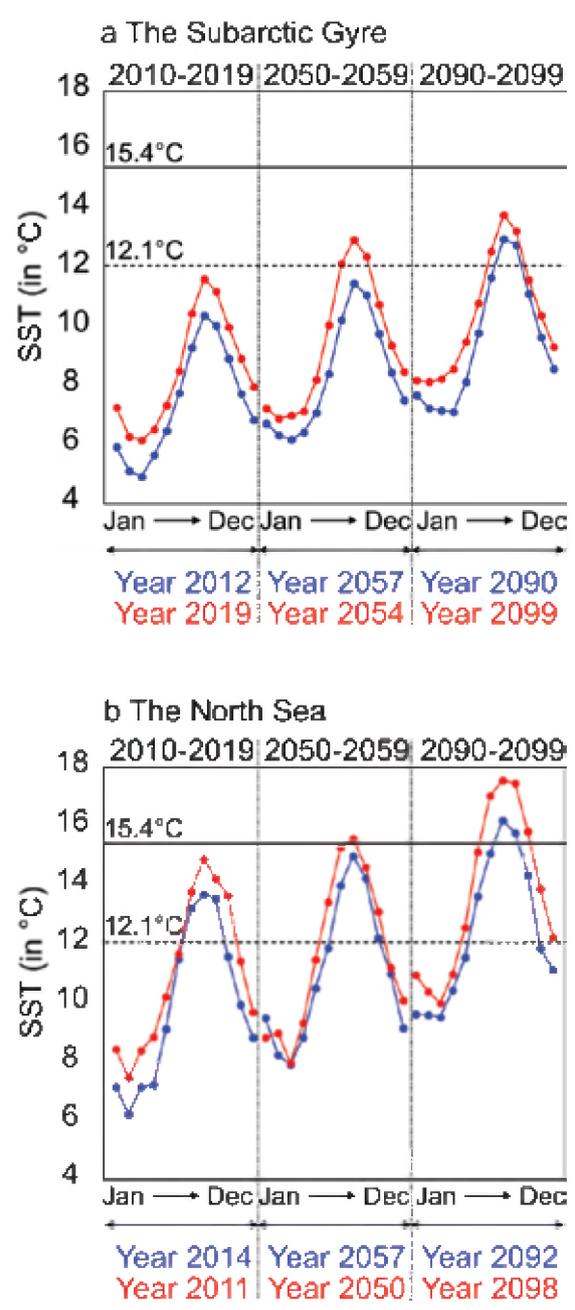


Fig. 9. Projection of annual SST for the coldest (in blue) and warmest (in red) years of the three decades (2010-2019, 2050-2059 and 2090-2099) using scenario A2 in (a) the Subarctic Gyre and (b) the North Sea. Thermal limits of the realised niche corresponding to the 95th (dashed line) and 99th (line) percentiles calculated on the cumulated abundance are superimposed.

## North Pacific plankton indicators

Sonia Batten, SAHFOS

The end of 2009 saw the development of an El Niño event in the equatorial Pacific and although the effects were not yet apparent in the NE Pacific, the second half of the year saw a weakly positive Pacific Decadal Oscillation index. The year began, however, with the cold conditions (and negative PDO) that were such a feature of 2008 (the coldest in over 50 years). This set the scene for the plankton indices shown here but overall 2009 will likely be a transition year with warmer conditions and the influence of the El Niño evident in 2010.

At the time of writing sample analysis is complete for the NE Pacific up to and including June 2009. Data for the remaining months are based on the samples analysed in BC, Canada – about 25% of the eventual number to be analysed. The seasonal cycle of mesozooplankton in 2009 was close to the average with a peak in May. The timing of the dominant spring copepod, *Neocalanus plumchrus*, was earlier than in 2008 by about 3 weeks, consistent with the somewhat warmer temperatures but the phenology indices were not as early as in the warmer years of 2004-06, emphasising that 2009 was not an unusual year in our 10 year record.

Community composition analyses of the summer samples (though data for 09 are not yet finalised) show a clear relationship between temperature and community composition (Fig. 10 and 11). Fig. 10 shows the breakdown of biomass into broad taxonomic groups and the contribution of small copepods to the overall biomass is significantly positively correlated ( $p < 0.01$ ) with summer temperatures (as measured at Amphitrite Pt lighthouse, shown in the background) while large copepods are significantly negatively correlated ( $p < 0.01$ ). This is both because of phenology (the seasonal cycle of large copepods is delayed in cold years so more may be present in summer months) and species preference with the smaller, typically more southern, copepods doing better and extending further north in warm years. A more detailed non-metric Multidimensional Scaling analysis of log-transformed abundance data for individual mesozooplankton taxa (Fig. 11) shows a clear gradient with the warmest years at the top of the plot and coldest years plotting at the bottom. Transition years (2003 transitioning from cold to warm, 2006 transitioning from warm to cold and tentatively 2009 cold to warm again) plot in the centre. 1997 stands out as an unusual year – it was the start of a strong El Niño, as does 2007 although there is no explanation for that year as yet. The y-dimension is significantly ( $p < 0.01$ ) positively correlated with the summer temperature. It will be interesting to see if the 2009/10 El Niño also has a strong influence on the NE Pacific plankton communities – watch this space!

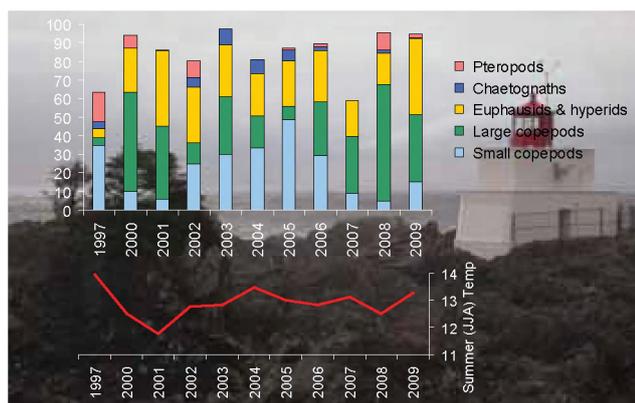


Fig 10. The contribution (%) of each major taxonomic group to mean summer mesozooplankton biomass (top) and the mean summer temperature ( $^{\circ}\text{C}$ ) as measured at Amphitrite Point Lighthouse (mean of June, July and August, bottom).

