Sir Alister Hardy Foundation for Ocean Science

Monitoring the health of the oceans since 1931

2012 Annual Report

The Continuous Plankton Recorder Survey Est. 1931

Refrigerated cargo ship BENGUELA STREAM

Owners: Seatrade Groningen NV, Netherlands.
Charterer: Geest Bananas UK Ltd
B route: Mid Atlantic to Portsmouth, UK
From January 2008

Containership REYKJAFOSS

Charterer: Eimskip, Reykjavik, Iceland
Owmers: Reidar Shipping BV, Netherlands
ZC, ZB and Z Routes
Newfoundland to Iceland, From June 2008

Fishery Protection Vessel PHAROS SG

Charterer: Government of South Georgia
Owner: Byron Marin, Stanley, Falklands
SF route: Falklands to South Georgia. From: March 2011

Passenger Ro-Ro ferry ARMORIQUE

Brittany Ferries, Roscoff, France
PR route: Plymouth to Roscoff
From March 2009

Ro-Ro CLIPPER POINT

Owners: Seatruck Ferries, Heysham, England
Charterers: DFDS Seaways
HE Route, Cuxhaven to Immingham. From July 2012

Cargo-Supply ship GREEN FROST

Charterer: Zahl Transport A/S, Bodo, Norway.
Owners: Green Reefers A/S Bergen. ST route: Svalbard to North Cape, Norway.
From November 2008

Ro-Ro/ Containership ATLANTIC COMPANION

Owners: Atlantic Container Line, Skarhamn, Sweden
E route: New York to Halifax, Nova Scotia and 52ºW
D routes: 33ºW to 7° West and Liverpool. From May 2008

Containership HORIZON KODIAK

Horizon Lines LLC, U.S.A.
AT route: N.E. Pacific: Tacoma, Washington State, USA to Anchorage, Alaska. From March 2004

Containership ENCOUNTER

Managers: Confeeder NV, Rhoon, Netherlands
Charterers: MacAndrews Ltd, London
SA Route, Bilbao to Land's End, England. From April 2012

Ro-Ro FLANDRIA SEAWAYS

DFDS Seaways, Copenhagen
R Route: Hook of Holland to the Shipwash Bank, off Suffolk, England.
From July 2000.

Ro–Ro FICARIA SEAWAYS

DFDS Seaways, Copenhagen. C route: Humber to Hanstholm Lighthouse, NW Denmark, then to Gothenburg. From July 2006

Containership SOPHIA

Charterer: MacAndrews Ltd, London
Owners: Draxl Schiffahrt, Haren Ems, Germany
IB and SB routes
Lisbon, Leixoes, 46°N, 53°N and Dublin
From December 2011

About Us

The Sir Alister Hardy Foundation for Ocean Science (SAHFOS) is an international charity that operates the Continuous Plankton Recorder (CPR) Survey. The Foundation has been collecting data from the North Atlantic and the North Sea on biogeography and ecology of plankton since 1931. More recently, as the Foundation has become more involved in international projects, work has been expanded to include other regions around the globe.

The results of the Survey are used by marine biologists, scientific institutes and in environmental change studies across the world. The CPR team is based in Plymouth, England, and consists of analysts, technicians, researchers and administrators, who all play an integral part in the running of the Survey.

The Foundation is a charity and company limited by guarantee. It depends on the voluntary cooperation of the international shipping community. A consortium of agencies from nine countries, the EU and international organisations provide financial support.

Contents

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Director's Review of the Year

It is a pleasure to be writing the Director's introduction to the Sir Alister Hardy Foundation for Ocean Science Annual Report. From my earliest days as a marine scientist I have had an interest in the Continuous Plankton Recorder Survey and the fascinating insight the unique data gives us on the marine ecosystem. I have also have a deep admiration of Sir Alister Hardy's books and paintings. Also, being a long-standing member of the Plymouth marine science community, and well remembering the formation of SAHFOS, it was a genuine privilege and honour to become its Director in September 2012.

Before reviewing some of this year's highlights, it is sad to record the deaths during the year of Dr Michael Colebrook and Professor Anne Warner FRS. Michael was a very long serving member of SAHFOS staff who started working on the CPR Survey in 1956 during the days when the Survey was based in Edinburgh. During his thirty-six years at SAHFOS and its antecedents Michael introduced many novel statistical approaches and techniques, the legacy of which continue to allow us to publish CPR data with analytical insight rather than description alone. I had the personal pleasure of having worked with Michael on some CPR data and he was a generous and inspiring collaborator. The esteem with which Michael was held was recognised by the award of a SAHFOS Distinguished Honorary Fellow; his contributions will be greatly missed. Professor Anne Warner was a valued Trustee and member of the SAHFOS Council. Anne joined the Council in 2005 and despite her ailing health in later years she was a regular attender at meetings, at which her contributions were insightful and highly regarded. We send our sincerest condolences to Michael and Anne's families.

There have been some notable achievements during 2012. It is difficult to put these in any priority order but I think it is probably right to highlight first that 2012 saw the greatest distance towed by the CPR since its inception, 81 years ago, at 133,521 nautical miles: this is a tremendous achievement. The logistics of the tows and everything behind them is detailed later in the report but I would like to record my personal thanks to all those outside of SAHFOS who make this unique Survey possible: thank you all.

SAHFOS would be nothing without its staff and it is with great pleasure to formally record and congratulate Martin Edwards on the attainment of a Professorship at the University of Plymouth. This is in recognition of the outstanding contribution he has made and his clear status within the plankton ecology community and the positive role in maintaining the excellent relationship between SAHFOS and Plymouth University. Continuing with Martin, he and long-standing SAHFOS research fellow Gregory Beaugrand were honoured with an 'Inspiration Award for Ecosystem Science' by the University of Oslo. The award is in recognition of their work which has been deemed by a panel to have been inspirational in the field of ecosystem science. The Award is represented by a 1930 volume of Sir Maurice Yonge's 'A Year on the Great Barrier Reef' and inscribed by him. In a very nice touch the volume has been designated (and the slip-case engraved) 'The Michael Colebrook Memorial Volume' which will ensure that Michael's contributions endure.

We also congratulate several of our students who successfully defended their theses this year: Vicky Harris, University College London; Steph Hinder, University of Swansea; Alice Jones, University of Southampton (NOC); and Manal Al-Kandari and Valentina Lauria, both at Plymouth University. Congratulations to them all.

As well as myself there were a number of new starters: Mrs Kate Brailsford, Administrator; Dr Alessandra Conversi, Marie Curie Research Fellow; and Mr Julian Morley, Workshop Technician. We wish them well in their new roles and for a fulfilling and successful career with us. And we said goodbye to Mrs Debbie Cracknell, Silk Preparer, and Ms Jess Haapkyla, NMBAQC Technical Secretary. Many thanks to them for their contributions.

Citadel Hill, Astrid Fischer

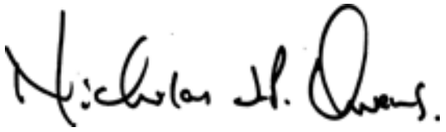
2012 was another highly productive year on the scientific front with many scientific articles and policy documents published. Of the latter, a notable first was a Global Marine Ecological Status Report based on CPR data collected from around the World by our 'sister' surveys in the Global Alliance of Continuous Plankton Recorder Surveys - GACS.

Research encompassed all aspects of marine science from studies on phytoplankton and carbon fluxes to whole ecosystem changes across multiple trophic levels. As well as providing evidence of spatial and temporal changes in the plankton community this year also provided a number of studies exploiting our new database on fish larvae in the North East Atlantic. These included studies on mackerel, sandeel and other commercial fish species and their long term trends in relation to fisheries. Two of our most topical research papers were published in the journal Nature Climate Change: one based on the long-term trends in diatoms and dinoflagellates under climate change and the other on multi-decadal changes in calcareous plankton in the North Atlantic. The latter is particularly topical considering the growing concerns of the effects of increasing acidification on ocean biology and productivity.

A more detailed account of some of our scientific activities can be found elsewhere in this report.

In drawing to a close I would like to thank SAHFOS's President, Professor Peter Liss FRS CBE, Trustees and Members of Council who voluntarily give of their time and skills to help us be a successful research organisation; I look forward to working with them in the coming years. I would also like to thank Professor Martin Edwards as acting Director and Gill Tanner who led SAHFOS very effectively for a number of months during the year prior to my appointment and also, together with all the staff, for all the help so generously given during my first months as Director.

I am sure you will find this report stimulating and interesting.



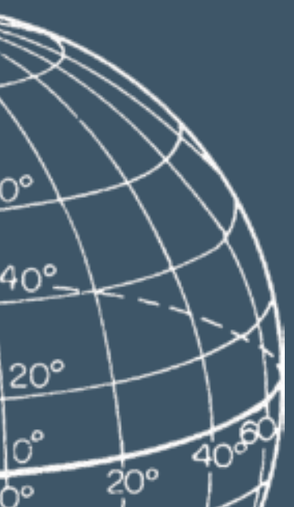
Left; Alister Hardy at work.

Right; Diatom and Dinoflagellate drawing by Alister Hardy.

SAHFOS Staff of 2012

Prof Nicholas Owens, Director
Prof Martin Edwards, Head of Research and Deputy Director

Roger Barnard, Workshop Technician
Dr Sonia Batten, Pacific CPR Project Co-ordinator
Kate Brailsford, Administrator
Gemma Brice, Analyst
Clare Buckland, Analyst and Education Officer
Robert Camp, Analyst
Maria Campbell, Analyst
Dr Claudia Castellani, Research Fellow and Analyst
Alec Colebrook-Clark, It Support and Web Developer
Dr Alessandra Conversi, Marie Curie Fellow
Debbie Cracknell, Technician
Dr Astrid Fischer, Analyst
Mike Flavell, Database Manager
Lance Gregory, Workshop Manager
Chris Harris, Workshop Technician
Jess Haapkyla, NMBAQC Technical Secretary
Julian Morley, Workshop Technician
Dr Pierre Hélaouët, Research Fellow
Linda Horsfield, Administrator
Usha Jha, Analyst
David Johns, Laboratory Manager and Research Fellow
Tanya Jonas, Senior Taxonomist
Dr Priscilla Licandro, Research Fellow
Dr Abigail McQuatters-Gollop, Science-Policy Research Fellow
Dr Delphine Nicolas, Post Doc Research Fellow
Doug Moore, Analyst (Canada)
Jean Nyman, Finance Officer
Capt Peter Pritchard, Head of Operations
Prof Phillip Reid, Senior Research Fellow
Jennifer Skinner, Analyst
Marion Smith, PA to Director and HR Manager
Dr Rowena Stern, Molecular Plankton Taxonomist
Darren Stevens, IT Manager
Gill Tanner, Head of Admininistration
Claire Taylor, Deputy Laboratory Manager
Dr Tony Walne, Research Fellow and Analyst
Marianne Wootton, Deputy Senior Taxonomist
Claire Wotton, Analyst



Survey Operations

In 2012 we.....

- Towed 133,521 nautical miles; the highest in the history of the Survey
- Have in total towed over 6.2 million nautical miles; equivalent to going to the moon and back 15 times!
- Had a 87.5% sampling success rate
- Ventured our furthest north 79°N for Arctic tows
- Developed a new methodology for multiple short-leg tows
- Produced over 1300 square metres of silk
- Fitted all CPRs with a prop protector
- Gained IMarEST recognition for our CPR Training Course

Tow logistics and Operations

Peter Pritchard

Since the first tows in September 1931 between Hull and Bremen by the German merchant ship *Albatross*, the CPR Survey has been towed for 6,203,558 nautical miles (nm). This is an incredible achievement and has produced one of the largest data sets of marine plankton from the most extensive and longest marine biological time series survey in the world. During 2012 ships of opportunity towed plankton recorders for 133,521 nm, which is the highest in the history of the Survey. Twenty-five ships completed 382 separate CPR tows over 24 routes covered in 2012.

The physical operation of the expanding CPR Survey over the past 81 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 assistance from the agents and port operatives in transporting the recorders to and from the vessels, are a fine testament to the shipping industry. The international marine scientific, fisheries, meteorological and oceanographic communities are greatly indebted to them.

Ships and companies participating during 2012 are shown in Appendix B. Photographs of the ships are inside the covers. Three changes of ships occurred in 2012. April: *Encounter* on the SA route; September: *Sea Cargo Express* on the M route, October: *Madame Butterfly* on the VJ route.

There were 116,858 analysable nautical miles. The overall 87.5% sampling success rate in 2012 reflects the conscientious, consistently professional work of the CPR workshop team. The team comprised: Lance Gregory, Roger Barnard, Chris Harris, Julian Morley and Debbie Cracknell.

The tow equipment aboard the ships has a planned maintenance and safety inspection regime complying with the International Lifting Equipment Regulations (LOLER) and Marine International Safety Management (ISM) code.

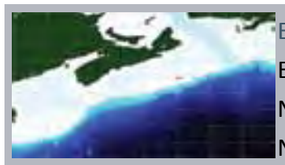
The following geographic areas were monitored by CPRs:

Arctic, North East Atlantic and Norwegian Sea

The ST route between the North Cape of Norway and Svalbard was towed monthly in April, May, July and September to November 2012 by the *Green Frost*. We are indebted to the owners Green Reefers of Bergen and charterers, Zahl Transport of Bodø, Norway. The NI route between Mosjoen, Norway, and Reydarfjordur, Iceland, was towed by the containership *S. Rafael* in January to March, May and July to September 2012. A new ship is being sought for the route in 2013.

Iceland to North America and Europe

We are very grateful to Reider Shipping BV Netherlands, for allowing their ship, the *Reykjafoss* to tow the Z route from Newfoundland to Reykjavik from January to March, May to September, and November to December 2012. Eimskip Shipping Company of Reykjavik has steadfastly supported the CPR Survey since 1933. They transfer the CPRs between the *Reykjafoss* and the UK bound ships at Reykjavik. They allow the Foundation to tow CPRs on the Immingham to SE Iceland (LR and V) routes from the *Selfoss.* The Foundation is also indebted to the Hafrannsoknastofnunin (Marine Research Institute) of Reykjavik for their support to the Survey. We are very grateful to Dr Astthor Gislason and the plankton research team.



East Coast of North America

E route: Towed by the RO-RO/ containership *Atlantic Companion* between Norfolk, VA New York, Halifax, Nova Scotia and south of Cape Race, Newfoundland, from February to December 2012. We are very grateful to the ship and Atlantic Container Line of Sweden for their professional assistance. The route has been run at five weekly intervals despite the busy operational schedule of the ship.

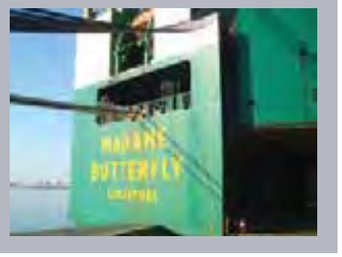
North Atlantic

The *Atlantic Companion* tows the DA and D routes every five weeks from February to December 2012. This is between 33°W and 7°15'W to the north or south of Ireland en-route to Liverpool depending on the prevailing North Atlantic weather.
B route: *Benguela Stream*, a fast refrigerated cargo ship completed four consecutive tows every 28 days from 40° West to Portsmouth, UK. Thirteen sets of 4 tows each, totalling 22251 nm were completed. We gratefully acknowledge the kind permission from the ship's managers, Seatrade NV, Groningen, and the charterers, Geest Line Ltd, Fareham and MMD Shipping Services, Portsmouth for their logistical support.

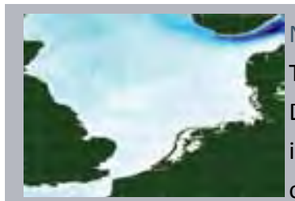
North Pacific

AT route: between Tacoma, Washington State and Anchorage, Alaska from April to October. We are very grateful to Horizon Lines LLC and their containership, *Horizon Kodiak,* for their continued professional support for this route since 2004. Twenty individual tows were completed to October, with 7,963 nm logged. Two technicians, Mark Savoie and Gary Lawley at Kinnetic Laboratories, Anchorage, Alaska, look after the CPRs. They unloaded, serviced and reloaded the CPRs at Anchorage, achieving with the crew of the *Horizon Kodiak* a splendid 99% plankton sampling success rate. Horizon Lines' Tacoma container terminal shore gang handled the CPRs to the ship. Thanks are due to the ship's Superintendent, Danny Ellis, Horizon Lines' shore gang, plus Ken Clinton and Vern Poulsen.

VJ route: During April and June the *Morning Cedar*, owned by Eukor of Singapore and chartered by Seaboard International Shipping Company of Vancouver, completed two westbound sets of seven 500 nm tows. In October the new ship *Madame Butterfly* completed 7 westbound 500 nm tows. The total towed on the VJ route was 10,512 nm. There were 9883 analysable nm. This gave 94% sampling success rate attributable to the care taken by the *Morning Cedar* and *Madame Butterfly* crews and Doug Moore, Sonia Batten and team on Vancouver Island. A Brancker XR620 CTD + F unit was successfully run on the three westbound voyages.



Tow points at upper left corners of stern openings from mooring decks of *Morning Cedar* (left) and *Madame Butterfly* (right)



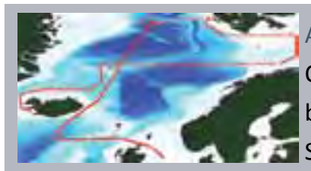
North Sea

The C, HE and LG routes have been consistently run each month by ships of DFDS Seaways, Copenhagen, fleet over many decades. The Survey is much indebted for their permission and for the logistical help from their port operatives at Immingham and Gothenburg. *Tor Dania,* chartered from Imperial Shipping Gothenburg, towed the HE route monthly from January to April. The chartered *Clipper Seaways,* owned by Truckline Ferries, resumed the route from July to November. DFDS Seaways' *Ficaria Seaways* and *Petunia Seaways* towed on the LG and C routes.

Flandria Seaways has towed the R route monthly between the Shipwash Bank and Hook of Holland since July 2000. The continued permission from the owners and managers plus logistical support from DFDS Seaways at Dooley Terminal, Felixstowe, are much appreciated.

The M route: between Aberdeen and Tananger, was towed from January to June by the freight RO-RO *S. C. Aberdeen* of Sea Cargo A/S, Bergen. The *Sea Cargo Express* towed the route from September to December. We gratefully acknowledge the kind permission from Sea Cargo of Bergen and Aberdeen and their ships over many years.

A route: between Lerwick and Aberdeen was towed from January to September, November and December by the freight RO-RO *Hildasay* chartered by Serco NorthLink Ferries Ltd from Seatruck Ferries, Heysham. We are very grateful for their permission and professional assistance to the Survey.



Arctic, Ocean Acidification Project

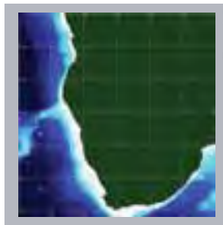
OA routes towed between Scotland, Norway, Svalbard and Iceland for 4184 nm by the British Antarctic Research ship *James Clark Ross* in June and July 2012. SAHFOS devised a methodology that would allow the CPR to tow a series of short multi leg tows, which highlights a new versatility for the CPR.

Portuguese and North Spanish coasts, Bay of Biscay and the Channel

SB route: this was towed in 2012 by the *Sophia* chartered by MacAndrews as on the IB route above. The SB route is from Cabo da Roca (38°50'N 9°53'West) 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.

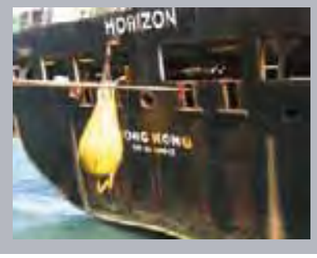
SA Route: was towed from April to December between Bilbao and Land's End by the new ship, *Encounter*, chartered by MacAndrews Ltd, London, from Confeeder NV, Rhoon, Netherlands. We are very grateful to the owners and charterers for their permission. Also to the crew of the *Encounter* for their consistent tows.

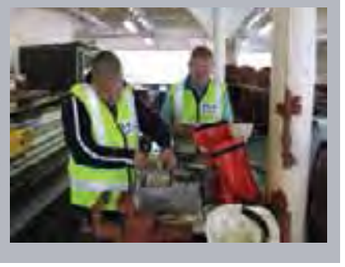
PR route: Brittany Ferries' *Armorique* towed each month from February to December. We are much indebted to Brittany Ferries for their kind permission and professional assistance.



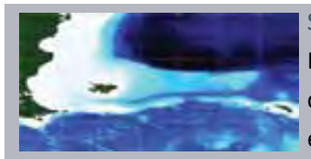
Southern Africa

CT route: Luanda, Angola, to Durban, South Africa. This route was towed using 5 consecutive filter cassettes in March 2012 by the containership *Horizon* of Shanghai Costamare Ship Management chartered by Ocean Africa Container Line, Durban. Horizon came off this route in June 2012.





