Sir Alister Hardy Foundation for Ocean Science

Plankton Science for Our Future Oceans

2016 Annual Report

Our Tow Routes and Ships

North Atlantic

IN route: Dublin to Liverpool
P&O: *Norbay*

IB route: 46°N Biscay to 53°N
SB route: Lisbon to Leixoes
MacAndrews: *Sophia*
Vega Reederie: *Vega Philipp*

D- & DA routes: 33°W to 7°W and Liverpool
EA & EB routes: Norfolk VA to Cape Race
ACL: *Atlantic Sea*

EA & EB routes: Norfolk VA to Cape Race
D- & DA routes: 33°W to 7°W and Liverpool
ACL: *Atlantic Cartier*

MB route: New York to Bermuda
Bermuda Container Line: *Oleander*

Z routes: Reykjavik to east of Newfoundland
Eimskip: *Reykjafoss*

B routes: 40°W to Portsmouth
MMD/ Geest Line: *Benguela Stream*

NI route: East Iceland to Sortland
MC route: Nova Scotia to Portland
Eimskip: *Skogafoss*

LG route: Gent to Gothenburg
DFDS*: Primula Seaways*

SA route: Bilbao to Land's End
MacAndrews: *Encounter*

DJ & DI Route: East Iceland to Denmark via Faroe's
Smyril Line: *Norrona*

A- route: Lerwick Shetland to Aberdeen
SERCO Northlink Ferries: *Hildasay*

ST route: Svalbard to North Cape Norway
Bring: *Norbjorn*

M- route: Aberdeen to Tananger
KC route: Immingham to Tananger
Freshney: *Norrland*

LR route: Immingham to Sule Skerry
V- route: Sule Skerry to South East Iceland
Eimskip: *Largarfoss*

PR route: Plymouth to Roscoff
Brittany Ferries: *Armorique*

R- route: Hook of Holland to Shipwash Bank
DFDS: *Anglia Seaways*

C- route: Humber to Hanstholm
DFDS: *Petunia Seaways*

HE route: Cuxhaven to Immingham
DFDS: *Hafnia Seaways*

NI
DJ
DI
V
A
M
KC
C
LG
LR
HE
R
IN
IB
PR
D
BA
BB
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BD
SA
SB
Z
ZB
ZC
MC
EB
EA
MB
ST

The CPR Survey would not be physically or economically possible without the generous support of ships, owners, charterers, managers, port operatives and its operational activities – we could not do it without your continuing support. We are extremely grateful to all those involved, helping SAHFOS in all its operational activities – we could not do it without your continuing support.

VJ route: Vancouver to Pusan South Korea
AAL Shipping: AAL *Melbourne*

AT route: Anchorage, Alaska to Tacoma, Washington State
Matson Shipping: *Matson Kodiak*

AT

VJ

Pacific

SF route: Stanley Falklands Islands to South Georgia
Byron Marine Ltd: *Pharos SG*

SF

South Atlantic

About Us

Sir Alister Hardy Foundation for Ocean Science (SAHFOS) is an internationally funded non-profit organisation that operates the Continuous Plankton Recorder (CPR) Survey. The Foundation has been collecting plankton with the resulting data providing information on biogeography and ecology of the planktonic community. The results of the Survey are used by marine biologists, scientific institutes, governmental bodies and in environmental change studies across the world.

We collect: Plankton, Fish larvae, Bacteria and Viruses.

Physical, chemical and biological observations of water masses.

We record: > 800 phyto and zooplankton taxonomic entries. Phytoplankton Colour Index (PCI). Ocean conductivity, Temperature, Depth and Chlorophyll-*a* fluorescence.

We analyse: Our data > 250,000 sample records.
> 175,000,000 biological records.

We share: Our data: available to external researchers and collaborators, private companies and policy-makers.

Our findings: we publish ~40 peer-reviewed papers a year.

Our knowledge: through training, consultation and our expertise services.

Supporting Us

SAHFOS is a non-profit organisation, further support is needed to help us continue our work. Donating to SAHFOS helps to ensure the protection of our oceans by backing plankton science. We can act together to safeguard a critical resource, contribute to maintaining healthy and sustainable oceans and encourage corporate social responsibility.

If you have an affinity to the ocean and plankton science, giving back by supporting the world's longest running most geographically extensive marine ecological survey, **no** matter how much, will make a difference.

For further information please see page 3.

On the cover: Artist Debby Mason's plankton etchings. See more page 41

www.debbymason.com/debby-mason/plankton

Design and Layout: Gemma Brice

Editorial Team: Gemma Brice, David Johns, Marion Smith, Martina Brunetta, Julian Morley and Astrid Fischer

Printer: Kingfisher, Totnes

Paper: Printed on recycled paper

ISBN 978-0-9566301-3-1

Charity number 1001233

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Contents

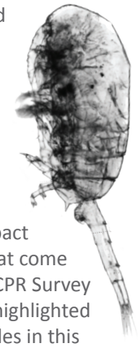
Director's Introduction

As my first full year raced by, my elevator speech is now finely honed: I can rattle off with aplomb about the impact of climate change on plankton and how this influences the oceanic food web; our global coverage from Arctic to Antarctic; our 150 dedicated staff and volunteers from port staff to shipping companies; our numerous high impact research papers; our internationally funded programme; the tremendous value for money we offer to ocean observing; and of course our 85 year CPR Survey which is the longest running, most geographically extensive, marine ecological survey in the world. I feel like I am getting acquainted with SAHFOS and I am increasingly proud to be its Director. Yet I am troubled by the proliferation of grey hairs I observe in the mirror each morning! I suspect that has something to do with my age, but also, by the political landscape. As an organisation that has a global focus and relies on close collaboration with partners around the world, many of whom rely on our data, I was personally stunned by the EU referendum (Brexit) result. We should be working together, not pushing apart. I noted in my message to staff shortly after I was the most shocked I have ever been at a political outcome. We are very definitely entering a period of uncertainty that I suspect will take many twists and turns over the next couple of years. Perhaps looking closer to home will be a starting point: SAHFOS is based in Plymouth, a city with a long and rich history of marine research. I believe closer working relationships and speaking with a united voice must be part of our future.

At SAHFOS, we conducted a rudimentary analysis of the impact of withdrawing from the EU and it is not as bad as you may think. Currently only 8% of our revenue comes from EU initiatives (this has varied from 8% - 15% over the last 5 years).
Most of our revenues come from either UK sources (NERC, Defra) or other non-EU countries (US, Canada, Norway); this is why we can describe ourselves as an "Internationally Funded" research organisation.
As an organisation that operates globally, with the CPR Survey as a unique selling point, we are actually in a strong position to continue to expand our funding base both within the EU (there is nothing to stop national funding agencies from within Europe from funding us) but also internationally. Diversifying our funding portfolio is critical; UK exit from EU will challenge us to be more creative. It is worth remembering that with change, there are always opportunities along with the challenges. I believe we are building a foundation that will help us take advantage of these opportunities.

There are too many great stories to try and highlight from our 2016 report, such is the diversity of the activities at SAHFOS. I will share some of my favourites here, but I would encourage you to read the report and find your own favourites. This year witnessed a significant change in our image and (dare I say it) branding. We started in April with the launch of our new website, in addition we developed a range of marketing materials that focussed on capitalising our excellence in plankton science. An excellent example of this is our new plankton of the week feature on the home page, it is accompanied by a short write up by one of our analysts and has proved popular on social media. Definitely check it out. In addition, you may have seen us out and about with our new trade stand where we showcased our technology and explain to an eager science community how we can help you get access to our data or even set up your own CPR survey, we have a wide range of options available (from running everything for you, to providing you with a CPR plus training to run a survey self-sufficiently) and can willingly walk you through the process. You can then join the Global Alliance of CPR Surveys (GACS), a coveted and close knit alliance that provides an amazing global observing service to the scientific community. We presented successful trade stands in Bergen (ICES annual meeting), Plymouth (Marine Technology Exposition), Liverpool (Challenger Society) and Glasgow (MASTS). Our blue t-shirts are getting noticed and each meeting introduces us to potential new collaborators and customers with leads already starting to bring in new funding opportunities for us.

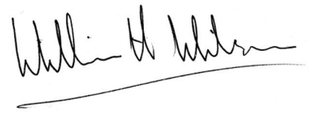
I was excited at our first tow in the Northwest Passage this year. We trained Devin Flawd to run the CPR on board the RRS *Ernest Shackleton* and we are eagerly awaiting results from data in this scientifically important region of the Arctic.
Our global reach of training also included scientists to operate the CPR in the Bay of Bengal (Dr Jyothibabu) and Southern Atlantic - South Georgia to Falkland Islands route (Victoria Foster). We take our training very seriously since these scientists go on to be the face of the CPR Survey and SAHFOS. In my discussions with them, I always emphasise that as CPR 'students' you become part of the SAHFOS family and we are always here to help. Credit must go to the operations team (Lance, Chris, Julian and Dave) who conduct the training with professionalism and enthusiasm, students always leave in good spirits.



Scientifically it has been another productive year, I am constantly amazed at the quality and quantity of high impact research publications that come from our scientists and CPR Survey collaborators. We have highlighted some of the best examples in this

report (note the virus publications by yours truly!). Noteworthy is the PNAS paper by our friend and colleague Luigi Vezzulli (co-authored by Martin Edwards, Pierre Hélaouët and Chris Reid) with a human disease angle that received considerable publicity. David Johns was a contributor to the RSPB State of Nature report which also received a huge amount of publicity at the time – SAHFOS contributed to the marine plankton trends noted in the report. I attended the launch of the report at the Royal Society where I bumped into Sir David Attenborough!

It was sad to see Roger Barnard retire after 25 years, I only knew him for a few months but it was instantly apparent to me that he had the respect and friendship of everyone at SAHFOS. I know he is missed, I wish you well in your retirement Roger. Finally I want to say thank you to all our staff, Trustees, Science Advisory Board, collaborators and volunteers who do an outstanding job at supporting SAHFOS.
I like to surround myself with brilliant people, it makes me look good!



Willie Wilson

Why should you support SAHFOS?

Donating to SAHFOS is helping to ensure the protection of our oceans by supporting plankton science. We can act together to safeguard a critical resource, contribute to maintaining healthy and sustainable oceans and encourage corporate social responsibility.

If you have an affinity to the ocean and plankton science, giving back by supporting the world's longest running most geographically extensive marine ecological survey, **no** matter how much, will make a difference. Giving is a reflection of inner values and can be **deeply fulfilling**.

Tax benefits can also be met from donating, in the form of **tax rebates**. It can be a good way to save up taxable income too.

As a business, donating to SAHFOS can help define **corporate identity**, show ethics and trustworthiness, define you as different from **the competition** and act as an important recruitment tool. Demonstrating social **and environmental** awareness and commitment to protecting our oceans can boost business reputation and become an essential part of a Corporate Social Responsibility programme. For staff it can help to enhance the importance of green issues as well as improve employee relations.

Giving to SAHFOS can also promote positive media coverage, better public relations and raise brand awareness an easy way to highlight to your customers (as well as potential new ones) that the company is dedicated to charitable causes.

There are many ways to show your support:

- Research grants
- Fellowships
- Specific donations
- Equipment donations
- Easyfundraising www.easyfundraising.org.uk/causes/sahfos/
- Directly through the SAHFOS website

SAHFOS already has a strong history of working partnerships through our networks of volunteer ships and we want to expand upon these mutually beneficial partnerships, inspiring others to work with us.

Our People

Prof Willie Wilson
Director

Mrs Gill Tanner
Director of Business Administration

Dr Sonia Batten
Director Pacific Survey

Roger Barnard
Marine Engineering Technician (until April)

Kate Brailsford
Administrator

Derek Broughton
Software Developer

Gemma Brice
Plankton Analyst

Martina Brunetta
Technician & Plankton Analyst

Clare Buckland
Plankton Analyst

Robert Camp
Plankton Analyst & Instrumentation Technician

Dr Claudia Castellani
Research Fellow

Dr Dave Conway
Contract Taxonomist

Prof Martin Edwards
Chief Scientist

Dr Astrid Fischer
Plankton Analyst, Technical Secretary to NMBAQC & Laboratory Assistant

Dr George Graham
Marine Instrumentation & Data Scientist

Lance Gregory
Operations & Workshop Manager

Nick Halliday
Contract Taxonomist

Chris Harris
Marine Engineering Technician

Dr Pierre Hélaouët
Research Fellow

Linda Horsfield
Administrator

Usha Jha
Plankton Analyst

David Johns
Plankton Analyst & Laboratory Manager

Mrs Tanya Jonas
Contract Taxonomist

Dr Priscilla Licandro
Research Fellow

Doug Moore
Plankton Analyst (Canada)

Julian Morley
Marine Engineering Technician

Jean Nyman
Finance Officer

Dr Clare Ostle
Post-Doctorate Research Assistant in Marine Numerical Ecology (from Feb)

Prof Chris Reid
Senior Research Fellow

Nicola Rickard
Fundraising & Publicity Manager

Dr Katrin Schmidt
Plankton Analyst

Jennifer Skinner
Plankton Analyst, Public Engagement & Education Officer

Marion Smith
PA to Director & HR Manager

Dr Rowena Stern-Kluckner
Molecular Plankton Ecologist

Darren Stevens
IT Manager

Claire Taylor
Plankton Analyst & Assistant Laboratory Manager

Dr Tony Walne
Instrumentation Technician

David Wilson
Ships Liaison Officer

Marianne Wootton
Senior Taxonomist

Claire Wotton
Plankton Analyst

Governance

SAHFOS is a company limited by guarantee with charitable status. Company Registration number 2563736 and Charity Registration number 1001233.

SAHFOS is governed by a Board of Trustees, who are also Directors under company law. In addition to the main Board, two sub committees have also been established:-

Science Advisory Board

Finance and Resources Committee

Our Director, Willie Wilson, has delegated responsibility from our Board of Trustees for the day-to-day running of the organisation.

Members of the Board of Trustees are elected at the AGM by the membership. The Board of Trustees appoints the Director who is accountable to the Board of Trustees.

Board of Trustees

Prof Peter Liss, CBE, FRS (Chair)
Prof Geoff Boxshall FRS
Prof Ann Bucklin (from April)
Mr Richard Coombs
Ms Beth Greenaway (until April)
Prof Paul Hart
Prof Patrick Holligan (Vice Chair)
Mr Rob Hubble FCA
Dr Samantha Lavender (from April)
Prof Jan Pentreath (until April)
Prof Judith Petts CBE (from April)
Prof David Southwood (from April)
Prof Peter Wiebe (until April)

Science Advisory Board

Prof Patrick Holligan (Chair)
Prof Geoff Boxshall FRS
Prof Martin Edwards
Dr Petter Fossum (until April)
Dr Kjell Gundersen (from April)
Dr Erica Head
Prof Mike Heath (from April)
Dr Stephanie Henson
Dr Tiziana Luisetti (from April)
Dr Julie Robidart (from April)
Dr Caron Montgomery
Dr Peter Wiebe (from April)
Dr Phil Williamson (from April)
Prof Willie Wilson

Our Fellows

Distinguished Honorary Fellows

Dr Bob Dickson CBE
Prof Robin Pingree

Emeritus Life Fellow

Dr Graham Hosie

Honorary Fellows

Prof Franciscus Colijn
Dr Paul Dowland
Dr Arnold Taylor
Dr Luigi Vezzulli

Research Fellows

Dr Gregory Beaugrand
Dr Anthony Richardson
Dr Declan Schroeder

Cost Effective, Proven and Reliable Since 1931

The Continuous Plankton Recorder

A platform for Integrated Ocean Observing

In addition to the traditional biological sampling undertaken by the CPR the towed body can be equipped with a range of sensing capabilities to extend its utility for integrated observing.