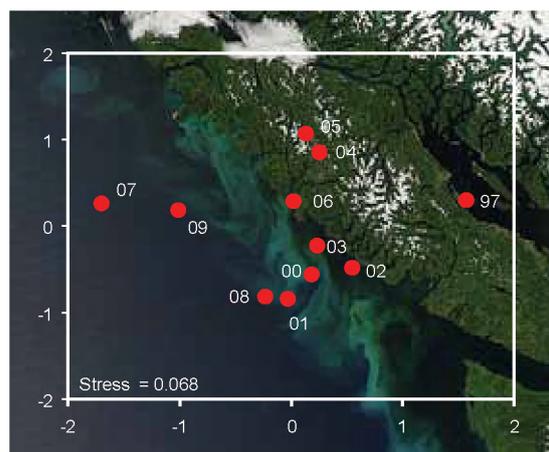


Fig. 11. Non-metric MDS plot of log ( $x+1$ ) transformed mean annual (from June 28th - August 31st) abundance data for each mesozooplankton taxon.

## Linking plankton data to recruitment of commercial fish species in the Skagerrak-Kattegat area: implications for management.

Andrea Belgrano, *Swedish Board of Fisheries, Sweden*

Current research in collaboration with Priscilla Licandro at SAHFOS deals with the use of SAHFOS plankton database for exploring the links between plankton dynamics and recruitment processes of commercial fish species in the Skagerrak-Kattegat area, and its implications for management. The CPR data covering the North Sea-Skagerrak-Kattegat area were investigated. The first statistical analysis using a Principal Component Analysis (PCA) method was based on standardized phytoplankton and zooplankton species abundance covering the period 1993-2007 to detect the presence of major shifts in species composition. A closer look at the data of 81 species revealed that a significant change in the zooplankton composition occurred around 2000, due

to an increase of warm water-species, in particular the cladoceran *Penilia avirostris*. *P. avirostris* is a non-native temperate-subtropical species; therefore its increasing dominance in the Skagerrak/Kattegat region is a possible indication of a SST warming related to hydroclimatic changes, as previously observed in other regions using the CPR data (Johns et al. 2005). During the second phase of the project phytoplankton and zooplankton data will be analysed in relation to a recruitment index for the commercial fish species (e.g. cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), flatfish) and hydroclimatic data to elucidate the mechanisms regulating recruitment processes (Edwards and Richardson 2004; Beaugrand et al. 2003).

Ultimately this research in progress will provide novel information for developing a sustainable management framework for the conservation and re-building of these commercially exploited fish stocks. This research activity is a contribution to the international project RECNOR – Recruitment Study on North Sea Fish Stocks 2007-2010 – PI: Dr. Geir Ottersen, Institute of Marine Research (IMR, Bergen, Norway) and the Centre for Ecological and Evolutionary Synthesis (CEES, University of Oslo, Norway).

## Climate extremes and plankton variability in European Seas

Juan Carlos Molinero, *IFM-GEOMAR, Germany*

A current challenge in global ecology is the expansion from the analysis of trends to a quantification of climate extremes and their consequences for ecosystem functioning. In plankton ecology however, little attention has focused on the dynamics of extremes, despite their importance for both theoretical and management reasons. The broadly documented modifications in climate phenomena in the last few decades have produced subsequent changes to the mean and the variance of atmospheric variables and, theoretically, have led to an increase in the probability of extremes. Here, new results on the dynamics of climate extremes and their consequences in pelagic communities in the central North Sea and the Northwestern Mediterranean are advanced.

Statistical analysis of hydroclimate conditions in the North Atlantic over the period 1950 to 2005 reveals two main thermal regimes. The former covers the years 1950-late 1970s and is characterized by generally low mean values with respect to the long term mean, and the latter which has dominated the signal since the 1980s, showed an enhancement in both mean

and variance. This has important implications, as the probability of situations exceeding critical thresholds (i.e. tails of distribution) changes substantially. In fact, the analysis of annual extremes, identified through the generalized Pareto distribution, unveils contrasting dynamics in the main atmospheric forcing relative to European seas. In accordance to this, the peak-to-peak plot plainly illustrates the change in climate variability (Fig. 12). Under the low temperature regime (before the 1980s), the interannual variations of the climatic signal roughly lie on a closed regular curve (the slice of a torus) underlying a quasiperiodic dynamic, whose mean and variance were 3-fold lower than the variability observed under the high temperature regime. In the latter case, the dynamics shifted towards a new attractor with larger peak amplitudes and shorter return times, where unprecedented extremes, relative to the 1950-2005 period, occur and novel maxima are reached.

The exposure to contrasting scenarios of climate forcing has altered the food web dynamics, as documented in European Seas. These results however, provide new interesting insights into the properties of the system by quantifying the probability of anomalous events (i.e. uncoupling between trophic levels) related to climate extremes. In fact, before the 1980s, low or null probability of uncoupling events in the predator-prey dynamics was found both in the North Sea and

the Northwestern Mediterranean, whereas after the 1980s, a noticeable enhancement of the probability and frequency of such events was observed (Fig. 13). These results warn of the fragility of European pelagic food webs under scenarios of climate change, which could be magnified by human perturbations related to ecosystem

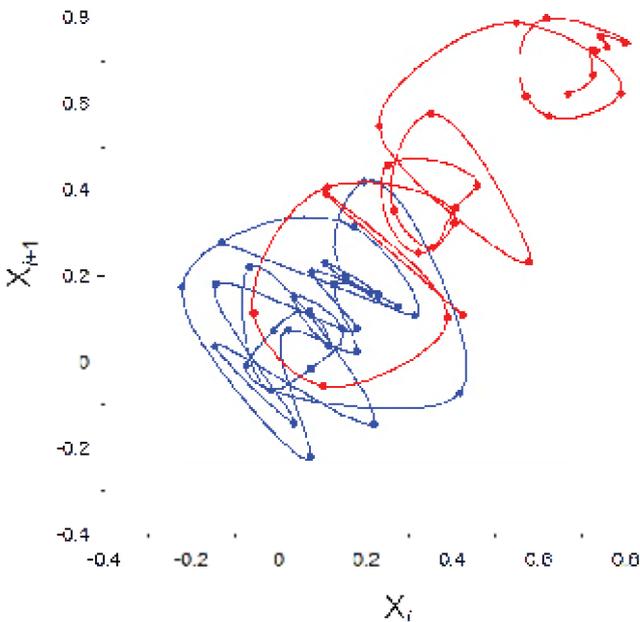


Fig. 12. Peak-to-peak dynamics of the interannual variability of hydroclimate conditions in the North Atlantic over the period 1950 to 2005. The blue line denotes the variability significant peaks identified before the 1980s, while the red line indicated the variability after the 1980s. The larger peak amplitudes and short return times in the second period indicate a higher recurrence of hydroclimate extremes.

degradation and overexploitation. Also, these results provide insights into the major role of hemisphere-wide climate processes on the functioning of European shelf seas, and may help to understand the reorganizations noticed during the 1980s in these ecosystems.

