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Workshop Report: Using Earth Observation for Water Quality Monitoring for the Caroline Herschel Framework Partnership Agreement for Copernicus User Uptake (Work Package Three)

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Acknowledgments:

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Contents

1 Context

Products derived from Copernicus satellite data have many applications for monitoring water quality in freshwater, estuarine and marine environments. Examples include seabed mapping, predicting species distribution, detecting eutrophication and toxic algal blooms, tracking oil spills, quantifying plastic pollution and helping to predict responses to climate change.

The Joint Nature Conservation Committee (JNCC) ran an online workshop to raise awareness of these products and how they may be accessed and used. This event was delivered as part of JNCC's Copernicus Project, which was launched in September 2019 to increase uptake of Copernicus data and services across the UK via capacity building and cross-border collaboration. Through a set of work packages including training sessions, thematic workshops, and development of practical applications, the project aimed to facilitate the use of earth observation (EO) data to deliver public environmental functions more efficiently or effectively across multiple policy areas.

JNCC's Copernicus Project is funded by the European Commission under the Caroline Herschel Framework Partnership Agreement on Copernicus User Uptake (FPCUP), which was established in 2018 to increase the use of Copernicus data, products and services. This report outlines the format and content of the workshop, provides links to workshop outputs, and presents statistics and qualitative feedback to illustrate the reach and impact of the event.

2 Format

The workshop was held online over two afternoons on 13 and 14 October 2020 using the GoToMeeting platform. The workshop programme comprised presentations, question and answer sessions, and a panel discussion. On both mornings, there was a training session delivered by Plymouth Marine Laboratory on how to select, access and process marine EO data made freely available under the Copernicus programme.

2.1 Presentations

The first day of the workshop was introduced and chaired by Emily Sym, Marine Data Specialist and Ecosystem Analyst at JNCC. Keynote speakers Professor Christine Maggs (Chief Scientist, JNCC) and Dr Carsten Brockmann (Brockmann Consult) set the scene by introducing the environmental and policy context for water quality monitoring and outlining the technology and products available. This was followed by a session on marine applications for EO data. Case studies demonstrated the use of EO for detecting marine litter, oil spills and harmful algal blooms, as well as mapping seabed habits, monitoring sediment disturbance and using ocean colour as an indicator of climate change.
The second day was introduced and chaired by Paula Lightfoot, Earth Observation Specialist at JNCC. It began with a session showcasing freshwater applications for EO data, including monitoring eutrophication, cyanobacteria and lake responses to climate change. This was followed by a session on future developments, in which we heard about new collaborative projects and innovative technology. This comprised presentations about the Geo AquaWatch initiative, the CERTO (Copernicus Evolution – Research for harmonised and Transitional water Observation) project, a prototype 'Living Laboratory' for the Forth Valley, and the benefits of data cubes.

2.2 Question and Answer Sessions

The MeetingPulse platform was used to enable attendees to submit written questions for speakers at any point during the presentations. Attendees could also up-vote questions asked by other participants in order to prioritise them. The programme included a 15-20 minute question and answer session at the end of each set of presentations. During these sessions, the co-chair read out questions to the speakers, prioritising questions based on the number of votes they had received.

2.3 Panel Discussion

The second day of the workshop concluded with a panel discussion on the subject of '*Innovation through to impact – linking policy priorities to R&D*'. MeetingPulse's 'brainstorm' function was used to enable attendees to submit and up-vote discussion topics or questions relevant to this subject at any point during the workshop. Two focal questions were used to provide a suggested structure for attendees' input:

(1) What are the priority applications for water quality monitoring to meet UK / EU policy requirements?
(2) What research and development are needed to make them operational?

The panel of experts comprised:

Jon Hicks	Copernicus Policy Lead and Earth Observation Centre of Excellence Secretariat Manager, Defra.
Andrew Tyler	Professor of Environmental Science, University of Stirling
Claire Neil	Senior Specialist Scientist, Scottish Environment Protection Agency
Gwawr Jones	Senior Earth Observation Specialist, JNCC
Helena Sykes	Lead Specialist Adviser, Remote Sensing, Natural Resources Wales
Shubha Sathyendranath	Merit Remote Sensing Scientist, Plymouth Marine Laboratory
Stefan Simis	Earth Observation Scientist (inland/coastal waters), Plymouth Marine Laboratory

Jon Hicks introduced the session, praising the scientific achievements showcased in speakers' presentations and asking what collaborative steps now need to be taken to ensure the benefits for domestic and international policy. He also reminded attendees of the importance of evidence and the need to consider the wider interaction between land, freshwater and marine environments.