Left: Four tonnes water bag, load test on the tow point of MV *HORIZON* at Durban to give 2 tonnes safe working load. Right: Marco Worship and Hans Verheye, DEA, Cape Town, load CPRs aboard.



South Atlantic: SF route: Falkland Islands to South Georgia

During 2012 the South Georgia Fisheries Protection Vessel *Pharos SG* chartered from Byron Marine of Southampton, completed four sets of eastbound double tows from Stanley to South Georgia. These were in late February/early March, May, August and November. 2,703 nm were towed with CPR 163. We wait for the unloading results of the November 2012 tows.

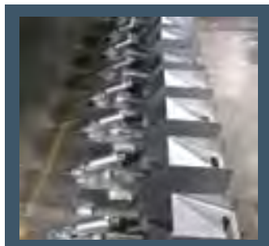
We are very grateful to Judith Brown at Stanley and Katie Brigden at King Edward Point, South Georgia for the care in unloading, servicing and reloading the CPRs. In December 2012, they handed over the CPR operation to Katherine Ross at Stanley and Susan Gregory at South Georgia. The support of the Master and crew of the *Pharos SG*, plus assistance from Byron Marine (David Allan) and permission from Dr Martin Collins, Director of Fisheries, Government of South Georgia, are very much appreciated. SAHFOS is contracted with the British Antarctic Survey (Dr Peter Ward) for these tows.

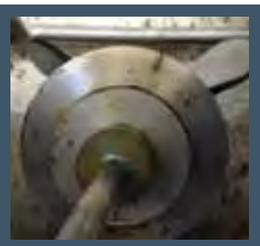
Irish Sea

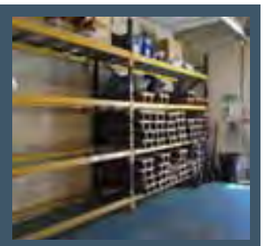
IB route: 46°North in Biscay to 53°North, off Dublin, was towed by the *Sophia* (chartered by MacAndrews Ltd, London from Mar Trust ship No. 2/ Peter Döhle Schiffahrts, Haren-Ems, Germany). She completed tows in January, March to May, July, September, October and December. The interruptions were due to industrial action in Portugal and Spain. We are very grateful to the crews, charterers, owners and managers for their professional assistance and permission.

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

CPR Workshop







A busy year: From left to right: The CPR fleet ready to go out, the newly fitted prop protectors, September saw every CPR out on a tow.

The SAHFOS workshop welcomed a new member in 2012. Julian Morley was recruited and started in May and with his skills and experience has proved to be an effective member of the team. December saw Debbie Cracknell leave SAHFOS to concentrate on her job at the National Marine Aquarium and her PhD. The workshop team consisting of Roger Barnard, Chris Harris, Julian Morley and Lance Gregory, enjoyed a productive 2012.

2012 was a particularly busy year for the SAHFOS workshop as a result of the CPR Going Global. We saw an increase of new CPRs being ordered (see Table 1). All new CPRs are purchased through the SAHFOS workshop and the final assembly, QC checks and full bench trials are completed by SAHFOS technicians before they are released for export.

The workshop is also producing record amounts of prepared CPR silk, 2012 was the highest towed mileage ever for SAHFOS and we are now producing silk for the following countries: USA, Australia, France, South Africa, New Zealand and Cyprus. In total SAHFOS produced 600 pairs of CPR silk in 2012, with each pair taking close to two man hours to produce. Over 1300 square metres of Shanghai woven silk were used to produce these silks

The SAHFOS workshop also hosted a training course for scientists who were using a CPR from the *James Clark Ross* on the Ocean Acidification cruises. The course was a success and demonstrated a new versatility for the CPR (highlighted on page 12).

During 2012 all SAHFOS CPRs operated from the UK were fitted with a prop protector (see image above), this device helps to keep the propeller free from detritus especially in sea areas where there is heavy plastic, discarded fishing gear, etc., helping to ensure the continuing high success rate of the CPR.

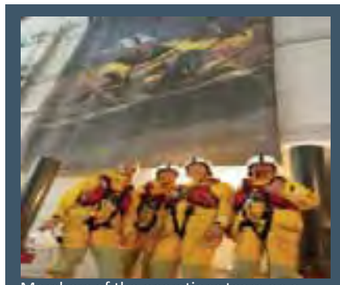
Losses of CPRs at Sea During 2012

13 March 2012: CPR 87 body with filter cassette 87/0 lost during the haul in the Kattegat from the *Petunia Seaways*. The wire end indicated a stretch break.

13 August 2012: CPR body 180 with cassette 180/1 lost before 1608 GMT during the tow north westwards by the *Horizon Kodiak* in the Gulf of Alaska en route to Anchorage. The wire break ends indicate that the tow wire could have been in contact with a part submerged object.

Training Courses Attended

Julian Morley successfully completed the Lifting Equipment Examiners course in October 2012, and he is now part of the team that ensures all towing and lifting equipment supplied to the ships is compliant and safe. Lance Gregory and Peter Pritchard also attended a refresher course to keep their qualifications current. Workshop staff also re-qualified as forklift operators in 2012.



Members of the operations team on a RNLI sea survivival course.

SAHFOS now offers IMarEST approved training.

In December 2012 Peter Pritchard, Dr Antony Walne, Julian Morley and Lance Gregory visited the RNLI headquarters in Poole to attend their sea survival course. The RNLI's facility has a wave and wind machine and helicopter winch which all adds to the realism on a first class course.

Vemco temperature minilogs are used on the BB, BA, DA, D, SA, SB, and IB routes. These are primarily for tow sequence verification. Star Oddi CTD units were used on the Norway to Iceland and North Norway to Svalbard routes.

IMarEST Recognition

The Workshop Team have produced a CPR Technical Training Course that was submitted to the Institute of Marine Engineering Science and Technology (IMarEST) in late 2012. The course has achieved recognition and a certificate by IMarEST as a course of Continuing Professional Development (CPD) for 5 years from 1st January 2013.

Technical Developments (Instruments) and The Workshop

The Brancker XR620 CTD unit has operated successfully on the LR and V routes between Immingham, Sule Skerry and SE Iceland. The other Brancker XR620 CTD+F unit has operated successfully on the VJ route to Hokkaido from Vancouver Island.

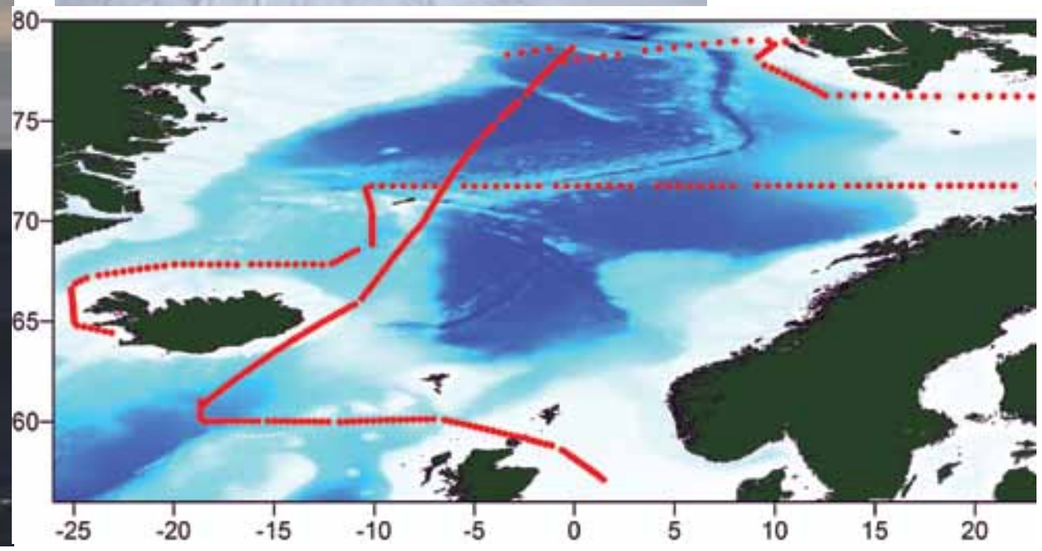
Drs Tony Walne and Rowena Stern and latterly Robert Camp have worked with the water sampler from CEFAS Lowestoft. This was deployed in CPRs 153 and 192 with a Star Oddi CTD and Minilog on the Plymouth-Roscoff PR route. The water sampler is being used to identify phytoplankton taxa that are too small to be successfully filtered by the 280µm CPR mesh. This route is being operated on a fast analysis basis, further details page 14.

Table 1. New CPRs ordered in 2012

CPR number	Number of internals	Customer/ SAHFOS Fleet	Export Date
194	5	Australia	Jan 2012
195	5	Australia	Jan 2012
196	3	SAHFOS	N/A
197	3	SAHFOS	N/A
198	2	S Africa	Sep 12
199	2	S Africa	Sep 12
200	2	S Africa	Sep 12
201	2	S Africa	Sep 12
202	2	S Africa	Sep 12
203	1	Cyprus	Held for Cyprus training course
204	1	SAHFOS	N/A
205	0	SAHFOS	N/A
206	0	SAHFOS	N/A
207	2	France	Nov 2012

Clockwise from left: An arctic scene, the J*ames Clark Ross* Research vessel, map showing all the OA tows, *JCR* breaking through the ice and deploying the CPR.

Photo credits Jeremy Young.



SAHFOS moves into Arctic Waters

The furthest north we have surveyed; a new methodology for short multi-leg tows

David Johns and Lance Gregory

During the summer months of 2012, the *James Clark Ross* towed a CPR in the Arctic, in the Greenland Sea, the furthest north a CPR has ever been towed (79ºN). This tow was part of a NERC-funded cruise, part of the UK Ocean Acidification Sea Surface Consortium, whose aim is to investigate acidification impacts on the surface ocean (www.surfaceoa.org.uk). The cruise set sail on the 1st June 2012, and visited the Norwegian, Barents and Greenland Seas, travelling as far north as the sea ice permitted. During the cruise, seawater samples were collected, with an aim to study the impact of changing chemistry on marine organisms and ecosystems, carbon and nutrient cycling, and air/ sea interactions. The planned route of the cruise meant that there would be multiple sampling stations, often with very short distances between. The CPR was felt to be an integral part of looking at the pelagic plankton community, but the multi-station, short-tow schedule posed a different set of conditions to the more normal use of the CPR.

CPRs have typically been deployed for long distance marine monitoring with a capability of sampling over 500 nautical miles on a single deployment. Used in this way they have proved to be a cost effective, proven and reliable ocean monitoring instrument. The CPR fleet has towed over 6,000,000 nautical miles over eight decades using this standard methodology. The planned OA cruise saw the CPR used in a new role. When scientists were looking for a plankton sampler to carry out a series of short multi leg tows between station points for the NERC project in the Arctic (and then a repeat in the Antarctic in 2013), SAHFOS devised a methodology that would allow the CPR to meet this criterion.

Visiting scientists attended a short course at SAHFOS in Plymouth where they were taught the techniques to successfully set up and deploy a CPR for short leg use. The course culminated in a full ‘dry run’ of the process, using ships logs and revised tow record sheets to simulate an actual cruise. The scientists were then able to see the transit data entered into console and view the sampling cutting points. In this way multiple, short tow legs were completed successfully, giving 26 separate ‘tows’, and providing almost 390 samples. The Arctic cruise was a great success and highlights a new versatility for the CPR.

As of writing, all these samples have been analysed, and the initial results look very interesting – watch out for some results coming soon!

Rapid Production of CPR Data

Dr Antony Walne

From March 2012 special priority has been given to the analysis of the Plymouth to Roscoff CPR route. This route is towed by the Brittany Ferries' vessel *Armorique*. Unlike the more usual SAHFOS procedure, the CPR is delivered and collected from the vessel by SAHFOS staff. The CPR is usually delivered to Plymouth one day and it is transported south by the vessel, it will then be towed northbound the following day and collected on return to Plymouth. The CPR is hauled at the end of the PR tow just before arrival in Plymouth and thus the CPR is back at the laboratory within 1.5 to 2 hours after sampling. This relatively rapid return is important as the CPR carries a Water Sampler and the samples need to be processed quickly as they are not preserved.

The only particular priority given to the route was to ensure that any analyst given a sample or a quality check was able to carry out that procedure within a few days. Each PR route usually produced 8 standard 10 nautical mile CPR samples and each was examined by a different analyst. In addition a further 5 or 6 SAHFOS staff were involved in the workshop and in the IT department. Each person's role is important and the progression from sampling to the production of data can stall if any of those personnel are away or cannot complete their task on time. The average time between sampling and the release of quality controlled data for the 9 successful tows between March (356PR) and December (366PR) 2012 was 61 days. The fastest production time was 16 days (356PR) and the slowest was 121 days (357PR). Five routes were completed in 51 days or less.

Figure 1 shows some of the results which can be provided within 2 months of sampling. Figure 1A shows the average Phytoplankton Colour Index for all samples against month on the x-axis together with the month average for tows between 2000 and 2011. Figure 1B shows the average 'total copepods' (individuals per CPR sample) again with the 12 year monthly average for 2000 to 2011 inclusive.

The same procedure could be applied to other CPR routes. Those CPR routes that are towed inwards towards the UK will be offloaded at their destination port and returned to SAHFOS less than a week after sampling. Obviously, longer tows will produce more samples, and this would represent an increase in the logistical issues of making sure there were sufficient staff available at a given time to ensure a rapid turnaround of work. However, with sufficient investment and planning, 60 days is a realistic target from sampling to release of quality controlled data.

Figure 1. Results available 2-months after sampling

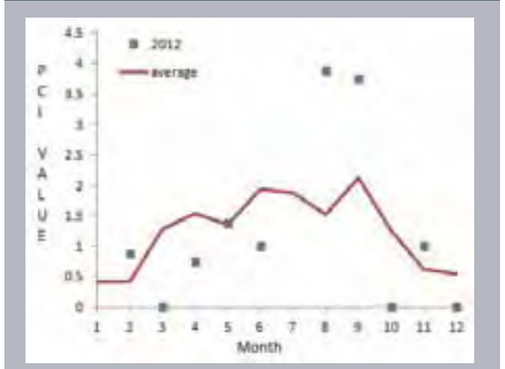


Figure 1A. 2012 Average Phytoplankton Colour Index compared with the monthly average for tows between 2000 and 2011.

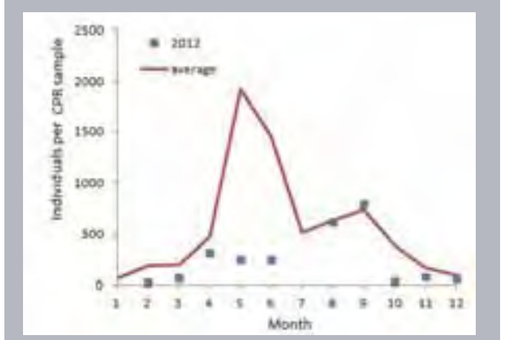


Figure 1B. 2012 Average 'total copepods' (individuals per CPR sample) compared with 12 year monthly average for 2000 to 2011 inclusive.

Database, IT Infrastructure, Software and Websites

Darren Stevens, Mike Flavell and Alec Colebrook-Clark

SAHFOS has seen the benefits this year of investing in the CPR Console when the new version was launched after an extensive testing procedure, in January 2013 (screenshot above left). The latest version has seen over 150 improvements and issues resolved over the previous version. This has included more automated Quality Assurance analysis, at the point of data entry and prior to commitment to the database, this will improve efficiency of the whole data entry process.

A complete year's worth of CPR data was released in August 2012 to the scientific community earlier than ever before. In-roads to earlier data release continue to be made. This is highlighted by the data from the Plymouth to Roscoff (PR) route, operated by our friends at Brittany Ferries, which is currently being released 4-6 weeks after collection, resulting in all 2012 data for this route available by January 2013.

The database for the Global Alliance of CPR Surveys has now been established (see Fig. 2 below). This has presented new challenges in order to ensure the data collectors are identified and referenced.

The GACS numerical ecologist is now working with the whole datasets in preparation for the next GACS meeting.

The SAHFOS Education website LifeAdrift.info was launched in June 2012 (above right). This site is aimed at the 5-18 age group as well as the general public. Much of the content is built into a single webpage providing a dynamic and visual method of site navigation. Young people have grown up with easy access to the internet and have higher expectations from the activity of a website. If the younger generation are to spend more time on the website, and increase the likelihood of return visits, it is important we provide them with a positive experience from the outset.

Behind the scenes SAHFOS has improved the Business Continuity Plan by implementing offsite mirroring for all our servers and data on a daily basis. This means that all data are now offsite at another location over 5 miles from Citadel Hill. The backup system for the CPR database files has also been improved to allow a more granular restore in the event of a system disaster.

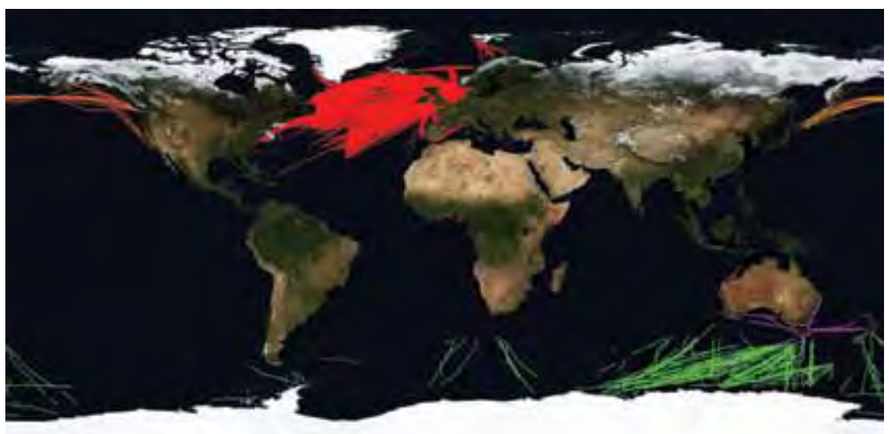
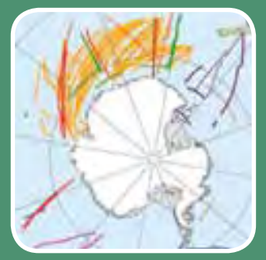


Figure 2. Map of all samples from the GACS database.

Map source Google Maps



Sister CPR surveys

Pacific CPR Operations

Dr Sonia Batten, Pacific CPR Project Co-ordinator

Sampling during the second half of 2012 did not go smoothly in the Pacific. On August 15th, the crew of the *Horizon Kodiak* towing the north-south AT transect pulled in the tow cable to change the second cassette to find the CPR no longer there. The cable was cleanly sheared which suggests an impact with a sizeable object, perhaps a submerged shipping container, somewhere in the Gulf of Alaska (below left). Only the southernmost section of the transect was therefore sampled in August. A second attempt was made to sample the whole transect, but a weld failed on the replacement tow body that was deployed in early September. This caused erratic towing, so the crew hauled in the CPR just a few miles into the transect. The body was repaired by the Kinnetic Laboratories team in Anchorage, and the transect was sampled again later that month – fortunately 3rd time lucky! The final sixth transect was sampled in October. In addition, the ship that had towed the east-west VJ transect since spring 2011 was suddenly switched to an Atlantic trading route, and so there was a last minute scramble to fit a towing point to the sister-ship, the *Madame Butterfly* (below right), so that the autumn transect could go ahead. It did so in October. In the end, we did sample the north-south transect 6 times, and the east-west transect 3 times as intended, though the sampling season was extended into October. Despite these mishaps, the Pacific CPR Survey continues to have a high success rate (99% on the AT route, and 94% on the VJ route).

Despite some mishaps the Pacific Survey had a high sucess rate in 2012

SCAR Southern Ocean CPR Survey

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

It has been another busy and successful year for the SO-CPR Survey maintaining our usual number of tows in the region, new countries joining the Survey, hosting a number of training workshops in Southern Ocean taxonomy and methodology and receiving a very favourable review.

The Southern Ocean CPR Survey completed 46 tows from six vessels during the 2011-12 season: October to March. Australia completed 18 tows south and west of Australia from the Australian icebreaker *RSV Aurora Australis*. Japan supplemented this with another seven tows from icebreaker *Shirase* and a further nine tows from the TRV *Umitaka Maru* in the same region. New Zealand completed eight tows between New Zealand and the Ross Sea from the *San Aotea II*. The Chilean Antarctic programme conducted a CPR tow across Drake Passage. South Africa has joined the SO-CPR Survey with successful tows covering 1386 nm south of Cape Town from the German polar research vessel *Polarstern*. In total 2,985 samples were collected by SO-CPR partners during the 2011/12 Antarctic season. Once the samples have been fully processed and data verified, this will increase the SO-CPR database to 36,928 sample records for approximately 230 zooplankton taxa coupled with environmental data.

Countries involved in SCAR surveys in 2012 include Australia, Japan, Chile, South Africa and Antartica.