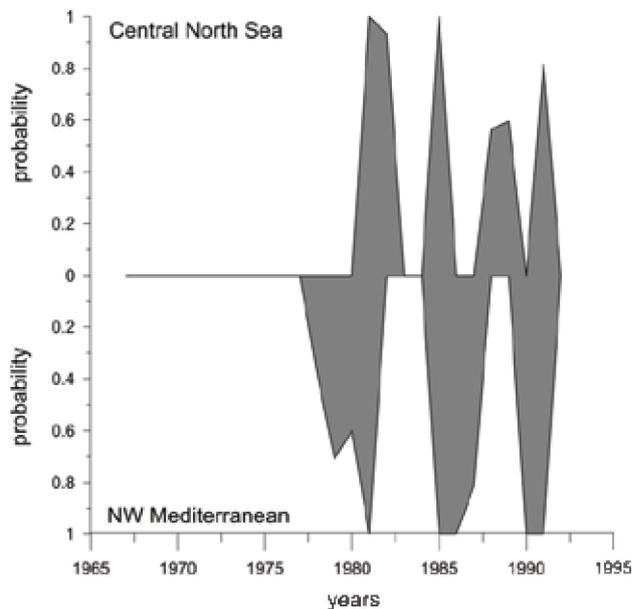


Fig. 13. Probability of anomalous events in predator-prey couples throughout the period 1967 to 1993 in the central North Sea (upper panel) and Northwestern Mediterranean (lower panel). Predator-prey couples consist in decadal records of copepods-phytoplankton (North Sea) and copepods-gelatinous carnivores (Northwestern Mediterranean). The probability of anomalous events, assessed by the generalized Pareto probability density function, dramatically increase in the two cases after 1980, and appears concurrent with the increase in hydroclimate extremes in the North Atlantic. Note the inverse scale in the lower panel.

## SeaWatch SW project

Russ Wynn, *National Oceanography Centre*

An Associated Researcher grant was again awarded to Russ Wynn in 2009 for research being undertaken as part of the SeaWatch SW project. This project is investigating how biotic and abiotic factors control the spatio-temporal distribution of migratory marine megafauna. The priority is the critically endangered Balearic shearwater, but other migratory seabirds as well as basking sharks, ocean sunfish and cetaceans are also the focus of intensive monitoring off southwest England.

For the third year running, effort-based monitoring of Balearic Shearwaters and other migratory megafauna was undertaken at Gwennap Head (Cornwall) between

15 July and 15 Oct 2008. A team of experienced volunteer observers helped man the watchpoint for 93 consecutive days, with 'dawn-to-dusk' observations totalling almost 1000 hours. The influence of the offshore Runnelstone reef (and its associated tidal-topographic front) on foraging seabirds, cetaceans and basking sharks is now being intensively monitored, with hi-res multibeam bathymetry, in situ zooplankton sampling and passive acoustic monitoring of small cetaceans all being used for the first time in 2009. A grant of £15,000 was awarded by the Total Foundation to support these new activities. A further grant application for £90,000 is also under consideration with NERC (David Johns of SAHFOS is a named collaborator), proposing to expand research into the influence of tidal-mixing and tidal-topographic fronts on marine ecosystems off southwest UK. Russ Wynn has recently been appointed as Head of Seafloor and Habitat Mapping at NOCS, providing further

opportunities to investigate environment-ecosystem linkage in UK waters.

A paper outlining the status of Balearic shearwaters in UK and Irish waters from 2004 to 2006 was published in *British Birds*. A further 900 Balearic shearwater records were submitted to SeaWatch SW from the UK and Ireland in 2009, reinforcing the overall spatio-temporal distribution pattern seen in 2007 and 2008. These multi-year data are now contributing to ongoing conservation action, including a report commissioned by Natural England investigating the potential for Lyme Bay to be a SAC for this species. A Balearic shearwater tagging programme is being initiated in 2010 (in collaboration with Prof Tim Guilford at University of Oxford), in order to better understand the at-sea distribution and behaviour of the species.

The third annual South West Marine Ecosystems (SWME) meeting, held in Plymouth in December 2009 again helped forge linkages between SeaWatch SW / SAHFOS and various government agencies, NGOs and universities in the region. The outputs from this meeting were featured on NERC Planet Earth Online and in regional media. A major theme was the impact of a third year

of unsettled weather on marine fauna. This led to an unusually early mid-summer influx of Portuguese Man-of-War, an unprecedented influx of Wilson's storm petrels, and a run of unusual southern seabirds including black-browed albatross and Fea's petrel. These conditions may also be contributing to low productivity of breeding kittiwakes in the region (as monitored by RSPB), and also the dearth of basking shark surface sightings in summer and autumn. A paper highlighting the anomalous temporal distribution of basking sharks off Gwennap Head in the last three years, driven by unsettled mid-summer weather, was presented at the first International asking Shark Workshop on the Isle of Man, and has been submitted to an accompanying special volume.

The project continues to yield tangible outputs in the form of publications and media publicity. A NERC-funded PhD student (Alice Jones, CASE-sponsored by SAHFOS) is continuing to work on SeaWatch SW data, together with several Masters-level students. A full programme of fieldwork is scheduled for 2010. Further details and all the news from the 2009 field season can be found on the project website ([www.seawatch-sw.org](http://www.seawatch-sw.org)).

## Taxonomic key to marine arthropod larvae

John A. Fornshell, *Smithsonian Institution, USA*

A taxonomic key to marine arthropod larvae has been developed; the key is based on the morphology, body segmentation patterns, numbers of appendages, and mode of locomotion, i.e. which appendages are used for swimming or walking by the larvae. In the case of decapod crustaceans three larval stages can be identified: nauplius, zoea and megalopa. All crustaceans have a nauplius stage, which is defined as a larval stage with three pairs of appendages, first and second antennae and mandibles, all of which are used for swimming. In the Decapoda, the nauplius is followed by the zoea, which in turn is followed by the megalopa larva. The zoea is defined as having functional thoracic appendages, which are used for swimming. This does not mean that the cephalic appendages are no longer used in locomotion. The megalopa stage is defined as

a larval stage in which the abdomen has functional swimming appendages. Some crustaceans pass the nauplius in the egg before hatching as a zoea. Others such as the mysid shrimp hatch from the egg in the adult form. In the case of isopods, the larval stages are passed in marsupial pouches and the larvae are never seen in the marine environment. In addition to the crustacea, larvae of the pycnogonida, chelicerata and arachnida (mites) are included. There are thirty-five larval forms and three juvenile forms with some larval characteristics included in the key. The key is in a printed format with illustrations of the major larval types. In addition a computerized version, Java programming language, which is suitable for use on any platform capable of supporting Java has been developed. A digital image file is being developed for the computer version. When completed the key will be submitted for publication in the refereed scientific literature.