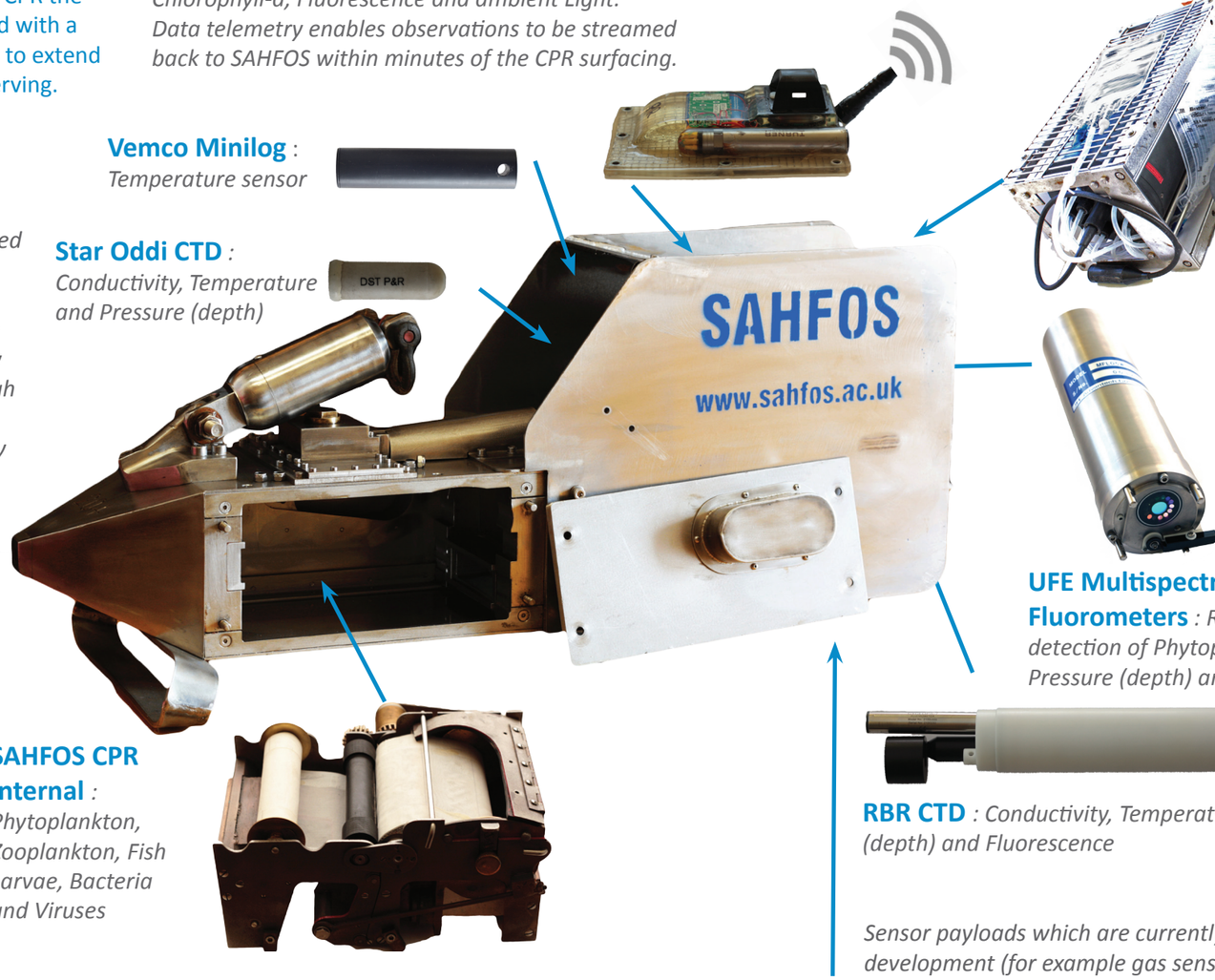
SAHFOS Planktag : *Conductivity, Temperature, Chlorophyll-a, Fluorescence and ambient Light. Data telemetry enables observations to be streamed back to SAHFOS within minutes of the CPR surfacing.*

SAHFOS WaMS : *Water and Microplankton sampler*

Vemco Minilog :
Temperature sensor

Seawater enters via the aperture. Plankton is captured on a filter silk band then covered by a further silk band. Long distances can be towed with the continuously moving band, wound through the CPR on rollers turned by gears, which are powered by a propeller.

Star Oddi CTD :
Conductivity, Temperature and Pressure (depth)



UFE Multispectral Fluorometers : *Rapid optical detection of Phytoplankton forms, Pressure (depth) and Temperature*

RBR CTD : *Conductivity, Temperature, Pressure (depth) and Fluorescence*

In 2016, on predominantly North Sea routes, instruments were routinely deployed on the top dive plane, front fin and rear cargo bay.

SAHFOS CPR Internal :
Phytoplankton, Zooplankton, Fish Larvae, Bacteria and Viruses

Sensor payloads which are currently under development (for example gas sensor for carbon dioxide concentration) can also be accommodated in the cargo bay.

Key Statistics

Length x width x height :
100 x 36 x 42 cm
Weight : 85 kg
Tow depth : 5 - 10 metres
Tow speed : 8 - 25 knots
Aperture size : 1.27 cm^2

Collects: Phyto- and Zooplankton, Fish larvae, Bacteria and Viruses.

Instruments record: Conductivity, Temperature, Depth, Chlorophyll-*a*, Fluorescence, ambient Light, and three-axis accelerations.

SAHFOS are involved with a range of ongoing and upcoming instrumentation projects. A range of developments are underway in our ability to communicate with instrumentation on the CPR and integrate more advanced sensing payloads with the CPR.

Interested in using our instrument data or wish to develop a project? please contact George Graham
geogra@sahfos.ac.uk

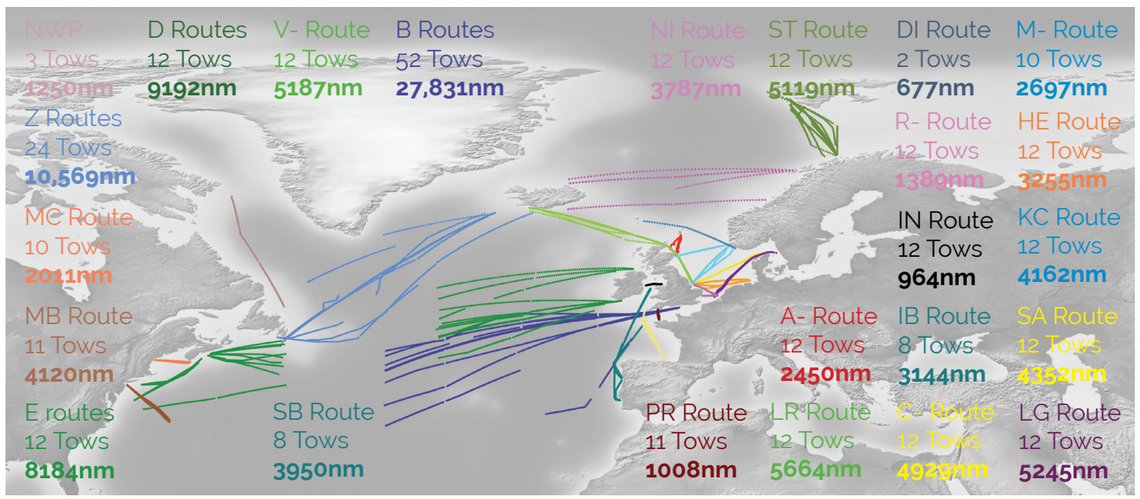
Operations

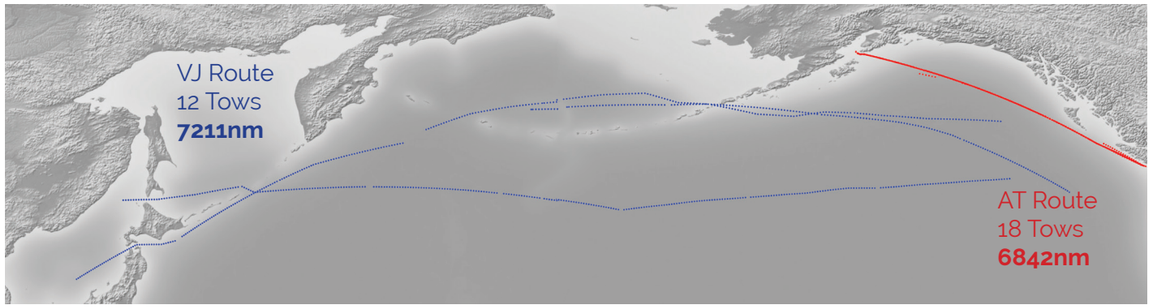
137,166 nautical miles towed in 2016

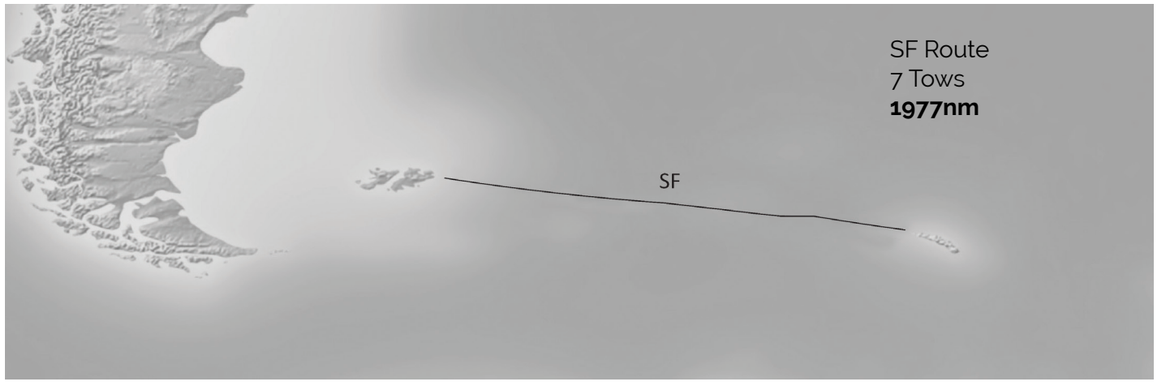
91.92% success rate

35 Routes regularly towed

6,647,274 nautical miles towed in total



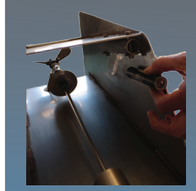




Services we offer : Operations

Purchasing a CPR

SAHFOS has a number of purchase or rental options available regarding our fleet of CPRs should you be interested in buying or renting one; from purchasing the basic set-up, renting for a one-off cruise or setting up a new survey and the complete set-up package.



Platform array

In addition to the capture of plankton samples, the CPR also offers an attractive payload platform for other environmental sensors. Our international fleet of CPRs have the capability to host additional sensory equipment which can provide remotely accessed data.

SAHFOS invites discussion regarding the potential suitability and availability of instruments which could be attached to a CPR on one or a number of our routes of scientific interest.

Training courses and workshops

SAHFOS hosts a series of workshops each year, offering essential training in plankton identification and technical CPR Survey operational skills. We can also offer bespoke courses across all levels, lasting from 1-2 days to 6 months or longer.

Course we run include:
IMarEST accredited CPR technical training: A 5 day practical course ideal for new technicians from established CPR Surveys or scientists/ technicians wishing to operate a CPR at sea.

Ship liaison course: A 5-day course for managers from established surveys and scientists wishing to begin a CPR Survey.

The CPR technical courses and ship liaison course can be combined to provide training in all operational tasks. **NR & LG**

For further information please contact lgreg@sahfos.ac.uk

Our robust and reliable CPRs

In 2016 SAHFOS CPRs towed 137,166 nautical miles and achieved a success rate of 91.92% on returned internals.

This is due to the inherent design of the CPR and to the dedication of the SAHFOS technicians who maintain them. To emphasise on how long lasting and robust the CPRs are; CPR 12 was first manufactured and used back in 1938 and is still in use on our regular routes today. LG

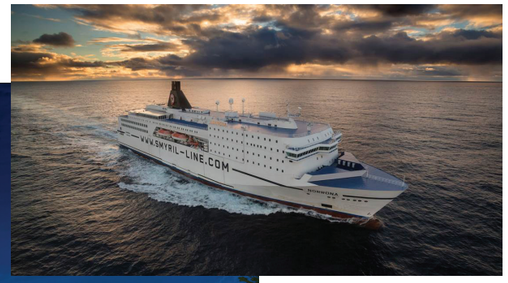
CPR 12 in regular use for almost 80 years.

Roger (centre) and the Operations Team.

Farewell after 25 years of service

Mid 2016 saw SAHFOS saying goodbye to Roger Barnard after 25 years of service to the CPR Survey. His technical expertise will be a hard act follow. We wish Roger well with his retirement as he explores the Cornish countryside in his three-wheeled sports car. LG

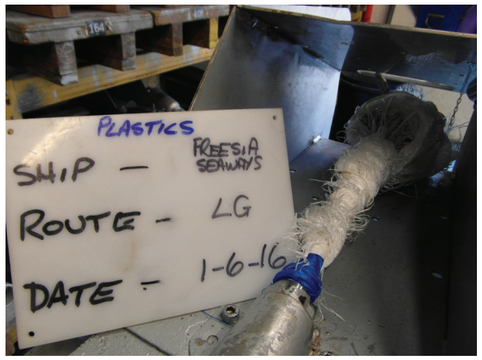
New route



The MV *Norrona* above. The new DI/DJ route left.

The Survey has just introduced a new regular route running between Denmark and Iceland via the Faroe Islands (DI/DJ route). We are very pleased to be working with the MV *Norrona* and Smyril Line, for what we hope is proved to be a scientifically valuable route. This is the first new regular route to SAHFOS' extensive network since the inception of the KC route in January 2013. LG

Plastic debris

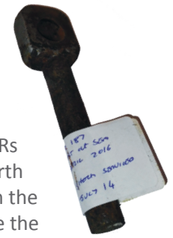


During 2016 we experienced above normal levels of CPR failures on the LG route (Ghent to Gothenburg), with jams recorded in April, May, June (image above) and July. These failures were due to heavy entanglement with plastic and fishing lines. The jams all appear to have happened near the beginning of the tow in the vicinity of Ghent.

We reversed the direction of the tow for the month of August. The CPR was again entangled with detritus but the silk had transported for nearly the whole of the expected length, allowing normal analysis of the route.

All UK based CPRs are now fitted with a blade on the propeller shaft (propeller protector image on right) and these have helped us to maintain a success rate of greater than 90% in areas of high debris. LG

Ocean tow tribulations



Unfortunately, the SAHFOS fleet lost three CPRs this year: one in the North Sea, one in the North Atlantic and one in an attempt to tow through the North West Passage. Two of these losses were the result of unusual occurrences that caused the 16 mm steel shock absorber pin (part number 1/33) to break. These pins have been tested to a breaking strain greater than 9.6 tonnes.

The SAHFOS workshop has now introduced an additional quality control measure (to its maintenance procedures). This enables us to trace the steel used in the manufacture of these pins to the original supplier. This also ensures that only the highest quality EN 16T grade steel is used during the manufacturing process. LG

Celebrating 85 years of partnership with the shipping community

With the CPR Survey and database growing in scientific importance with every mile towed, it is important to stop and reflect on the fact that we are very much a collaborative organisation and that the Survey is a shipping industry and SAHFOS joint endeavour. We are extremely grateful to our contacts in the shipping community, who assist us with the day to day running and logistics of the Survey. We operate a programme of port and ship visits so we can meet with the volunteers (calculated ~120) who do so much behind the scenes. Another enjoyable aspect of our job is when we go on-board to thank the Captains and crews of the towing ships. LG & DW

CPR logistics and new ships

Readers of this report will deduce that many of our routes are long-standing. This being said, the logistics chain does throw up some unexpected challenges and without the help of our portside volunteers we would indeed experience gaps in the time series of our Survey.

During 2016 we welcomed the volunteers in the port of Hirtshals, Denmark, who handle the boxes for the new DI/DJ route.

The *Encounter* that tows the SA route has had several alterations to her normal schedules this year. This has resulted in her going to Tilbury instead of Liverpool on several occasions.

In the port of Tilbury we have now made useful and important contacts with London Container Terminal. They are keen supporters of our work and have agreed to handle the CPR boxes ensuring continuity of this route.

At the very core of our Survey stand the volunteer ships. Without the Captains and crews co-operation we could not maintain our wide ocean scale coverage. LG & DW

Ships we welcomed to our volunteer fleet in 2016 (from L to R) *Primula Seaways* towed from August 2016 on the LG route. *Atlantic Sea* towed from November 2016 on the E and D routes. *Norrona* from December 2016 on DI/DJ route. *Vega Philipp* from December 2016 on SB and IB routes.

We wish to thank wholeheartedly the Owners, Operators, Charterers, Captains and Crews of all the vessels that tow and support our global Survey and extend a warm invitation to visit us any time at our Citadel Hill Laboratory in Plymouth, UK.

Dave Wilson : 12 months as SAHFOS' Ships Liaison Officer

"LIAISON" - Communication or Co-operation which facilitates a close working relationship between people or organisations.

Although a small organisation in numbers of employees, the weight of the scientific output to International and Global organisations far exceeds its size. I quickly grasped the importance of what the scientific plankton evidence tells us all (and the need for regular data received from our volunteers around the world). My job is to ensure each of our routes has a ship towing a CPR. By the very nature of life at sea, we have regular changes of ships and personnel and the danger is to have missed tows that break the continuous flow of data. My job fits snuggly into the definition at the top of this segment. It is my job to ensure each voyage route has minimal disruption throughout the year. When a ship that has been towing for us for a number of years comes to the end of its life, my job is to find a replacement. In general we can do a straight swap using the same owners with their new ship on that route. Sometimes it may be the same agent but a different owner with a different ship. There is an endless list of scenarios we can encounter; nevertheless good, clear and regular communication is the key. This year we had a number of ship changes and I am pleased to say all have been successfully replaced. We have a new route with a new shipping company and completely new towing arrangement and the first tows were completed in December 2016. I have paid visits to our port volunteers in Immingham, Liverpool, Faroe Islands and Iceland. Without them we could not operate the Survey. DW

A cup of tea and chatting science

On a recent visit to Iceland, Dave Wilson had the pleasure to see first-hand how Eimskip help the CPR Survey. On his tour of the warehouse and wharf he was introduced to Gísli Nielsson; a long established supporter and volunteer of the Survey, over a cup of tea they chatted about the long-standing partnerships between SAHFOS and shipping companies to aid science.

It was good to chat to Gísli as he has been involved with our CPRs for many years.

Gísli joined the crew of the MV *Largarfoss* in September 1974 but his first encounter with SAHFOS was when he joined the MV *Selfoss* in 1981. At this time MV *Selfoss* was voyaging between Iceland and the USA.