South Africa continued their efforts in the Southern Ocean by starting the 2012/13 season with 2262 nm of tows in July 2012 during the maiden voyage of the new South African polar research and supply vessel, *MV SA Agulhas II*. The tows started soon after leaving the ice edge heading north, providing much needed data on plankton in winter. Very few ships operate in the Antarctic in winter. Another 2023 nm of tows were conducted by the ship in September and October. Further tows are planned for mid summer. The tows by the *SA Agulhas II* will add significantly to the 25 tows already completed by the *Aurora Australis* for 2012/13, seven tows from *Umitaka Maru*, eight from *San Aotea II*, and six tows expected from *Shirase* and three from *Tangaroa*. France has also joined the Survey and has conducted three tows to date from the RV *Marion Dufresne II* in the Kerguelen and Crozet Island area of the southern Indian Ocean, an area that has seen few plankton studies. Overall we expect the 2012/13 Antarctic season to very successful with more than 60 tows completed from eight vessels around Antarctica.

South Africa trainees Bokamoso Lebepe, exchanging the internal plankton sampling mechanism of the CPR.

A maiden voyage by MV *SA Agulhas II* will provide much needed data on Antartic plankton in the winter

Hans Verheye (front) and Marco Worship (left) deploying the CPR in the Southern Ocean from South Africa's snow-covered polar research and supply vessel *SA Agulhas II* during her maiden voyage in July.

Workshops

The SO-CPR Survey involves a dozen countries with analyses conducted by experienced and well recognised plankton and Antarctic researchers in five laboratories. Nonetheless, we take every opportunity when we meet to run workshops on methods and taxonomy to ensure we are maintaining the highest level of procedures and identification standards for Quality Control and Assurance. We also regularly exchange information and images electronically. A number of workshops and discussions were conducted through the year for existing members in Tokyo and Wellington, and a series of back to back workshops were conducted in Hobart. Plankton biologist Prof Erik Muxagata from the Universidade Federal do Rio Grande, Brasil, spent two weeks at the laboratory of the Australian Antarctic Division working with Operations Manager and Senior Analyst John Kitchener and Analyst David McLeod learning

Southern Ocean plankton taxonomy and comparing results. Prof Muxagata will be processing samples collected in the Drake Passage. His visit was funded by SCAR's Expert Group on CPR Research. Antarctic plankton specialist Dr Doo Byoul Lee, Korea Polar Research Institute, also visited for two weeks to check his methodology with the AAD based team. Korea has a CPR for their new polar research vessel RV *Araon* and plan to use it in the Pacific sector of the Antarctic between the Ross Sea and the Antarctic Peninsula, an area where there has been little plankton sampling and have only been able to conduct a few tows through Russia's participation. Prof Philippe Koubbi, Antarctic fish and ichthyoplankton specialist from Laboratoire d'Océanographie de Villefranche, Université Paris VI, spent time with the team learning to prepare and maintain the CPR in preparation for the start of France's new survey around Kerguelen and Crozet.

Analysis is conducted in five laboratories; every opportunity is taken when meeting to run workshops on methods and taxonomy to ensure we maintain high levels of quality control and assurance

SCAR Expert Group on CPR Research

The Scientific Committee on Antarctic Research provides a focus and support for the SO-CPR Survey as an official international research programme. The database is recognised as a SCAR Business Product. SCAR created an Expert Group on CPR Research in 2006 to help develop and enhance the SO-CPR Survey including providing some funds for training and exchange programmes such as Prof Muxagata's visit to Hobart. For the past six years I have been co-Chief Officer of EG-CPR with Prof Mitsuo Fukuchi, National Institute of Polar Research Tokyo. As from July 2012, I took over as the Chief Officer of SCAR's Scientific Standing Group – Life Sciences, which overseas SCAR's life science work and subsidiary groups such as EG-CPR. Consequently, I have asked Dr Kunio Takahashi, NIPR, to take over as CO of EG-CPR. Dr Takahashi has been a very active member of the SO-CPR team, participating in numerous Antarctic expeditions, and has been leading the Japanese CPR since 1999. He is very well skilled in all aspects of CPR work from preparation of the CPR, deployments at sea, plankton processing/identification, data analysis and he has produced several CPR publications.

Programme review

The SO-CPR Survey started in 1991 as an Australian Antarctic Division research project before other countries joined from 1999 onwards and eventually being recognised by SCAR as an international programme. The Australian component, and hence the whole Survey, was resubmitted for review and re-assessment during 2012 as part of Australia's new Antarctic Science Strategic Plan 2011-12 to 2020-21. The Survey received very favourable and supportive reviews, and subsequently received one of the top scores by the Australian government assessment committee. The Survey has now been approved within the Australian Antarctic programme for the duration of the current strategic plan, i.e. to the end of the 2020-21 season, subject to satisfactory progress.

The SO-CPR Survey received one of the top scores in a recent review by the Australian government.

US NOAA Survey

Dr Chris Melrose, Research Oceanographer, NOAA/ NMFS/NEFSC, Narragansett, USA

The U.S. National Oceanic and Atmospheric Administration's (NOAA) Northeast Fisheries Science Center (NEFSC) Oceanography Branch currently maintains three CPR routes: one crossing the Gulf of Maine from Boston to Nova Scotia, one from New York (passing through the Gulf Stream) across the Mid-Atlantic Bight and a third across the Sargasso Sea (Fig. 3). All of these routes include concurrent expendable bathythermograph (XBT) and thermosalinograph (TSG) sampling in partnership with NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML). Additionally, the Gulf of Maine route includes pCO2 measurements in partnership with AOML, and the Mid-Atlantic Bight route includes Acoustic Doppler Current Profiler (ADCP) measurements in partnership with the University of Rhode Island and Stony Brook University.

The US NOAA is the second longest running CPR Survey program after SAHFOS

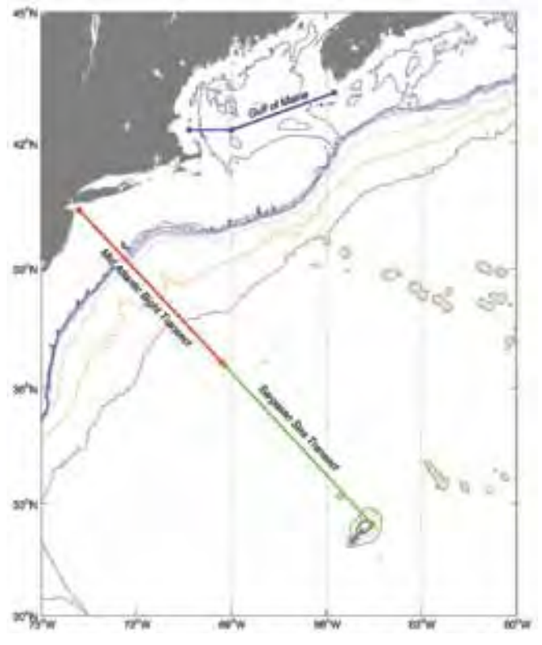


Figure 3. The three CPR routes maintained by the US NOAA Survey.

A total of 29 successful CPR deployments were conducted on the three NOAA operated routes in 2012. There were 8 tows in the Gulf of Maine, 10 tows across the Mid Atlantic Bight, and 11 tows across the Sargasso Sea. The Sargasso Sea time series began in October of 2011; therefore this was the first complete year of sampling along that route. One CPR was lost on the Mid Atlantic Route as a result of a broken tow wire. There were sufficient CPR bodies remaining in NOAA's inventory to avoid a disruption in operations as a result of the lost equipment.

Going forward there will be changes to the NOAA CPR operations in 2013. Starting in April of 2013, the Gulf of Maine route will be anchored on the western end in Portland, Maine rather than Boston, Massachusetts. This will result in a northward shift of our sampling transect across the Gulf of Maine. This change also represents a return to Portland for this time series. In the past, CPRs were towed on NOAA's Gulf of Maine CPR route from Portland by the vessel *Yankee Clipper*. The vessel *Oleander* operated by Bermuda Container Lines provided support for both the Mid-Atlantic and Sargasso Sea CPR lines. The *Reykjafoss*, a contract vessel operated on behalf of Eimskip, provided support for the Gulf of Maine survey. We wish to thank Bermuda Container Lines, Eimskip and the helpful crews of *Oleander* and *Reykjafoss*. Without their cooperation this work would not be possible.

NOAA continued participation in the GACS in 2012, and was represented at the first annual GACS Board of Governors meeting held in Paris, France. NOAA's CPR plankton data were added to the global GACS database. NOAA's CPR data were also made available through the Ocean Biogeographic Information System (OBIS) in 2012, with generous help from SAHFOS who are hosting the data.

Analysis

Sample Analysis and Analysts

Tanya Jonas

Over the last 81 years, the CPR analysis team has analysed more than a quarter of a million samples from over six million miles of tows in the North Sea, Norwegian Sea, North and South Atlantic, North Pacific and Indian Oceans (Fig. 4).

During 2012 there was no turnover of staff within the analysis department and we are making good progress in building a team of knowledgeable analysts. In October 2012, a new staff structure took effect, separating laboratory and analysis management from the taxonomic element. David Johns was appointed Laboratory Manager and Claire Taylor his Deputy. Tanya Jonas became the Senior Taxonomist with Marianne Wootton as her Deputy. Sixteen CPR analysts (fourteen employees and two contractors) worked at the Plymouth Laboratory in 2012. Overseas we retain two analysts (Sonia Batten and Doug Moore) in Canada and a further three independent analysts (Sanae Chiba, Tomoko Yoshiki and Yuka Sasaki) work in Japan.

Over the last 15 or so years, SAHFOS has expanded its remit beyond the North Atlantic, and CPRs are now regularly towed in the North Pacific and South Atlantic and are often used in one off tows as part of special projects or pilots for sister surveys.

In 2012, 115,666 nautical miles were sampled with 4979 samples for analysis (Fig. 5 and Table 2). The regular North Atlantic and North Sea tows have provided, to date, 4362 samples for analysis, though we still await the return of some tows from the Norwegian Sea.

The analysis of Pacific tows is now shared between Plymouth, Vancouver and Yokohama. In 2012, CPRs sampled 18,254 nautical miles in the Pacific and the Vancouver and Plymouth laboratories analysed 418 of the samples collected.

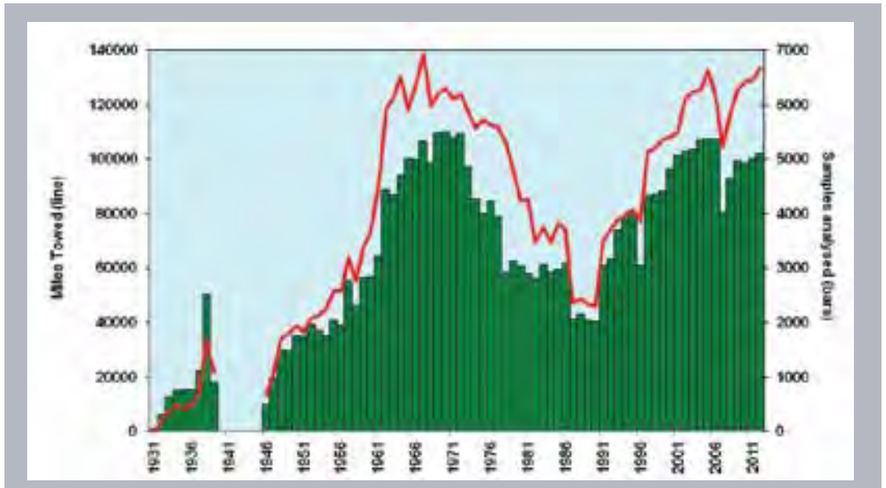


Figure 4. Miles towed and samples analysed since the inception of the Continuous Plankton Recorder Survey in 1931.

As part of a contract for the British Antarctic Survey (BAS), we use *MV Pharos* to tow a CPR, bi-monthly, between the Falkland Islands and South Georgia. Samples are returned to Plymouth every six months and we hope they will provide, for the first time, a year-round picture of the plankton in the Scotia Sea. The NERC Ocean Acidification project in the Greenland, Norwegian and Barents Seas has seen the furthest north CPR tow in the history of the Survey, and we are now analysing its samples. We also await the return of some more samples from the Ocean Acidification project collected in the most southerly of oceans.

As part of our commitment to helping sister surveys through the GACS, we also analysed phytoplankton from samples collected from around South Africa.

Being able to analyse plankton from such a broad range of taxa in such diverse seas makes SAHFOS analysts incomparable in their field.

Table 2. Monthly break down of all CPR sampling in 2012

Month	Tows Made [1,2]	Tows for Analysis [3]	Samples for Analysis [4]	Miles Sampled
January	21	16	267	6113.85
February	23	21	376	7294.03
March	26	24	414	8850.14
April	34	32	439	12091.56
May	32	26	393	9786.52
June	61	58	711	16852.37
July	33	26	420	10429.98
August	28	25	335	7795.46
September	29	27	482	10239.50
October	31	26	362	9885.76
November	25	24	403	8680.63
December	23	21	377	7646.72
Total	366	326	4979	115666.52

1. In Appendix B figures will be different as tows and CPRs set up by SAHFOS but carried out by some sister surveys are included, split tows are counted twice and some individual tows that straddle two months assigned to a different month from those recorded in this table.
2. Includes all failed and as yet non-analysed tows.
3. Includes only those tows that have currently been processed for analysis. At 6 March 2013; 569 allocated samples from 2012 are still awaiting analysis.

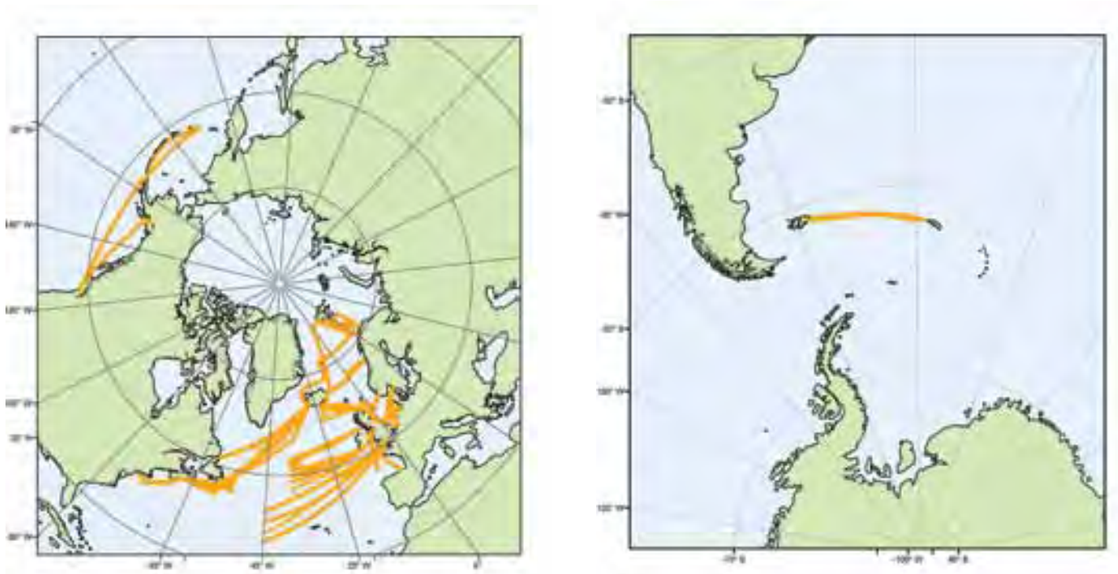


Figure 5. 2012 CPR sample map, showing Northern and Southern Hemispheres (left and right respectively.)

Analysis Laboratory
Astrid Fischer

Training

In 2012 we conducted a number of in-house training sessions for all analysts covering plankton identification (Coccolithaceae, Neoceratium, Tintinnida, Euchaetidae, Metridinidae, Calanidae and gelatinous taxa), analysis methodology, microscope ergonomics and use of digital cameras. The final end-of-year training session was in the form of a fun quiz organised and run by Marianne Wootton and Gemma Brice.

Analysts are encouraged to make the most of training opportunities, either by taking external courses or by suggesting experts we might invite to SAHFOS for the benefit of the whole team. One member of staff, Claire Wotton, was a full participant in the 2nd International Marine Phytoplankton Workshop, jointly hosted by SAHFOS and the MBA at the Citadel Hill Laboratory.

A number of analysts also took advantage of the opportunity to attend the Workshop lectures given by leading phytoplankton authorities. Claire Taylor and Gemma Brice were the SAHFOS representatives on the organising committee of the Workshop and did an excellent job, as their article in this report shows (see page 54 for further info).

In 2012 we trained three international scientists: Carmela Gonzalez from Spain and Janine Van Der Poel and Kholeka Batyi from South Africa. In May Carmela learnt how to identify zooplankton from the Gulf of Cadiz. Janine and Kholeka took part in the Phytoplankton Workshop and then spent a further two weeks learning CPR analysis methodology and how to identify phytoplankton in CPR samples from South African waters, collected as part of the GACS programme.

Console and Data Availability

For the past four years, Console has been the user interface for entering data into the CPR database. Over the last 18 months our Database manager, Mike Flavell, has been making improvements to the software at the backend and at the user interface. Mike addressed over 150 issues and the testers trialled each new version—it has been quite an undertaking.

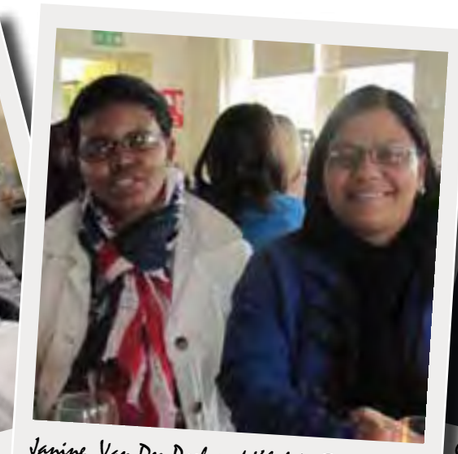
The 2011 core North Atlantic data was once again available in mid August. Early in 2012 we decided to prioritise one route (PR) just to see how quickly we could make quality-controlled data available (see Rapid Production of CPR Data page 14).

Laboratory Facilities, Equipment and Archive

We continue to enjoy the new laboratory facilities and during 2012 took delivery of a new Nikon CPR microscope, which is yet to be in full use as we await delivery of a suitable fume hood.

The sample archive, which dates back to the late 1950s, is increasingly recognised as a useful resource and is being used for a number of innovative projects such as investigations into temporal and geographical changes in quantities of marine microplastics and molecular studies involving the genus *Vibrio.*

Analyst training session in the lab



Janine Van Der Poel and Kholeka Batyi

Claire Wotton receiving certificate from Carmelo Tomas

Carmela Gonzalez and Claudia Castellani

Winning team of end of year quiz with prizes

Analyst training session in the lab

Taxonomy

An Identification Guide to the Plankton of the North Atlantic

Dr Claudia Castellani

'Marine Plankton: A practical guide to their identification and ecology for the North Atlantic' represents SAHFOS's latest contribution to taxonomic research on plankton. The majority of marine phyla have representatives that spend at least the initial part of their life as a planktonic stage; thus, their identification is the first step towards the appreciation of the diversity and of the ecological importance of species living in the marine environment. Existing guides of marine plankton for the North Atlantic are dated, poorly structured or taxonomically limited to the organisms found in coastal areas. Hence the need for an up-to-date and comprehensive plankton guide bridging existing gaps in taxonomic listing, contents and layout. This timely book, which is the first of its kind for many decades, is the product of a vast bibliographic research spanning over the past 150 years and integrating knowledge on plankton taxonomy and ecology of over 20 authors within and outside SAHFOS. The main purpose of 'Marine Plankton' is to provide a practical and user-friendly reference ID guide to plankton for both students completely new to plankton and professionals alike. The book is divided into 3 sections: plankton ecology, taxonomic identification and sampling methodology. The taxonomic section represents the core of the book and provides a comprehensive, highly informative and referenced guide to the identification of the main plankton species found in the western and eastern Atlantic, North Atlantic and the North Sea, from sub-arctic to sub-tropical regions and from the epipelagic to the mesopelagic zone. Given the existence already of numerous and authoritative guides on phytoplankton taxonomy, the main focus of 'Marine Plankton' is the zooplankton, although there will be sections dealing succinctly with the most important representatives of the microplankton. The structure and layout used in this book makes it accessible and intuitive to use; the text is reduced to the minimum whereas more emphasis is placed on annotated illustrations. Figure 6 provides an example of the book for the copepod genus *Centropages*. The preparation of this ambitious project has proven a remarkable learning and challenging experience for SAHFOS and others involved. This is not only because of the vast number of taxa and sheer scale of information we have dealt with. By comparing the work of different authors, we soon realised we had to "dig deep" into the taxonomic literature of the 19th century to clarify the many inconsistencies we encountered, some of which remain unresolved. One of the most astonishing findings (although not entirely surprising, given the time and skill-demanding task) is that most of the illustrations of plankton species can be attributed to a handful of taxonomists, whereas all subsequent drawings are usually a modification of the original version. One undesirable consequence of copying from originals is that mistakes can creep in and alterations may result in the loss of important information. During the course of this work we discovered several instances in which these inconsistencies have generated confusion and led in some case to the publication of wrong taxonomic keys!