## Towards understanding diatom potential reaction to climate warming and validate global biogeochemical models using CPR data

Dionysios E. Raitsos, *Institute of Oceanography, Athens, Greece*

Here the CPR data were used to test two different hypotheses. A) To identify macroscale factors that affect diatom abundance and predict their potential reaction to further oceanic warming, and B) validate biogeochemical models using the CPR 50-year ocean colour dataset. Both results were published/In press in international peer-review journals.

A) Diatoms exist in almost every aquatic regime, are responsible for ~20% of global carbon fixation, ~25% of global primary production, and are regarded as a key food for copepods that are subsequently consumed by larger predators such as fish and marine mammals. A decreasing abundance and their vulnerability to climatic change in the North Atlantic Ocean have been reported in the literature. In the present work, a data matrix composed of concurrent satellite remote sensing and CPR in situ measurements was collated for the same spatial and temporal coverage in the Northeast Atlantic. Artificial Neural Networks (ANNs) were applied to recognise and learn the complex non-monotonic and non-linear relationships between diatom abundance and spatiotemporal environmental

factors. Due to their ability to mimic non-linear systems, ANNs proved far more effective in modelling the diatom distribution in the marine ecosystem. The results of this study revealed that diatoms have a regular seasonal cycle with their abundance most strongly influenced by Sea Surface Temperature [SST] (Fig. 14). The models indicated that extreme positive SST decrease diatom abundances regardless of the other climatic conditions. These results provide information on the ecology of diatoms that may advance our understanding of the potential response of diatoms to climatic change.

B) Assessing the skill of biogeochemical models to hindcast past variability is challenging, yet vital in order to assess their ability to predict biogeochemical change. However, the validation of decadal variability is limited by the sparsity of consistent, long-term biological datasets. The Phytoplankton Colour Index (PCI) record from the Continuous Plankton Recorder survey, which has been sampling the North Atlantic since 1948, is an example of such a dataset. Converting the PCI to chlorophyll values using SeaWiFS data allows a direct comparison with model output. Here we validate decadal variability in chlorophyll from the GFDL TOPAZ model. The model demonstrates skill at reproducing interannual variability, but cannot simulate the regime shifts evident in the PCI data. Comparison of the model output, data and climate indices highlights under-represented processes that may be necessary to include in future biogeochemical models in order to accurately simulate decadal variability in ocean ecosystems.

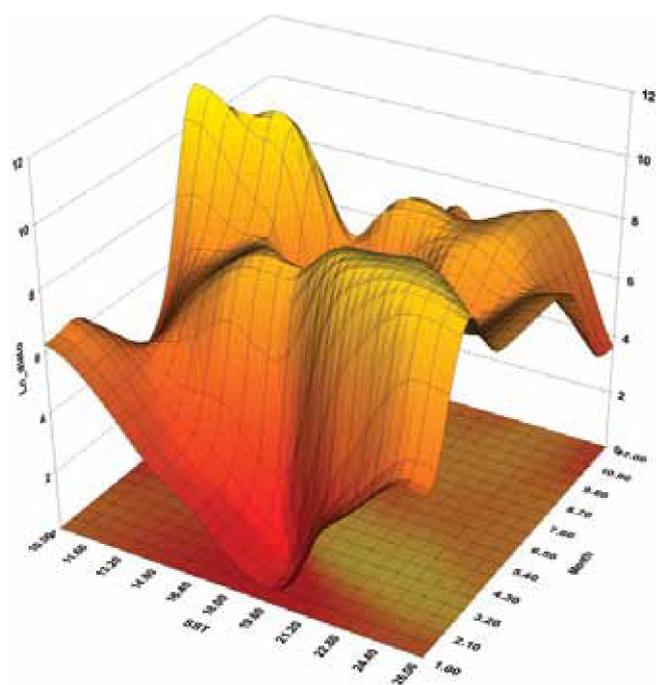


Fig. 14. Three dimensional plot predicting diatom abundance for SST versus month. The 3D plots, based on the training set of neural networks, predict the possible reaction of diatoms in relation to temperature changes. For almost every SST scenario, diatom abundance remains low during January and February, while during April and May diatom abundance increases rapidly between a temperature range of 14 and 23 °C. The pattern of abundance decreases during late summer and early autumn. The model also predicts an increase in diatom abundance during late autumn and the early winter months (November-December) when the SST is high (14-20 °C); however it decreases rapidly in a scenario where SST exceeds 21 °C.

# Meroplankton spatio-temporal dynamics in the North Sea over the last 50 years

Marcos Llope, *University of Oslo, Norway* and Priscilla Licandro, *SAHFOS*

Although marine plankton populations reorganize at many spatial and temporal scales, the studies addressing their dynamics have primarily focused on temporal scales. Here we explore simultaneously the spatio-temporal variability of the zooplankton functional groups collected by the Continuous Plankton Recorder in the North Sea. In our approach, we apply an analysis which simultaneously includes the spatial and temporal variation in the same statistical model, being able to identify periods of different distributions from the data itself. The variation over time is analyzed in a continuous fashion and the spatial distribution patterns described by contours. The model formulation is built under the Generalized Additive Models (GAM) framework but allowing the inclusion of one, two or more different spatial distributions, i.e., threshold GAM formulation.

Total zooplankton biomass has been decreasing in the North Sea since 1958. The Orkney/Shetland region is one of the areas showing the greatest spatio-temporal variability, with meroplankton being the group that contributed the most to these changes. Meroplankton decreased continuously until the early 1980s and underwent a sudden increase in 1984 (Fig. 15 lower panel).

In contrast to other zooplankton functional groups, meroplankton are mainly concentrated in the shallow southern and north western North Sea, avoiding the deeper northeast quadrant. It is in this northern quadrant where this functional group showed the most remarkable spatial changes (Fig.15). Three main distributions can be recognized for meroplankton, separated by the years 1977 and 1984. The relative decrease in the late 1970s around the Orkney-Shetland was primarily driven by a decrease in the detritivorous bivalves. After 1983, total meroplankton biomass relatively decreased over the region off Firth of Forth and increased east of Orkney-Shetland resulting in the development of a secondary maximum and the establishment of a two-core spatial distribution. This second spatial change was primarily due to an increase in echinoderm larvae (detritivorous).