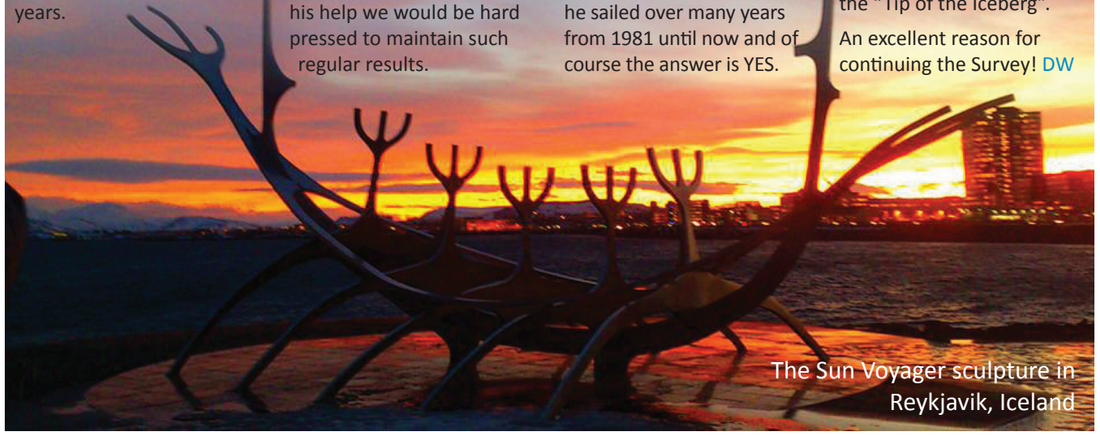
In 1990 Gísli hung up his sea legs and moved into the shore side operation of Eimskip in Reykjavik. Gísli is our main point of contact for the movement of our CPRs to and from the ships that sail from and return to Reykjavik and without his help we would be hard pressed to maintain such regular results.

He told me that all the crew he sailed with were very aware of what the CPR does and he confidently told me that he can speak for other mariners when he says that they are enthusiastic in helping the Survey. As seafarers, they know and appreciate how important the state of the ocean is! He certainly hopes we continue to inform and educate the crews of our volunteer ships.

Gísli asked me if I could let him know if we had found any changes in the routes he sailed over many years from 1981 until now and of course the answer is YES.

Several papers have been written on the North Atlantic based on the results of the CPR Survey. One item that sticks out is the phytoplankton *Neodenticula seminae* from the Pacific that can now be found in the Atlantic Ocean. Evidence suggests that due to reduced ice cover in the Arctic in the 1990's, this phytoplankton has been able to transit into the Atlantic Ocean via the North West Passage. We are unsure if this is an isolated incident or just the "Tip of the Iceberg".

An excellent reason for continuing the Survey! DW



The Sun Voyager sculpture in Reykjavik, Iceland

Training Courses

We offer bespoke training courses for persons operating CPRs. During 2016 we had the pleasure of running three distinct courses:

In Summer 2016, the Marine Institute of Memorial University of Newfoundland collaborated with SAHFOS on a pioneering voyage through the Northwest Passage to collect scientific data. Led by research scientist Dr. Jonathan Fisher from the Centre for Fisheries Ecosystems Research in St. John's, NL, this project aimed to collect baseline plankton data on board the RRS *Ernest Shackleton*, using CPR equipment. SAHFOS also provided CPR Operations training for visiting PhD student Devin Flawd, as well as logistics management and support throughout the trip. As climate changes continue to alter the Arctic cryosphere, the samples collected will provide valuable insight, for local and global communities, into the state of the ecosystem and help fill key knowledge gaps. LG & DF

Devin Flawd (2nd from the right) at the end of his course, with Lance Gregory, Julian Morley, Chris Harris and Willie Wilson.

Victoria receiving her course certificate from Willie Wilson

Victoria Foster is the next incumbent fisheries officer to be stationed on South Georgia with the British Antarctic Survey. Victoria will be looking after the SF route, with support from SAHFOS for the next two years.

British Antarctic Survey scientists have to be able to turn their hands to anything while working at King Edward Point (KEP), South Georgia, and this includes running the CPR. New to the role and with no prior knowledge of CPRs, I joined Lance, Chris and Jules in the SAHFOS workshop for a four-day training course. Whilst intensive, it was also very enjoyable and educational, and the team were fantastic.

The wild weather and large following seas make towing the CPR a challenge in the South Atlantic. However, on my first trip across from Stanley to KEP the Captain managed to get the CPR in for one full tow, allowing me to experience the entire process from deployment to re-loading the cassette. I am looking forward to maintaining such an important data collection service in what is otherwise a poorly studied area. VF & LG

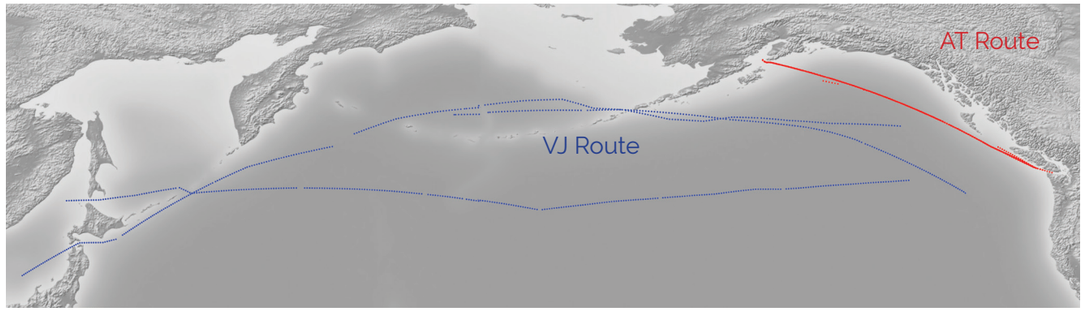
We welcomed Dr R Jyothibabu from CSIR, Kochi, India on a CPR Operations course. The course covers all the skills required to operationally run a CPR Survey, including the interactions with the ships and shipping community. Dr Jyothibabu has reported that subsequent to the course he carried out a successful first CPR tow in the Bay of Bengal from the ORV *Sindhu Sankalp*. LG

Dr Jyothibabu loading a CPR internal with Chris Harris.

Interested in attending one of our CPR Operations training courses? Please contact Lance Gregory lgreg@sahfos.ac.uk

Pacific Operations

There were no changes to the ships operating the Pacific routes in 2016, although the trans-Pacific VJ route continued to be variable, beginning offshore in spring, en route to Asia from California rather than British Columbia, and sampled well south of the Bering Sea in summer owing to storms. The autumn transect did follow the usual BC to Asia great circle route. The Washington state to Alaska (AT) route was towed 6 times as usual in 2016, again with very little variability in the transect position. SB



2016 Tows across the Pacific Ocean. The VJ route (in blue) usually tows across the higher pathway shown, but during the summer months transected across the lower route.

The CPR continues to expand globally

Over recent years we have seen the global footprint of the CPR increase significantly. The Operations Team has supported this effort in the main by supplying equipment, silks and ongoing technical support to the growing number of international sister Surveys.

In 2016 we exported to eight International partners and to-date 27 CAD (computer aided design) type CPRs and 75 CAD internals have been manufactured for sister Surveys. LG

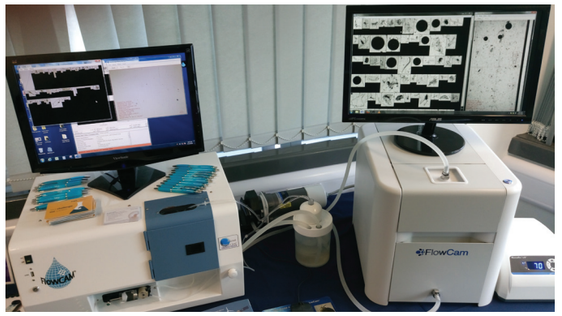
Merchant Navy Welfare Board visit

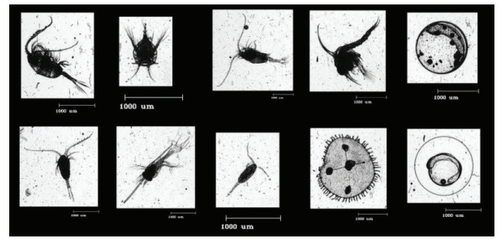
We were very pleased to welcome to our Laboratory the Merchant Navy Welfare Board for their annual meeting. This is just a small way in which we, as an organisation, can say thank you to the shipping community for over 85 years of continuing collaboration. We were fortunate in that we were able to give presentations and tours on our collaborative work to the meeting. We extended through the various member organisations an invite to host a visit for any visiting crews to Plymouth. LG

Showcasing our technology

At the 58th Marine Measurement Forum, at Plymouth Marine Laboratory, around 70 delegates from a wide variety of backgrounds were given the opportunity to explore the current research activities. Presentations were made by thirteen organisations as well as networking opportunities.
SAHFOS were given several slots, with Robert Camp presenting on the use of a FlowCam® Macro for rapid quantification and identification of zooplankton captured by CPRs (Fig. 1), and George Graham discussing his work in integrating additional autonomous sensors to the laboratory's fleet of CPRs. Antony Walne was also given an opportunity to share results from his work with the Water and Microplankton Sampler (WaMS) and preliminary data from the Multi-spectral fluorometers SAHFOS has recently purchased (see page 7).
There was a great deal of interest in all SAHFOS' presentations, particularly as we are the first institution to deploy most of these instruments, so others are keen to see results. RC

> We are the first institution to deploy these instruments, so there was a great deal of interest





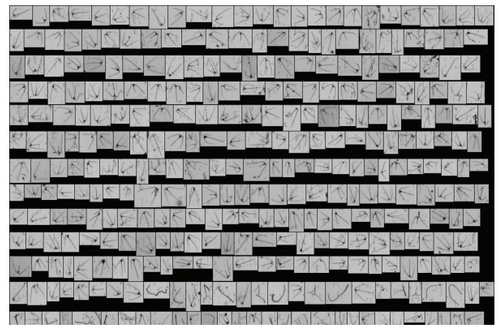


Figure 1. Above: Fluid Imaging Technologies Inc. FlowCam® on left and FlowCam® Macro on right.

The FlowCam® Macro, funded by AtlantOS, will be used for rapid zooplankton analysis to add value to CPR data including biovolume and functional groups.

Right: The FlowCam® Macro output. The machine is capable of imaging all particles 250µm – 5mm in real time. Functional groups can be categorised, and taxonomic libraries created.

Organised by Plymouth City Council the 'Marine Tech Expo' aimed to promote the city as a centre for marine technology, innovation and research. Experts from across the globe met with over 100 delegates to present and discuss research and business opportunities.
Delegates were given an opportunity to visit Plymouth's research vessel fleet, explore the marine station, and were given demonstrations of autonomous surface vehicles and blue technology in operation.

In addition to the SAHFOS trade stand, we achieved a world first – operating Fluid Imaging Technologies Inc. FlowCam® and FlowCam® Macro in parallel (Fig. 1), imaging all particles in a live sample from 2µm – 5mm in real time. The simplicity of both systems and the rapid rate of image acquisition demonstrates the potential to augment traditional analysis methods, as well as use of this technology in underway systems on research vessels and ships of opportunity.

Chaired by SAHFOS' George Graham, delegates heard presentations from keynote speakers on new frontiers of satellite applications, big data, future ship building, marine research, marine biogeochemistry and ocean observation, maritime cyber security, Oceansgate: Plymouth's newest world-class hub for marine industries, and presentations on exporting by UKTI. RC

Robert Camp demonstrating the FlowCam® Macro on the SAHFOS trade stand at the Marine Tech Expo.

Analysis

In 2016, just over 5000 samples were collected for analysis, from the North Atlantic and Pacific, with samples from previous tows in the South Atlantic also analysed (Fig. 2). The continued widespread nature of sample collection, and the wide variety of pelagic plankton captured, gives the strength to the Analysis Team.

The previous year's data (collected in 2015) were quality controlled and entered into the database ahead of schedule, ready for use in early summer. This was the earliest yet for data delivery and represents a great deal of hard work by not only the Analyst Team but SAHFOS as a whole.

During 2016, we continued to collect and store samples from the Gulf of Maine region, after the cessation of the program funding in previous years. However, despite the importance of this time series, difficult decisions will have to be made if adequate funding cannot soon be found.

Seventeen analysts (fourteen employees and three contractors) worked at SAHFOS in 2016, including two (Sonia Batten and Doug Moore) based in Canada.

In addition, a further three analysts (Sanae Chiba, Tomoko Yoshiki and Yuka Sasaki) worked on Pacific samples based in Japan.

SAHFOS is regularly approached to offer support to students with their projects and in the summer we hosted Dani Bridger, a PhD student from Plymouth University, who received plankton identification training.

Dani is investigating the effects of open ocean mussel farming on ecosystem services by studying a mussel farm currently being developed in Lyme Bay, Dorset.

To further develop strong links with Plymouth University, SAHFOS staff delivered a series of marine plankton ecology and taxonomy lectures/practical sessions on the MSc Marine Biology course in November - December.

As well as the training of external scientists and students, SAHFOS analysts regularly take part in internal training events. The highlight of the year was the Big Fat Plankton Quiz of the year, held in December. This is a team event where analyst's identification skills and background knowledge are tested with themed activities and a treasure hunt. This is a fun session aimed at minimising skills drift over time and highlights where an individual's strengths/ weaknesses may lie. DJ & MW

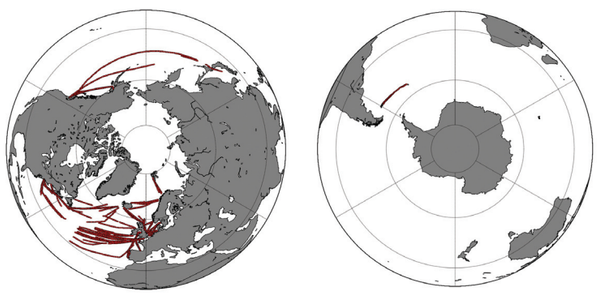
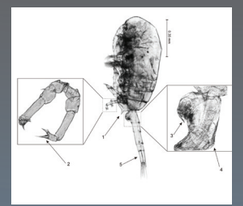


Figure 2. 2016 CPR sample map showing Southern and Northern Hemisphere tows.

Services we offer : Analysis

Considered an International Centre of Excellence for planktonic taxa identification and with experience in plankton analysis from around the world our experienced staff, who participate in the IPI NMBAQC scheme, are able to offer a range of services:



Sample Analysis

If you have collected plankton samples yourself we are able to offer analysis of the samples. We have expertise in:

- Fish larvae, phyto- and zooplankton taxonomy (morphological and molecular, harmful or nuisance) including organisms such as bacteria and gelatinous zooplankton, and viruses.
- Morphological and molecular analysis of plankton specimens, including preserved archival samples that pose a challenge to molecular analysis.
- Laboratory-based experimentation, e.g. zooplankton respiration and egg production rates.
- Bioinformatics analysis of next generation sequencing metagenetic datasets from marine environmental samples.

International CPR Survey Analysis

SAHFOS analysts can carry out all analysis from your CPR Survey. The tow length and area samples are collected from will determine the cost of analysis.

Training Workshops

We host a series of training workshops each year, offering essential training in plankton identification. Our taxonomic courses and workshops include:

- **International Marine Phytoplankton and Zooplankton Workshops:** Aimed at early career scientists, technicians, post-graduates and marine ecologists with a basic knowledge of marine phytoplankton and zooplankton.
- **Plankton Identification Training:** A 6-week intensive course aimed at CPR analysts from new or existing surveys, who have a basic knowledge across marine plankton.

We can also offer bespoke courses across all levels, lasting from 1-2 days to 6 months or longer. We are able to offer training in our own laboratories or can discuss conducting training at your facilities.

Our laboratory is exceptionally well equipped, with a wide range of microscopy equipment and an extensive taxonomic library. A range of bench fee options are available to use these facilities. **NR**

If you wish to discuss further any of the analysis services or training we offer please contact David Johns djoh@sahfos.ac.uk

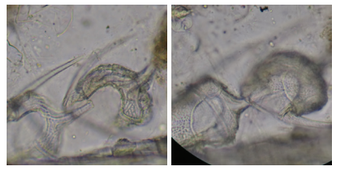
Taxonomy

Interesting and unusual biodiversity records

Phytoplankton

Some types of phytoplankton are known to produce toxins. When environmental conditions are favourable, they can reproduce in large numbers causing what is known as a Harmful Algal Bloom (HAB). Not only are these HABs damaging to other marine organisms, they can also be harmful to humans, causing a variety of shellfish poisoning symptoms. Of the species known to produce such toxins, approximately 70% belong to a group of dinoflagellates within the Class Dinophyceae. Within this group are the genera *Phalacroma* and *Dinophysis*, species of which are routinely recorded by the CPR Survey.

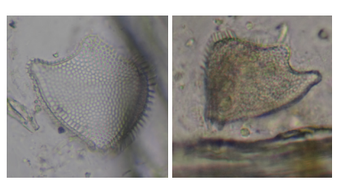
On the same October sample where the *P. favus* were found, another unusual dinoflagellate, *Tripos paradoxides* was identified; representing another first for the Survey. Despite the Survey routinely identifying almost 50 species of *Tripos* (previously known as *Ceratium*), there are no previous records of this taxa being found.



The dinoflagellate *Tripos paradoxides*, another first for the Survey in 2016

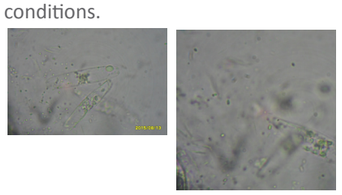
We may have been surveying for 85 years but 2016 saw four 'first for the Survey' species

In the Bay of Biscay region, a species new to the Survey, *Phalacroma favus*, was recorded on a sample taken in August and again in October. This species is known to be uncommon in North Atlantic waters and certainly represents an interesting find for the Survey. Peculiarly not all species of *Dinophysis* and *Phalacroma* are toxic; however, many species look morphologically very similar. If we are to understand the ecology of these organisms and potentially protect human health, accurate identifications must be made: highlighting the need for skilled and experienced taxonomists.