By looking into all the historical literature we also gained some interesting insights into how most of the known information on plankton species was obtained. Many of the original plankton illustration's we still use today were drawn from sample collections gathered during the 19th Century world-wide voyages and explorations of the high seas, such as the voyage of the *Beagle* (1831-36), the *Challenger* expedition (1872-76) and the *Discovery* expedition (1901-04) to name a few, which often combined the military and scientific interests of nations. Military vessels were usually borrowed from the Navy and adapted as research laboratories. Scientists, often also trained naval officers, were entrusted with the collection, preservation and cataloguing of the specimens during the voyage. Crates full of samples were shipped back to the marine research centres which had commissioned the collections and made available to scientists from different countries who applied to study them. The drawings of the most famous 19th Century planktologists such as Sars (1837-1927), Haeckel (1834-1919) and Giesbrecht (1854-1913) were largely derived from such collections. These scientists named the species they discovered sometimes after themselves and sometimes after the morphological peculiarity of the species. In some instances, however, species were named after the collection from which the specimen originated as revealed in an article, by Christiane Groeben, the curator of the History of Science Unit at the Stazione Zoologica Anton Dohrn at Naples (SZN), on the three-year circumnavigation by the Italian corvette *Vettor Pisani* (1882-1884) a "joint-venture" between the Italian Navy and SZN. The Chierchia's collection (Chierchia 1885), assembled by Lieutenant Gaetano Chierchia (1850-1922) during this voyage, was probably the one in which Giesbrecht discovered, and after which he named the copepod *Centropages chierchiae*, in 1889. 'Marine Plankton' is nearing its completion, so all you keen planktologists WATCH THIS SPACE.....

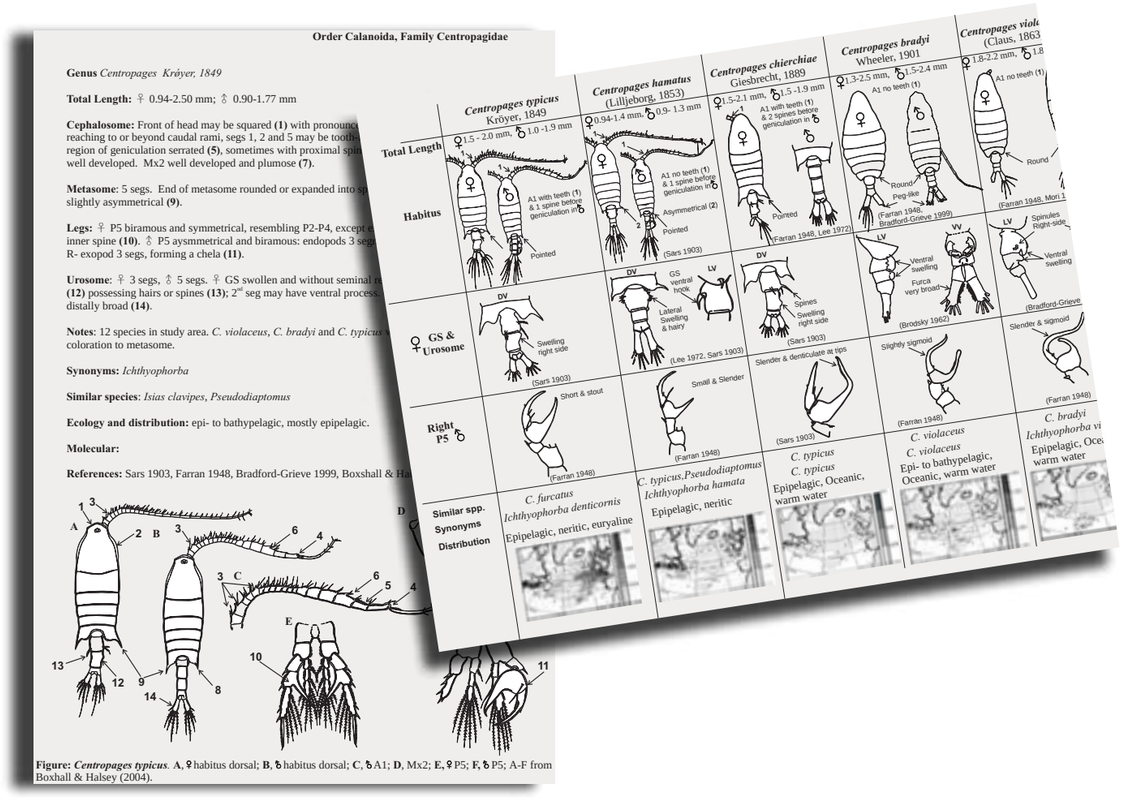


Figure 6. A sneak preview inside the book 'Marine Plankton: A practical guide to their identification and ecology for the North Atlantic'.

Interesting and Unusual Biodiversity Records in 2011/2012

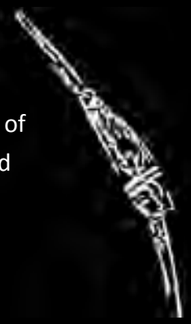
Marianne Wootton

Phytoplankton

After appearing for the first time in a number of years in 2011, *Pronoctiluca pelagica*, a non-photosynthetic dinoflagellate, reappeared again in the July of 2012 in the mid North Atlantic and moved into the English Channel in the August.

Blepharocysta, an armoured dinoflagellate associated with warm waters, was recorded several times in 2012: off the coast of New York, the western approach to the English Channel and off the northwest and northeast coast of Scotland. Prior to 2012 there have only been 16 records of *Blepharocysta* in the CPR Survey.

Other rare warm-water dinoflagellates observed in 2012 include: *Neoceratium falcatum* found off the coast of Nova Scotia (3 previous records), *Neoceratium inflatum* in the Bay of Biscay (5 previous records) and *Neoceratium pavillardii* found around the Azores (1 previous record).



During the autumn of 2011 several *Neoceratium* species, typically associated with warm and oceanic waters (such as *Neoceratium arietinum*, *Neoceratium hexacanthum* and *Neoceratium compressum*), were observed on samples from around the Arctic Circle in the Norwegian Sea. These are the most northerly records of warm-water *Neoceratium* taxa in the history of the CPR Survey.

Two new records for the CPR Survey in 2012 include *Dinophysis schroederi* found in the subtropical mid North Atlantic in June, and *Dinophysis odiosa*, recorded off north east coast of England in September. Several species of *Dinophysis* are known to form blooms when conditions are favourable and are associated with the production of a compound which is toxic to both animals and humans.

Zooplankton

Fusopsis incertae sedis, thought to be a resting stage in the lifecycle of a tintinnid, is a protozoa of unknown taxonomic placement and is regularly recorded in the CPR Survey. In May 2012 however, it was found in unprecedented numbers around the Grand Banks region of Newfoundland stretching north east for approximately 150 miles and in relatively high abundance around Bear Island in the western Barents Sea.

In October 2012 an anguilliform (eel-like) fish larvae was found on a CPR sample from the southern region of the Longhurst North Atlantic Drift province. Eel larvae are generally poorly sampled by standard plankton sampling as they have a fast escape response, so to find one on a CPR sample is extraordinary (or unlucky if you're an eel). Once commercially important, the European eel is considered critically endangered by the International Union for Conservation of Nature (IUCN).

Paedoclione doliiformis is a shell-less mollusc endemic to the North East Atlantic. In July 2012 it was recorded on a sample from the south east coast of Nova Scotia and is the first record of this organism in the CPR Survey in over 10 years (with less than 30 records in total). *Paedoclione* belongs to the taxonomic order of shell-less molluscs called Gymnosomes, which are commonly referred to as sea angels: appearing to fly through the water using their modified wing-like foot. Despite their affectionate common name however, Gymnosomes are ferocious carnivores and predate solely on their planktonic Molluscan cousins.

Peculiar fibres

In August 2012, numerous samples on one of our mid North Atlantic subtropical routes were found to be densely covered in thin, branched, strand-like fibres, which we suspect to be marine fungal hyphae. The samples are being investigated using molecular techniques to ascertain a correct identification.

Fish Egg Identification

Marianne Wootton

In 2011 SAHFOS produced a spatial-temporal fish larvae atlas of the NE Atlantic, from CPR results from 1948-2005. Despite focusing on 7 of the most common fish species, the work that went into this fish larval project identified 75 taxa; one of which being the genus *Maurolicus. Maurolicus* are small (approx. 8cm in length) oceanic fish and are commonly known as pearlsides or silvery lightfish, probably so named because of their luminescent abdominal photophores.

Fish eggs are regularly seen on CPR samples and although routinely counted, are not routinely identified as belonging to a specific taxon.

Additional data that usually accompanies our fish egg counts include egg diameter and presence/absence of oil globules; important features used in fish egg identification. One genus of fish however, which is easily identifiable at the egg stage is *Maurolicus.* Eggs from the common NE Atlantic species, *Maurolicus muelleri*, are spherical, 1.2-1.6mm in diameter and have a distinctive hexagonal pattern. This characteristic morphology allows us to identify *Maurolicus* eggs within the CPR Survey (Fig. 7C), despite any damage caused by sampling. *Maurolicus* eggs are now recorded separately in our database and in April 2012 eggs were observed on samples to the south of Iceland and in the Bay of Biscay.

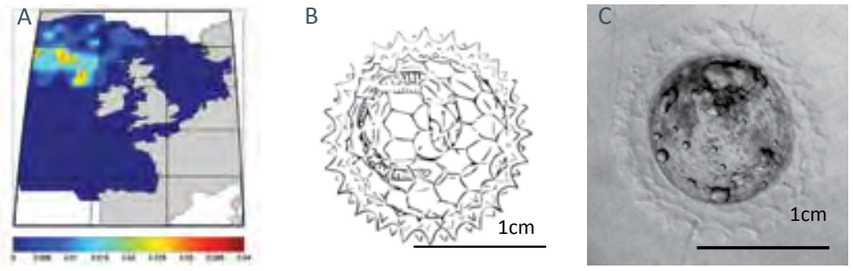


Figure 7. A) Map of Maurolicus larvae from CPR samples from 1948-2005. Intensity of colour represents abundance (blue low abundance, red higher abundance), B) the distinctive hexagonal pattern with fish larvae inside C) a Maurolicus egg from a CPR sample. Scale bar 1cm .

Porcupine Meeting

In March 2012, SAHFOS was represented at the 'Why Marine Taxonomy?' conference held at The Deep in Hull by Marianne Wootton, Claire Taylor, Robert Camp and Gemma Brice. The conference was hosted by the Porcupine Marine Natural History Society who are concerned with the biodiversity, ecology and distribution of marine flora and fauna in the North East Atlantic and the dissemination of this understanding to a wider audience. Previous conferences, addressing such issues as marine taxonomy and biodiversity, have rarely included plankton, therefore this was an excellent opportunity to showcase the work that goes on at SAHFOS. The conference hosted over 20 speakers and was attended by both amateur naturalists and key scientific figures. Attending this conference was an important step for SAHFOS as it was the first time a group of analysts have presented their work and skills as para-taxonomists to an external audience. Marianne gave a presentation introducing SAHFOS and how the taxonomic expertise we have at SAHFOS relates to the wider marine environment. The group also displayed two posters entitled 'Phytoplankton – Why small things matter' and 'Zooplankton – just whale food or something bigger?'(see page 30). These posters highlighted how research findings, dependent upon taxonomic knowledge from the CPR Survey can directly influence global marine science as a whole.

Recording Biodiversity: *Neoceratium*

Gemma Brice

Neoceratium are dinoflagellates with robust armoured thecal plates which preserve well and withstand sampling stress on CPR samples. It is a cosmopolitan genus with representatives of many species occurring in most oceans. Subtle differences between the species are distinguished by the CPR Taxonomic Analyst Team. Species vary in shape according to their distribution; warm-water species tending to be long and delicate to allow them to float in warmer water, and cold water ones being more robust. In the CPR Survey, using light microscopy, we identify 48 out of the 75 accepted marine *Neoceratium* species (the majority of the other species occurring outside of our sampling areas).

A visit by Dr Karen Steidinger in July 2012 (as part of the 2nd International Phytoplankton Workshop) aided the CPR Taxonomic Analyst Team in the identification of asexually dividing *Neoceratium*. We had noticed these cells appearing on samples from the North-West Atlantic. The cells looked like stunted versions of the 'mother' cells, and on closer inspection of other cells on the block, various stages of the asexual reproduction could be seen: from the smooth appearance on one side of the cell; to the splitting and subsequent stunted 'daughter' cell appearing in unison. Recording this extra information about life stages could prove beneficial when looking at changes in distribution of the species.

In the last 10 years data from the CPR Survey has shown several species of warm-water *Neoceratium* have been found unusually close to the UK including *N. arietinum, N.lamellicorne* and *N. pentagonum*; the northern-most records for these species ever to be found in the North East Atlantic.

Coupled with the invasion of certain warm-water species, in the last decade some regions of the North Sea have experienced a dramatic reduction in the abundance of the *Neoceratium* genus (particularly *N. macroceros*) as well as other dinoflagellate species. In the last two years abundance of *Neoceratium* has recovered somewhat. These discoveries are only possible through the specialised ability of the CPR Taxonomic Analyst Team in the skill of being able to identify down to a species level of one of the most diverse genera in our oceans.

Asexually divided and developing *Neoceratium* cells on CPR samples.

Zooplankton: Just Whale Food or Something Bigger?

Marianne Wootton, Gemma Brice, Robert Camp, Maria Campbell and Claire Taylor.

Zooplankton are a critical link between microscopic algae and larger organisms (such as fish and whale species) in the marine food web. Not only are they a major source of food for many organisms, but the majority of aquatic taxa will spend part of their life history as zooplankton.

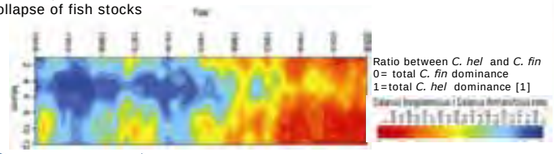
Climate change and biodiversity loss are already impacting our seas and fuelling the reduction in ecosystem health and functioning. In order to develop relevant marine planning policies, science needs unique multi-assessors at large ecological scales and robust and sensitive indicators of environmental change and ecosystem health. The CPR Survey can provide this through its intensive work on zooplankton sampling and identification of ~ 250 zooplankton taxa, coupled with consistent methodology over a long-term time series has allowed for an ecological 'baseline' at large geographical scales to be developed, from which temporal and spatial changes can be observed and monitored.

SAHFOS uses traditional light microscopy complemented with molecular techniques to study and monitor this globally important group of organisms. Here, we present several important zooplankton discoveries and research outputs made during 80 years of CPR sampling.

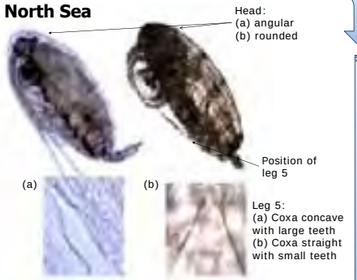
Rising Sea Surface Temperatures (SSTs)

Copepods: consequences of a warming North Sea

- *Calanus finmarchicus* (*C. fin*) and *Calanus helgolandicus* (*C. hel*) are small crustaceans belonging to the subclass Copepoda and are useful indicator species
- *C. fin* prefers cooler, subarctic waters and *C. hel* prefers warmer waters
- *C. fin* and *C. hel* are a major component of the North Atlantic mesoplankton
- A shift in species dominance from *C. fin* to *C. hel* in the North Sea occurred during the 1980s in response to increased SSTs
- *Calanus spp.* biomass in the North Sea has decreased since the 1960s
- Shift in species dominance and decrease in biomass has been linked to the collapse of fish stocks



Ratio between *C. hel* and *C. fin*
0= total *C. fin* dominance
1=total *C. hel* dominance [1]

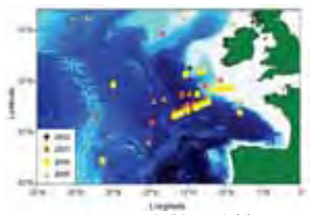


Taxonomic features used to distinguish (a) *C. hel* (b) *C. fin* © Gemma Brice

Increase in snake pipefish and seabird population crash

- Pipefish larvae are identified in the CPR survey by their vermiform shape, long slender snout and tough scales
- 2002 saw record numbers of pipefish in NE Atlantic CPR samples
- Molecular techniques on CPR specimens identified the species as the snake pipefish *Entelurus aequoreus*
- Increase linked to rising SSTs causing either a reduction in the male brooding time [2] and / or a change in plankton prey [3]
- A decline in nutritionally rich sandeel populations and an increase in nutritionally poor snake pipefish is directly linked to poor or catastrophic breeding outcomes in seabirds [4]

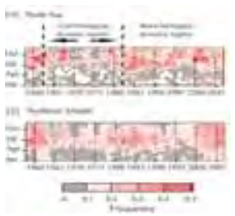
Brooding adult male with eggs visible on abdomen [2] Inset: juvenile *E. aequoreus* from CPR sample. Length 1cm. © R Kirby



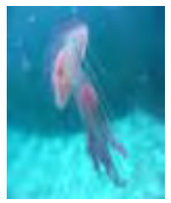
CPR survey pipefish records [5]

Blooming jellyfish

- Cnidaria tissue is frequently found on samples analysed by the CPR survey (presence / absence data)
- CPR data shows an increase in the occurrence of Cnidaria in the NE Atlantic since 2002
- Molecular analysis has suggested that the main blooming species responsible for the increase is *Pelagia noctiluca* [6]
- Blooms of *P. noctiluca* and other Cnidaria may be favoured by hydroclimatic changes and increased SSTs
- *P. noctiluca* is a venomous, warm water scyphozoan and population outbreaks have been responsible for farmed fish mortalities along the Irish coast
- Increases in jellyfish numbers may impact upon other zooplankton taxa and larval fish recruitment



Cnidarian frequency in CPR samples [6]



P. noctiluca © Fabien Lombard

Change in plankton composition, less nutritious food available for higher trophic levels (fish, seabirds, humans)

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[2] Kirby, R.R.., Johns, D.G. and Lindley J.A.. (2006) Fathers in hot water: rising sea temperatures and a Northeastern Atlantic pipefish babyboom. Biology Letters 2: 597-600.

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Global Alliance of CPR Surveys

Dr Graham Hosie, Chair of the Board of Governance

The Global Alliance of CPR Surveys commenced in September 2011 with the goal of understanding changes in plankton biodiversity at ocean basin scales. A Board of Governance was established and it was agreed that working groups would also be formed to address the objectives of GACS, and a regular ecological status report on global plankton biodiversity would be produced. During 2012 the GACS community focussed on establishing these groups, producing the first status report and promoting GACS in various forums.

Two new members joined the Board of Governance in 2012, Prof Nick Owens and Dr Sun Song. Prof Owens joined GACS as the new Director of SAHFOS. He has a long distinguished career as a researcher and also the former Chief Executive and Director of Science of the Plymouth Marine Laboratory, and recently as the Director of the British Antarctic Survey. He has played a key role on numerous UK and international committees. Dr Sun Song is the Director of the Institute of Oceanology, Chinese Academy of Science in Qingdao, China. He also has a distinguished career in marine research, on krill and plankton, and has long had an interest in establishing marine observations around Chinese and Antarctic waters. He is also well known on a number of international committees. Both gentlemen bring considerable experience and knowledge in plankton research and marine observations to GACS.

Prof Nick Owens and Dr Sun Song who joined the Board of Governance in 2012

The two working groups on Standards and Methodology (WGSM) and Database (DWG) have been established, with the Terms of Reference and membership set. The CPR is unique in being a standardised instrument that has changed little since Sir Alister Hardy's second design in 1931. In association, the CPR has recognised standards in usage, sample processing and a growing list of analytical methods for studying changes in plankton biodiversity, abundance and development in relation to time and geography.

The WGSM, chaired by Dr Hans Verheye (South Africa, Benguela Current CPR), has the task of ensuring the methods and standards are agreed and properly documented for all CPR operations, from setting up the machines through to the analysis of data. In order to ensure these are maintained, WGSM is also tasked with developing training programmes within and between CPR laboratories, as well as considering capacity building.

The DWG, chaired by Dr Sonia Batten (Canada, SAHFOS North Pacific CPR Survey) has the job of coordinating the creation and development of the global CPR Database. This includes agreeing on a common schema for data input and ease of access, and what should be stored in the database in addition to the obvious taxonomic and ecological plankton data. The database, when fully developed will be held at SAHFOS. Various CPR datasets have been identified and have already started flowing in.

The Board of Governance (BoG) and the working groups DWG and WGSM held their first annual meetings from 17 to 20 September at UNESCO, Paris, hosted by IOC-GOOS. Available members

of the BoG, members of the two working groups, SAHFOS staff supporting GACS, observers/ representatives from IOC, POGO, SCAR and a developing CPR Survey were in attendance (Fig.9). The BoG and working groups have done much to progress the objectives of GACS through email exchange prior to Paris, but nothing really beats getting everyone together in the same room to properly exchange ideas, discuss plans and set future directions for GACS.