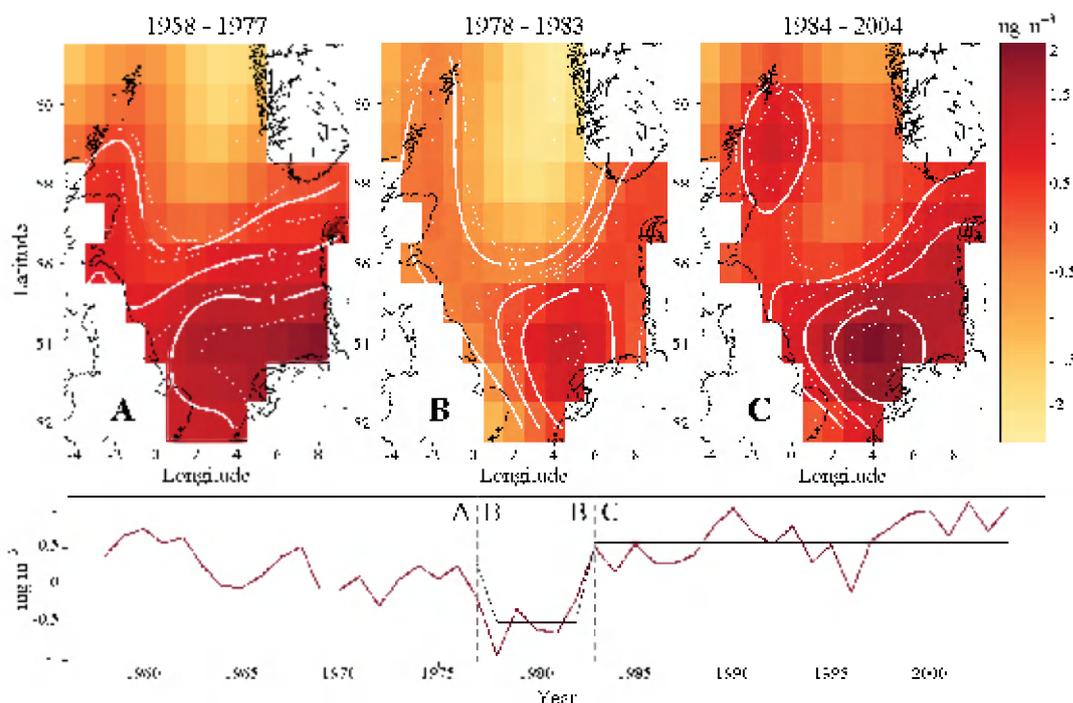


Fig.15. Meroplankton spatial patterns. Spatial distributions of the meroplankton biomass for the three main periods detected in the North Sea (upper panels) through the statistical analysis. The meroplankton values were derived by predicting the level of meroplankton for each pixel within each regime. The colour scale (right side) allows comparison among periods. The red contours are the positive deviations for each period referred to the intercept during each regime. The 95% upper and lower confidence intervals (black dashed contours) were calculated from bootstrapping. Although it helps to identify the richer areas for each period, they cannot be used for inter-comparison as they are deviations from the intercept (different for each period). The lower panel shows its temporal evolution averaged for the whole North Sea. The vertical dashed lines define the regimes, whose spatial pattern is shown above, while the horizontal red line represents the three different intercepts.

## A study on jellyfish collected by the Continuous Plankton Recorder

Priscilla Licandro, SAHFOS and Richard Kirby, University of Plymouth

An increase in the occurrence of cnidaria jellyfish has been recorded from the CPR Survey in the North Sea since the middle 1980s and in the Northeast Atlantic, where cnidarians now appear earlier in the year and persist longer through the winter months, since 2002 (Fig.16). The morphological identification of cnidarians in CPR samples is impossible. In a new approach we used molecular methods to identify the main jellyfish taxa in CPR samples that were responsible for outbreaks in Northeast Atlantic and Northern North Sea during 2007 and 2008 between 45°N to 58°N and 1°W to 26°W.

The results of our research show that the scyphomedusa, *Pelagia noctiluca*, was the dominant cnidarian in CPR samples. This warm-temperate holoplanktonic species occurred over a large area coincident with the greatest recent increase in jellyfish frequency, i.e. between 40°N to 58°N and 10°W to 30°W. To help understand the changes that have occurred in the Northeast Atlantic, we have compared our results to observations of cnidaria in the Western Mediterranean where long-term records are also available. Overall, the seasonal occurrence of high densities of *P. noctiluca* in the Western Mediterranean and Northeast Atlantic appears to be influenced by

surface hydrography. In the Western Mediterranean, the occurrence of *P. noctiluca* swarms follows the progression of the Atlantic Surface Water stream, that flows eastwards from the Atlantic through the Strait of Gibraltar along the North African coast before circulating anticlockwise around the Western Mediterranean basin. In the Northeast Atlantic, outbreaks of *P. noctiluca* appear to follow the progression of the North Atlantic Current and the surface Continental Slope Current, which flows along the eastern slope boundary of the European basin.

Long-term records from the Mediterranean since the late 19th century reveal that outbreaks of *P. noctiluca* are now more frequent. As outbreaks of *P. noctiluca* appear to be associated with warm winters, the recent increase in Western Mediterranean SST could explain their increasing frequency in this region. Warmer waters in the Northeast Atlantic may have similarly influenced *P. noctiluca* populations in that region.

Predictions of global climate change suggest the Northeast Atlantic and North Sea will continue to warm. In that scenario increased advection and mixing of warmer and offshore waters into coastal shelf seas, may carry *P. noctiluca* and other cnidarians into environments with higher food resources, promoting jellyfish blooms that may become more frequent and extend over a greater proportion of the year than previously.

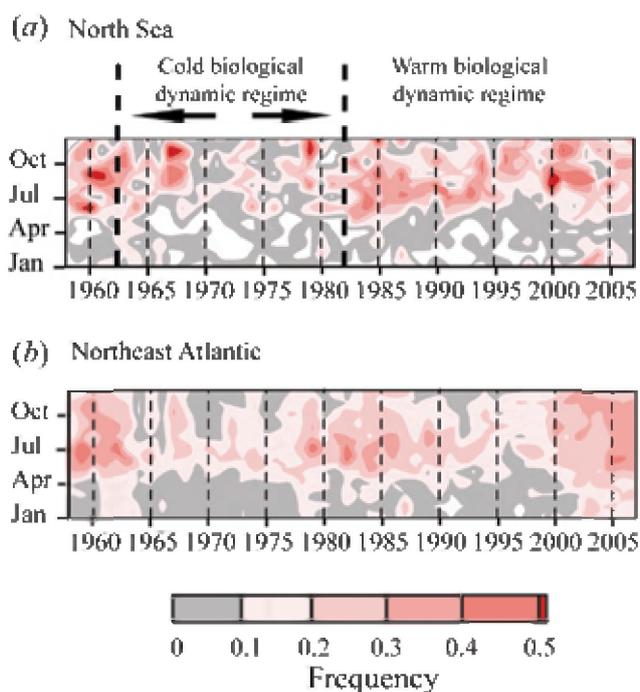


Fig. 16. Average monthly frequency of cnidaria in (a) North Sea and (b) Northeast Atlantic CPR samples in 1958-2007.