The panel then discussed the following topics which had been raised by attendees:

- how to facilitate ongoing knowledge sharing between UK public sector bodies;
- how the UK's departure from the EU might impact the ability to access and use Copernicus data and to influence future developments in service provision;
- the need for *in situ* reference data to improve understanding of uncertainty;
- how best to communicate uncertainty in EO-derived products to end users;
- and how to improve understanding of the relationship between Chlorophyll-a measurements and habitat condition in freshwater environments.

2.4 Training Sessions

In conjunction with the workshop, Plymouth Marine Laboratory (PML) ran a short online course on how to select, access and process marine EO data made freely available under the Copernicus programme. The same workshop was delivered on each morning for a different set of participants. Attendees learnt where marine data and products can be found across the Copernicus landscape, and how to design workflows tailored to match applications to the most appropriate marine EO data and/or products.

The training was delivered by Lauren Biermann and Oliver Clements at PML, both highly experienced remote sensing scientists and very engaging tutors. They demonstrated how to access optical datasets and images from the NERC Earth Observation Data Acquisition and Analysis Service (NEODAAS), European Space Agency (ESA), European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the Copernicus Marine Environment Monitoring Service (CMEMS).

Using the WeKEO DIAS[1] hosted processing system, Sentinel Application Platform (SNAP) software and Jupyter Notebooks, attendees learnt about a variety of data processing methods, including those routinely used by NEODAAS at PML.

3 Workshop Resources

Resources from the workshop were made publicly available via JNCC's online Resource Hub portal on the 26 October. All speakers gave written consent for public dissemination of their contributions. Attendees were advised in advance that workshop and training sessions would be recorded and made publicly available, but that their names and images would be excluded from recordings.

The workshop resource page contains 21 outputs from the workshop: the videos, presentation slides, workshop programme and a document collating useful links and resources about using EO for water quality monitoring.

The training session resource page contains 6 outputs from the training session: the video, presentation slides, information on software and code for processing EO data, a quiz and a Sentinel-3 sample dataset.

4 Workshop Reach and Impact

The reach and impact of the workshop were evaluated using metrics derived from attendance figures, evidence of engagement, access to resources, social media activity and feedback from attendees. The results of this evaluation are presented in this section of the report.

[1] WEkEO is one of the five Copernicus DIASs (Data and Information Access Services) which enhance access to Copernicus data by providing computing power and user support. WEkEO is the service for marine environmental data. A comparison of the DIASs can be found on the Certo Project website.

4.1 Attendance

The workshop was free to attend but participants had to register in advance. Registration opened on EventBrite on 8 September and closed on 9 October. During that period, 235 people from 36 different countries registered to attend. The actual total attendance across both days was 174 participants from 20 countries, which translates roughly to a 74% attendance rate. The first day was attended by 165 participants from 20 countries, while the second day was attended by 108 participants from 13 countries.

Countries of residence of workshop attendees are shown in Figure 1 and are listed in Appendix 1. The majority of participants were UK-based, as expected, but over one-third of participants attended from outside the United Kingdom.