One day meetings were conducted for both working groups prior to the BoG. Each working group developed various work plans, procedures and recommendations for consideration and ratification by the BoG. Primarily, these were to ensure the successful development of the global CPR database and continuation of a standardised set of methodologies for CPR based research. Procedures were agreed for the incorporation of data, access of data and display of data products. Metadata descriptions of the global CPR data will be made publicly available through the GACS website.

The BoG reviewed the progress of each GACS objective and noted significant development has been achieved. We agreed that we need to focus more on our capacity building objective "facilitate new CPR Surveys and develop capacity building procedures". This will include developing our exchange programme of staff between CPR laboratories, training workshops and we will be producing a 'Start-up Kit' that will provide the basic information required for those wanting to develop a new survey. The kit will include information on how the CPR works, designing and establishing CPR routes, at sea methodology, laboratory procedures, taxonomic tools, data storage and analysis. Training workshops are being scheduled over the next year aimed at both novices wanting to acquire the correct skills and experienced personnel seeking to maintain their standards. A number of training sessions have already been conducted during 2012. Workshops in 2013 will focus more on plankton identification.

Thanks to the enthusiasm of all participants, the meetings were highly successful. The GACS community was particularly grateful to Tom Gross and Simonetta Haond at IOC-GOOS for hosting the meeting and providing access to excellent meeting facilities.

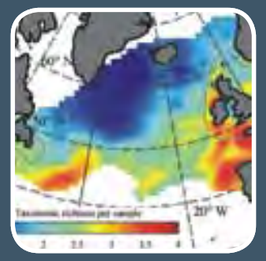
Figure 8. New tools available from GACS. A) The newly launched website, B) the Global Ecological Status report, C) map of samples of all the GACS routes.

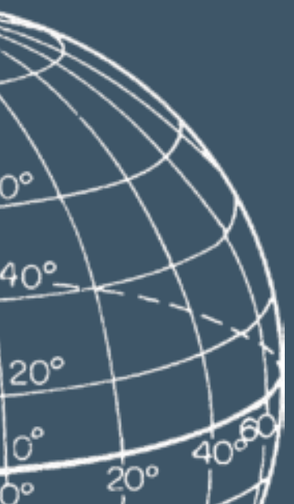
The GACS website (www.globalcpr.org, Fig. 8A) officially went on line on 8 February 2012. Further developments to the website will include the addition of various data products such as an online map of all GACS sample positions, gridded mean abundances and metadata records. The first annual Global Marine Ecological Status Report (Fig. 8B) has now been distributed and is available online at http://www.sahfos.ac.uk/research/publications/ecological-status-report.aspx. The combined CPR database is coming together. This has allowed us to start new joint analyses of data within and between regions (Fig. 8C).

The individual GACS partners have continued to develop their regional surveys. South Africa conducted a number of tows in the Antarctic region during winter, providing much valuable information on the winter composition of plankton. Little is known about Southern Ocean plankton during winter, primarily because of the lack of ships operating in the region at that time. South Africa is also now a member of the Southern Ocean CPR Survey. In October 2012, New Zealand completed the longest CPR run with 10 tows across the South Pacific between Wellington and Valparaiso. This is another region not previously surveyed by the CPR. A new CPR Survey by France commenced during the 2012/13 Austral summer around the Kerguelen and Crozet archipelagos in the southern Indian Ocean. This region is an important area of elevated phytoplankton production supporting high concentrations of seabirds, marine mammals and fish. Australia completed a pilot tow between Brisbane and Fiji to support the Pacific Islands Global Ocean Observing System (PI-GOOS), and SAHFOS reached a significant milestone of 6 million nautical miles of CPR tows.

GACS continues to be enthusiastically supported and welcomed by the international community. During 2012 GACS become an affiliated programme with SCOR and also the Southern Ocean Observing System (SOOS), which adds to our stakeholder associations with GOOS, POGO, PICES and SCAR. Numerous presentations were made at various international meetings such as The 2nd International Symposium: Effects of Climate Change on the World's Oceans, in Yeosu, South Korea; the GEO Blue Planet Symposium in Sao Paolo, Brazil, and SCAR Open Science Conference, Portland, USA. Attendances, presentations and reports were also made at annual meetings of POGO, ICES, SCOR, SCAR and GOOS. GACS is very grateful for the support offered by these various agencies, as well as the home institutes leading the regional CPR surveys.

Figure 9.The GACS meeting in Paris





Research Highlights

In this section....

Long-term responses of North Atlantic calcifying plankton to climate change

Dr Gregory Beaugrand and Dr Abigail McQuatters-Gollop

The global increase in atmospheric carbon dioxide concentration is potentially threatening marine biodiversity in two ways. First, carbon dioxide and other greenhouse gases accumulating in the atmosphere are causing global warming. Second, carbon dioxide is altering sea water chemistry, making the ocean more acidic. While temperature has a cardinal influence on all biological processes from the molecular to the ecosystem level, acidification might impair the process of calcification or exacerbate dissolution of calcifying organisms.

The examination of six calcifying taxa routinely collected with the CPR revealed changes in spatio-temporal distribution between 1960 and 2009 (Fig. 10). The pteropod mollusc *Clione limacina* (sea angels) showed a reduction in both spatial extent and maximum abundance while the other pteropod *Limacina spp.* (i.e. sea butterflies) exhibited the same pattern, although a biogeographical poleward movement is observed along the European continental shelf-edge, which is similar to biogeographical shifts reported for copepods. Echinoderm larvae extended their spatial distribution to the northern part of the North Sea, with an increase in average abundance in the region. Bivalve larvae exhibited a pronounced reduction in spatial extent from the 1960s to the 2000s and are now only observed in higher abundance in the northern North Sea. Foraminifera and coccolithophores both increased in frequency of occurrence in all oceanic regions covered by this study.

We investigated whether these biological changes originated from long-term changes in annual Sea Surface Temperature (SST), large-scale hydro-climatic forcing or changes in pH. Examination of the results further indicates that modifications in annual SST were positively correlated to changes in foraminifera, echinoderms and coccolithophores and negatively to alterations in pteropods and bivalves. Modifications in calcifying plankton were also correlated to changes in pH (negatively for foraminifers, coccolithophores and echinoderms and positively for pteropods and bivalve larvae). The first-order partial correlation between pH and our index of calcifying plankton, keeping constant the linear effect of annual SSTs, was smaller than the first-order partial correlation calculated between annual SST and calcifying plankton removing the linear effect of pH. These results suggest that annual SST had a more direct statistical effect on calcifying organisms than the pH during the period 1960-2009. This supports earlier findings which suggest that we should be cautious in the attribution of current changes in calcifying plankton (Moy *et al.* 2009) to ocean acidification because plankton are also highly sensitive to temperature as well as other physical and chemical factors.

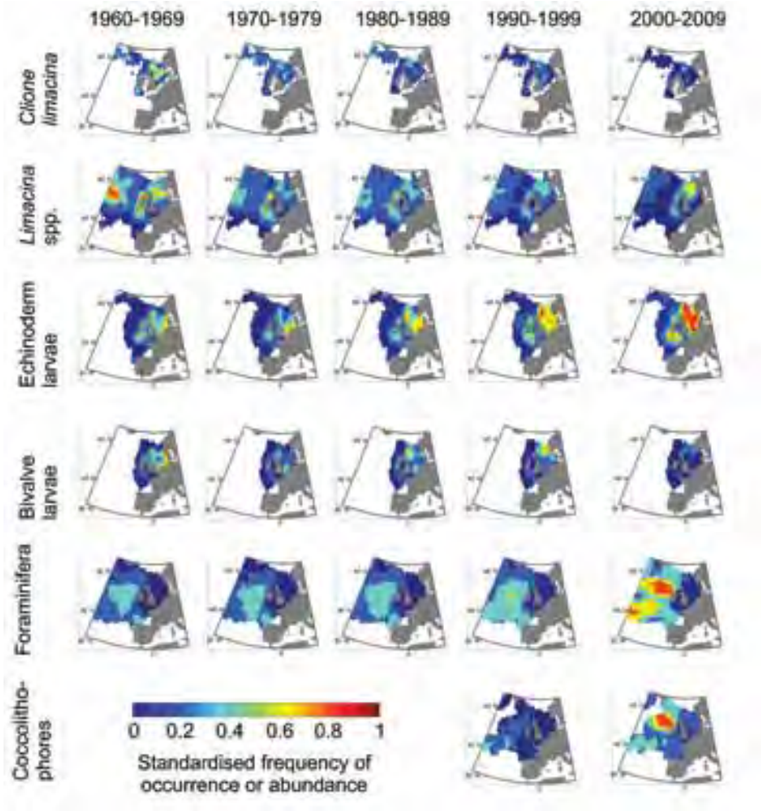


Figure 10. Decadal changes in the modelled spatial distribution of calcifying plankton in the northeast Atlantic. Frequency of occurrence (coccolithophores and foraminifers) or abundance (pteropod and non-pteropod molluscs and echinoderm larvae) were standardized between 0 and 1.

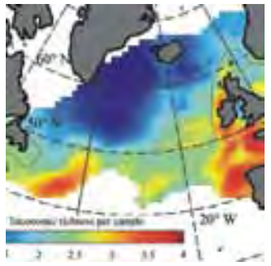
For more information see:

Beaugrand, G., McQuatters-Gollop, A., Edwards, M. & Goberville, E. Long-term responses of North Atlantic calcifying plankton to climate change. Nature Climate Change doi:10.1038/nclimate1753 (2012).

Bottom-up effects of climate on fish populations—data from the Continuous Plankton Recorder

Dr Sophie Pitois, Dr Nick Halliday and Prof Martin Edwards

The CPR dataset on fish larvae has an extensive spatio-temporal coverage that allows the responses of fish populations to past changes in climate variability, including abrupt changes such as regime shifts, to be investigated. The newly available dataset offers a unique opportunity to investigate long-term changes over decadal scales in the abundance and distribution of fish larvae in relation to physical and biological factors. A principal component analysis (PCA) using 7 biotic and abiotic parameters is applied to investigate the impact of environmental changes in the North Sea on 5 selected taxa of fish larvae during the period 1960 to 2004. The analysis revealed 4 periods of time (1960–1976; 1977–1982; 1983–1996; 1997–2004) reflecting 3 different ecosystem states. The larvae of clupeids, sandeels, dab and gadoids seemed to be affected mainly by changes in the plankton ecosystems, while the larvae of migratory species such as Atlantic mackerel responded more to hydrographic changes. Climate variability seems more likely to influence fish populations through bottom-up control via a cascading effect from changes in the North Atlantic Oscillation (NAO) impacting the hydrodynamic features of the North Sea, in turn impacting on the plankton available as prey for fish larvae. The responses and adaptability of fish larvae to changing environmental conditions, particularly to changes in prey availability, are complex and species-specific. This complexity is enhanced with fishing effects interacting with climate effects and this study supports furthering our understanding of such interactions before attempting to predict how fish populations respond to climate variability.



Why is it so difficult to set Marine Strategy Framework Directive indicators and targets?

Dr Abigail McQuatters-Gollop

In 2008 the EU's Marine Strategy Framework Directive (MSFD) came into force. The objective of the MSFD is to achieve Good Environmental Status (GES) of European seas by 2020. Each EU member state must use ecological indicators to monitor towards environmental targets for GES; however, the MSFD gives little guidance on how to select indicators, set targets or even determine what GES looks like. All of these decisions are the responsibility of the individual member states; SAHFOS is leading the development of pelagic indicators and targets for the UK's implementation of the MSFD. The implementation process has highlighted some challenges to selecting indicators and setting targets for the MSFD. Most aspects of the marine ecosystem are not only influenced by anthropogenic pressures, but also by climate variability. Any indicators and targets developed to meet MSFD requirements must account for the influence of climate change.

During the past 50 years, a biogeographical shift has occurred in the distribution of some marine taxa with calanoid copepods, a key zooplankton indicator group, experiencing a 1000 km northward shift. The presence of warm-water/sub-tropical plankton species have progressively increased in the more temperate areas of the Northeast Atlantic while cold-water taxa have retreated poleward. As a result *Calanus helgolandicus*, a warm-water copepod species, is replacing *Calanus finmarchicus*, a cold-water species, in the North Sea. The change in distribution of these two copepods, regularly used as indicators because of their tight link with climate, is significant due to their key place in the North Sea food web. If a species or group of species is designated as MSFD indicators, the fact that its abundance is shifting due to climate must be accommodated in any target that is set. It may not be practical, however important a taxa is, to set a target for it at the limits to its distributional range if that taxa may soon not be found there due to unmanageable climatic influence. Therefore it may make more sense to set a qualitative or trend-based target, rather than a target for absolute abundance, for indicators undergoing such progressive changes.

SAHFOS is leading the development of pelagic indicators and targets for the UK's implementation of the MSFD

It can be difficult to tease apart anthropogenically-induced and climatic changes. Comparing changes observed in coastal waters, which are normally more severely impacted by land-based anthropogenically activities, to changes observed in less-impacted open waters, is one such method that can be used to separate the two signals. Investigation of North Sea CPR data indicates that many changes in coastal phytoplankton are also observed in the less-anthropogenically impacted open North Sea, suggesting that North Sea phytoplankton dynamics are not dominantly driven by nutrients, but by large-scale climatic drivers. Climate change may even exacerbate eutrophication in the North Sea; although nutrient concentrations are decreasing in coastal waters, increasing water clarity and SST have extended the growing season, enabling phytoplankton to make better use of lower concentrations of nutrients. In other words, climate change may increase the sensitivity of coastal waters to anthropogenic eutrophication. Therefore regulation of anthropogenic nutrients is especially important; we need to focus on what we can manage and set ambitious targets, accounting for climatically-induced changes but still encouraging the regulation of nutrient inputs, for eutrophication-related indicators.

Interactions between climate and anthropogenic pressures must be accounted for when selecting indicators and setting targets for the MSFD implementation process. Climate can confound or exacerbate human-induced changes on the marine environment and a holistic approach, accounting for both anthropogenic and climate influences, is needed to effectively manage our seas. The MSFD presents such an ecosystem-based approach to management, but responsible implementation of the Directive is crucial to its success.

For more information, see: McQuatters-Gollop, A. Challenges for implementing the Marine Strategy Framework Directive in a climate of macroecological change. Philosophical Transactions of the Royal Society 370, 5636-5655, doi:10.1098/rsta.2012.0401 (2012).

Long-term retrospective analysis of mackerel spawning in the North Sea: A new time series and modelling approach to CPR data

Dr Teunis Jansen and Prof Martin Edwards

In this study we presented a unique view of mackerel (*Scomber scombrus*) in the North Sea based on a new time series of larvae caught by the CPR Survey from 1948-2005. This time-series covered the period both before and after the collapse of the North Sea mackerel stock. Hydrographic backtrack modelling suggested that the effect of advection is very limited between spawning and larvae capture in the CPR Survey. Using a statistical technique not previously applied to CPR data, we then generated a larval index that accounts for both catchability as well as spatial and temporal autocorrelation. The resulting time series documents the significant decrease of spawning from before 1970 to recent depleted levels. Spatial distributions of the larvae, and thus the spawning area, showed a shift from early to recent decades, suggesting that the central North Sea is no longer as important as the areas further west and south. These results provide a consistent and unique perspective on the dynamics of mackerel in this region and can potentially resolve many of the unresolved questions about this stock.

Monitoring both seasonal timing and abundance of a targeted species using the ecological niche concept

Dr Pierre Hélaouët

The ability to monitor both seasonal timing and abundance of targeted species offers the possibility of quantifying population changes due to the changing climate and therefore the associated ecosystem evolution. Directly based on the theory that the ecological niche represents the requirements of a species regarding its environment, the method is designed to calculate a seasonal standardised index of habitat suitability.

This method is applied using the CPR time series on both *Calanus finmarchicus* (*C. fin.*) and *Calanus helgolandicus* (*C. hel.*) as a case study to emphasise the dynamic of the North Sea ecosystem. *C. fin.* is probably one of the most important components in the North Sea plankton community by being representative of the Atlantic Arctic biome (cold oceanic environment). Therefore, a change in the abundance of that species in the North Sea in favour of its congeneric species (i.e. *C. hel).* adapted to more temperate water masses) may indicate that the subarctic biome has moved northward, potentially having deep repercussions on the food web.

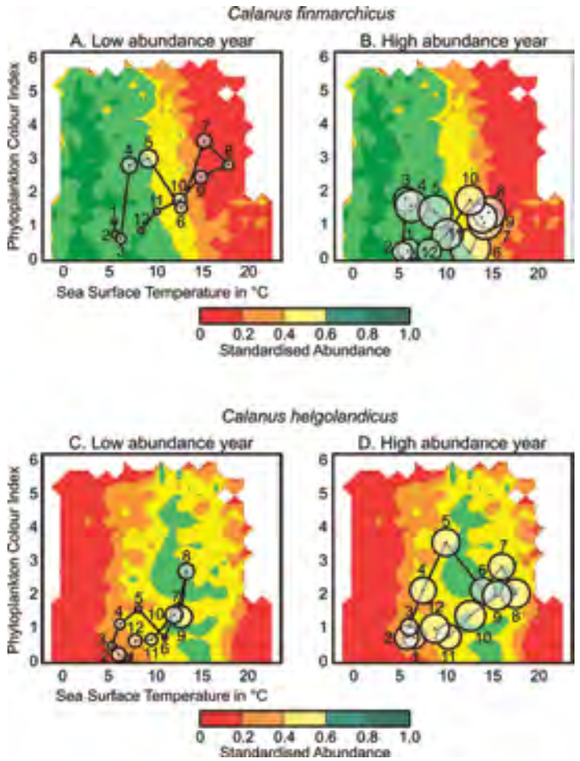


Figure 11. Representation of the environmental conditions (SST and PCI) observed in the North Sea in the niche space for years corresponding to the highest and lowest observed abundance of *Calanus finmarchicus* and *C. helgolandicus*. (A) the warm year 1997 (*C. finmarchicus*); (B) The cold year 1966 (*C. finmarchicus*);. (C) The cold year 1962 (*C. helgolandicus*); (D) the warm year 2003 (*C. helgolandicus*). Monthly abundances of each species were standardised between 0 and 1 to allow both seasonal and year-to-year fluctuations to be compared. Seasonal trajectories are represented by lines.

We first define for both species a two-dimensional ecological niche by calculating the averaged abundances for each species and for each of the categories of Phytoplankton Colour Index (PCI, used as an index of food) and the Sea Surface Temperature (SST) (Fig. 11). Then, we projected at a monthly scale a given species habitat (the North Sea) within the ecological niches to obtain a habitat suitability index for each month of a 51 year time period (1958 - 2008) (Fig. 12A and 12B). To assess the quality of the index, a correlation coefficient has been calculated between the annual averaged abundance of each species and an annual averaged of the index (Fig. 12C and 12D).

Despite the use of a limited number of dimensions, the characterisation of the niche of *C. fin.* and *C. hel.* was precise enough to reflect the degree of mismatch between the environmental conditions and their niche, thereby explaining the long-term changes in the abundance of both copepods in the North Sea. The warming of the North Sea and its pronounced opposite effect on these two key species, appeared mainly in two phases after the 1980s abrupt ecosystem shift and more recently after the mid-1990s. Because the two species are indicative of the position of the boundary between the Atlantic Polar biomes and the Atlantic Westerlies Wind, the decrease in the abundance of *C. fin.* associated to an increase in *C. hel.* reflects an extreme structural reorganisation of the North Sea ecosystem, which is likely to affect both species interactions and ecosystem services

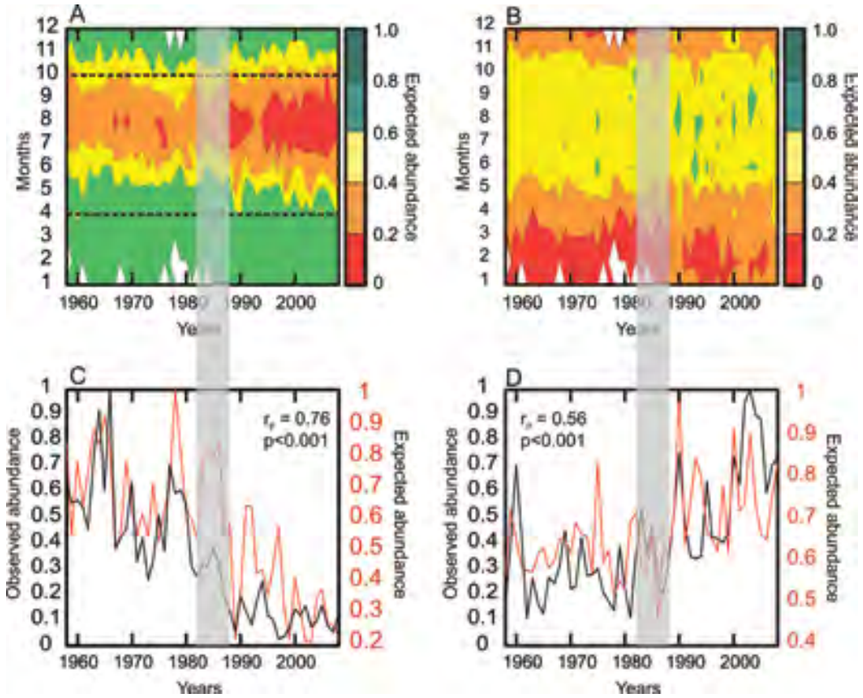


Figure 12. Representation of the long-term changes in the expected abundance of (A) *C. finmarchicus* and (B) *C. helgolandicus* as a function of months and years for the period 1958-2008 (matrix 12 x 51). (A) Dashed black lines represent the months selected (from April to October) to calculate *C. finmarchicus's* expected abundance. For *C. helgolandicus*, all months were included (from January to December). Both observed (in black) and expected (in red) annual mean abundance of (C) *C. finmarchicus* and (D) *C. helgolandicus* are compared using a Pearson correlation coefficient. The period 1982-1988 characterising the abrupt ecosystem shift in the North Sea is represented by a shaded strip.