# British Antarctic Survey Continuous Plankton Recorder tows

Tanya Jonas, SAHFOS

A prototype Continuous Plankton Recorder (CPR) was first deployed by Alister Hardy, in 1926, during the Discovery expedition to the South Atlantic. Some eighty years later, in 2005, the British Antarctic Survey (BAS), in partnership with SAHFOS started a series of austral summer CPR tows, in the South Atlantic Ocean. During 2008/9, the BAS ship *RRS James Clark Ross* carried out six tows (13 to 18SF), in the Scotia Sea. SAHFOS analysed 84 of the 136 samples collected from three of the tows; 29 from 13SF (November 2008); 25 from 15SF (December 2008) and 30 from 18SF (April 2009, Fig. 17)

Each year, diatoms, silicoflagellates, and coccolithophores have dominated the phytoplankton and 2008/9 was no exception. High Phytoplankton Colour Index (PCI) values recorded on 15SF samples could be attributed mainly to large numbers of *Fragilariopsis kerguelensis*, *Thalassiothrix antarctica* and *Eucampia antarctica*. By April the phytoplankton

bloom had apparently all but gone with very low counts of diatoms, no dinoflagellates and just a few coccolithophores. Copepods, euphausiids and hyperiids formed the majority of the larger zooplankton in the samples. *Calanus simillimus*, *Rhincalanus gigas* and *Metridia lucens* were the most commonly recorded copepods. *Heterorhabdus austrinus* was recorded for the first time ever in a few of the CPR samples from 15 and 18SF tows. Of the euphausiids recorded *Thysanoessa* spp. dominated the counts.

BAS are conducting a further six tows during the austral summer 2009/10. These tows will be the last of a series for the present SAHFOS/BAS five year contract. The results of the BAS CPR programme thus far have shown biogeographically, the region of the Polar Front and the distribution of a number of key taxa in the Scotia Sea. SAHFOS and BAS would like to continue the collaboration and are presently seeking funding for future tows. With this in mind BAS are currently negotiating with the South Georgia government to use a fisheries protection vessel, during its monthly patrols, between the Falkland Islands and South Georgia and so continue the CPR survey in the region.

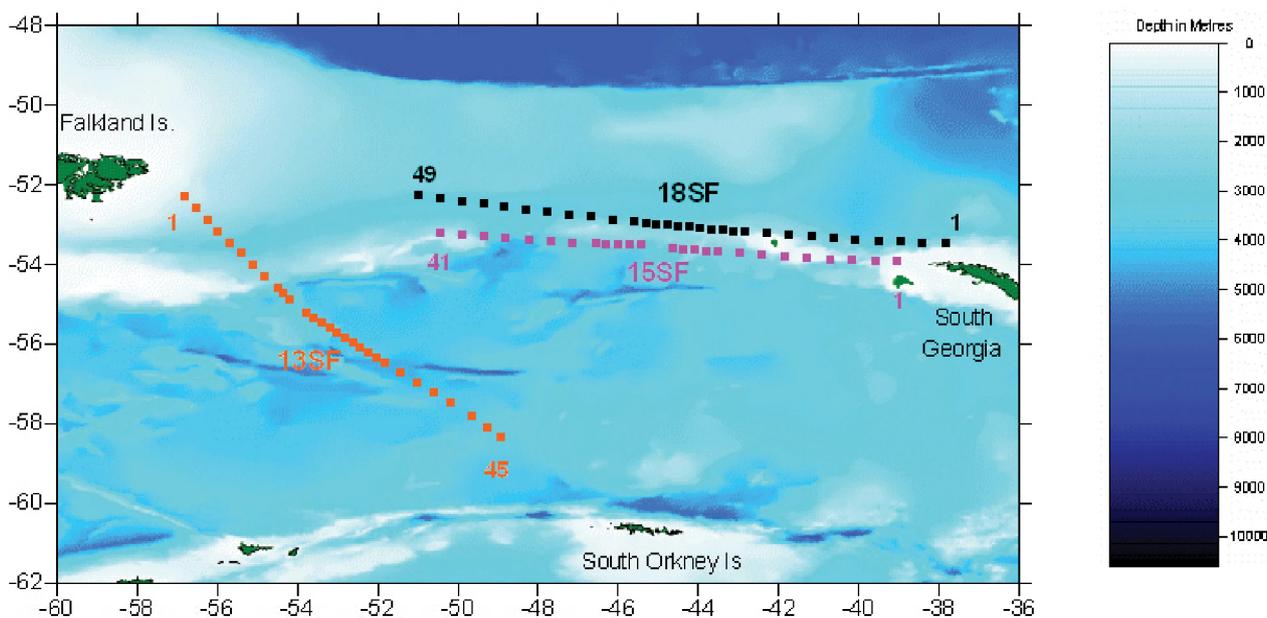


Fig. 17. Positions of the CPR samples analysed from 13 15 and 18SF.



# Education and publications



## Education and Outreach activities in 2009

In 2009, SAHFOS decided to continue running school challenges for the successful 'You're Hired' competition alongside Tamar Education Business Partnership and other Plymouth based employers. The project aims to enhance the employability skills of Year 12 students in full time education. SAHFOS carried out challenges at Torpoint Community College, Devonport High School for Girls and Saltash Community College. The city final was held at the Duke of Cornwall Hotel in June, where SAHFOS designed and ran a CPR based challenge for the finalists to complete. Lance Gregory and Clare Buckland chose Ashley Phillips from Devonport High School for Boys as the 'Best Future Marine Technologist'.



March was a busy month for the team. The BBC One Show came to make a short film about plankton in March. Lance Gregory and Anthony Walne accompanied the film crew and presenter on a short cruise to show how the CPR collects plankton at sea. We were also visited by a French film crew who were making a short film about plastic pollution at sea. SAHFOS ran an interactive event to celebrate National Science and Engineering Week at the Plymouth City Museum and Art Gallery alongside Plymouth Marine Laboratory and the University of Plymouth. Around 500 school children and 100 members of the general public came along to the event to learn more about Naming Nature. Students from Ridgeway Community College visited SAHFOS in March for a talk about the CPR survey and the importance of plankton, plus a guided tour of the SAHFOS laboratory and workshops.



The Plymouth Marine Sciences Partnership Symposium was held in April at the University of Plymouth. The symposium aimed to encourage young Plymouth researchers to present their research. Abigail McQuatters-Gollop gave a talk and chaired one of the workshop sessions, Peter Burkill also gave a talk and Clare Buckland took along publicity materials to promote SAHFOS.

In July, Wembury PROBUS group visited SAHFOS and had a tour of our laboratory and workshops. This was part of SAHFOS promoting membership through the 'Friends of the Oceans'. We also held an open day at the end of July and invited those interested in joining 'Friends of the Oceans'. In August, Clare Buckland and Strike Designs started designing and producing the new SAHFOS animation. The 3D animation will be used on our website and at outreach events to help promote the role of plankton in the marine environment and the work carried out by SAHFOS. The animation is due to be completed in Spring 2010.