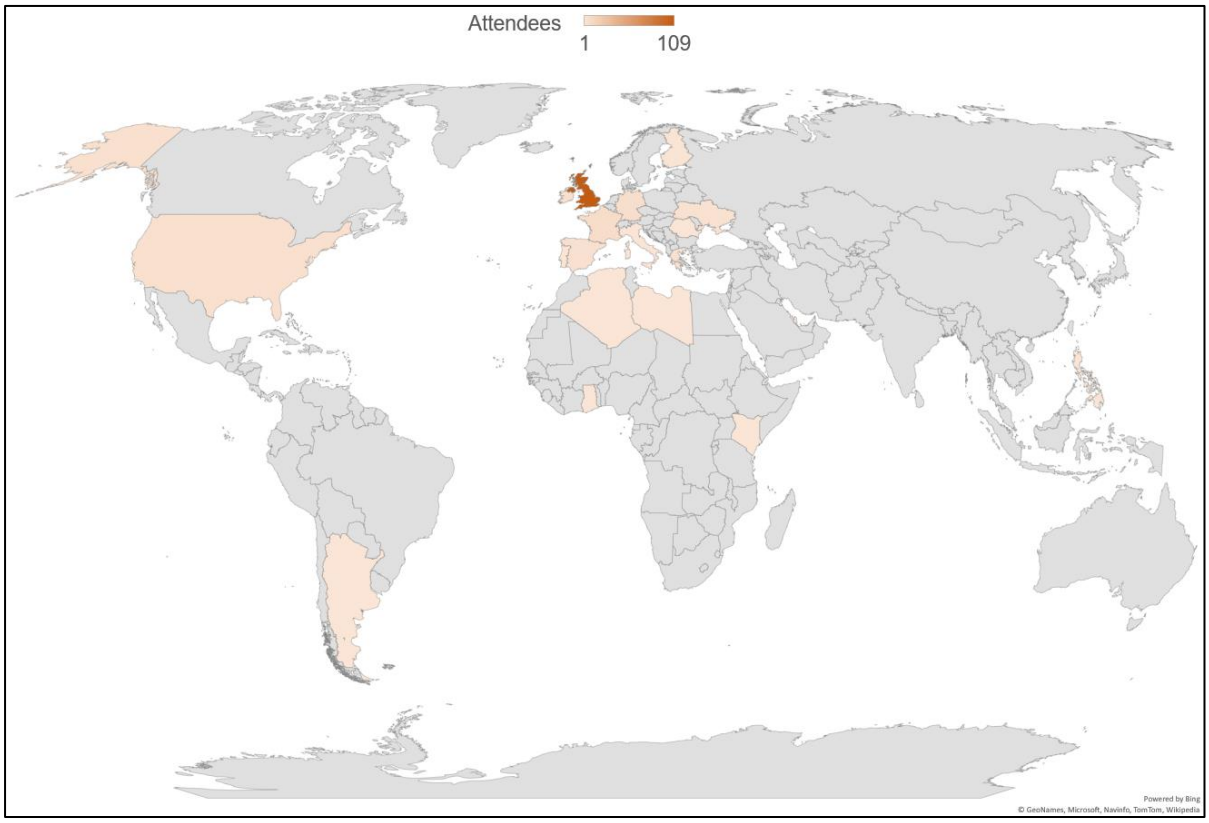

Figure 1: Map showing the countries of residence of workshop attendees.

Participants represented at least 62 different organisations, which are listed in Appendix 2. The sectors represented by workshop participants are shown in Figure 2.

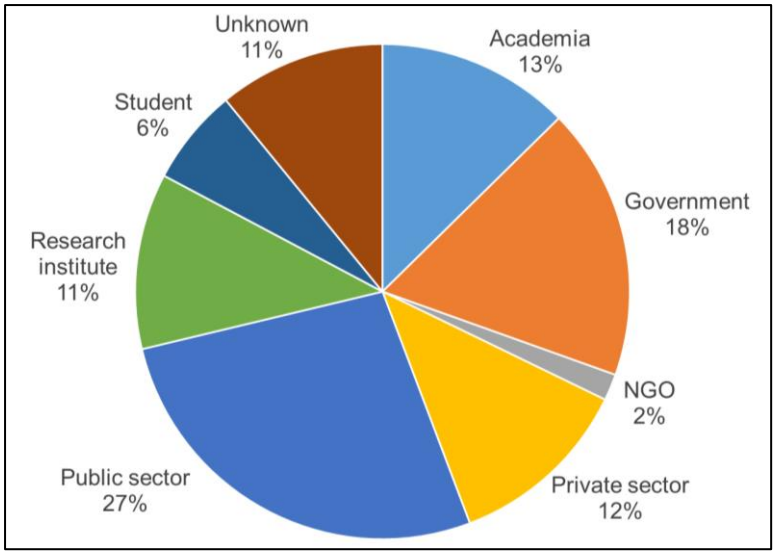

Figure 2: Pie chart showing the sectors represented by workshop attendees.

The number of places on the training workshop run by PML was deliberately restricted to ensure a good tutor to student ratio. The two sessions were attended by 33 people in total, all from the UK or Republic of Ireland, representing 20 different organisations.

4.2 Engagement

Participants were able to engage actively in the workshop by asking questions or suggesting discussion topics on MeetingPulse, or by making comments in the GoToMeeting chat function.

The level of engagement by asking questions on MeetingPulse is shown in Table 1. Although only 31 attendees asked questions of the speakers, a larger number of participants engaged by upvoting questions which they wanted to hear answered. This reduced duplication and ensured the question and answer sessions were relevant to the interests of the audience.

Table 1: Summary statistics of questions asked and answered during the workshop.