Influence of climate change and trophic coupling across four trophic levels in the Celtic Sea

Dr Valentina Lauria, NUI, Galway and Prof Martin Edwards

Climate change has had profound effects upon marine ecosystems, impacting across all trophic levels from plankton to top predators. Determining the impacts of climate change on marine ecosystems requires understanding the direct effects on all trophic levels as well as indirect effects mediated by trophic coupling.

The aim of this study was to investigate the effects of climate change on the pelagic food web in the Celtic Sea, a productive shelf region in the Northeast Atlantic. Using long-term data, we examined possible direct and indirect 'bottom-up' climate effects across four trophic levels: phytoplankton, zooplankton, mid-trophic level fish and apex predators (seabirds).

During the period 1986-2007, although there was no temporal trend in the North Atlantic Oscillation index (NAO), the decadal mean SST in the Celtic Sea increased by 0.66 ± 0.02°C. Despite this, there was only a weak signal of climate change in the Celtic Sea food web, with indirect bottom-up effects on mid-trophic level fish and seabirds. Changes in plankton community structure were found, however this was not related to SST or NAO. A significant negative relationship occurred between herring abundance *Clupea harengus* (0- and 1-group) and spring SST. Seabird demographics showed complex species–specific responses. There was evidence of direct effects of spring NAO (on black-legged kittiwake *Rissa tridactyla* population growth rate) as well as indirect bottom-up effects of lagged spring SST (on razorbill *Alca torda* breeding success). Negative relationships between breeding success and population growth rate of razorbills and common guillemots (*Uria aalge*) may be explained by interactions between mid-trophic level fish.

Our findings show that the impacts of climate change on the Celtic Sea ecosystem are not as marked as in nearby regions (e.g. the North Sea), emphasising the need for more research at regional scales in order to understand how climate change is impacting upon the marine environment.

CPR derived indices of krill condition in offshore British Columbia waters

Jennifer Putland, Institute of Ocean Sciences, Department of Fisheries and Oceans

The intent of this project was to assess CPR-collected krill nutritional condition through examination of krill digestive gland length (relative to carapace length). The digestive gland size is a measure of recent (~1 week) feeding history, with larger sizes indicative of better feeding conditions and higher growth rates. The colour of the digestive gland also provides information on prey recently consumed (e.g. white glands are indicative of a diet based primarily on zooplankton). While the method has primarily been used for *Euphausia superba*, it can also be applied to other species of krill. Indeed, digestive glands were readily observed (and easily dissected and measured) in *Euphausia pacifica* that were collected from La Perouse Bank and the Strait of Georgia (British Columbia coastal waters) with bongo nets and preserved (at least over short, ~3-4 month, time scales) in a suspension of 10% buffered formalin (Fig. 13).

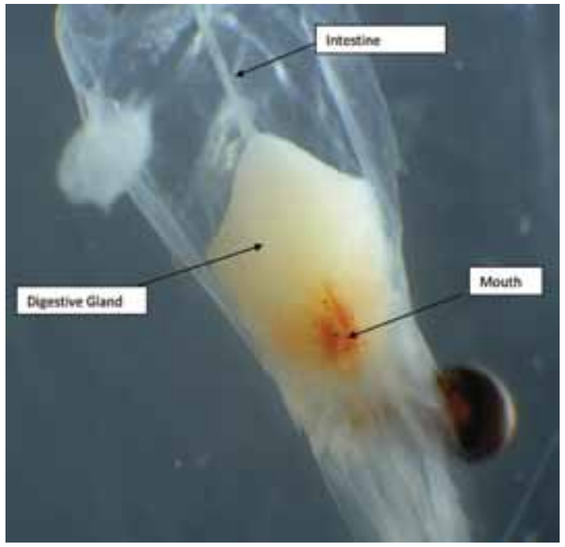


Figure 13. Ventral view of *E. pacifica*. Collected with bongo nets.

In contrast, application of the method to krill (primarily *E. pacifica*) that were collected with the CPR proved challenging. Most of the CPR-collected krill examined (~100 total) were crushed (Fig. 14). Crushed digestive glands could not be removed from krill thereby necessitating measurements through the carapace. Reliable length measurements of the digestive glands (and carapaces) could not be acquired from crushed krill. Edges of the digestive glands could not be discerned mainly because samples were crushed, but also because of the similarity in colour of the digestive gland and animal.

Many of the krill examined from the CPR samples had intact stomachs (Fig. 14). Stomach content analysis is a direct approach to help determine recent feeding history. The method is time consuming, identification of material in the stomach is not always possible (e.g. when material is partially digested and/or relatively fragile), and it is difficult to quantify material within the stomach. Nevertheless, dissecting stomachs and examining their contents on slides can provide insight into the recent diet of krill.

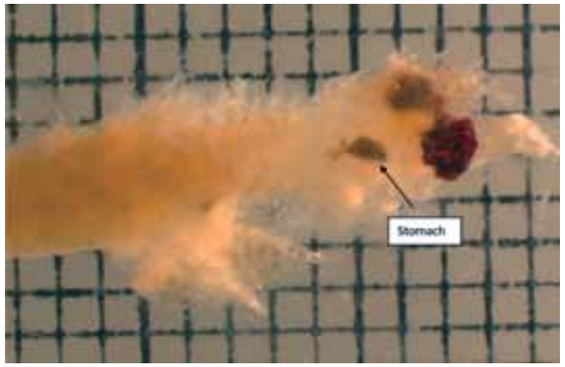


Figure 14. Example of an intact stomach in a crushed *Euphausia* sp. from a CPR sample.

Krill stomach content varied between samples; Some contained a lot of unidentifiable material (Fig. 15), suggesting that these krill may have been consuming a diet rich in heterotrophs (e.g. microzooplankton and/or copepods). In contrast, krill from later months were likely mainly herbivorous; their stomachs mainly contained frustules from diatoms such as *Chaetoceros* sp., *Rhizosolenia* sp., *Thalassiosira* spp., and *Neodenticula seminae.*

Analysis of CPR-collected krill stomach contents could provide information on krill dietary differences over broad spatial and temporal scales in the North Pacific Ocean.

Figure 15. Stomach contents from various *E. pacifica.* The unidentifiable material suggests these krill may have been consuming a diet rich in heterotrophs.

Impact of environmental change on the recruitment of clupeoid fish

Dr Priscilla Licandro

Long-term records of zooplankton biomass derived from CPR records have been used to investigate a possible link between the change in plankton communities and the poor recruitment of North Sea herring, which has been consecutively reported since 2001. Indeed it has been hypothesized that environmental change is the main driver responsible for the recent recruitment failure, as after the collapse of the stock during the 1970s, which determined the closure of the fishery in the 1980s, North Sea herring has been considered a well-managed stock. Previous studies have shown that the recent failure in recruitment is mainly due to low survival of early-stage herring larvae. The analysis of long-term CPR records suggests that since early 2000 herring larvae are more vulnerable to zooplankton competitors/predators, which have significantly increased around the main North Sea spawning grounds. In addition during the same period zooplankton suitable as food for the larvae have decreased around herring nursery grounds in the central and southern North Sea. A significant increase of ambient temperature also coincided with the period of herrings' low recruitment, re-enforcing the idea that productivity of clupeiods is directly driven by environmental change.

Changes in marine dinoflagellate and diatom abundance under climate change

Dr Stephanie Hinder, Dr Anthony Walne and Prof Martin Edwards

Marine diatoms and dinoflagellates play a variety of key ecosystem roles as important primary producers (diatoms and some dinoflagellates) and grazers (some dinoflagellates). Additionally, some are harmful algal bloom (HAB) species and there is widespread concern that HAB species may be increasing accompanied by major negative socio-economic impacts, including threats to human health and marine harvesting. Using over 90,000 samples from the CPR Survey, we generated a 50-year (1960–2009) time series of diatom and dinoflagellate occurrence in the northeast Atlantic and North Sea (Fig. 16). Dinoflagellates (Fig. 16A), including both HAB taxa (e.g. *Prorocentrum* spp.) and non-HAB taxa (e.g. *Neoceratium furca*), have declined in abundance, particularly since 2006. In contrast, diatom abundance has not shown this decline(Fig 16B), with some common diatoms, including both HAB (for example, *Pseudo-nitzschia* spp.) and non-HAB (for example, *Thalassiosira* spp.) taxa increasing in abundance. Overall these changes have led to a marked increase in the relative abundance of diatoms versus dinoflagellates. Our analyses, including Granger tests to identify criteria of causality, indicate that this switch is driven by an interaction effect of both increasing sea surface temperatures combined with increasingly windy conditions in summer.

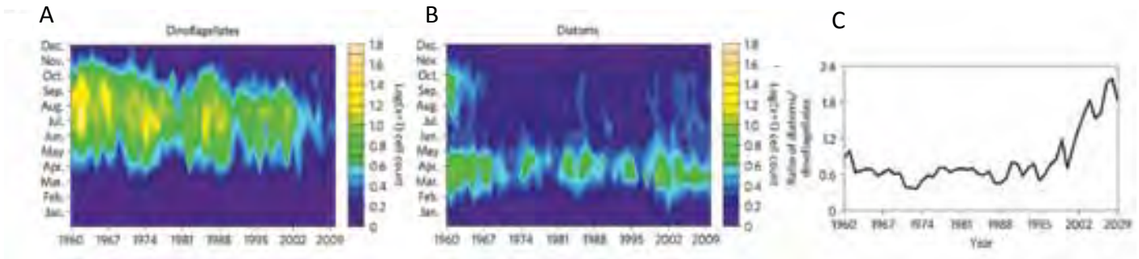


Figure 16. Abundance of dinoflagellates and diatoms in the northeast Atlantic region from 1960 to 2009 based on twelve diatom taxa and nine dinoflagellate taxa routinely identified in CPR samples A,B Monthly mean cell numbers per sample of dinoflagellates (A) and diatoms (B). C, The relative abundance of diatoms/ dinoflagellates, highlighting the shift from dinoflagellates to diatoms during the past 50 years.

Confirmation of the presence of microplastic debris in UK waters

Saeed seyed Sadri, Plymouth University

Collaborative work in the past has shown the importance of CPR data in assessing microplastic abundance (as reported by Thompson *et al*. 2004) and led SAHFOS to include the inspection of samples for 'suspected' microplastic pieces as part of their standard visual analysis protocol. This inspection is based on a visual examination and reporting of samples which appear to contain particles resembling plastics. For small particles it can be difficult to distinguish plastics from natural debris based on visual examination alone. The most conclusive method to confirm the identity of unknown fragments that are potentially plastic is to use Fourier Transform Infrared (FT-IR) spectroscopy, however, this method is time-consuming and the equipment is expensive. One of the objectives of this project was to examine the accuracy of SAHFOS analysts in detecting microplastic fragments under the microscope during their normal plankton analysis (Fig. 17). If confirmed then these reports could provide a valuable index of microplastic debris and facilitate monitoring and spatiotemporal analysis of microplastic debris using data from both the on-going survey and archived data.

Results so far confirm the presence of microplastic debris in CPR samples from marine surface waters around the UK and provide evidence for reliability of SAHFOS's analysts to visually detect microplastic debris during their standard analysis of plankton samples. This, along with the long-time archive of CPR samples and the broad spatial coverage of the Survey, could prove to be a useful method to monitor and investigate spatiotemporal trends of the floating microplastics in the marine environment.

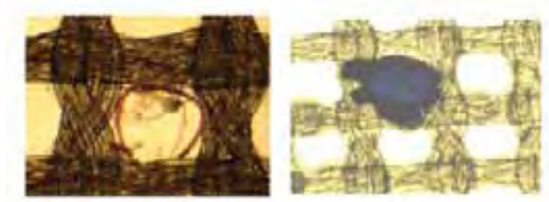


Figure 17. Examples of microplastic debris found in CPR samples. Nylon monofilament (left) and Polyethylene terephthalate fragments (right). Scale bar 270 µm.

Temporal variability of tidal mixing fronts and its effect on ecosystems of the SW UK continental shelf

Lavinia Suberg, NOC

The UK is committed to the establishment of a network of marine reserves to protect species of conservation interest. These include commercially important fish and highly mobile apex predators, whose distribution is temporally very variable. To achieve effective protection within limited space, diversity hotspots need to be identified. Tidal mixing fronts, which separate well mixed coastal and stratified shelf waters during summer, have been proposed to be such places of ecological significance. While a positive effect of these features on Primary Productivity (PP) is well established, consequences for marine organisms of various trophic levels remain somewhat inconclusive. Over the South Western European Continental Shelf, the two predominant tidal mixing fronts are the Ushant Front and the Celtic Sea Front (Fig. 18). In order to examine the temporal variability of these two features and investigate its effect on the abundance of marine biota off SW UK, 20 years of Advanced Very High Resolution Radiometry (AVHRR)- derived frontal maps (01/1990-12/2010), CPR data and marine mega-vertebrate abundance collected over 15 years by MarineLife and ORCA are being analysed.

Preliminary results indicate an increase in Fmean (mean temperature gradient) of both fronts since

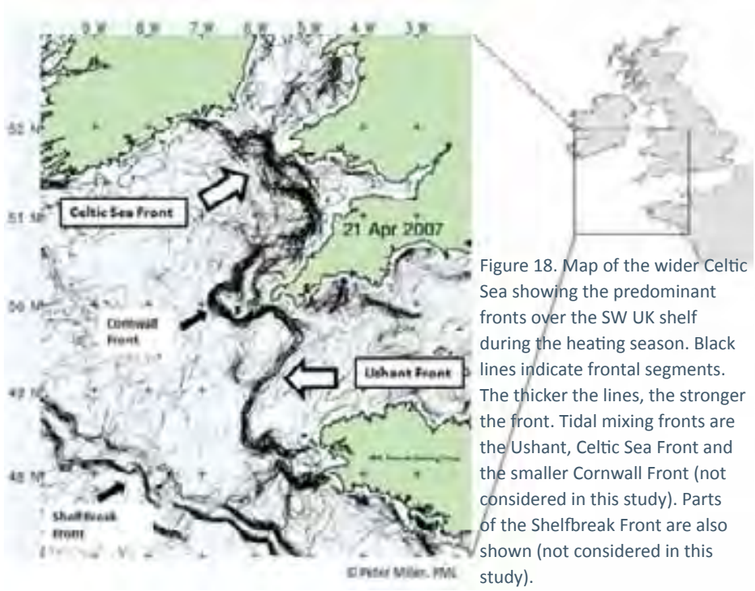


Figure 18. Map of the wider Celtic Sea showing the predominant fronts over the SW UK shelf during the heating season. Black lines indicate frontal segments. The thicker the lines, the stronger the front. Tidal mixing fronts are the Ushant, Celtic Sea Front and the smaller Cornwall Front (not considered in this study). Parts of the Shelfbreak Front are also shown (not considered in this study).

the late 90's, but a decrease in Fcomp (indication of persistence in time and space) (Fig. 19). The intensification of Fmean is partially due to higher seasonal peak values and partially due to a temporal extension of the frontal 'high season'. In general, frontolysis begins in May and frontal break up occurs in October. Seasonal peak values are found in July/ August (Celtic Sea Front) and August/ September (Ushant Front). During the second half of the time series there has been a significant increase in June and October Fmean values of both fronts and therefore, prolonging the period of higher Fmean. In contrast, the observed decrease in Fcomp is due to a drop in seasonal maxima only. Celtic and Ushant Fronts display similar inter-annual patterns, suggesting underlying drivers of the observed variability act over regional scales rather than locally. Interestingly, analyses of the effect of meteorological forcing (including net heat flux, precipitation, wind stress, NAO and regional SST) on Fmean and Fcomp of both fronts indicate that NAO and wind stress are not important covariates. Forces acting from within the water column (net heat flux and SST) on the other hand, were found to have a significant effect on frontal variability. The results suggest that, once tidal mixing fronts are established, these features are stable and immune to temporally short surface forcing, but also subject to potential effects of climate change.

Visualization of selected planktonic components collected by the CPR suggest that tidal mixing fronts act as semi-permeable boundaries, shaping overall species-specific plankton distribution (Fig. 20). They partition the marine environment into distinct ecosystems of characteristic physical properties, in which plankton is distributed within their physiological limitations. First numerical analyses indicate that the wider Ushant Front area is associated with elevated zooplankton biomass. In contrast, the Celtic Sea Front displays the lowest plankton numbers measured within the spatial range of the data set. Therefore, frontal zones are not aggregation sites *per se*, but their importance needs to be assessed for each feature individually.

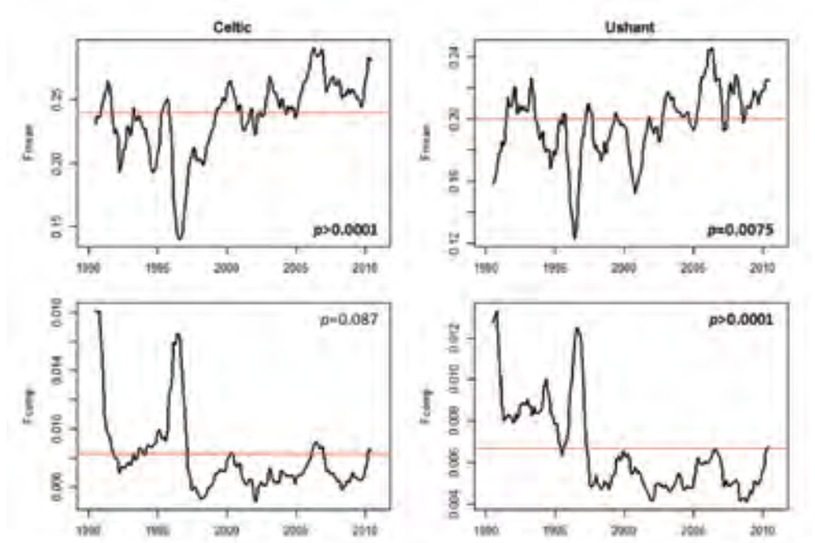


Figure 19. Trend of decomposed time series of Fmean and Fcomp of Celtic Sea and Ushant Front from January 1990 to December 2010, based on monthly data. Red line represents the overall mean for each metric. Numbers are p-values of Generalised least square regression of seasonally adjusted frontal metrics against time, with AR(1) structure to account for inherent temporal autocorrelation and VarIdent structure to allow for different variances between years. Significant p-values are in bold.

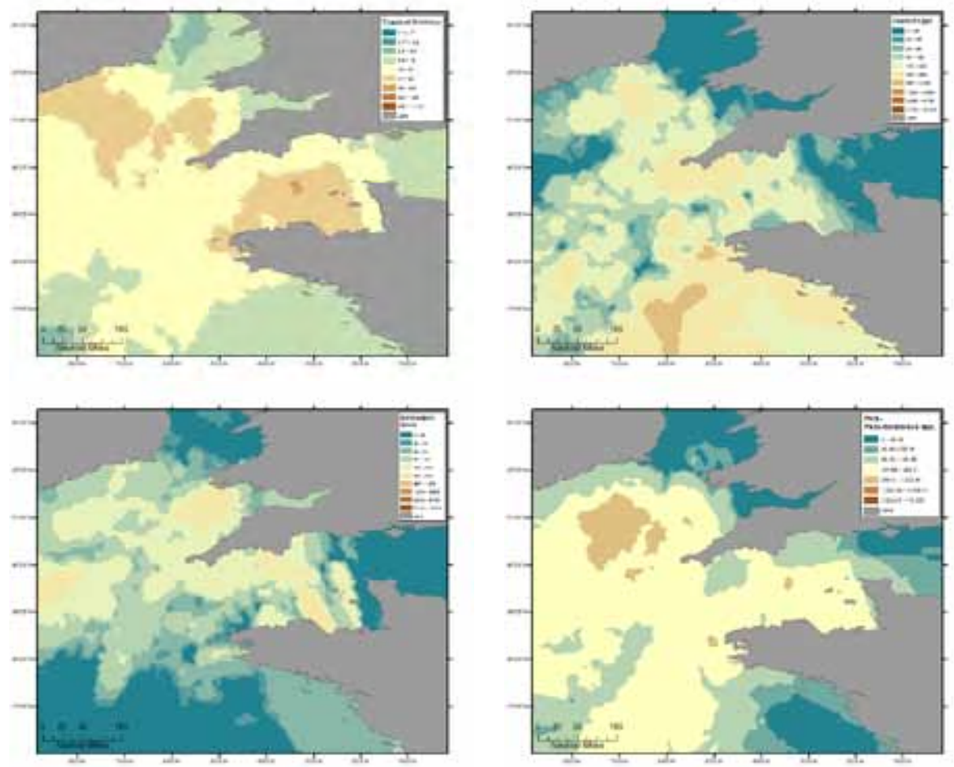


Figure 20. Interpolation maps based on Radial Basis Function with a Kernel smoother for selected planktonic components (as labelled).