SAHFOS and other organisations took part in BIOBLITZ at Wembury Beach in August. The project was part of the Natural History Museum's OPAL Project and aimed to produce a full inventory of species from many habitats at Wembury Point and the River Yealm. The event was a huge success with many members of the general public joining experts in the field to catalogue anything from plants, insects and birds to taking part in a bat survey at night. SAHFOS carried out net sampling of plankton from Wembury Beach and also took part in a night dive to collect plankton.



SAHFOS and the CPR survey on T.V.



## International Phytoplankton Taxonomy Workshop

The first International Phytoplankton Taxonomy Workshop was organised by SAHFOS and the MBA to improve the present taxonomic knowledge of scientists working on phytoplankton. The workshop comprised a mixture of presentations and laboratory sessions with an emphasis on practical microscopy skills.

The workshop was limited to twenty delegates from 9 countries with support from the NERC Strategic Ocean Funding Initiative and the British Ecological Society. The British Phycological Society and the Challenger Society supported the attendance of various students.

We managed to secure expert speakers including Prof. Carmelo Tomas (University of North Carolina, USA), Dr Diana Sarno (Stazione Zoologica Anton Dohrn, Napoli, Italy), Prof Linda Medlin (Observatoire Oceanologique de Banyuls-sur-mer, France) and Dr Barry Leadbeater (University of Birmingham, UK). The workshop proved very successful, the delegates enjoyed the course and

were complimentary about the MBA and SAHFOS and appreciated the amount of effort put in by the organisers. Specific comments included:

*“This is the third taxonomy course I’ve done and the most enjoyable by far! Very organised, very friendly and all the staff were extremely approachable. Thank you all very much, I think I learned a lot and enjoyed it too”*

*“I think the various tutors have been very well chosen. Each of them seemed to be a passionate specialist in their specific area”*

## Stad Amsterdam tows the CPR across the globe

Across the globe 2009 saw people celebrate the 200th anniversary of the birth of Charles Darwin and the 150th anniversary since the



publication of his most famous, and still to this day controversial, work – *On the Origin of Species*. Not only did this work challenge how scientists perceived the world around them, it brought into question some of society's deeply held beliefs. It described the history of the world where man, far from being at its centre, was a result of a combination of processes: a result of gradual genetic differentiation over millennia and selection due to environmental pressures; a process of natural selection; and of evolution.

Much of the evidence for the theory of evolution was collected by Darwin on a five year round-the-world expedition aboard *HMS Beagle*, where he famously visited the Galapagos Islands. To commemorate this voyage the *Stad Amsterdam*, a Dutch clipper, set sail from Plymouth on September 1st to re-sail the route taken by the historic *Beagle* around the globe. The 250 ft luxury clipper is equipped to carry out scientific experiments and observations and throughout its voyage

will host a wide range of scientists, from microbiologists to astrobiologists.

During a calm period on board the *Beagle*, Darwin made his own plankton net and saw that the waters surrounding him were teeming with microscopic life. Following in Darwin's footsteps SAHFOS eagerly took the opportunity to sample plankton along part of the clipper's journey, from Falmouth to Rio de Janeiro, and installed a CPR onboard the ship. To ensure the success of each CPR deployment throughout the 4,500 nm leg of the voyage, a marine scientist member of crew visited the Plymouth laboratory for training. Katja Philippart from the Royal Netherlands Institute for Sea Research (NIOZ) received tuition in all tasks associated with the technical set-up and maintenance of the two CPR bodies used to collect the plankton.

Although not yet delivered back to the UK, it seems all 12 tows made between Falmouth and Brazil were successful. Not only is this the first time a CPR has been towed by a sailing ship, it is also the first time a CPR has been used to sample plankton from tropical south Atlantic waters.

To document and share with the public the recreation of this famous expedition, VPRO, a Dutch television company has been following events on board the ship and are in the process of making a 35 part series. Several of these episodes have included footage of the CPR and members of the Plymouth CPR team.



## SAHFOS contributions to policy 2009

Abigail McQuatters-Gollop, SAHFOS

Since its conception in 1931, the purpose of the CPR survey has evolved with changing environmental policy, from purely monitoring to addressing major marine management issues such as fisheries, harmful algal blooms (HABs), biodiversity, conservation, pollution, eutrophication and climate change impacts. Policy drivers continue to influence research at SAHFOS and an important aim of the organisation is to use CPR data and the expertise of SAHFOS scientists to deliver evidence-based advice to policy makers and ecosystem managers.

The Marine Strategy Framework Directive (MSFD), the EU's thematic strategy on the protection and conservation of the marine environment, came into effect in 2008. The aim of the MSFD is to achieve good environmental status (GES) of Europe's seas by 2020 through the monitoring and assessment of ecological indicators towards GES targets. Historically, CPR research has been aligned with the Directive's GES targets, particularly in the fields of biodiversity, eutrophication, climate impacts, HABs, marine food webs and benthic-pelagic coupling. SAHFOS is contributing to the development of these indicators and targets through involvement in the UK Marine Monitoring and Assessment Strategy (UKMMAS) Healthy and Biologically Diverse Seas Evidence Group (HBDSEG) and the authorship of the report 'A marine assessment and monitoring framework for application in UKMMAS and OSPAR, for phytoplankton and

zooplankton' which evaluates current and potential plankton indicators with respect to UK and EU policy initiatives.

The UK's Marine Climate Change Impacts Partnership (MCCIP) issued a series of Marine Climate Change Ecosystem Linkages Report Cards in 2009 which take a 'big picture' approach to understanding the links between climate change impacts on the oceans. SAHFOS expertise and CPR data contributed to two of the report cards and associated review reports: 'A view from above: changing seas, seabirds and food sources' and 'Marine non-native species'. During 2009 work continued on Charting Progress 2: An Integrated Assessment of the State of UK Seas. This report, commissioned by HBDSEG, involves the collation and assessment of data and information from UK monitoring initiatives. Due to be published in 2010, SAHFOS is leading the chapter 'Biological indicators of state: the plankton'. Assessments such as these provide a mechanism to transfer scientific information to decision makers and facilitate the evidence-based development of monitoring programmes and policy measures.

In 2009 SAHFOS expertise and CPR data also contributed to policy-relevant products for the following UK, European and international bodies: Defra, Joint Nature Conservation Committee, Scottish Natural Heritage, OSPAR, the EU, the European Marine Observation and Data Network (EMODNET), ICES, WWF, the National Science Foundation, Department of Fisheries and Oceans, Canada, and the French government. As in 2008, SAHFOS research has been featured in the EU's Science for Environment Policy: DG Environment News Alert Service.





## Publications

### Publications

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# Appendix A: Financial summary 2009

## INCOME

The principal sources of funding for 2009 are broadly derived from grants and contract income from Core Funding Organisations and Research & Academic Organisations.