	Questions asked	Attendees who asked questions	Upvotes received	Questions answered during the workshop (+ number of post-workshop comments in brackets)
Day 1	50	19	162	30 (+5)
Day 2	30	16	79	11 (+8)
Both days	80	31	241	41 (+13)

The complete list of questions asked during the workshop is provided in Appendix 3. This shows which questions were answered during the workshop, the number of votes received, and includes post-workshop comments by some of the speakers. The broad topic areas covered by the questions are shown in Figure 3.

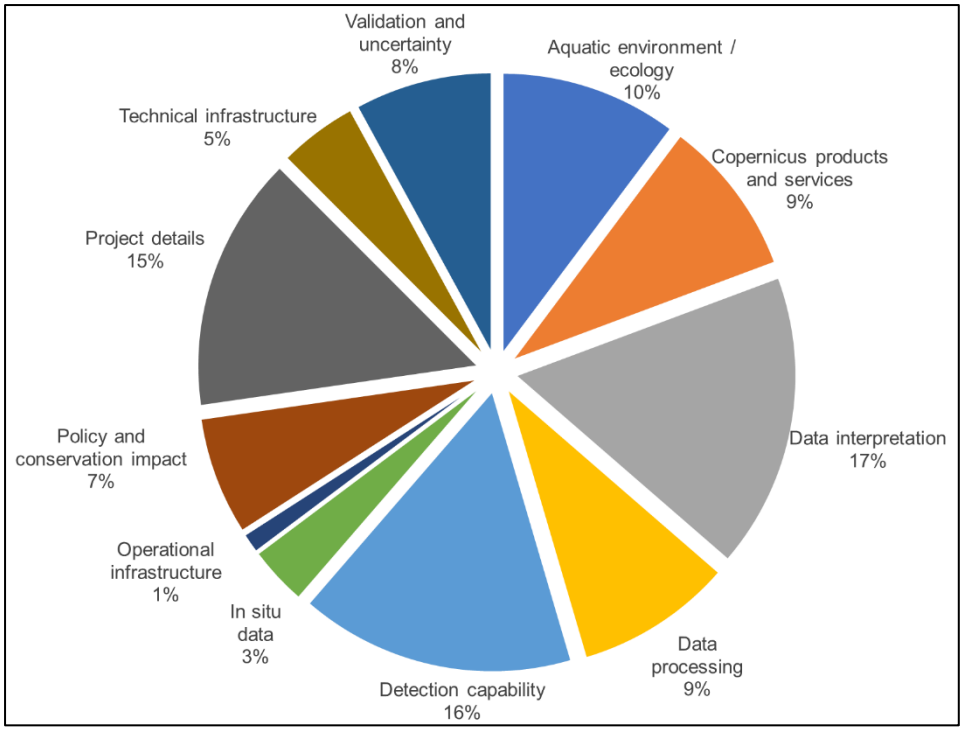

Figure 3: Broad topics covered by questions asked by attendees during the workshop.

Participants used MeetingPulse to suggest 11 topics for discussion, which received a total of 45 votes. The four topics receiving the most votes were discussed during the panel discussion session on day 2. The complete list of topics raised by delegates is shown in Appendix 4, and the issues raised are summarised in Section 5 of this report.

The GoToMeeting chat function was used for communication regarding the running of the workshop and for posting links to resources. Participants used the chat function to make 32 public posts on the first day and 16 public posts on the second day.

4.3 Access to workshop resources

A news item was posted on the JNCC website on 8 September to promote the workshop. This page enabled users to download the workshop programme, information on using GoToMeeting and MeetingPulse, and a document collating useful links and resources relevant to the workshop's theme. From 8 September to 14 October, this page was in the top ten most visited pages on the JNCC website, receiving 1,517 views from 816 unique visitors.

Recordings of the presentations were made available on JNCC's YouTube channel on 22 October. Links to the videos were collated with other workshop resources on JNCC's Resource Hub on 26 October. A news item was posted on the JNCC website on 27 October to advertise these resources. Table 2 shows the number of YouTube views for each item between 22 October and the time of writing in December 2020.

Table 2: Number of YouTube views for each video between 22 October and 18 December 2020.

Video	YouTube views
Day 1, Session 1: Introduction and keynote talks	45
Day 1, Session 2: Marine Applications (part 1)	37
Day 1, Session 2: Marine Applications (part 2)	19
Day 2, Session 3: Freshwater Applications (part 1)	26
Day 2, Session 3: Freshwater Applications (part 2)	16
Day 2, Session 4: Future Developments	76
Day 2, Session 5: Panel Discussion	13
Plymouth Marine Laboratory Training Session	40
Total YouTube views	**272**

4.4 Social media statistics

JNCC activity on social media during the event resulted in the following engagement on Twitter (Table 3 and Table 4), Facebook (Table 5) and LinkedIn (Table 6). All social media statistics were generated on 21 October, one week after the event. 'Impressions' signifies the number of times content was displayed, 'reach' is the total number of people who saw the content, and 'engagement rate' is the proportion of those seeing the content who engaged with it in any way, e.g. clicking links or images, 'liking', sharing or commenting.