The spatio-temporal distribution and habitat associations of marine mega-vertebrates off Southwest UK

Dr Alice Jones, NOC

Dr Alice Jones recently completed a PhD in marine ecology at the National Oceanography Centre, Southampton, receiving a studentship from NERC and CASE sponsorship from SAHFOS and supervised by Dr Russell Wynn, Prof Paul Tyler, Prof Simon Josey (NOCS) and David Johns (SAHFOS). She also received support and data from Dr Peter Miller at PML and Dr Phil Hosegood at Plymouth University. Her research used over 4000 hours of wildlife sightings data collected between 2007 and 2010 in an intensive, effort-based visual monitoring survey in southwest Cornwall, UK (SeaWatch SW). The survey was carried out from a strategic watchpoint overlooking a regionally unique seabed feature, the Runnelstone Reef, which has previously been identified as a key site for all three of the study's target species: harbour porpoise *Phocoena phocoena*, basking shark *Cetorhinus maximus* and Balearic shearwater *Puffinus mauretanicus*. The location of the survey site is perceived to be a productive coastal marine 'hotspot' by local wildlife observers, eco-tour companies, conservation bodies and commercial fishermen. The aim of the study was to use a multidisciplinary approach to investigate why this site had higher abundance

and diversity of marine wildlife compared to other areas in the region. A wide range of environmental information, from fine-scale bathymetry (seafloor maps) to remote-sensed oceanographic data, was used in an attempt to understand the interactions between the target species and their environment at a variety of scales.

The three target species all face significant threats throughout their range due to human impacts and are listed as species of conservation concern on a number of UK, European and International Directives and Conventions. Therefore, improving our understanding of their distribution and highlighting interactions between the animals and their environment is an important objective, both for science and conservation.

The study found that more porpoises were recorded in the surveys during westerly tidal flows and in areas of highest seabed slopes along the 'drop off' at the southern edge of the Runnelstone Reef. Using an Acoustic Doppler Current Profiler (ADCP) to collect fine scale information on the current flows around the reef it was found that the shape of the rocky reef affected the fine-scale flow of water around the survey area. The current profiles showed that, in the area where most porpoises were observed, there were identifiable features in the flow, such as shear boundaries and turbulence, which appear to be attractive to porpoises.

ocean fronts in the vicinity of the survey area was examined and evidence supported a positive effect on the number of basking shark sightings recorded. This result supports previous suggestions that productive areas associated with thermal fronts may provide important foraging habitat for this plankton-eating species.

A review of the broad scale spatio-temporal patterns of occurrence of Balearic shearwater using sightings data from the UK, Ireland and France was undertaken. The results show that the species continues to be recorded in significant numbers throughout these areas, which were previously considered to be the northernmost part of its range. Record counts of passing birds were recorded off southwest UK in the last two years, along with unprecedented aggregations in bays along the Brittany coast, comprising approximately 20% of the estimated global population. This part of the research provides much-needed quantitative information on the at-sea distribution and behaviour of this Critically Endangered species during the interbreeding period, and supports earlier studies, which suggested the migratory distribution of the species was shifting northward, possibly as a result of climate change and the associated changes in the distribution of plankton and fish.

In line with previous national scale studies of basking sharks, statistical modelling (using GAMs) showed that the number of shark sightings in the visual survey was significantly affected by SSTs. There was also evidence for a change in seasonal abundance compared to the long-term pattern for the region, with peak sightings occurring later in the year than expected. In addition the effect of local-scale thermal

Alice Jones observing at Runnelstone Reef as part of the SeaWatch SW Survey

Molecular Research

Dr Rowena Stern

In 2012, molecular studies have focused on biodiversity of CPR samples. Our first successful high-throughput trial of eukaryotic protists revealed a wide array of organisms representing five eukaryotic kingdoms, see Fig.21. In addition to familiar organisms, such as diatoms and dinoflagellates (including two types of harmful algae), several unknown taxa were identified, related to Alveolata and Heterokonts. Unknown taxa similar to Cnidaria and Chlorophyta (left unshaded in Fig. 21), were also found. Such results reveal the astonishing array of organisms captured on CPR silk. Many of these taxa are under 5µm or soft-bodied and not identified microscopically on CPR samples. These proof of concept studies shows the enhanced capabilities of CPR samples that can highlight new biodiversity and changes in plankton diversity for a broad range of planktonic organisms. It also shows that the DNA extracted from formalin-preserved CPR material is amenable to new genetic technology to generate novel biodiversity datasets.

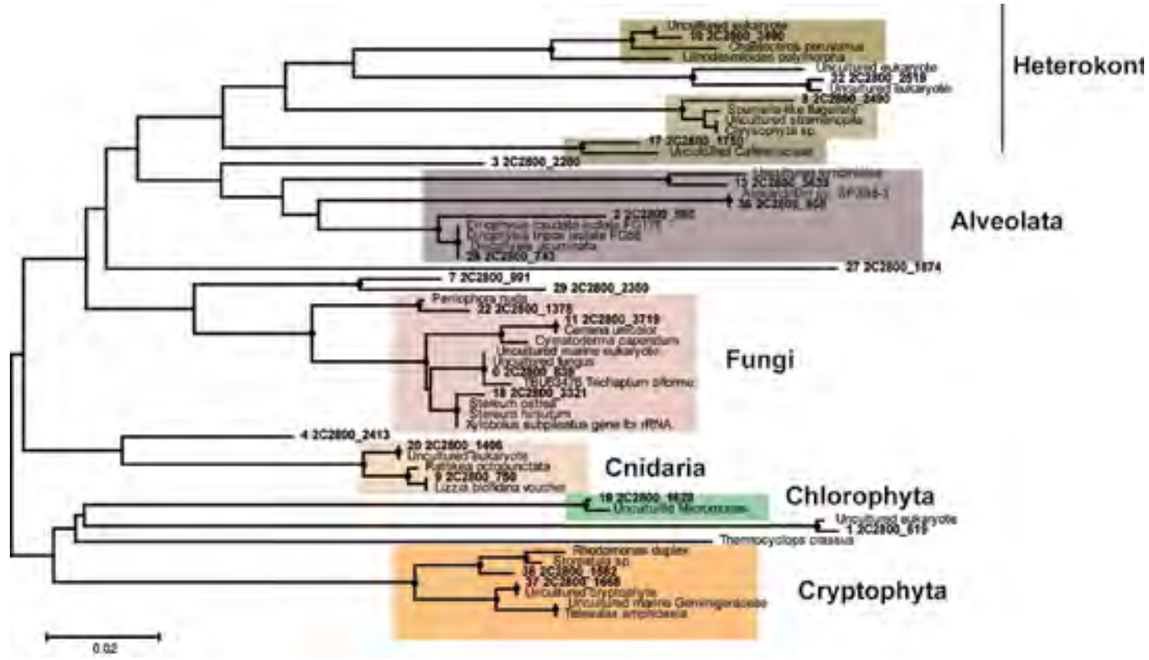


Figure 21. Diversity of taxa found in North Sea sample, July 2003

Dinophysis in Scottish Waters

Dr Rowena Stern

One of the major genera of alveoates identified in the North Sea is the toxic dinoflagellate algae, *Dinophysis* (see Fig. 22). This organism is sometimes difficult to identify to species-level because of the variety of sizes and life-forms that it presents with. Together with Eileen Bresnan, SAHFOS conducted a comprehensive molecular investigation of single *Dinophysis* cells to find the best genetic identifying marker for future identification. We found a marker that could work for a group of toxic species known as the *Dinophysis acuminata* complex. Our research also found unusual occurrence of a toxic *Dinophysis* species in Scottish waters that will aid monitoring efforts. Additionally, we found an unusually divergent *Dinophysis* isolate that feeds on different algae, not previously identified to our knowledge. *Dinophysis* are mixotrophic, they can photosynthesize but need to feed on other algae species to survive. The story of *Dinophysis* feeding

is unusually complex and interesting. *Dinophysis* harbour chloroplasts from different types of algae, known as cryptophytes. However, *Dinophysis* cells cannot obtain their chloroplasts directly from feeding on cryptophyte prey because the prey has defence mechanisms. Instead, researchers found they obtain cryptophyte chloroplasts indirectly by feeding on another heterotrophic cells called *Myreonecta rubra*, that are able to feed on cryptophytes and retain their chloroplasts too (Park, 2006). Researchers also found a link between cell concentrations of cryptophytes and high concentrations of *Dinophysis* cells, or blooms (Nishitani, 2005). However, the complex relationship between *Dinophysis*, *M. rubra* and cryptophytes make predictions about *Dinophysis* blooms difficult. The finding of this new trophic relationship provides an additional ecological connection of this toxic dinoflagellate, with other types of algae.

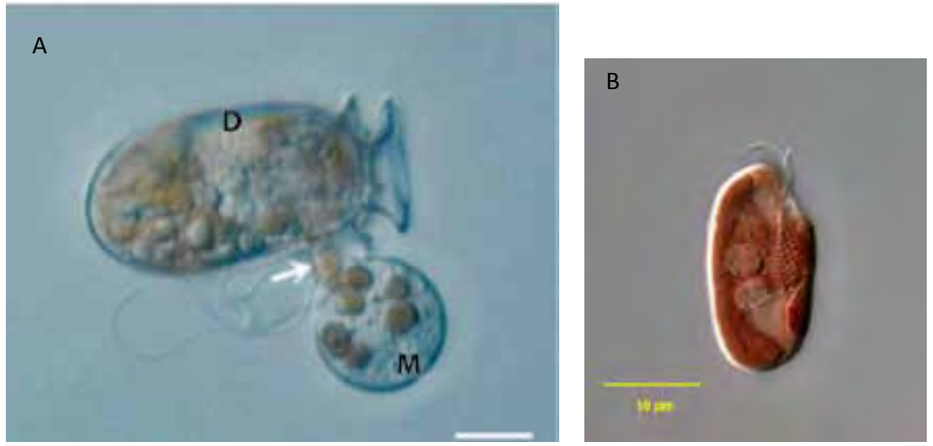


Figure. 22. *Dinophysis* cell (D) feeding on chloroplasts from M. Rubra (M) from Park *et al*. (2006) (Fig. A), and ultimate chloroplast source, cryptophytes (Fig. B) from Bourland, B (EOL) (http://eol.org/data_objects/5225603).

Pseudo-nitzschia spp. in the Pacific North-West

Dr Sonia Batten, Vera Trainer (Northwest Fisheries Science Center) and Stephanie Moore (NOAA)

In the Pacific North West, there has been a change in the type of algae occurring there over the last 10 years. *Pseudo-nitzchia* spp. has increasingly negative impacts on the aquaculture industry and a powerful neurotoxin to marine mammals and humans. *Pseudo-nitzschia* cannot be readily identified by the microscope, often being classified into two broad types that encompass dozens of species. In fact, due to the fact that *Pseudo-nitzchia* can reproduce sexually, there are hundreds of different species, that have variable levels of toxins, and the current microscopic classification is not informative enough. With 10 years of CPR sampling around this area, we investigated whether we could detect *Pseudo-nitzschia* in past samples. After searching for the right DNA marker that can work with CPR samples, we were able to identify three different species of *Pseudo-nitzschia* from three climatically anomalous years. This work means we can retrospectively map different *Pseudo-nitzschia* species distributions more accurately in the Pacific North West and relate these to changes in environmental conditions that may allow the development of a predictive model of occurrences of toxic *Pseudo-nitzschia*.

A *Pseudo-nitzchia spp* (likely *P. seriata*) from the CPR Survey.

Mysterious organisms in the Hook of Holland

Marianne Wootton and Dr Rowena Stern

In July 2011, an entire CPR tow was covered in mysterious smelly, black material from Ghent to Brevik. The smell had an odour of oil and sweet, aromatic organic compounds. In order to identify the black material, genetic investigations were performed to identify all microscopic organisms. Results revealed only a small variety of species, mostly bacteria and fungi. Some of the most common fungi found on this sample were dark-coloured moulds that emit volatile organic compounds that may be linked with the distinct odour of this sample. Other fungi found may be plant pathogens. The bacteria found mostly belonged to the diverse and mostly environmental Flavobacteriaceae family that function in carbon cycling of nutrients.

In addition to these findings other animal pathogenic bacteria were found of significance to humans and fish. Other bacteria were found to be metabolisers of hydrocarbons and methanol-related compounds.

Pacific Research

Dr Sonia Batten

A lot can happen in a year! Two areas of the NE Pacific receive special focus because of the interests of the funding agencies that support the North Pacific CPR consortium. One region is the Alaskan shelf at the northern end of the AT route, and the second is the oceanic area west of British Columbia which is sampled by the early sections of both the AT and the VJ transects (Fig. 23). In producing updates for each area it became clear that the last couple of years have shown extreme variability. Fig. 24 highlights this.

2011 saw anomalous lows of both diatoms and zooplankton on the Alaskan Shelf. The underlying cause of this low productivity year is unknown as yet, but 2011 was a field research year for the North Pacific Research Board's Integrated Ecosystem Research Project for the Gulf of Alaska so it was intensively studied. Low light levels leading to smaller species, low iron levels and high numbers of salps are all being considered as having an effect (Suzane Strom and Russ Hopcroft, pers. comms.). 2012 CPR data are only finalised up to June, with July to October only partially complete but it seems that the low productivity has reversed and the anomalies are close to (diatoms) or above (zooplankton) normal. 2011 also saw the lowest diatom anomaly in the oceanic region, which again has reversed in 2012 (Fig. 24). There is a strong

Figure 23. The two regions described in this report; Alaska Shelf (Blue) and oceanic NE Pacific (green).

correspondence in the diatom anomaly time series between the two regions, and this is likely related to climate effects. Both correlate significantly with the Pacific Decadal Oscillation (PDO) so that when the PDO is negative, as it has been for some years now, conditions are cool and the abundance of the larger diatoms retained by the CPR is low.

Zooplankton biomass in the oceanic region in 2012 is likely to be the highest of the time series once the final sample analyses are completed. This contrasts sharply with 2010 which saw the lowest anomaly to date. Examining the taxonomic data it was evident that large copepods and hyperiids were especially numerous, which have high individual biomass. 2012 was an interesting year with a controversial iron fertilization exercise occurring west of Haida Gwaii, in the north of the oceanic region shown in Fig. 23. The iron was introduced in mid-late July and a chlorophyll bloom was evident in August satellite data. CPR data suggest that zooplankton biomass was already high in June, prior to the event (the June mean zooplankton biomass value was the highest June value recorded in the time series and data for this month are complete) and caused by larger organisms that have an annual life cycle. Large diatoms were below, or at, mean monthly levels in 2012 so at present the CPR data have little evidence of the iron causing an increase in plankton, although once the late summer and autumn data are complete further analyses will be undertaken.

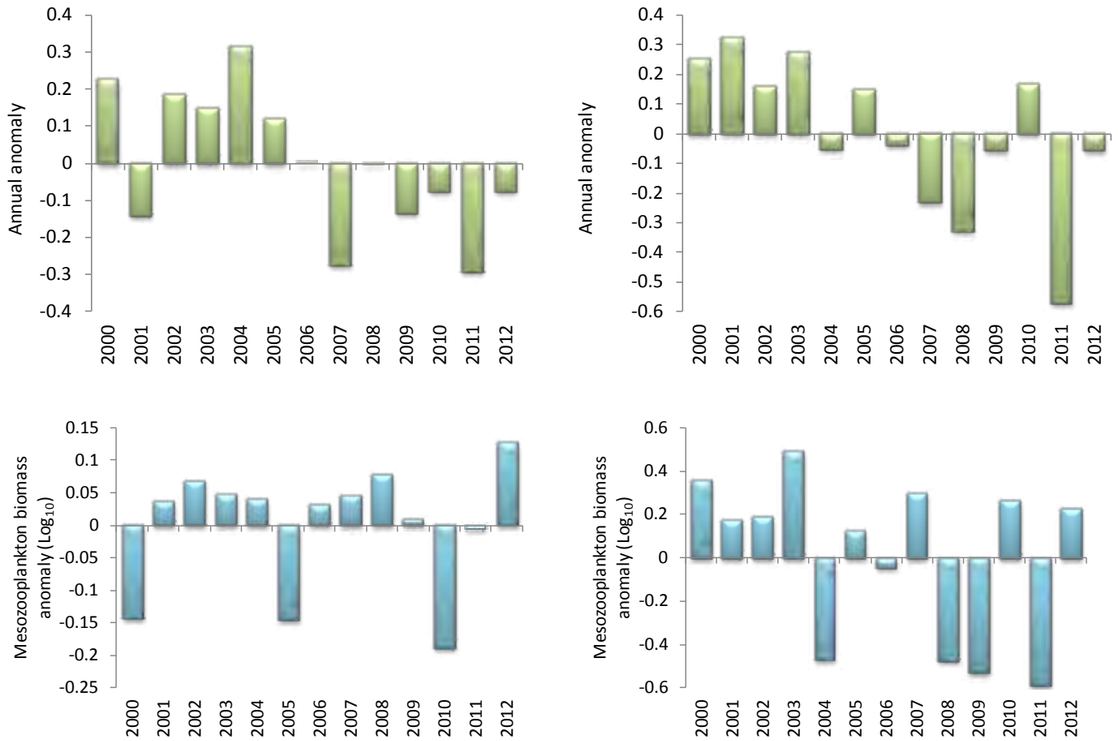


Figure 24. Time series of annual diatom abundance (top) and annual mesozooplankton biomass (bottom) anomalies for the Alaska shelf (right) and oceanic NE Pacific regions (left).

Our congratulations go out to the following this year.....

Our associated students

Dr Steph Hinder, from University of Swansea, who gained her PhD with her thesis 'Harmful algal blooms and climate change, by data mining the CPR'.

Dr Alice Jones from National Oceanography Centre, Southampton, who gained her PhD with her thesis 'The Spatio-temporal distribution and habitat associations of marine mega-vertebrates off southwest UK'.

Dr Valentina Lauria from Plymouth University, who gained her PhD with her thesis 'Impacts of climate change and fisheries on the Celtic Sea ecosystem'.

Dr Manal Al-Kandaria from Plymouth University, who gained her PhD with her thesis 'Molecular studies of *Karenia mikimotoi* (Dinophyceae) from the Celtic Sea region'.

Dr Vicky Harris, University College London, who gained her PhD with her thesis 'Multiscale analysis of integrated and species-specific response to climate forcing and eutrophication in northern European Seas'.

Our staff

- Martin Edwards who was awarded Professorship and (along with Gregory Beaugrand) the first Inspiration Award in Ecosystem Science from the University of Oslo.
- Chris Reid (along with Gregory Beaugrand) whose paper was shortlisted for the Lloyds Science of Risk Prize.
- Rowena Stern who was accredited in Harmful Algae Identification from the Intergovernmental Oceanographic Commission (IOC).
- Priscilla Licandro who was nominated chair of the ICES WGSPEC (Working Group on Small Pelagic Fishes, their Ecosystems and Climate Impact).
- Claire Wotton who recieved BEQUALM (phytoplankton quality assurance) and Phytoplankton Workshop accreditation.
- Abigail McQuatters-Gollop received the Challenger Society Fellowship Award for achievement and promise in marine biology, election onto the Challenger Society Council, New Scientist interview, and had the top cited author award from Elsevier.

Knowledge Exchange

Education and Outreach Activities

Clare Buckland

In early 2012 SAHFOS was represented in the Forms Most Beautiful exhibition at Plymouth City Museum and Art Gallery. The whole exhibition was a celebration of plankton and larval forms, featuring original artwork by local artist Debbie Mason. Debbie had spent some time in the SAHFOS lab drawing and sketching planktonic larval forms. The exhibition ran from January to April 2012 and was visited by hundreds of general public (see page 57).

Clare carried out the first of her University lectures in January 2012 at Plymouth University. Further talks and workshops were run throughout the year including a guest lecture and zooplankton workshop at the University of Leicester in June. Clare also taught two lectures to MRes students studying at Plymouth University.