New to the Survey a *Phalachroma favus* recorded on August and October samples.

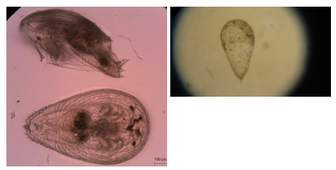
In 2014, we reported unusually high occurrences of the delicate diatom *Ephemera planemembranacea* in the region of the Orphan Basin north of the Grand Banks of Newfoundland, during summer months; such high abundances have not been observed in the Survey for over 20 years. Interestingly it appears that numbers show no sign of decreasing, with 2015/2016 again showing widespread blooms in this same region and time of year, with blooms also stretching eastwards into the northern mid Atlantic. This diatom is associated with cold boreal-type waters and its persistence in this region perhaps indicates a change in hydro-climatic conditions.



The diatom *Ephemera planemembranacea*, which was first described in 1988 by the CPR Survey from a collected specimen.

Zooplankton

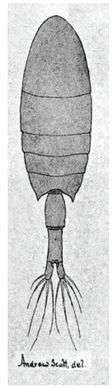
In 2016 the Survey recorded its first ever facetotecan larva, or 'Y-larva' found on a sample taken from the western English Channel in March. Despite being first described over a century ago and found throughout the world, facetotecans are curious organisms whose adult stage is yet to be discovered in the wild. They belong to the taxonomic subclass Thecostraca, a group which includes the cirripedes, commonly known as barnacles. Resembling cirripede larvae in appearance, they possess a distinctive faceted-like carapace, from which they derive their name. In experiments designed to determine what these larvae might metamorphose into, when exposed to hormones known to induce moulting and development in cirripedes, facecotecan larvae are transformed into an uninspiring worm-like blob. This indicates that their adult form is most likely to be a type of endoparasite, perhaps explaining why the adult stage, so far, remains undiscovered.



A facetotecan larva, or 'Y-larva'

Our taxonomists not only have to identify species they are familiar with, but be skilled to recognise new species they have never seen before

On a November 2015 sample, the CPR Survey recorded its first ever *Calanopia americana* in North Atlantic waters. *C. americana* is a small copepod, measuring between 1-2mm in total length and belongs to a family of copepods known as the Pontellids. Unlike most other copepods, Pontellids often possess well developed eye lenses and are renowned for inhabiting surface waters. In contrast, *C. americana* lacks the distinctive optical structures associated with the family and is known to undergo strong vertical migration: mostly living at depth during the day and accumulating in surface waters after sunset. The CPR specimen was taken from a sample collected after midnight in the west Atlantic, to the southeast of Nantucket, on the southernmost edge of the Georges Bank. Although *C. americana* is common around the gulf coasts of the eastern USA, its northernmost range is only thought to extend up to North Carolina, and is recognised as sub-tropical to tropical species. As well as being new to the CPR Survey in this region, the occurrence of *C. americana* so far north of its typical distribution also appears to be highly unusual. MW



The copepod *Calanopia americana* issued from A. Scott in Siboga-Expedition, 1909

International Plankton Sample Archive

Unlike most other biological surveys, SAHFOS archives all of its CPR samples and has approximately half a million samples in storage, which, although priceless would cost an estimated £125 million to build a similar archive. Collected throughout the history of the Survey and with samples dating back to the 1950s, the SAHFOS CPR archive is the largest, most geographically expansive, plankton archive in the world.

Samples are stored and carefully curated, providing a bank of specimens for future analysis. Despite routine CPR samples being preserved in formalin, recently developed molecular techniques have proven to be successful in the genetic analysis of phytoplankton, zooplankton and bacterioplankton specimens. Retrospective analysis has so far taken place on topics such as fisheries, cholera and micro-plastics in the marine environment and has led to the publication of many peer-reviewed publications.

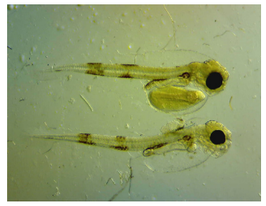
The sample archive has proven to be an invaluable resource and has allowed researchers to travel back in time to look at samples, many of which have been collected decades ago. The CPR Survey holds in its hands a unique and globally significant heritage asset waiting to be explored. MW, NR & AF

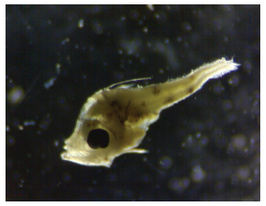
Should you want to know more about the Archive or wish to develop a project please contact Marianne Wootton mawo@sahfos.ac.uk

SAHFOS now holds the archive for NOAA samples

The Narragansett Laboratory, part of the National Oceanic and Atmospheric Administration (NOAA), has run the MB and MC routes since the 1970s, see map right for sample positions. Unfortunately, a lack of funding for these transects meant that the CPR Survey could no longer be operated by NOAA and in 2014 SAHFOS made the decision to continue to operate these routes to avoid a gap in this valuable time series. In June 2016, NOAA transferred their sample archive to the UK and SAHFOS received 120 boxes filled with samples. These are now being processed for further curation and will join the ever expanding SAHFOS global plankton archive. MW & AF

Fish Larvae Identification Workshop



In November, SAHFOS held a three-day introductory fish larvae identification workshop.

Despite the economic and environmental importance of fisheries research and monitoring, opportunities to gain hands on taxonomic training in fish larvae identification are rare; there have been no known open workshops such as this in Europe for over 15 years.

Lectures were delivered by Nalani Schnell (Muséum National d'Histoire Naturelle, France), Cindy van Damme (Wageningen Marine Research, The Netherlands) and Chris Lynam (Cefas, UK). This practical course covered: fish egg identification; lifecycle and development; sampling and preservation methods; policy; and key larval identification features to 13 common North Atlantic families.

The course was well received and attended by 18 participants from across the UK and Europe. MW & AF

We advertise all of our taxonomic workshops on our website. For bespoke courses please contact Marianne Wootton mawo@sahfos.ac.uk


Images. Top left to right: Fish larve: *Callionymus* spp., *Gadus morhua*, *Gadus sp.*, *Bregmaceros sp.*,
Bottom left: Practical laboratory session. Bottom right: Group photo outside Citadel Hill Laboratory.

Zooplankton Ring Test

The Northeast Atlantic Marine Biological Analytical Quality Control Scheme (NMBAQC) is represented by SAHFOS via Astrid Fischer (Technical Secretary) and David Johns (current Chair). The group receives feedback from the Healthy and Biologically Diverse Seas Evidence Group (HBDSEG), who also help with the development of new areas for the scheme. As chair, David attends the HBDSEG group, who meet quarterly.

After a trial run two years ago, in 2016 SAHFOS organised the first international NMBAQC zooplankton ring test, and received sign-ups from 12 laboratories from 5 countries worldwide. This ring test aims to ensure that participating laboratories make the correct identification in zooplankton analysis. The test consists of practical identification, written and enumeration tests. The ring test will be concluded by a workshop held at the Citadel Hill Laboratory to discuss results in March 2017.

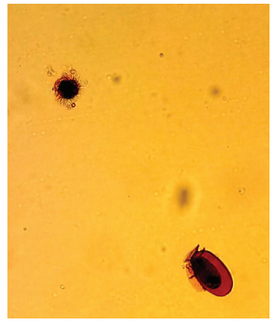
NMBAQC also runs similar ring tests for benthic invertebrates, fish, macroalgae, particle size analysis and, in collaboration with the Marine Institute Ireland, for phytoplankton. To ensure competency in phytoplankton analysis, Astrid Fischer took part in the International Phytoplankton Inter-comparison exercise for SAHFOS and received a 100% score in the taxonomic identification part of the harmful algal blooming species test. AF

Interested in participating in an accreditation ring test? Please contact Astrid Fischer acfi@sahfos.ac.uk

Harmful Algae Taxonomy and Identification Workshop

Harmful algal blooms (HABs) are a natural phenomenon that can have potentially devastating effects on human health, coastal economies and the environment. Some phytoplankton species, which appear in high concentrations, either cause the water to be unsuitable for the life of fish and mammals, or produce toxins that can travel through the food web, posing a serious threat to human health.
In August 2016, Martina Brunetta represented SAHFOS amongst 17 participants on the 1st U.S. Course on Harmful Algae Taxonomy, held over two weeks, at Bigelow Laboratory for Ocean Sciences in East Boothbay, Maine. The goal of the course was to pass on to the new generation the knowledge of some of most accomplished experts in the field; to provide a comprehensive and certified training needed to effectively and accurately identify HAB species; and to create and maintain a network of managers, scientists and technicians involved in HAB monitoring. The course comprised lectures on harmful algae genetics, automated detection methods, electron microscopy, sampling, settling and counting techniques. Internationally renowned taxonomists Dr Rita Horner, Dr Karen Steidinger and Dr Carmelo Tomas led the participants through numerous lectures followed by hands-on sessions, where around 60 species were described and examined under light microscopy.
Considering the rapid increase in global aquaculture production, monitoring HAB events and understanding their ecology, with the final aim to reduce or prevent their impacts, is becoming an ever more pressing priority. Light microscopy identification remains the standard, quick and cost-effective approach to early-warning and monitoring, and it is able to offer a crucial support for the development and validation of nontraditional monitoring tools, more rapid or automated methods to count and identify HAB species. MB





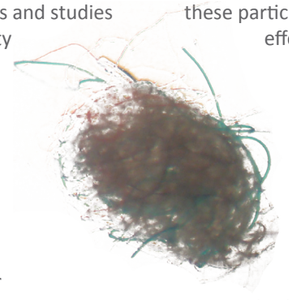
Images. Top: A plankton bloom. Below L to R. Participants on practical exercise. *Dinophyisis acuta* inside the tintinnid *Favella sp., Dinophysis acuminata* approaching its meal (*Mesodinium sp.*)

Monitoring of microplastics

Pollution of the marine environment by litter has received increasing media attention over recent years and studies suggest that plastics account for the majority of debris entering our oceans. The impact that large pieces of plastic have on marine animals is often distressingly obvious, with entanglement causing deep lacerations and, in the case of air breathing animals, suffocation.

However, as these large pieces of plastic begin to physically break apart, they can fragment into potentially millions of smaller pieces of microplastic.

Microplastics typically measure less than five millimetres and come from a wide variety of sources: from monofilament fishing gear to clothing fibres.



With experimental research demonstrating the uptake of these particles by several zooplanktonic groups, their effect on the marine environment is unknown and a growing concern around the globe.

Microplastics have been recognised on CPR samples for a number of years and in 2004 the SAHFOS Survey began to officially record their presence on individual samples. Although the presence of microplastics in the ocean is thought to be ubiquitous, little quantitative information is known. In an attempt to try to address this question, in summer 2016, the Survey began trailling a new method of recording microplastics found on CPR samples by documenting particle size, type and abundance. MW

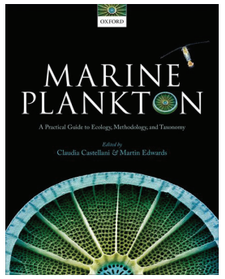
Our Impact

SAHFOS is involved in a wide variety of research activities, ranging from blue-sky research and new technologies, to policy-driven work. As such, research is carried out not only by the Research Group at SAHFOS, but also in the wider scientific community all over the world, by researchers, students and in major research projects.

We published 36 peer-reviewed papers and produced 15 technical reports

Our 2016 publications have already been cited 86 times

Our Global Change Biology article: “Global impacts of the 1980s regime shift.” was one of 2016’s most-download article
*according to Web of Science®



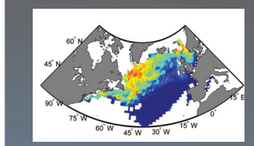
We edited and contributed to several chapters in this extensive book on Marine Plankton


Chapter 12

Sea Life (Pelagic and Planktonic Ecosystems) as an Indicator of Climate and Global Change

We contributed to 26 book chapters

Services we offer : Research

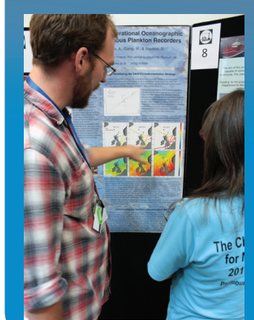


Collaborations

We have expertise in:
- Ecology, macro-ecology and marine environmental change
- Numerical data analysis and modelling
- Molecular techniques

Data

Data lies at the heart of SAHFOS, it is a valuable resource to us and the wider scientific community. Our plankton observations, ancillary datasets and associated metadata are freely available to collaborating researchers conducting research into global change and environmental science.



Consultancy

In addition to offering CPR data, the team at SAHFOS can provide expert knowledge, independent and impartial advice or provide evidence for a wide range of marine scientific projects.

Staff have already provided advice and reports to Non-Governmental Organisations, governmental bodies, Competent Monitoring Authorities and private companies, at both national and international levels, on a variety of plankton-themed areas of work.

If you wish to discuss further any of the research services we offer, please contact Willie Wilson wilwil@sahfos.ac.uk

Our Expertise

In 2016 SAHFOS researchers gave expertise to the organisations below; either through providing data, their membership on working groups, committees and steering groups or through consultancy.

Cefas · INSITE · ipbes · AWI · JNCC Joint Nature Conservation Committee · pogo

International Council for Science SCOR Scientific Committee on Oceanic Research · European Environment Agency · MARS The European Network of Marine Research Institutes and Stations · Sea Mammal Research Unit Instrumentation · SEPA Scottish Environment Protection Agency · GACS Global Alliance of Continuous Plankton Recorder Surveys

British Antarctic Survey Natural Environment Research Council · National Oceanography Centre Natural Environment Research Council · PML Plymouth Marine Laboratory · UK Biochar Research Centre

ICES CIEM · OBIS Ocean Biogeographic Information System · OSPAR Commission Protecting and conserving the North-East Atlantic and its resources · EUROMARINE European Marine Research Network · The Global Ocean Observing System GOOS

PICES · MCCIP · cnrs · BODC · United Nations · NMBAQC Scheme

rspb giving nature a home · Iceland Liechtenstein Norway eea grants · The Marine Biological Association Est. 1884 Incorporated by Royal Charter · UNESCO · IOC · Scottish Association for Marine Science · EcAp PRHA Ecosystem Approach to Regional Habitat Assessments This project is co-financed by the European Union

defra Department for Environment Food and Rural Affairs · Met Office · EMODnet · Marine Ecosystems Research Programme · Foreign & Commonwealth Office · European Commission

Institute of Marine Engineering, Science & Technology IMAREST · Marine Institute with Plymouth University · NERC Science of the Environment · The Royal Society · cig Chelsea Technologies Group · CNOOC nexen

Research Highlights

Plankton indices explain interannual variability in Prince William Sound herring first year growth

Pacific herring (*Clupea pallasii*), once an important fishery in Prince William Sound (PWS), were affected by the 1989 oil spill. The stocks have never recovered but the reasons why are still not clear - disease, predation by humpback whales and environmental variability could all play a role. There has been continued funding by the Exxon Valdez Oil Spill Trustee Council for research on herring as well as the oceanography of the region, and for the last five years SAHFOS has been part of the long-term monitoring programme funded alongside the herring program. Batten *et al.*, 2016 represents the first published collaboration between the two groups.

Scale measurements of the first year growth of the herring were made from 4-6 year old fish. While the scale data extends back for 30 years, there is a decade of overlap with CPR sampling from the Alaskan shelf adjacent to PWS, which should provide data on the productivity of the wider shelf area. Interannual variability in first year growth showed a strong relationship with plankton indices (Fig. 3), stronger than temperature, and only with plankton groups that would be appropriate-sized food for the first-feeding herring. While first year growth is only one factor in the success or otherwise of the fish, it is one step in understanding the stock variability. SB

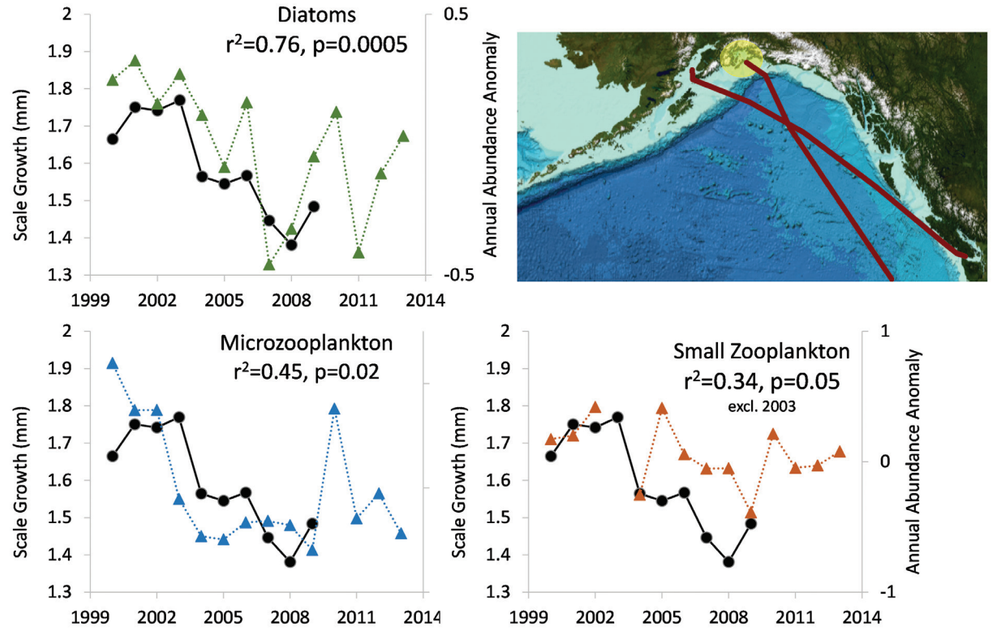


Figure 3. Map, top right, shows location of Prince William Sound (yellow) and the CPR transects (red lines) that provided the shelf plankton data. Graphs show herring first year scale growth (black lines with circles) versus annual abundance anomalies of selected plankton groups (coloured lines with triangles). Small zooplankton are those organisms <2mm. Microzooplankton includes ciliates that can be counted in CPR samples, such as tintinnids and foraminifera. Correlation between time series in each case is shown on each graph. Non-significant relationships occurred with plankton >2mm (not shown).