Core Funding Organisations provide general funding to enable the general operation of the CPR Survey. In 2009 these were: UK Natural Environment Research Council (NERC), UK Department of Environment, Food and Rural Affairs (Defra), & NOAA. Research and academic organisations commission SAHFOS to undertake specific research, or tow specific routes. SAHFOS may also collaborate with other research groups, sometimes under the umbrella of International Organisations. In 2009 these were *Exxon Valdez* Oilspill Trust, the North Pacific Research Board, Dept of Fisheries & Oceans Canada, British Antarctic Survey, IFREMER France, the European Union, CEFAS, ICES, Institute of Marine Research Norway, and others.

Grants and contract income for 2009 have increased during the year and together with other income from charitable activities, are reported at £1,790,087 (2008 £1,412,613).

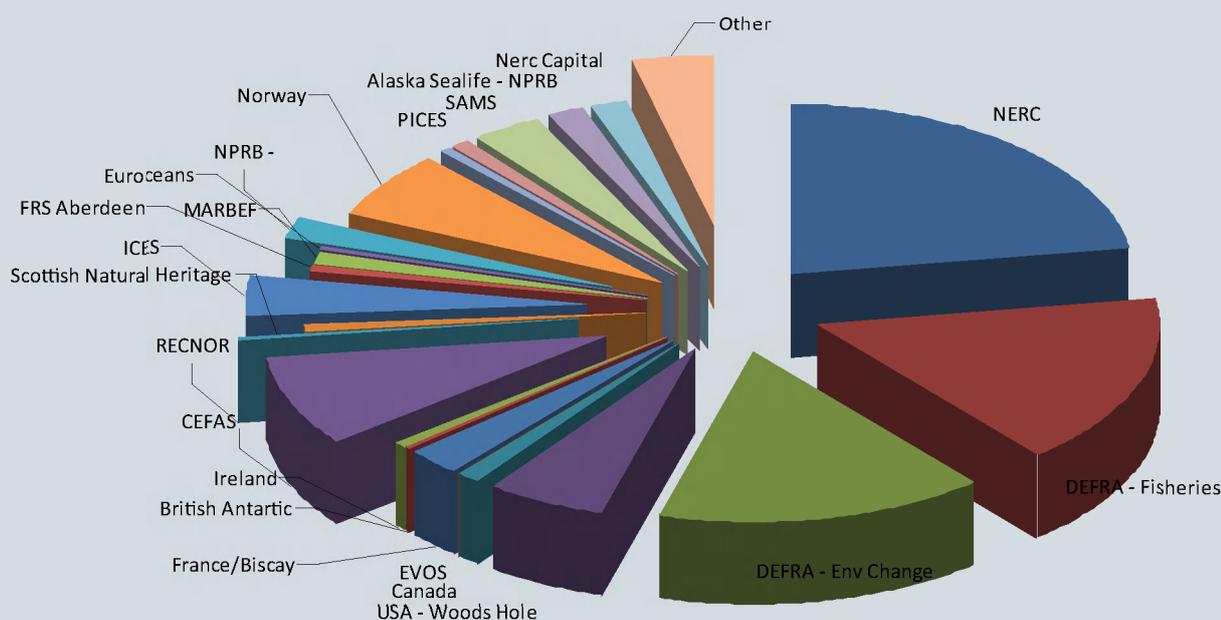
Resources expenditure for 2009 has also increased during the year reporting £1,428,054 (2008 £1,165,077), with the result that there are overall net reported incoming resources of £362,033 (2008 £284,124).

The Foundation is dependent on securing funding from external sources through contracts and grants to enable it to continue its work. Different sources of funding continue to be investigated in order to diversify the funding stream.

## EXPENDITURE

Audited expenditure for 2009 was £1,428,054

The total is defined here in percentages by funding bodies.



## Appendix B. Shipping companies assisting the CPR survey in 2009

Routes	Towing vessels	Shipping Company
A	<i>Hascosay</i>	NorthLink Orkney & Shetland Ferries Ltd, Stromness, Orkney, Scotland
AT	<i>Horizon Kodiak</i>	Horizon Lines LLC, Charlotte, North Carolina, USA and Tacoma WA, USA
Ba,Bb,Bc,Bd	<i>Benguela Stream</i>	Seatrade NV, Groningen, Netherlands. Charterers: Geest Bananas Ltd, Fareham, England
C	<i>Tor Ficaria</i>	DFDS Tor Line, Copenhagen, Denmark
D, F & W	<i>Jonni Ritscher</i>	Charterers: Hapag Lloyd, Hamburg. Owners: Transeste Schiffahrts GmbH, Hamburg
Eb, Ea, D & W	<i>Atlantic Companion</i>	Atlantic Container Line, Skarhamn, Sweden
FR	<i>Stad Amsterdam</i>	Rederij Clipper Stad Amsterdam, Netherlands
HE	<i>Tor Dania</i>	Chartered by DFDS Tor Line from Imperial Shipping AB, Gothenburg, Sweden
IB & SB	<i>Velazquez</i>	Owners: BBC, Burger Bereederungs Contor, GmbH, Germany
IB & SB	<i>Perseus J</i>	Chartered by MacAndrews Ltd, London from Jüngerhans Maritime Services GmbH, Haren, Ems Germany
IN	<i>Norbay</i>	P&O Ferries (Irish Sea) Ltd, Larne, Northern Ireland
LG	<i>Tor Petunia</i>	DFDS Tor Line AB, Copenhagen, Denmark
LR & V	<i>Selfoss</i>	Eimskipafelag, Reykjavik, Iceland
M	<i>S C Aberdeen</i>	Sea Cargo A/S Bergen, Norway
NI	<i>BBC Reydarfjordur</i>	Chartered by Eimskip, Reykjavik from Phoenix Reederei Bereederungs, Leer, Germany
PR	<i>Bretagne &amp; Armorique</i>	Brittany Ferries, Roscoff, France
R	<i>Maersk Flanders</i>	Norfolk Line Ltd, Felixstowe, Norfolk Line BV, Scheveningen, Netherlands, part of the Maersk Group, Copenhagen, Denmark
SA	<i>Pride of Bilbao</i>	P&O Ferries (Dover) Ltd
SF	<i>RRS James Clark Ross</i>	British Antarctic Survey, Research Vessel Services, NERC, UK
ST	<i>Green Frost</i>	Green Reefers AS, Bergen, Norway
VJ	<i>Skaubryn</i>	Seaboard International Shipping Company, North Vancouver, British Columbia, Canada
Z, Zb ,Zc	<i>Reykjafoss</i>	Chartered by Eimskipafelag, Reykjavik, Iceland from Reider Shipping BV, Winschoten, Netherlands





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