Long term volunteer Stuart Queen started at SAHFOS at the beginning of March 2012. Stuart is photographing live zooplankton from net caught samples in the English Channel and the images will be used for training purposes, outreach and in the new SAHFOS plankton book.

SAHFOS National Science and Engineering Week 2012 event took place in the Plymouth City Museum and Art Gallery 13-17th March with Plymouth Marine Laboratory and Plymouth University. Diversity in Motion was designed to demonstrate how an organism's morphology is perfectly adapted its habitat. The event was visited by 340 Plymouth school children and their families and was very successful in promoting science. In addition to SAHFOS's activities at the museum, Gemma Brice spent two days at Paignton Zoo delivering plankton workshops as part of the Whose Water Science Fair. 'The Secret World of Plankton' included a true/ false fact finding game and debate, catching plankton from trays and looking under microscope then creating their own plankton with special adaptations. Over 200 Key stage 3 and 4 pupils were involved.

Clare Buckland and Claire Wotton at Plymouth Museum for National Science and Engineering Week.

In April, an Introductory Zooplankton Identification course for undergraduates was run in the Marine Biological Association Resource Centre. The course is designed to encourage an interest in taxonomy and classification in undergraduates and give them experience of British zooplankton forms. Students learnt about the work carried out by SAHFOS and the importance of the CPR Survey.

A 'Wild About Plymouth' event was run in the Resource Centre in April as part of the Plymouth City Museum and Art Gallery programme. The events are designed to inspire families and the general public about wildlife and nature in and around Plymouth. Participants examined and learnt about larval organisms found in the plankton from the English Channel.

In June and September school talks and tours of SAHFOS were provided for Tavistock College as part of their 'inspiring futures programme'. The programme is aimed at promoting science and demonstrating the application of school subjects in the workplace.

A two week work experience programme was run in August 2012. Kimberley Pearce took on the volunteer curation assistant position, which involved assisting with the SAHFOS lab library books and filing of important publications. Thomas Tangye joined the CPR workshop team assisting them with the maintenance of CPRs, boxes and other equipment. Both volunteers were given letters of reference after their time at SAHFOS to enhance their CVs for future employment.

Collaborative events with the National Marine Aquarium (NMA) were also run in 2012. The first one in September, was STEMFest a schools science event as part of Plymouth's Marine Festival Week. Clare presented three plankton identification workshops to school groups. The second event was the NMA's Annual Teachers Evening which took place in October to promote the educational work and resources available through Plymouth's marine organisations. The event was very well attended by teachers and trainee teachers from across the South West.

The new education website: Life Adrift was completed in the summer. Life Adrift is aimed at all age groups from 5 years olds up to students studying at University. There are dedicated pages for each age group and resources available to download for use at home or in the classroom. There is also an area specifically designed for teachers providing information and resource sheets to assist teaching marine science across the science national curriculum.

The new Life Adrift education website which can be found at lifeadrift.info

2nd International Phytoplankton Workshop

Claire Taylor and Gemma Brice

Following on from the success of the first international phytoplankton identification workshop SAHFOS once again joined forces with the Marine Biological Association to run a second training course in July 2012.

Claire Taylor and Gemma Brice represented SAHFOS and planning started in earnest in order to ensure a sucessful repeat performance. The workshop again proved extremely popular, with over 250 people applying to participate; however, spaces were limited to twenty delegates working within marine ecology. A week before the workshop one of the participants withdrew due to funding problems, leaving 19 participants in attendance. Representatives came from 10 different countries.

"The course has been most enjoyable and I have realised there is so much more to learn in the world of phytoplankton"

Application for support from The British Ecological Society was successful along with ACP, Marinexus and POGO supporting the event. The Society of Biology provided credits for continuous professional development.

We were very grateful to Zeiss for the loan of state-of-the-art microscopes, and to Abdul Chrachri who gave an introduction to microscopy techniques, ensuring participants achieved maximum benefit from the equipment provided.

The course comprised a mixture of presentations and laboratory sessions with an emphasis on practical microscopy skills. The participants had a microscope each and worked with advice and guidance from the speakers, organising group and other SAHFOS and MBA staff.

Samples used for training (live and fixed material) were from a variety of sources. These included: preserved tow-net samples collected locally during the last 12 months, fresh tow-net samples, living cultures from the MBA Culture Collection and samples from both lecturers and participants from their own geographical area of interest.

To open the workshop Dr Gerald Boalch showed that technology is not always necessary, presenting a slideshow of phytoplankton he has seen during his research around Plymouth and imparted his vast knowledge from his long-spanning career on phytoplankton.

Dr Rowena Stern then gave two talks; one on algae classification and one introduction to molecular techniques, not easy subjects! Fellow expert Dr Karen Steidinger commented that was the best introduction to molecular techniques lecture she had ever heard.

Dr Karen Steidinger, a new speaker to the workshop this year from University of South Florida, covered dinoflagellates. Karen gave a series of well structured lectures and practicals and organised one of the highlights of the course for many students: the opportunity to model their own clay dinoflagellate. This gave them the chance to really explore their plate structure and subsequently provided an excellent learning platform; the work displayed by the students was very impressive.

"Thank you for everything, very good course, I can recommend it to everybody"

We were very privileged to welcome back Prof Carmelo Tomas, from the University of Carolina, for the full two weeks. The participants benefitted enormously from his input, knowledge and enthusiasm. He covered harmful algal blooms, cell isolation techniques and enumeration/settling as well as providing his expertise on most things phytoplankton!

We welcomed Dr Ian Probert from the Station Biologique de Roscoff who had the tricky task of covering Haptophytes in a morning. After a whistle-stop but thorough overview, he had the participants puzzling over his mystery samples whilst they attempted to identify with the information they had just learnt.

Diana Sarno from the Stazione Zoologica Anton


The course organisers


Carmelo Tomas teaching


Practical session


Speakers Carmelo Tomas, Gerald Boalch and Karen Stedinger


Phytoplankton modelling


Ian Probert and Laura Pezzolesi

Dohrn, Naples finished the week on diatoms. Diana was a fundamental speaker of the first workshop and she continued her passion, imparting her knowledge of many species through both lecture and practical sessions. Diana also provided the participants with some excellent notes.

"The venue was wonderful – being able to see samples and know what is was is super valuable"

Participants were informed about the work of each organising institution; receiving lectures by Gemma Brice and Richard Pipe and tours of the facilities by Claire Taylor.

Social events were an integral part of the workshop to allow participants and speakers to forge relationships for future work. The first week was an enjoyable evening meal at B.E.D restaurant.

On Saturday there was a visit to the Eden Project and we were grateful for the warmth offered by the Biomes after an unusually wet and cold July!

The course finished with an evening meal in the Common Room. Marilyn and her team did a fantastic five-course meal and we are also very grateful to them for the fantastic lunches they provided every day. Entertainment took the form of a marine-themed Charades and Pictionary game.

All of the delegates replied to our feedback forms and were extremely positive. The delegates enjoyed the course, most achieving their objectives whilst giving the speakers a high rating. They were all complimentary about and SAHFOS and the MBA and appreciated the amount of effort put in by the organisers.

The course participants, lecturers and organisers of week one outside the Citadel Hill laboratories.

Forms Most Beautiful

Debby Mason

'Forms Most Beautiful' at the Plymouth City Museum and Art Gallery from January to April 2012 was a beautiful exhibition portraying some of the amazing creatures around Plymouth's coastline; many of which are smaller than a pin-head and almost invisible to the eye. On show were large-scale images of microscopic marine life alongside specimens from the Museum's natural history collection.

Photographs and journals gave a fascinating insight about the lives and discoveries made by the people who had studied and collected them since the 1800's.

I was delighted to be asked to exhibit some of my etchings of plankton. Through SAHFOS the opportunity to study and draw plankton arose, and my interest, excitement and passion increased as the microscope opened up a whole new world of marine creatures that I'd never thought of drawing before. Etching is the perfect medium for my work with its fineness of line and the ability to lend itself to the meticulous detail that attracts me to marine life as subjects.

All the prints are made on copper plates etched in nitric acid, hand-printed and hand coloured. Each edition is a limited set of identical prints and is individually and consecutively numbered. Once the complete edition is printed the plate is destroyed by drilling a hole through it or engraving a line across it to prevent further printing Most of my work evolves from memories, and as a small child, I remember having afternoon tea with Sir Frederick and Lady Russell at Wardour House, I never dreamt that I would one day be observing and drawing plankton at the Laboratory on Citadel Hill. I would like to thank all at SAHFOS for their encouragement and enthusiasm.

Long-term Volunteer Programme

Stuart Queen started at SAHFOS as a volunteer in March 2012. Stuart is studying Marine Biology and Oceanography at the University of Plymouth and is currently in his final year.

As a keen photographer and biologist, Stuart has been sorting, identifying and photographing zooplankton specimens from net caught material in the English Channel (L4). The original aim was to develop a 12 month 'picture' of the zooplankton community around the UK shores, with a view to producing a calendar for outreach purposes.

However since summer 2012 Stuart has been assisting Clare Buckland with photographs of decapod larvae for the SAHFOS plankton book. During 2013 Stuart will be focussing his efforts on the copepods from the SAHFOS reference collection. He will produce good quality photographs for the plankton book and for the 'Laboratory on the Hoe' heritage project.

Science and Policy Update

Dr Abigail McQuatters-Gollop

Policy drivers 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. SAHFOS continues to hold a place on the UK Marine Monitoring and Assessment Strategy (UKMMAS) Healthy and Biologically Diverse Seas Evidence Group (HBDSEG). In addition to its involvement in HBDSEG, SAHFOS remains active in the Cefas/Defra-funded Marine Ecosystem Health Working Group and multiple ICES and SCOR Working Groups, as well as the INTERREG ISECA project in order to help guide project deliverables towards policy relevance.

SAHFOS's aim is to deliver evidence based advice to policy makers and ecosystem managers.

In 2012 SAHFOS expertise and CPR data also contributed to policy-relevant products for the following UK, European and international bodies: Defra, Scottish Natural Heritage, the Marine Climate Change Impacts Partnership (MCCIP), OSPAR, the European Environment Agency, the European Marine Observation and Data Network (EMODNET), ICES, WWF, the American National Science Foundation, and the Canadian Department of Fisheries and Oceans.

SAHFOS science is directly influencing UK and European marine policy. SAHFOS is currently leading the pelagic habitats team, a component of the UK's implementation of the EU Marine Strategy Framework Directive (MSFD), the objective of which is to achieve Good Environmental Status in European waters by 2020. In the spring of 2012 the pelagic team's proposed targets and indicators went out to public consultation in the UK and received overwhelmingly favourable reviews; the targets and indicators are now legally binding in the UK. As a result, SAHFOS is now also leading OSPAR's pelagic habitats team for MSFD implementation. The goal of the OSPAR work is to identify common indicators and targets which will be monitored at the OSPAR regional scale.

Dr Abigail McQuatters-Gollop has recently published a paper about the challenges of MSFD implementation in a climate of macroecological change in the Prospectus for UK Marine Science special issue of Philosophical Transactions of the Royal Society (see page 37).

In 2012, Abigail was invited to speak about the MSFD indicator and target development process and the CPR's use as a policy tool to the EU's Marine Observation and Data Expert Group, the University of Sheffield, Plymouth Marine Laboratory, the National Oceanographic Centre and as a keynote plenary speaker at the PICES Oceans of Change conference. Additionally, she developed and chaired a session on marine policy and resource management at the Challenger Society for Marine Science Ocean Challenges in the 21st Century. She was also elected to the Challenger Society Council in order to increase communication and uptake of UK marine science. In May, a presentation was given at Marine Strategy 2012: Research and Ecosystem-Based Management Strategies in Support of the Marine Strategy Framework Directive, an international conference bringing together hundreds of EU scientists and policymakers working on the implementation of the MSFD. Assessments, talks, and roles such as these undertaken by SAHFOS provide a mechanism to transfer scientific information to policy decision makers and facilitate the evidence-based development of monitoring programmes and policy measures. These activities also increase the profile of the CPR dataset and SAHFOS research.

SAHFOS science is directly influencing UK and European marine policy.

During 2012 SAHFOS continued to excel at translating scientific research into an accessible policy-relevant format. SAHFOS research and CPR science contributed to several EU-level reports, including climate change, impacts and vulnerability in Europe 2012: An indicator-based report. This report is a product of the European Environment Agency and provides a succinct and easily interpretable synopsis of major climate driven changes in Europe. In addition to membership of the UK's Marine Climate Change Impacts Partnership (MCCIP) Steering Group, SAHFOS also lead MCCIP's plankton climate report card and contributed to the harmful algal bloom report card. SAHFOS continues to host the technical secretariat of the UK's National Marine Biological Analytical Quality Control Scheme which provides a source of external quality assurance for laboratories engaged in the production of marine biological data.

Dr Abigail McQuatters-Gollop speaking to policy-makers

Data Requests

David Johns

During 2012, there were 70 external requests for CPR data, up slightly from 2011. Just over one third of these were from the UK, the remainder coming from Canada, Denmark, Eire, Faroes, France, Germany, Iceland, India, The Netherlands, Norway, Portugal, Russia, Saudi Arabia, Spain and the USA. The majority were from established researchers (often repeat requesters from previous years) and to input into ongoing projects, but over a dozen requests came from students. These students included undergraduates, Masters and Phd projects, with collaboration from SAHFOS staff. In addition to providing the actual data, SAHFOS provides expert advice on the use of CPR data, and encourages collaboration between SAHFOS and external researchers.

The data required covered all aspects of taxa that SAHFOS enumerates, from the smallest recorded phytoplankton (coccolithophores), zooplankton species and grouped products (totals of various functional groups) through to the rarest organisms that have been seen (one request was for the copepod *Haloptilus longicornis* – there are only 9 records in the SAHFOS database of over 200,000 samples). This proves the value of the high number of taxa routinely identified by SAHFOS analysts, an essential product when examining pelagic biodiversity.

Publications

SAHFOS staff in bold

*Associated Researchers/ Research fellow/ PhD students

Refereed Publications

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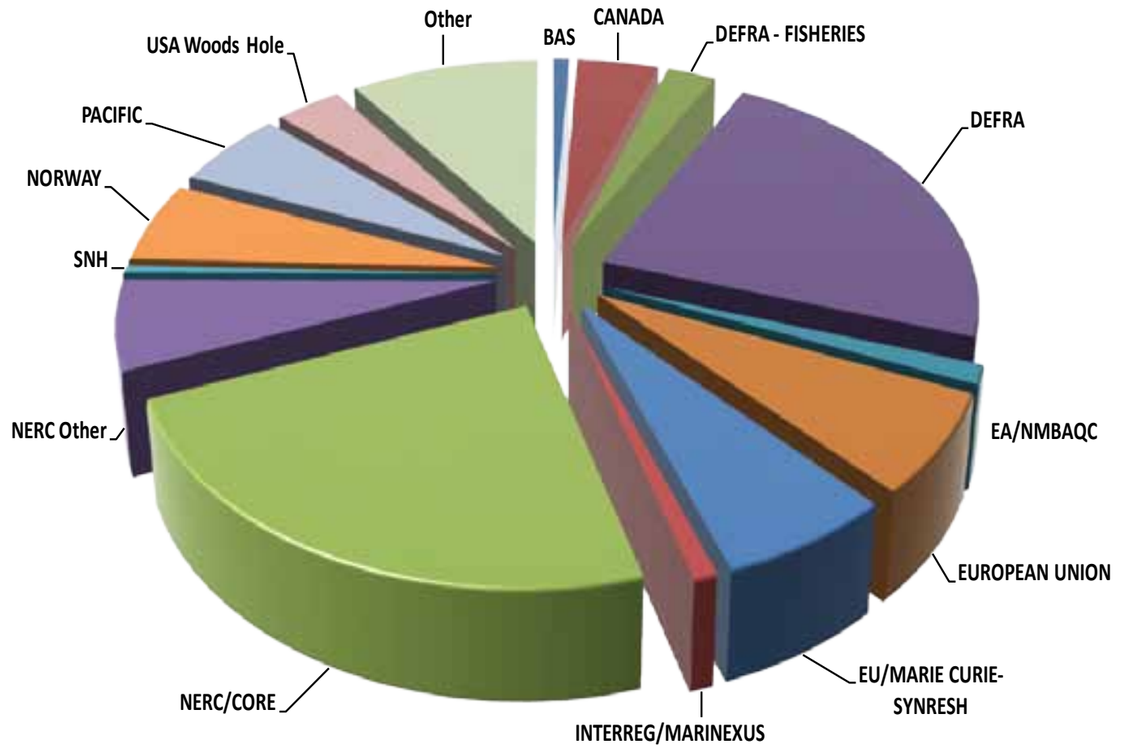
Left:Alister Hardy at work.

Below: One of his taxonomic drawings on jellyfish.

Appendices

Appendix A. Financial Summary



The principal sources of funding for 2012 are broadly derived from grants and contract income from core funding organisations, and research and academic organisations.

Core funding organisations provide support funding to enable the general operation of the CPR Survey. In 2012 these were : UK Natural Environment Research Council (NERC), UK Department of Environment, Food and Rural Affairs (Defra) & National Science Foundation U.S. (NSF).

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 2012 these were: Exxon Valdez Oil-spill Trust, North Pacific Research Board, Dept of Fisheries & Oceans Canada, British Antarctic Survey, European Union, European Environment Agency, Institute of Marine Research Norway, the Marie Curie Institute, Scottish Natural Heritage, and others.

Appendix B. Shipping companies assisting the CPR Survey in 2012

(see inside covers)

Routes	Towing Vessels	Shipping Company
A-	*Hildasay*	Chartered by Serco NorthLink Orkney & Shetland Ferries Ltd, Stromness, Orkney, Scotland. Owners: Seatruck Ferries of Warrenpoint and Heysham.
AT	*Horizon Kodiak*	Horizon Lines LLC, Charlotte, North Carolina, USA and Tacoma, WA, USA.
BA, BB, BC, BD	*Benguela Stream*	Seatrade NV, Groningen, Netherlands. Charterers: Geest Line Ltd, Fareham, England.
C-	*Petunia Seaways*	DFDS Seaways, Copenhagen, Denmark.
CN	*Polarstern*	German Goverment.
CT	*Horizon*	Chartered by Ocean Africa Container Line, Durban, South Africa from Shanghai Costamare Ship Management, China. Towed in March 2012.
D-, DA, EA, EA	*Atlantic Companion*	Atlantic Container Line, Gothenburg, Sweden.
HE	*Tor Dania*	Chartered by DFDS Seaways, Copenhagen from Imperial Shipping AB, Gothenburg, Sweden.
HE	*Clipper Point*	Chartered by DFDS Seaways from Seatruck Ferries Ltd, Heysham, UK.
IB & SB	*Sophia*	Chartered by MacAndrews Ltd, London from Peter Doehle Schiffahrts KG, Haren/ Ems, Germany.
IN	*Norbay*	P&O Ferries (Irish Sea) Ltd, Larne, Northern Ireland.
LG	*Ficaria Seaways*	DFDS Seaways AB, Copenhagen, Denmark.
LR & V-	*Selfoss*	Eimskipafelag, Reykjavik, Iceland.
M-	*S C Aberdeen*	Sea Cargo A/S Bergen, Norway.
M-	*Sea Cargo Express*	Sea Cargo A/S Bergen, Norway.
NI	*S. Rafael*	Chartered by Eimskip, Reykjavik, Iceland from Briese Shiffahrts GmbH, Leer, Germany.
PR	*Armorique*	Brittany Ferries, Roscoff, France.
R-	*Flandria Seaways*	DFDS Seaways, Copenhagen, Denmark
SA	*Encounter*	Chartered by MacAndrews Ltd, London. Managed by Confeeder Shipping, Rhoon, Netherlands.
SF	*Pharos SG*	Owners: Byron Marine Ltd, Southampton, England. Charterers: Government of South Georgia & South Sandwich Islands, Stanley, Falkland Islands.
ST	*Green Frost*	Green Reefers AS, Bergen, Norway.
VJ	*Morning Cedar*	Owners: Eukor Car Carriers, Singapore. Charterers: Seaboard International Shipping Company, North Vancouver, British Columbia, Canada.
VJ	*Madame Butterfly*	Owners: Wallenius Wilhelmsen, Singapore Charterers: Seaboard Shipping, Vancouver.
Z-, ZB, ZC	*Reykjafoss*	Chartered by Eimskipafelag, Reykjavik, Iceland from Reider Shipping BV, Winschoten, Netherlands.

The Sir Alister Hardy Foundation for Ocean Science (SAHFOS) is an internationally funded charity that operates the Continuous Plankton Recorder (CPR) Survey. The Foundation has been collecting data from the North Atlantic and the North Sea on biogeography and ecology of plankton since 1931. More recently, work has been expanded to include other regions around the globe including the Arctic and Southern Ocean. The results of the survey are used by marine biologists, scientific institutes and in environmental change studies across the world. The SAHFOS team is based in Plymouth, England and consists of analysts, technicians, researchers and administrators, who all play an integral part in the running of the Survey.

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