Batten, S. D., S. Moffitt, W. S. Pegau and R. Campbell (2016). "Plankton indices explain interannual variability in Prince William Sound herring first year growth." Fisheries Oceanography **25**(4): 420-432.

Resetting nature's clock: shifting seasons and species relationships

Every year, many of us look in fascination at the movement of nature's clock, looking forward to seeing wild plants coming into bloom or the arrival of the first swallow. Less obvious, but just as dramatic, populations of plankton bloom below the surface of seas and oceans. However, the timing of these seasonal events is changing, often because these changes in seasonal biological events are sensitive to climatic conditions. For this very reason, they continue to be used by the Intergovernmental Panel on Climate Change (IPCC) as tangible indicators of global warming. Shifts in the biological seasons are likely to have significant effects upon ecosystems, and the goods and services that they provide to society, now and in the future. Importantly, species have been changing their seasonal behaviour by different amounts over time, and this could disrupt the seasonal relationships between plants and animals. To understand what the consequences of these changes are likely to be, it would be useful to know which species groups are most, and least, sensitive to climate change. This would allow us to identify species that are particularly effective climate change indicators, and to make some tentative projections of what the future might have in store.

Species that change their seasonal behaviour by different amounts over time, could disrupt seasonal relationships between plants and animals, and the ecosystem function

In a recent study we combined a wealth of biological records from the UK, for as many species as possible, both from the terrestrial and aquatic environments, and information on the climatic conditions that might be affecting their seasonal activities. These incredible datasets were gathered not only by professional scientists, but also by voluntary citizen scientists. Altogether, we gathered more than 370,000 records for over 800 aquatic and terrestrial plant and animal species, collected over many years. We then related the seasonal behaviour of plants and animals to local temperature and rainfall. Furthermore, we developed a new statistical method to assess which parts of the annual temperature or rainfall cycle species were most sensitive to. Importantly, we examined and compared how much the seasonal activities of different species groups, such as plants and herbivores, predators and prey, change with temperature and precipitation.

We examined and compared how much the seasonal activities of different species groups, such as plants and herbivores, predators and prey, change with temperature and precipitation

Using this approach, we were able to show that the seasonal activities of UK plant and animal species are less sensitive to rainfall than to temperature.

We found predatory species were less responsive to climate change than prey species

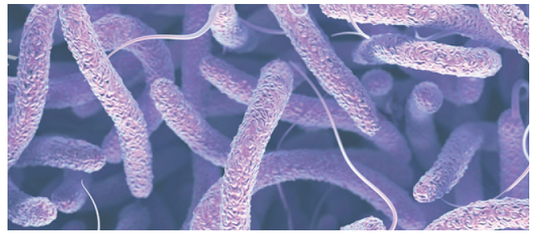
Generally, many natural seasonal events occur earlier under warmer conditions. It was also clear that species are usually sensitive to temperature changes only in certain periods of the year. A clear pattern was that this temperature sensitivity varied among species at different levels in the food web. In particular, we found that predatory species were less responsive to climate change than prey species. This was the first time that such a pattern had been observed among so many species and habitats, and at a national scale. Changes in the relative seasonal timings of predators and their prey may alter food webs, with implications for UK biodiversity and ecosystem health. If, as predicted, climate warming continues into the future, then the disparity in responses of predators and prey is also likely to increase. Interactions between species are complex, with changes in one species likely to have knock-on effects for others, which may result in effects that cascade throughout ecosystems.

We must now make every effort to understand the extent to which these effects may be realised, and to do this, we must recognise the immense value of long-term ecological research, and continue to invest in this activity. Crucially, environmental change often acts through complex networks of species interactions and relationships, and so we must also take care to monitor at the whole-ecosystem scale. Without this long-term view, we will be unable to detect emerging threats or to learn from our successes and failures in local environmental management and mitigation. ST & DJ

Spring flowers emerging in the snow - a more common event?

Thackeray, S., **P. Hélaouët**, **D. G. Johns**, **M. Edwards** *et al.* (2016). "Phenological sensitivity to climate across taxa and trophic levels." Nature **535**(7611): 241-245.

Vibrio infections on the rise as climate change warms oceans

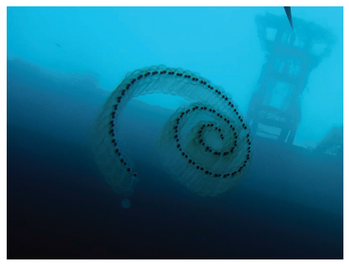


Climate warming may explain why in recent years more people appear to be contracting *Vibrio* infections from swimming in the ocean and eating seafood. Bacteria represent the largest living biomass in the world's oceans. Most are not harmful to humans, however *Vibrio*—a genus which includes several deadly human pathogens such as the headline-grabbing, flesh-eating bacteria—can be acquired by eating undercooked seafood or exposing an open wound to seawater.
With climate warming increasingly linked to rising ocean temperatures, researcher Luigi Vezzulli and colleagues investigated how these changes are impacting marine bacteria. Focusing on the North Atlantic and North Sea, the researchers examined preserved plankton samples, collected between 1958-2011 by the CPR Survey, and reconstructed how *Vibrio* species populations have fluctuated during the last century. Based on statistical correlations and modelling, the researchers determined that increases in sea surface temperatures promote long-term increases in *Vibrio* populations. Furthermore, these expanding concentrations of *Vibrio* may explain recent increases in human infections, based on an analysis of documented *Vibrio* infections, known to be caused by species contained in the CPR samples, in Northern Europe and the Atlantic coast of the United States. LV & ME

Researchers determined that increases in sea surface temperatures promote long-term increases in *Vibrio* populations

Vezzulli, L., **P. C. Reid**, **P. Hélaouët**, **M. Edwards** *et al.* (2016). "Climate influence on *Vibrio* and associated human diseases during the past half-century in the coastal North Atlantic." Proceedings of the National Academy of Sciences: 201609157.

Plankton influences seasonality of pH



Biology is a strong driver of seasonal changes in pH, which can show high variation at differing spatial scales. The increase in pH shown in Figure 4 is primarily due to the spring bloom of phytoplankton, with high photosynthetic activity, decreasing the amount of dissolved CO_2 and hence hydrogen ions. The lower pH in the autumn is likely due to the increased abundance and activity of non-photosynthetic marine organisms, including phytoplankton predators (zooplankton), decomposers (mostly bacteria) and benthic invertebrates. Respiration by these organisms returns CO_2 to the seawater (decreasing the pH), and deepening of the mixed layer follows, mixing carbon rich waters to the surface, which continues to lower the pH (Fig. 4). Upper ocean pH values are highest in spring, and lowest in autumn at L4. These changes reflect the seasonal cycles in photosynthesis, respiration (de-composition) and water mixing. CO

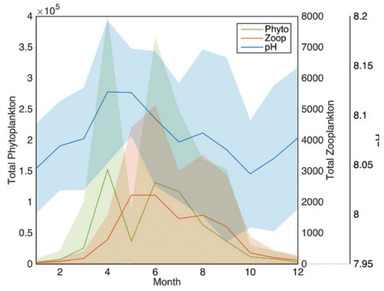


Figure 4. Monthly mean total phytoplankton counts = green, and total zooplankton counts = red, collected within 5° radius of L4 (station within the English Channel), and calculated pH at L4 = blue from 2008 to 2013. The shaded area represents the standard deviation.
Image left: RRS *Discovery* CTD view of salps

Ostle C., **M. Edwards** *et al.* (2016). "Carbon dioxide and ocean acidification observations in UK waters: Synthesis report with a focus on 2010 - 2015". Defra

Does grazing shape the seasonal bloom?

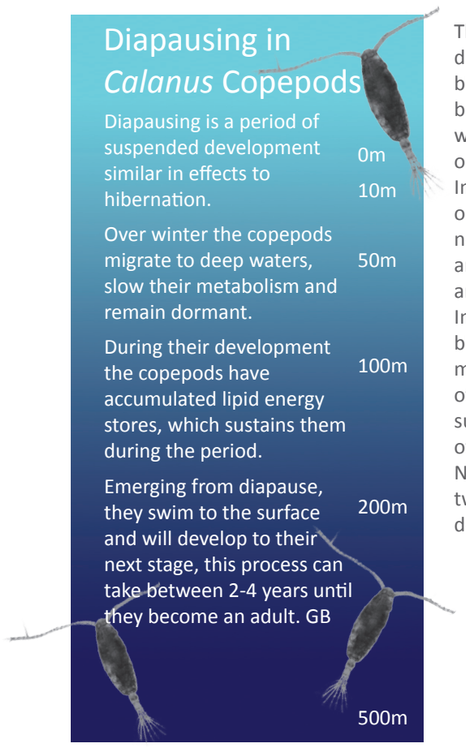
Diapausing in *Calanus* Copepods

Diapausing is a period of suspended development similar in effects to hibernation.

Over winter the copepods migrate to deep waters, slow their metabolism and remain dormant.

During their development the copepods have accumulated lipid energy stores, which sustains them during the period.

Emerging from diapause, they swim to the surface and will develop to their next stage, this process can take between 2-4 years until they become an adult. GB



The North Atlantic Ocean contains diverse patterns of seasonal plankton blooms, the first bloom of the year begins during spring into summer with later bloom start dates generally occurring at higher latitude.
In regions where spring blooms occur at high frequency, they show a negative correlation between timing and duration, indicating early blooms are longer lasting.
In much of the north-east Atlantic, bloom development extends over multiple seasons resulting in a peak of chlorophyll concentration in summer. Based on the characteristics of spring and summer blooms, the North Atlantic can be classified into two regions either having 1) a well-defined within seasonal bloom; or, 2) a bloom extended over multiple seasons. We tested the hypothesis that the distribution of diapausing (see box left) copepods (*Calanus finmarchicus*, *C. helgolandicus*, *C. glacialis*, and *C. hyperboreus*) may contribute to the contrast in bloom development between these two regions.
Peak abundance of diapausing copepods was generally associated with areas having a well-defined seasonal bloom, implying a link between shape and diapausing copepods. This suggests either that grazing is a factor in shaping the seasonal bloom or that bloom shape determines whether a habitat is conducive to diapause, and both factors can re-enforce each other. DJ

Friedland, K. D., **D. G. Johns** *et al.* (2016). "Seasonal phytoplankton blooms in the North Atlantic linked to the overwintering strategies of copepods." Elementa: Science of the Anthropocene **4**(1).

First evidence of global regime shift provided by the CPR Survey

A stepwise increase after the mid-1980s in the Phytoplankton Colour Index (PCI), sampled by the CPR in the seas around the UK, provided the first evidence for what was later called a regime shift in the North Sea. Significant statistical evidence from 72 long time-series demonstrated that this regime shift centred in 1987 occurred a planetary scale.
The event is evident in a wide range of the Earth's biophysical systems ranging from the atmosphere (stratosphere and troposphere) winds, pressure, storms, carbon dioxide, temperature; to the depths of the oceans, currents, biology (including PCI), temperature, salinity; on land, in rivers and lakes, river flow, pH, biology, phenology (e.g. seasonal timings), forest fires, temperature; to the cryosphere, sea-ice, snow and in the carbon sinks of the land and oceans.

The 1980s regime shift was much larger than any similar event, previously or since, within the last century and probably within the last 1000 years, based on evidence of the flowering dates of cherry blossoms in Japan.

Using simulations from a group of IPCC models (CMIP5) and statistical modelling, it is hypothesised that the mechanism for the regime shift is a rapid rebound that followed cooling induced by the major El Chichón volcanic eruption in 1982, when natural and anthropogenic forcing combined to produce a sudden acceleration in global warming. The scale and speed of the increase in temperature that followed after the regime shift is considered to be the main forcing of the cascade of environmental changes at this time, although volcanic and human aerosols, interactions with clouds and global brightening may also be involved. PR

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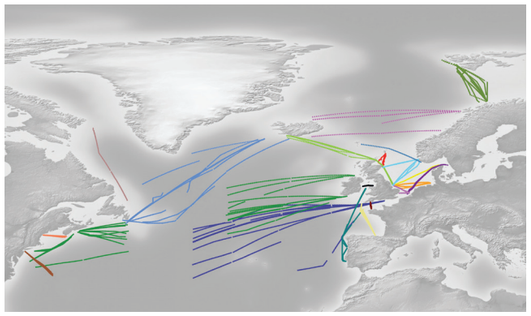
Reid, P. C., *G. Beaugrand, *E. Goberville *et al.* (2016). "Global impacts of the 1980s regime shift." Global Change Biology **22**(2): 682-703. doi: 10.1111/gcb.13106

Developing priority variables

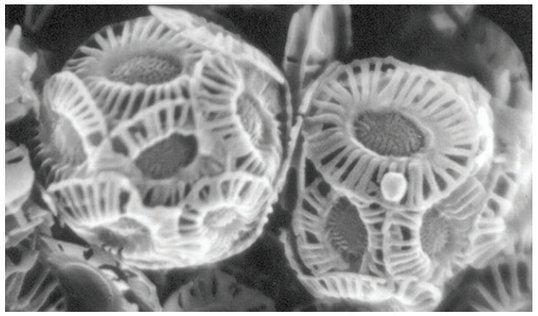
A key component for the success of producing Essential Ocean Variables is the need for the variable to have a high impact in responding to scientific and societal needs and crucially to have a high feasibility of sustained observation. Ocean observations are the 'bread and butter' of ocean and climate change science and the network of CPR surveys operating around the world were seen as a critical ongoing network for a sustained and internationally coordinated effort for biological observation at the global scale. ME



The sample tows of 2016 in the North Atlantic; the CPR Survey (which operates globally) has a wide coverage of the Ocean.

Constable, A. J., **M. Edwards** *et al.* (2016). "Developing priority variables ("ecosystem Essential Ocean Variables"—eEOVs) for observing dynamics and change in Southern Ocean ecosystems." Journal of Marine Systems **161**: 26-41.

Indigestion in copepods!



Scanning Electron Microscope image of *Emiliania huxleyi* cells; the right hand cell has a virus attached to it.

When the coccolith (chalk) covered microalga, *Emiliania huxleyi*, is infected by viruses, it becomes unpalatable to copepod grazers, appearing to give them a rudimentary form of indigestion. This virus-induced grazing dynamic could alter food web structure likely, resulting in lower food web efficiency. Clearly the role of viruses, beyond simply killing cells, must be considered in modelling the oceanic food web. WW

Vermont, A., J. M. Martínez, J. Waller, I. Gilg, A. Leavitt, S. Floge, S. Archer, **W.H. Wilson** and D. Fields (2016). "Virus infection of *Emiliania huxleyi* deters grazing by the copepod *Acartia tonsa*." Journal of Plankton Research.

Jellyfish: sink or swim

The cnidarian jellyfish *Muggiaea atlantica* is a main component of the plankton community at low-to mid-latitudes in the three major oceans. In the late 20th century expansion of the species' distribution has been reported in different regions, including the Mediterranean and the South Pacific.

As increasing occurrence of *M. atlantica* has been recently reported in Scottish coastal waters, a study was undertaken to verify whether this change represented the establishment of resident populations, or transient populations reliant on immigration. Results show that on the west Scottish coast (Loch Ewe) the interannual variability in the species' abundance was significantly determined by immigration via the surface continental slope current. However, on the east coast (Stonehaven) results were less conclusive, probably due to the less direct influence of the surface Continental Slope current. PL

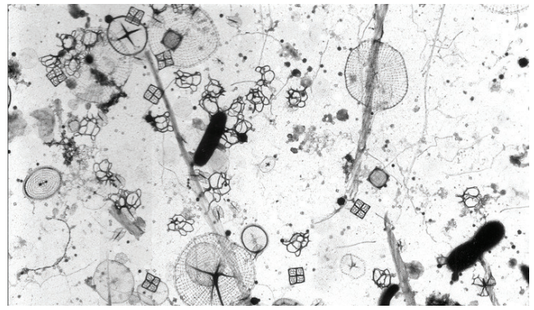
A *Muggiaea atlantica*. Image credit Mike Blackett.

*Blackett, M., C. H. Lucas, K. Cook and **P. Licandro** (2016). "Occurrence of the siphonophore *Muggiaea atlantica* in Scottish coastal waters: source or sink?" Journal of Plankton Research.

Viruses in the ocean

Viruses are extremely abundant in the ocean, with anywhere between 1 million to 100 million observed in a teaspoon of seawater. All these viruses play important roles in cell death, nutrient cycling (through release of organic matter from dying cells) and horizontal gene transfer. As obligate parasites they require a host, hence measuring virus-host ratios can provide information on the functionality of viruses in a given ecosystem.

It had previously been accepted that this ratio was typically 10:1; however, detailed global analysis of virus-host numerical data in this paper revealed a wide variation in ratios. The data are important because by measuring some straightforward virus-host numerical information it may provide clues to ecosystem functioning. WW



Transmission electron micrograph of scales from different marine flagellates, bacteria and virus-like particles in a seawater sample from coastal Norway. Viruses are by far the most numerous biological entity in the ocean. Image courtesy of Gunnar Bratbak and Mikal Heldal, University of Bergen, Norway.

Wigington, C. H., **W. H. Wilson**, *et. al.* (2016). "Re-examination of the relationship between marine virus and microbial cell abundances." Nature Microbiology **1**: 15024.

Using CPR data to test models

Projections of plankton biogeography under future climate change scenarios are increasingly used as a tool to manage marine resources in the medium and long term. CPR Survey Data (Fig. 5) was used to test the reliability of the main statistical species distribution models which are currently used to predict future plankton distribution. Results show that plankton might be particularly challenging to model, due to their short life span and highly variable dispersion, and that a strong spatial variations in model accuracy exists. The relationship between the occurrence of a species and its surrounding environment are unique and may even vary for the same species within a large study area. Consequently, the potential performance of a projection has to be thoroughly assessed and critically communicated. PL

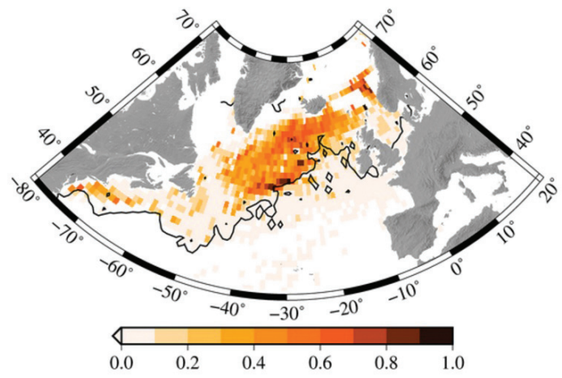


Figure 5. Spatial pattern of True Skill Statistic (TSS) for random forest model predictions of *Calanus finmarchicus*. TSS is a metric indicating the overall performance of the model, with the highest TSS value indicating correctly predicted presences and absences of the species.

Brun, P., T. Kiørboe, **P. Licandro** and M. R. Payne (2016). "The predictive skill of species distribution models for plankton in a changing climate." Global Change Biology **22**: 3170-3181.

Zooplankton as ocean fertilisers

During digestion, zooplankton absorb or recycle nutrients and trace elements

When asked about the role of zooplankton we immediately think of them as the food source for fish, seabirds and whales.
Indeed, zooplankton have a central position in pelagic food webs linking organic carbon from microscopic algae to higher trophic levels.
However, there is more to zooplankton than being a dish for charismatic megafauna – they also fertilise the ocean. Key to this is their strong gut flora that allows them to digest silicified, calcified or otherwise armored microorganisms. No wonder, copepods guts have been described as 'biogeochemical hotspots' when their combination of low pH, anoxia and powerful enzymes was first discovered. Thus, during digestion, zooplankton also absorb or recycle nutrients and trace elements that are incorporated in their food.

Why is this recycling of nutrients so important? Most algae have high requirements for nitrogen, phosphate and iron, and with a lack of these nutrients they cannot continue their photosynthesis and may even die. Deep mixing of the water column in winter usually re-supplies surface waters with nutrients for the spring bloom.
However, recycling processes become more and more important later in the season when the water column is stratified and most nutrients have already been taken up by algae. Interestingly, in some regions primary production is limited by the lack of nitrogen (e.g. low-latitude oceans), while in others it is the lack of iron (e.g. eastern equatorial Pacific and the Southern Ocean) or phosphate (many lakes).

Zooplankton grazing can be beneficial to phytoplankton blooms

We studied the iron-cycling by Antarctic krill at the island of South Georgia (Southern Ocean). Our first finding was that krill sampled near glacial outlets contained more lithogenic particles (tiny bits of rock) in their stomachs and more iron in their tissue than specimens off-shore.
The high iron concentrations in the krill tissue most likely derived from their ingestion of glacial flour which is naturally rich in iron. Until now, it was only known that zooplankton can recycle iron that is already incorporated in organic material, but our study shows that their gut flora are strong enough even to absorb iron from inorganic sources such as lithogenic particles.
These bits of rock can derive from river discharges, wind-blown dust, melting glaciers or re-suspended seabed sediment – and zooplankton including copepods, euphausiids, mysids, amphipods, salps and even ciliates often ingest them during their suspension feeding.
Therefore, the mobilisation of lithogenic iron during gut passage may not be restricted to krill but wide-spread among zooplankton.

Krill gut flora are strong enough even to absorb iron from inorganic sources such as litho-genic particles (tiny rocks)

Our calculations suggest that at South Georgia substantial proportions of the phytoplankton iron demand can be supplied via this previously over-looked pathway.

Our second finding was that even in years with high krill grazing impact at South Georgia the phytoplankton bloom was not entirely suppressed, but rather displaced downstream of the krill habitat. There, the blooms were more intensive and longer lasting than in years with low krill abundances at South Georgia. Processes that led to these intensive blooms are not yet entirely understood, but most likely on-shelf iron mobilization and recycling by krill and other heterotrophs plays an important role. Overall, our study underlines that zooplankton grazing can be beneficial to phytoplankton blooms, just as well-managed livestock grazing maximises growth and biodiversity in meadows on land. KS

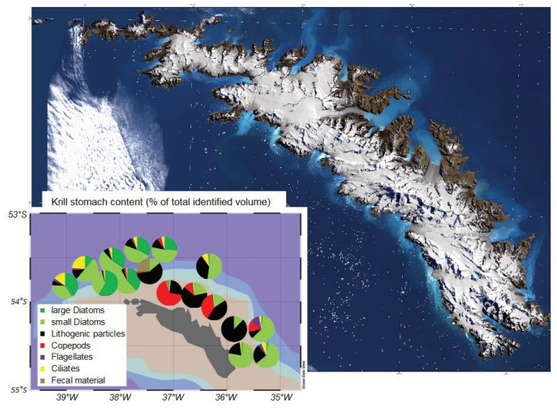


Figure 6: Krill grazing at South Georgia. Land satellite image showing glacial flour in freshwater plumes in coastal waters of South Georgia. Inset graph: Stomach content of freshly caught krill.

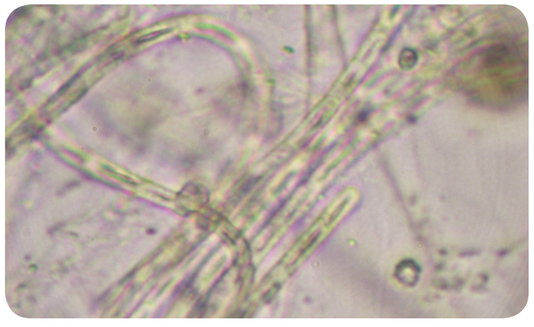
Schmidt, K., C. Schlosser, A. Atkinson, S. Fielding, H. J. Venables, C. M. Waluda and E. P. Achterberg (2016). "Zooplankton gut passage mobilizes lithogenic iron for ocean productivity." Current Biology **26**(19): 2667-2673.

Trichodesmium in cold North Atlantic waters

Trichodesmium were found year-round in North Atlantic

Trichodesmium, blue-green algae, are responsible for half of the global marine nitrogen fixation. They are unique in that they can use dissolved nitrogen when organic nitrogen sources are limiting but have very high iron requirements. Numerous studies have related *Trichodesmium* blooms with Saharan iron-rich dust deposition in the subtropical and tropical Atlantic, yet little is known about *Trichodesmium* at higher latitudes. Investigations of interdecadal variability in *Trichodesmium* distributions in the temperate and subpolar North Atlantic, challenge the view that it requires temperatures above 20°C. *Trichodesmium* was present year-round outside of the tropics, in higher latitudes of the North Atlantic (38-65°N) for the last five decades. Furthermore, matching *in-situ* temperature measurements for each CPR sample with the International Comprehensive Ocean Atmosphere Data Set (ICOADS) showed presence of *Trichodesmium* in waters with temperatures ranging between 0-27°C.
Since *Trichodesmium* variability appeared to be decoupled from trends seen in other phytoplankton groups also surveyed with the CPR, the study focused on potential drivers that would have a greater differential effect on *Trichodesmium* : 1) iron fertilization from African dust deposition, 2) nitrogen supply, or 3) drift associated with reversals of the Portugal Current.
It is proposed that these episodic increases could be explained by iron inputs from African dust, perhaps in combination with nitrogen limitation in the region or drift. Based on model simulations, none of the other two alternative hypotheses could be considered as sole drivers but may have contributed to the iron fertilization effect. It is suggested that *Trichodesmium* distribution has been underestimated and biased by physiological limitation assumptions derived from laboratory studies. Resolving the question of whether or not there is a *Trichodesmium* strain capable of fixing nitrogen at colder temperatures is important, as the whole-ocean nitrogen budget remains uncertain.
Having an accurate picture of global *Trichodesmium* distributions is crucial in projections for the nitrogen cycle under future elevated CO_2 conditions, the increasing anthropogenic nutrient deposition, desert dust variability and stratifying oceans. SR-C & DJ

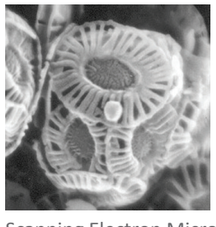
Possible drivers for *Trichodesmium* increases are increased dustiness, nitrogen limitation and drift



Trichodesmium on a CPR sample

*Rivero-Calle, S., C. E. Del Castillo, A. Gnanadesikan, A. Dezfuli, B. Zaitchik and **D. G. Johns** (2016). "Interdecadal *Trichodesmium* variability in cold North Atlantic waters." Global Biogeochemical Cycles.

Virus hijacking



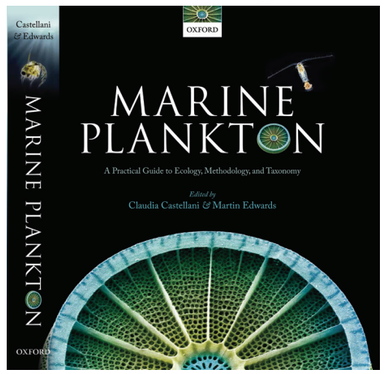
Scanning Electron Microscope image of *Emiliania huxleyi* cells; attached in the centre of the cell is a virus.

During virus infection of the phytoplankton *Emiliania huxleyi*, the virus hijacks the host replication machinery to make multiple progeny viruses, which ultimately leads to host cell death. During this dramatic transformation from life to death, the metabolism of the infected host cell changes completely to facilitate the production of new viruses. It is a process that is controlled by the genetic blue print (genes), and how these genes are switched off and on (gene expression). Virus infection leads to a cascade of significant changes in the expression of host genes, which likely leads to the observed reduction in photosynthetic performance of the infected host. WW

Gilg, I. C., **W. H. Wilson** *et al.* (2016). "Differential gene expression is tied to photochemical efficiency reduction in virally infected *Emiliania huxleyi*." Marine Ecology Progress Series **555**: 13-27.

Book Chapter Highlights

Marine Plankton: A Practical Guide to Ecology, Methodology and Taxonomy



SAHFOS is delighted to announce the release of Marine Plankton - A Practical Guide to Ecology, Methodology and Taxonomy. A comprehensive guide, written by SAHFOS staff and collaborators, and edited by **Claudia Castellani** and **Martin Edwards**.

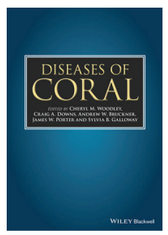
Marine Plankton provides a practical guide to plankton biology and it is divided into three sections: an overview of plankton ecology; an assessment of methodology in plankton research covering sampling, preservation and counting of samples; and a taxonomic guide richly illustrated with detailed line drawings to aid identification. This is an essential reference text suitable for senior undergraduates and graduate students taking courses in marine ecology (particularly useful for fieldwork) as well as for professional marine biologists. It will also be of use to environmental scientists, conservation biologists, marine resource managers, environmental consultants and other specialised practitioners.

State of Nature 2016

'It's not too late to save UK nature but we must act now' - is the conclusion from a coalition of more than 50 leading wildlife and research organisations behind the State of Nature 2016 report. Following the groundbreaking State of Nature report in 2013, leading professionals from 53 wildlife organisations pooled expertise and knowledge to present the clearest picture to date of the status of our native species across land and sea. This includes plankton data from SAHFOS. The report reveals that over half of UK species studied have declined since 1970, while more than 1 in 10 (1,199 species) of the nearly 8,000 species assessed in the UK are under threat of disappearing from our shore altogether.

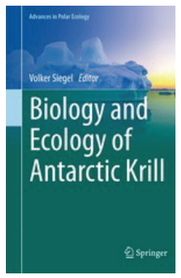
Sir David Attenborough launched the State of Nature 2016 report in London.

Diseases of Coral



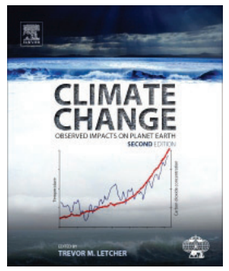
Chapter 19. **Wilson W. H**. and Woodley C. M: Viruses and coral disease; This book chapter summarises the state of knowledge on the role of viruses in coral disease. Very clearly they have been under-reported despite high observations of viruses associated with corals. Increased temperature associated with warming events appears to exacerbate coral disease and although this is a classic trigger for inducing latent virus infections, they are rarely considered as the causative agent. Recent research on marine viruses is starting to redress this balance.

Biology and Ecology of Antarctic Krill



Chapter 5. **Schmidt, K**. and A. Atkinson: Feeding and food processing in Antarctic krill. Antarctic krill (*Euphausia superba*) is a keystone species in Southern Ocean foodwebs. This book gives a unique insight into the current knowledge of krill population dynamics including distribution, biomass, production, recruitment, growth and mortality rates. Detailed analysis is provided on food and feeding, reproduction and krill behaviour. The volume provides an overview on the aspects of natural challenges to the species, which involve predation, parasites and the commercial exploitation by a growing krill fishery. The chapter on feeding and food processing covers traditional topics such as their feeding mechanisms and ingestion rates, but also current-day concerns such as the effect of increased temperature, melting sea ice and ocean acidification on their feeding abilities, and the role of krill in Southern Ocean carbon flux and nutrient cycles.

Climate Change: Observed Impacts on Planet Earth



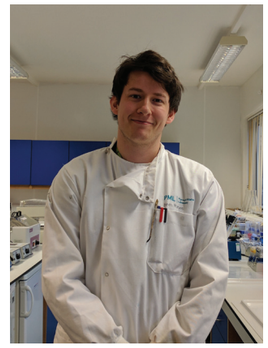
Chapter 11. **Edwards, M.** Sea Life (Pelagic Ecosystems) focuses on the epipelagic zone, which comprises 71% of the planetary surface, where biological production, biogeochemical cycles and marine food webs are maintained by the inhabiting planktonic organisms. The highlighted case studies collectively indicate that there is substantial observational evidence that many pelagic ecosystems, both physically and biologically, are responding to changes in regional climate caused predominately by the warming of sea surface temperatures (SST), ocean current changes and to a lesser extent by the modification of precipitation regimes and wind patterns. The biological manifestations of climatic variability have rapidly taken the form of biogeographical, phenological, biodiversity, physiological, species abundance changes, community structural shifts and whole ecological regime shifts. Summarising the observed case studies, of note is the sensitivity and rapidity of the pelagic and planktonic response, be it biogeographically or phenologically, to climate warming and global change compared to their terrestrial counterparts.

Explaining Ocean Warming: Causes, scale, effects and consequences

Chapter 1. **Reid, P. C.** Ocean warming: setting the scene and Chapter 3. **Edwards, M**. (2016). Impacts and effects of ocean warming on plankton: Ocean warming may well turn out to be the greatest hidden challenge of our generation. This report represents the most comprehensive review to date on ocean warming. To build up the report, leading scientists from around the world were invited to join with colleagues to contribute individual chapters. It contains many recommendations from the scientists on capability gaps and research issues that need to be resolved if we are to tackle the impacts of ocean warming with greater confidence in the future. The focus of the report is on gathering facts and knowledge and communicating this to show what is now happening in and to the ocean. There is purposefully much less focus on political ramifications.

Our Students

The role of viruses in methanol cycling in the marine environment



Kevin Purves is a PhD student with Willie Wilson

Kevin is investigating virus-host interactions of methanol-degrading methylotrophic bacteria. These bacteria oxidise methanol to formaldehyde, which is the intermediate step required for assimilative (growth) and dissimilative (energy) metabolism. The impact of viral infection upon these organisms is a novel area of research, which will help to further clarify the gaps in knowledge surrounding the global methanol budget sinks and sources. This is important as methanol is the second most abundant organic compound within the atmosphere (after methane), and is the more reactive compound: with a lifetime of a few weeks compared to methane at one decade. This multi-disciplinary project derives methods from microbiology, virology and biogeochemistry, and is facilitated by supervision available across the country. This project, based at Plymouth Marine Laboratory is a Doctoral Training partnership (DTP) with the EnvEast DTP, which allows Kevin to benefit from all the advantages associated with these partnerships and provides a network of contacts in different fields.

Investigating the effects of large scale changes in prevailing conditions on plankton community indicators

Jacob Bedford is a PhD student with David Johns

Jacob's research is contributing to our understanding of the influence of large scale climate variability and climate change on plankton communities. He is working on integrating the CPR data in the North Sea with a 'rescued' dataset of plankton surveys undertaken by ICES between 1902 and 1912. This can help increase the temporal scale at which we understand climate change impacts on plankton, and develop methodologies for comparing plankton data from other sources with the CPR dataset. Based at Plymouth University's Centre for Marine Conservation and Policy Research, his project focuses on the application of this understanding of climate-driven plankton community change to the development of indicators for the EU Marine Strategy Framework Directive. This is because the status of plankton communities must be assessed relative to 'prevailing conditions', therefore requiring a thorough understanding of the climatic influences on plankton indicators. He is also exploring the potential applications of plankton climate change indicators derived from the CPR Survey to the assessment of the wider marine ecosystem.

Spatial and temporal variation of copepod body size in the North Atlantic

Olivia Moudy and Miriam Pierotti (pictured) are Master students with Claudia Castellani

Recent studies have indicated that global warming will result in a spatial reorganisation of marine communities favouring an increase in smaller species. Such changes are predicted to affect both marine food webs and biogeochemical cycling through decreases in total biomass, in the size fraction available to higher trophic levels and in downward carbon export. Because of their high abundance and trophic position at the base of the food web, accurate determination of zooplankton size is key for the estimation of biomass and productivity within marine systems. Yet, data on zooplankton size, particularly over wide spatial and temporal scales, are rare. Predictive ecological models estimate zooplankton biomass mainly using temperature-size relationships. This approach is likely to result in gross estimate errors, which at the present remain unquantified. The present study assesses spatial and temporal changes in zooplankton size for the North Atlantic, through a reanalysis of the CPR samples. We found considerable temporal and regional variation in copepod prosome length across the basin mainly in relation to temperature and Phytoplankton Colour Index (PCI, as a proxy for food availability). The results of this study were presented at a seminar held at the Wood-Hole Oceanography Institute (WHOI) in October 2016.

Our Congratulations

Our congratulations go to Dr Clare Ostle who completed her PhD with the University of East Anglia and SAHFOS. Her thesis 'How does plankton distribution and activity influence the variability of carbon dioxide uptake in the North Atlantic?' Pictured on right with primary supervisor Carol Robinson.

Data

Data lie at the heart of SAHFOS, they are a valuable resource to us and the wider scientific community. Our plankton observations, ancillary datasets and associated metadata are freely available to collaborating researchers and conducting research into global change and environmental science. We actively encourage and promote use of CPR data in order to accelerate scientific progress. Applications for data access via our Data Request Form found on our website. NR

80 Data Requests

36 Papers Published

>3 million Taxonomic abundance data entries

>250,000 Sample records

Most popular requests:
Calanus finmarchicus
C. helgolandicus
Phytoplankton Colour Index
Total Diatoms
Total Dinoflagellates

Most rare taxa requests:
Blepharocysta
Fusopsis
Podolampas

The most requests came from: *United Kingdom*

The most requests came from: *Universities*

Newcomer to our data?

We offer aggregated datasets which are consistent over the time of the Survey, and provide a wealth of information without the overload of 'raw' data. Likewise, data can be requested from Standard Areas as monthly means, again making the data-sets more user-friendly. Our staff have many years' experience using the data, and regularly offer advice and suggestions to external scientists, which builds collaborations and is a benefit to all. DJ

Interested in using our data? For further information check out our website or contact David Johns djoh@sahfos.ac.uk

Our Website

www.sahfos.ac.uk

25% of website traffic arrives directly

12% of traffic is generated through our social media

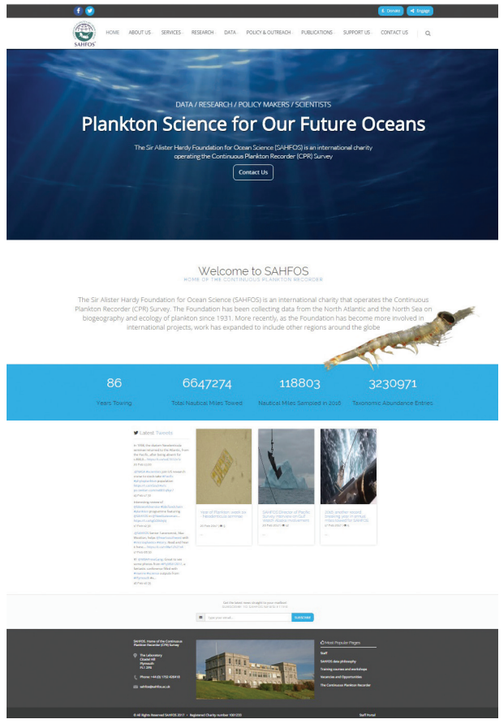
The internet is an effective tool of communication for SAHFOS and, following months of considerations, research and planning, a refreshed SAHFOS website was launched in April 2016.

We wanted to improve navigation, streamline the amount of data available online, encourage more direct interaction and improve usability. The website is now an ongoing working tool for SAHFOS.

Using Google Analytics we have been monitoring which pages work and which do not and altering pages accordingly.

Visitors are now spending longer on our website and the number of return visitors has also increased.

According to Google Analytics, more website visitors are going directly to the SAHFOS website, as opposed to looking for it through a search engine first (e.g. Google). Since the refresh, nearly 25% of website traffic is arriving directly on our website. 12% of traffic was generated through our social media channels. NR & DS



Our data are interactive

We have entered unchartered territory in SAHFOS' virtual representation. It is now possible to interact with the CPR data online – producing charts and maps showing the temporal and spatial distribution of CPR data. Check it out on our website (www.sahfos.ac.uk) underneath the Data tab. NR & DS

Data Sharing

SeaDataNet

SAHFOS benefited this year from our collaboration with the AtlantOS community to give us a clear idea on the way ahead, for data sharing and interoperability. From the conversations with our AtlantOS partners it has been decided that SAHFOS will continue to submit our plankton data to EMODnet/OBIS. SAHFOS will become established as a SeaDataNet node and our physical data will be sent to SeaDataNet. The decision has also been taken to provide our data, where possible, in netCDF format to allow for easier integration into ocean web services.

SAHFOS has also entered into an agreement with the US National Data Repository to make data from the CPR samples collected from the Western Atlantic openly accessible online. DS

Information Technology

The investment in the development and testing environment and the virtual infrastructure has paid dividends during 2016, allowing the IT department to work on servers and services in relative safety away from the production environment. Key services (i.e. documentation management, the SAHFOS Image Library, and Geoserver) which were put on hold, have been actioned, allowing staff and users to make use of new functions and services. The testing environment has pushed this work forward faster than in previous years and will continue to do so with the development of a new version of CPR Console and other data products. The IT dept have also designed an IT asset database, for use across the Citadel Hill site, allowing closer monitoring of hardware, software and support contracts, resulting in easier forward planning for upgrading and expansion of services and equipment.

The GACS Database Technical Team were able to push ahead with suggestions for the recording of micro-plastics – consistent across all Surveys. At present SAHFOS has adopted the same system as our AUSCPR partners, this is being trialled with a decision on the way ahead to be made early 2017. DS

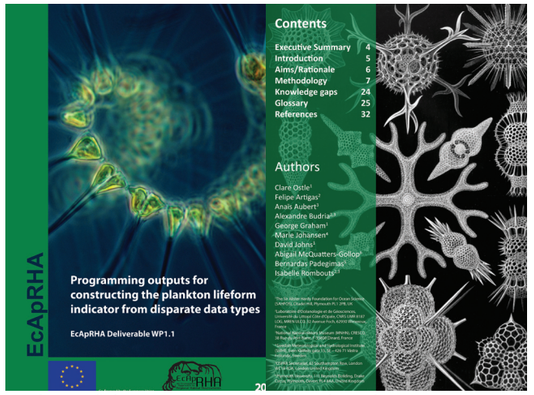
Policy

Since its inception, CPR data have always been used to answer questions, initially for fisheries but rapidly expanding to include climate change, human health and many other topics, as the dataset increased in length and questions changed. One key area where SAHFOS has been involved for many years is policy science. What do we mean by this? Well, SAHFOS has endeavoured to ensure its work, scientific outputs and the questions we continue to ask are relevant to the wider community and can provide answers to benefit society as a whole. When we are asked 'why should I care about plankton', SAHFOS has a solid background in applying its science to emerging issues from the wider community.

During 2016, we continued to deliver evidence-based advice to policy makers and ecosystems managers, through the interaction in UKMMAS and HBDSEG, as well as many UK and International bodies: Defra, MCCIP, OSPAR, EMODnet, ICES, RSPB, American NSF and Canada DFO. Those of you who have been regular readers of our Annual Reports, and who follow our science, will know that a key area of work has focused on the EU Marine Strategy Framework Directive. Much of this work is led and championed by a former SAHFOS employee, Dr Abigail McQuatters-Gollop, and we are grateful for her continued support of the Survey. SAHFOS is involved in developing and improving 'Indicators' that provide an insight into the health of the marine environment, at both the national and international level. We were involved in an international project to develop indicators at an EU level, EcApRHA 'The Ecosystem Approach to (sub) Regional Habitat Assessment'.

SAHFOS has endeavoured to ensure its work, scientific outputs and the questions we continue to ask are relevant to the wider community and can provide answers to benefit society as a whole

The EcApRHA project aimed to address gaps in biodiversity indicator development for OSPAR (Oslo Paris convention for the protection of the seas) regions. This project involved a large consortium of international research groups, including SAHFOS, PML, Plymouth University,



Findings of the EcApRHA project work package

MNHN, IEO, CNRS, Cefas, JNCC, BioConsult and more. Work packages within the consortium were divided into food webs, benthic and pelagic habitats, with an aim to integrate regional assessments from the habitat to an ecosystem level. SAHFOS were strongly involved in the pelagic habitat assessments with CPR data contributing significantly to the deliverables, and feeding into the OSPAR 2017 Intermediate Assessments, and initial implementation of the Marine Strategy Framework Direction (MSFD) to develop approaches for region-specific common indicators. The reports of different indicator approaches and integration techniques from this project can be found on the OSPAR website. (www.ospar.org)

This project highlights the success of international policy and science coming together to co-ordinate developments for the protection of our seas and resources, and the importance of continuing to support such initiatives and collaborations. DJ & CO

British Science Week

In partnership with the Marine Biological Association, we welcomed 120 primary and secondary school children to Citadel Hill for 3 days of marine science activities.

Plymouth University

We delivered a series of lectures & identification practicals to students, as part of the MRes Biological Oceanography course.

8th Aquatic Virus Workshop

We organised this international workshop. Over 80 delegates focussed on advances in the field of aquatic virology, the exchange of ideas, new methods and developments.

Bioblitz

This annual event aims to count the number of species in a specified location over 24 hours. This year over 1024 species were recorded on Plymouth Hoe.

Merchant Navy Welfare Board

This national charity supports members of the Merchant Navy and their families in times of need. It was a pleasure to host their Annual Meeting at SAHFOS.

Knowledge Exchange

Communicating SAHFOS science and engaging with a variety of audiences is at the heart of our organisation. Activities such as training workshops, delivering presentations at scientific conferences and introducing school children to the wonders of the marine environment are all part of the rich calendar of events we carry out each year.

MASTS Annual Science Meeting

The Marine Alliance for Science and Technology for Scotland holds this cross-disciplinary meeting to promote and communicate research. We showcased our new trade stand here.

Cornwall College Training

As part of a new BSc in Marine Zoology programme at Cornwall College, we hosted 3rd year undergraduate students, providing a day of lectures and practical plankton identification.

CPR Technician Training

The workshop delivered three training courses this year to individuals seeking to tow a CPR off India, the South Atlantic and through the North West Passage.

NMBAQC Ring Test

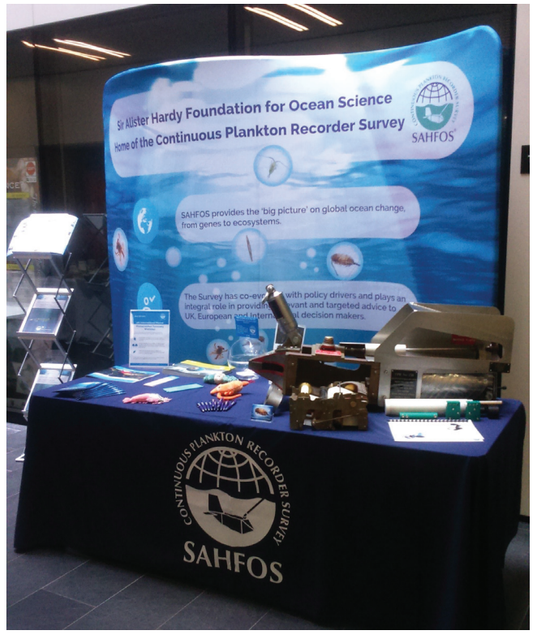
We organised the first international Northeast Atlantic Marine Biological Analytical Quality Control Scheme (NMBAQC) zooplankton ring test, a quality control scheme for the analysis of zooplankton samples.

Citadel Hill Open Day

As part of Plymouth's Ocean City Festival, Citadel Hill Laboratories opened its doors to the general public for a day, inviting them to come in and learn about what goes on in its Research Laboratories.

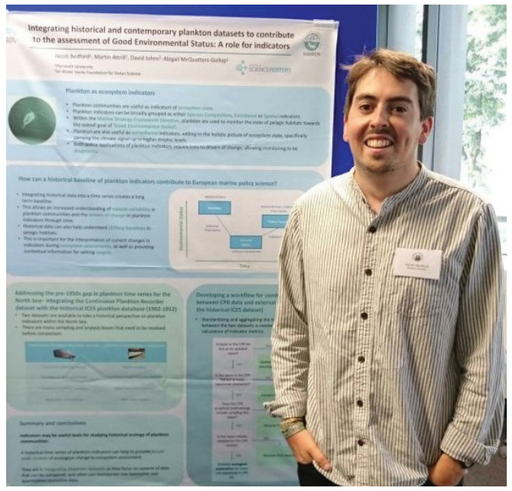
ICES 6th Zooplankton Production Symposium

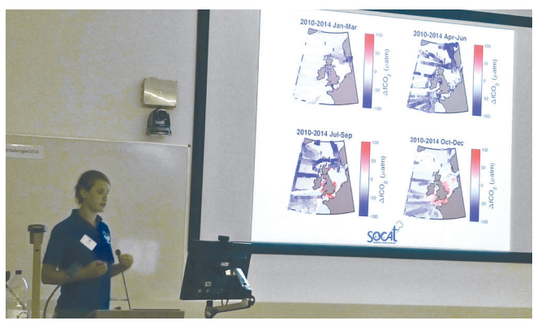
Held every 4 years, this prestigious event brings together plankton experts from around the world, to share ideas, discuss research and build collaborative partnerships. This years' event was attended by over 400 delegates and provided an excellent occasion at which to launch the SAHFOS trade stand (see right). Featuring the new look website, information leaflets, a suite of instrumentation and a CPR, the stand offered delegates the opportunity to learn more about the CPR Survey and the services we offer. Many talks throughout the conference mentioned the CPR Survey or had used CPR data, highlighting the unique value of the Survey to the international scientific community. SAHFOS was well represented during the event, with Sanae Chiba delivering an inspiring plenary lecture before further presentations by Willie Wilson (on behalf of Rowena Stern), Sonia Batten and Claudia Castellani and poster contributions by Priscilla Licandro and Pierre Hélaouët. Mike Blackett, former SAHFOS PhD student, also presented a talk on his work and won the award for best oral presentation. JS



Challenger

Held every two years this event is aimed at early career scientists, and features a full and varied lecture programme over 3 days. The SAHFOS trade stand was on display, offering delegates the chance to find out more about the CPR Survey and how they might access SAHFOS data to support their research. Willie Wilson chaired a special session on the "Use of long-term ecological time series to monitor the health of the ocean" while Katrin Schmidt, George Graham, Robert Camp, Clare Ostle and PhD student Jacob Bedford each contributed to the conference programme through presentations and posters. JS





Images. Below Clare Ostle's oral presentation. Right. Jacob Bedford in front of his poster presentation. Below right Robert Camp, Katrin Schmidt and Jennifer Skinner looking at Ernst Haeckal books.

Plankton Art Masterclass

SAHFOS joined forces with local artist Debby Mason to host the first Plankton Art Masterclass, transforming the SAHFOS laboratory into an art studio. Participants spent the morning learning about plankton, SAHFOS and Debby Mason's work, before being taught some expert drawing techniques. These were then put into practice, drawing sketches from 3D plankton models, seashells and net caught plankton samples from around the world.

Following a tasty lunch, the budding artists then got their hands dirty, employing these newly learnt skills to create their own ink prints. Attendees were offered a behind the scenes tour of the National Marine Biological Library and were able to see some of the rare books held there, including works by Haeckel, Couch and Sir Alister Hardy. After the success of this first Masterclass, further courses will be run in the future so keep an eye on our website! GB

Images. Top left A variety of the block ink prints created. Bottom left Sue Lewendon with her drawing of *Tripos*. Right: Beatriz De Francisco (on left) with Debby Mason

Services we offer : Knowledge Exchange

Media

We want to share the world-class science emanating from SAHFOS and are happy to handle enquiries from across all media platforms. Our scientists are also available for media interviews on recent marine biological findings or areas of our expertise that are in the news. This expertise covers a wide range of fields and specialities including: climate change, biodiversity, plankton taxonomy, jellyfish, harmful algae, fisheries and marine policy. With scientists from across a wealth of countries, we can attend to enquiries from non-English speaking communities.

Policy

The CPR Survey has co-evolved with policy drivers and through SAHFOS' development of policy-relevant applied indicators, the CPR has played an integral part in providing relevant, targeted advice to UK, European and international decision-makers. The uniqueness of the CPR dataset means SAHFOS holds a distinctive position in the marine scientific policy community. The Survey's issue-driven focus and applied indicator approach have played key roles in ensuring the continuation of this monitoring programme during tenuous economic climates; therefore maintaining the applied aspect of CPR research is crucial.

Training

We are keen to share our knowledge and offer a selection of training courses or can tailor-make a course to suit your requirements. Check out our website for further details or contact sahfos@sahfos.ac.uk

Social Media and Publicity

Twitter

This social media platform brings us our most engagement and interaction. Nearly 800 new followers were gained and 269,000 impressions (the number of Twitter account streams our posts were exposed to) were made throughout 2016.

The most well received Tweet came in November: An electron microscope image of a Coccolithophore – it received 65 likes and 38 retweets (see right).

Facebook

Facebook likes grew at their best rate in 2016. The page started the year with 476 likes and finished with 674, a growth of 198 likes. All new followers and reach are organic, we do not pay for any new followers.

The SAHFOS posts combined received 3,000 likes across the year in total.

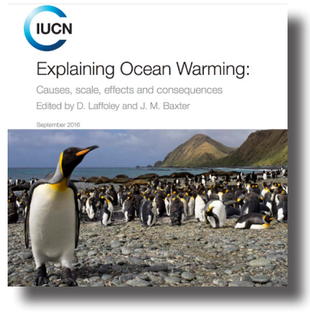
Similar to Twitter, the best performing Facebook post was again the electron microscope image of a Coccolithophore. There were 48 post reactions and the post reached the timelines of 1,326 people. NR

Publicity

Alongside the refreshment of the SAHFOS website, we also engaged with strengthening our 'brand' and the maintaining and building our reputation. We were involved in a number of high profile papers and publications in 2016, which brought good spells of publicity to the Foundation. The two that featured most prominently were:

The State of Nature report, produced by the RSPB and in collaboration with more than 50 other wildlife organisations, revealed that over half (56%) of UK species studied have declined since 1970, while more than one in ten (1,199 species) of the nearly 8000 species assessed in the UK are under threat of disappearing from our shores altogether.

The story was picked up by most national and local television, radio, print and online outlets.



SAHFOS also featured strongly in the IUCN report "Ocean warming: causes, scale, effects and consequences".

Philip Reid wrote Chapter One 'to set the scene' of what we are facing with ocean warming. He highlighted that our oceans have absorbed more than 93% of the extra heat produced from climate change since the 1970s:

"By absorbing a disproportionate amount of heat from global warming and by taking up the rapidly increasing emissions of carbon dioxide, the ocean has shielded the world from even more rapid changes in climate.

However, the extent to which it can continue to do so in the near and distant future is far from clear."

To help visualise it, consider that if the same amount of heat absorbed by the upper 2km of the ocean had gone into the atmosphere, the Earth's surface would have warmed by 36°C in the past century, rather than 1°C.

Martin Edwards explored the impacts and effects of ocean warming on plankton. It is here, at the base of the marine food web that the largest impact is felt:

"Due to their sensitivity to change, some of the most convincing evidence for the biological response to climate change in the ocean comes from phytoplankton and zooplankton communities."

The story was covered by New Scientist, Independent, National Geographic and The Guardian amongst many others. NR

Publications

Peer-reviewed Publications

SAHFOS Staff in bold.
Associate Researchers/ Students / Fellows*

*Blackett, M., C. H. Lucas, K. Cook and **P. Licandro** (2016). "Occurrence of the siphonophore *Muggiaea atlantica* in Scottish coastal waters: source or sink?" Journal of Plankton Research. **39** (1) 122-137

Barton, A. D., A. J. Irwin, Z. V. Finkel and C. A. Stock (2016). "Anthropogenic climate change drives shift and shuffle in North Atlantic phytoplankton communities." Proceedings of the National Academy of Sciences **113** (11): 2964-2969.

Batten, S. D., S. Moffitt, W. S. Pegau and R. Campbell (2016). "Plankton indices explain interannual variability in Prince William Sound herring first year growth." Fisheries Oceanography **25** (4): 420-432.

*Beaugrand, G. and R. R. Kirby (2016). "Quasi-deterministic responses of marine species to climate change." Climate Research **69** (2): 117-128.

Brown, C. J., M. I. O'Connor, E. S. Poloczanska, D. S. Schoeman, L. B. Buckley, M. T. Burrows, C. M. Duarte, B. S. Halpern, J. M. Pandolfi, C. Parmesan and *A. J. Richardson (2016). "Ecological and methodological drivers of species' distribution and phenology responses to climate change." Global Change Biology **22**: 1548-1560.

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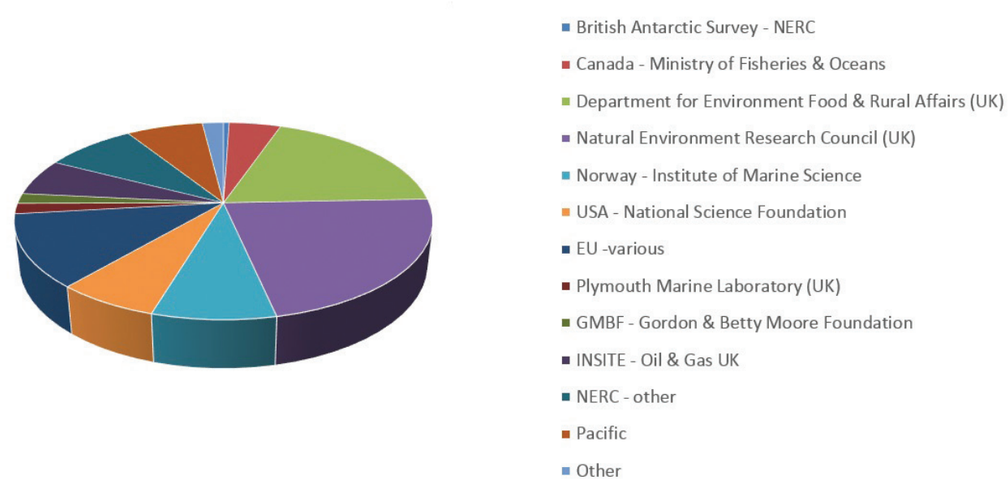
Financial Summary



The principal sources of funding for 2016 are broadly derived from grants and contract income from Primary Funding Organisations, and Research & Academic Organisations.

Primary Funding Organisations provide support funding to enable the general operation of the CPR Survey.
In 2016 these were:
- UK Natural Environment Research Council (NERC)
- UK Department of Environment, Food and Rural Affairs (Defra)
- National Science Foundation U.S. (NSF)

Research & 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 2016 these were:
Prince William Sound Science Centre, North Pacific Research Board, Dept. of Fisheries & Oceans Canada, British Antarctic Survey, European Union, European Environment Agency, Institute of Marine Research Norway, Oil & Gas UK, Greenland Institute, Gordan & Betty Moore Foundation and others.

Total incoming resources for 2016 together with other income from charitable activities, are reported at £1,716,376 (2015 £1,548,556). The complete audited accounts are available on the SAHFOS website.

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

Global Alliance of CPR Surveys

The Global Alliance of Continuous Plankton Recorder Surveys, known as GACS, brings together the regional CPR surveys around the globe to foster collaboration within the CPR community and to act as an interface between it and other global observing programmes.

To find more out about the Global Alliance of CPR Surveys please visit our website www.globalcpr.org

SAHFOS provided CPR technician training for the National Institute of Oceanography in Kochi, India. Subsequently, in May 2016, an 80 mile test deployment of a CPR was carried out in the Bay of Bengal from the ORV *Sindhu Sankalp.*

The New Zealand CPR Survey: Tows continued from New Zealand to the Ross Sea with the FV *San Aotea II* in the austral summer of 2015-2016 and will for the 2016-2017 summer. A rare winter sampling trip also took place from May-July 2016, getting as far as 64°S, which will hopefully provide a valuable record of winter community composition for the Southern Ocean CPR Survey. Northerly CPR runs were also carried out in May along the east coast of the North Island of New Zealand, repeating tows made in 2015 to provide some coastal information.

MedCPR: In October 2016 the MedCPR completed two years of successful monthly tows in the eastern Mediterranean Sea. Up till now only one route has been sampled (Cyprus-Israel) while discussions have taken place to consider a second route (Cyprus- Greece). Although in its infancy, the Survey has demonstrated great potential for capturing the spatial variation in plankton distribution. The major trend to date appears to indicate two distinct systems: a highly oligotrophic system close to the Cypriot coast and open sea and a more productive system close to the Israeli port. Reinforcement and expansion of the Survey is being attempted through regional research proposals.

Northwest Pacific samples are being used to test a new technique recently developed by JAMSTEC, using micro X-ray computed tomography (CT) to quantitatively measure acidification impact on planktonic organisms. The Japanese CPR team started a feasibility study to apply this technique to measure variation in shell density of foraminifera collected by the CPR. Once the feasibility is established within the GACS framework, it could be a global standard method to monitor ocean acidification impacts on marine ecosystems.

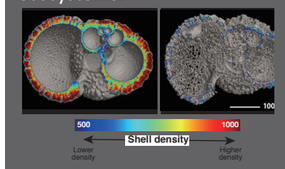
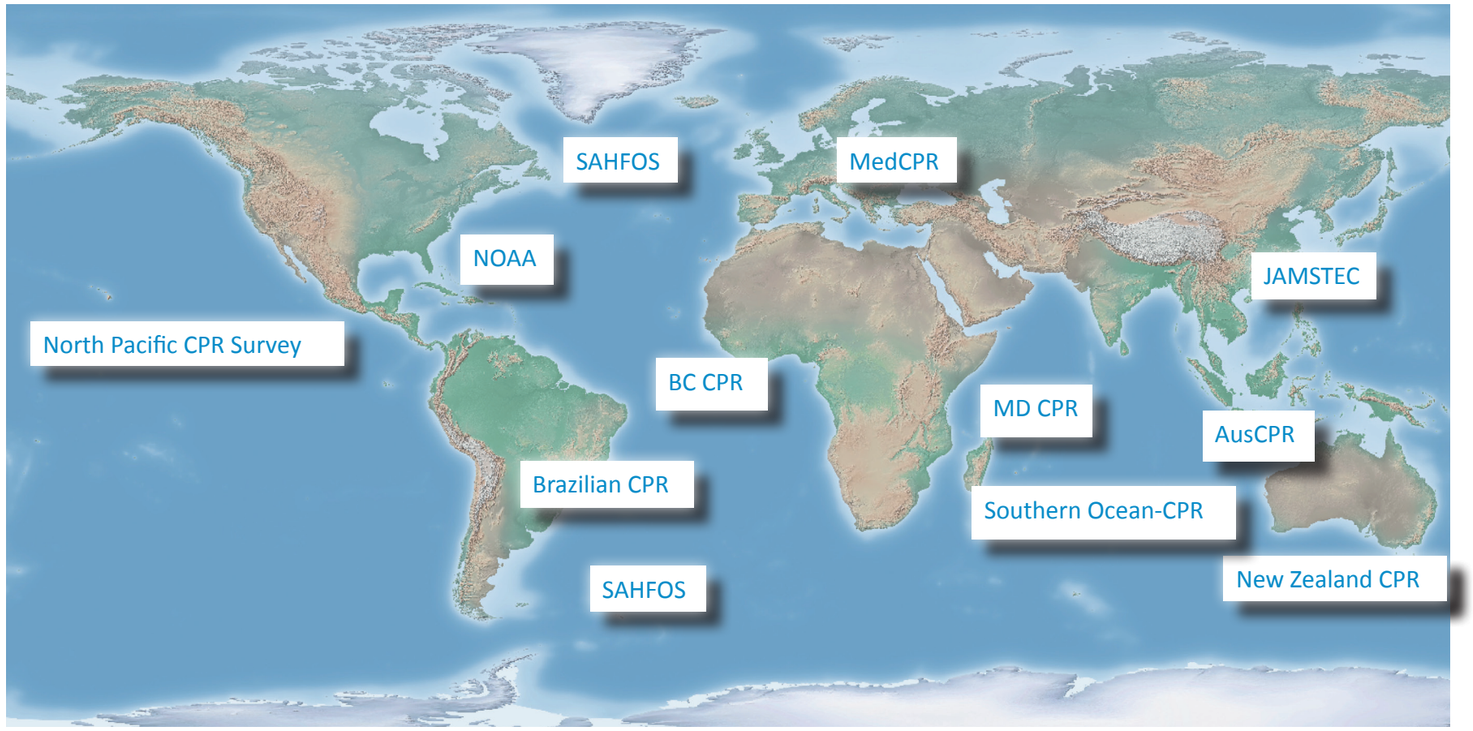


Image credit. Katsunori Kimono, JAMSTEC



AusCPR: The plankton data formed a substantial portion of the State of Environment 2016 Report. This is the premier environmental report in Australia and comes out every five years. For the first time it included extensive data on plankton. It specifically shows the poleward expansion of *Noctiluca scintillans* as waters have warmed, time series of HABs (*Dinophysis* spp. and *Pseudo-nitzschia* spp.) at different reference stations around Australia, the replacement of cold-water copepods with warm-water species off southeast Australia, and the time series of zooplankton calcifiers in response to changes in ocean acidification.

Brazilian CPR: The Brazilian CPR Survey undertook 720 miles of towing across Drake's Passage and into the Southern Ocean in February 2016. This transect was where the first CPR was deployed by Alister Hardy himself on the Discovery Expedition in 1927!

BC CPR: Due to the decommissioning of the CV *Horizon* regular tows in the Benguela Current Large Marine Ecosystem have been suspended for 4 years, however negotiations have hopefully achieved the re-establishment of quarterly tows. Opportunistic tows have occurred in the Indian Ocean, on the Agulhas Bank and between Cape Town and the Southern Ocean. Once all samples can be analysed (currently a major challenge due to recent changes in the Department of Environmental Affairs research priorities) these, and subsequent CPR tows, will provide an opportunity to examine seasonal variations in the abundance, distribution and diversity of phyto- and zooplankton assemblages in the Atlantic and Indian sectors of the Southern Ocean. They will also make significant contributions to the CPR databases of SCAR's international SO-CPR Survey and GACS' global CPR Survey.

Training: A week long workshop was held at the Australian Antarctic Division in Hobart, Australia involving members of the Scientific Committee on Antarctic Research (SCAR) Southern Ocean-CPR Expert Group. Karen Robinson (NIWA, NZ), John Kitchener (AAD), Kunio Takahashi (NIPR, Japan), along with Graham Hosie (past GACS Chair) discussed a range of topics covering laboratory methods (preservation and storage, with emphasis on maintaining pH), future training of new analysts, updating of species identifications (in particular foraminifera and euphausiid larvae identification/staging) and future workshops/conferences including comprehensive training workshops for emerging SO-CPR Survey partners (India). An updated version of the 2010 Standards Workshop held in Tokyo, Japan will be produced as a result of this meeting.

Southern Ocean-CPR: All 18 CPR tows were sucessful for the SO CPR survey from 3 Aurora Australis voyages, south and west of Australia, during the 2015/16 season (Oct-Jan). This equates to 6,912 nautical miles, or 1,382 (5 nm) samples. Now mid-way through the 2016/17 season, there have been 8 tows (all successful) from 1.5 voyages (out of the 3 planned cruises).

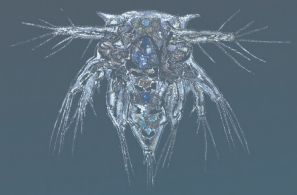
A tightening funding situation in Australia, and increasing difficulties with sourcing ships to service routes because of short charter times are challenging the Aus-CPR program. Nevertheless, continued sampling on routes around Australia, such as between Brisbane and Perth, occurred during 2016. While the future may include reduced funding, the importance of the data to the IMOS (Integrated Marine Observing System) is recognised, especially inclusion in modelling activities, which should help continue support.

MD Survey, France: Since 2013, France has towed CPRs annually once per year during the Austral Summer from the RV *Marion Dufresne* in the Indian part of the Southern Ocean between the French Southern Antarctic Territories (TAAF of Crozet, Kerguelen, Saint Paul and New Amsterdam). The oceanographic survey is supported by IPEV, the French Polar Institute. On December 12th, 2016, the French government declared an extension of the Marine Reserve in the Crozet, Kerguelen and New Amsterdam EEZ.
The extension covers 672,000 km² including large oceanic areas. CPR Surveys will help to monitor this new Marine Reserve and the consequences of global change.

Sir Alister Hardy Foundation for Ocean Science (SAHFOS) is an internationally funded non-profit organisation that operates the Continuous Plankton Recorder (CPR) Survey. The Foundation has been collecting plankton with the resulting data providing information on biogeography and ecology of the planktonic community. The results of the Survey are used by marine biologists, scientific institutes, governmental bodies and in environmental change studies across the world.

The SAHFOS team is based in Plymouth, England, and consists of scientists, technicians and administrators, who all play an integral part in the running of the Survey.

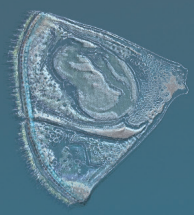
Plankton Illustrations by Debby Mason



Cirrepede nauplius (Barnacle)

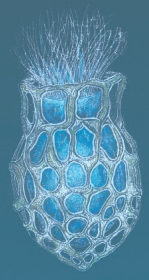
Echinoderm Larvae

Meganyctiphanes norvegicus (Krill)



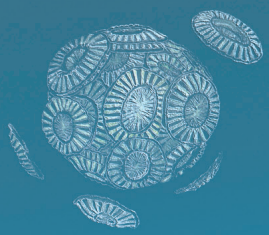
Cyphonautes Larvae

Calanus finmarchicus



Dictyocysta (Tintinnid)

Zoea larvae (Crab)



Emiliania huxleyi (Coccolithophore)

Ceratium mixed

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