Table 3. Statistics on activity by the JNCC Twitter account relating to the workshop.

No. of tweets	Impressions	Total engagement	Likes	Retweets	Link clicks	Average engagement rate[2]
13	19,527	476	107	55	19	2.4%

Table 4. Twitter analytics for use of the #JNCC_EO4water hashtag by all contributors.

Number of tweets	Contributors	Potential impressions	Potential reach
100	41	283,242	70,145

Table 5. Statistics on activity by the JNCC Facebook account relating to the workshop.

Number of posts	Impressions	Reach	Engaged	Liked	Shared	Average engagement rate[3]
4	699	607	24	17	2	4%

Table 6. Statistics on activity by the JNCC LinkedIn account relating to the workshop.

Number of posts	Impressions	Clicks	Reactions	Shares	Average engagement rate[4]
3	1,962	29	26	4	1.9%

[2] On Twitter, big brands consider an engagement rate of 1.5% as 'Good'. The average engagement rate for not-for-profits is 0.055%.
[3] On Facebook, the average engagement rate for not-for-profits is 0.17%.
[4] The average engagement rate across LinkedIn is 0.7%.

4.5 Attendee feedback

An online feedback survey was circulated to participants during the workshop via GoToMeeting chat and after the event via automated e-mail from EventBrite. The survey received 26 responses. Overall, participants were very satisfied with the event, with 62% of respondents rating the workshop as 'excellent' and 35% as 'good'.

Holding the workshop on two consecutive afternoons was considered a good format by 96% of respondents. Comments showed that this format enabled participants to fit the workshop around other work commitments and prevented "brain overload" by spreading content over two days. One respondent commented that despite the two-day format the workshop was very intense, requiring participants to take in a lot of information very quickly. However, they added that the ability to review the recorded presentations after the event could help to rectify this.

Participants were generally satisfied with the technology used to deliver the workshop. EventBrite was rated excellent or good by 80% of respondents, GoToMeeting was rated excellent or good by 92%, and MeetingPulse was rated excellent or good by 72% (some users found MeetingPulse did not work correctly on older versions of Internet Explorer). A few participants experienced problems because there were different GoToMeeting links for each day of the workshop, and one participant experienced problems with registration due to the need to register separately for the training course and the workshop.

The majority (75%) of respondents said that they would be more likely to use Copernicus data, services or products in their work or studies as a result of the workshop, while 10% said they were already using data or products quite extensively. Several respondents mentioned specific applications for which they would start to investigate use of Sentinel data, including river water quality assessment, monitoring nutrients in coastal waters, and using water column data to aid a full ecosystem approach to marine management. One comment suggested that the workshop may be a catalyst for dialogue with EO specialists in pursuit of practical applications: "I will use this workshop to start communications with our remote sensing specialist, to see if in my role and other colleagues in the same discipline can work together with her to start to use the EO data for assessment work*."*

Suggestions for how the workshop could have been improved included integrating 'virtual networking' sessions, having a discussion session on both days rather than just on the second day, being stricter about time-keeping, and allowing more time for questions.

Feedback for the workshop as a whole was extremely positive, as exemplified by the following selection of comments received via the online survey and the GoToMeeting chat function:

- The most important thing was to hear high-level scientists talking about their projects – that was excellent, and they provided good replies to the questions raised during the talks.
- I thought it was excellent. Chairing and co-ordination of presenters etc was really slick, content was really good, so clearly well planned too.
- I am benefiting a lot from all the talks, many thanks for organising this excellent web conference.
- The most valuable thing was the case study approach, always good to see what has been done, hear problems and limitations, rather than just generic theory.
- My goal was to sharpen my knowledge on the discussed subject and of course to network with people in my field of research, I learned a lot of information from the

conference, and I emailed privately some of the attendees to cooperate for future projects.
- I learned the many potentials of Copernicus constellation in water resources studies and I plan to explore its application in my research
- It was interesting to get an overview of how remote sensing has progressed, and the usefulness of different satellites. And to see innovative examples of EO applications. It was good that many presenters highlighted the importance of *in situ* data for validation.
- I liked the training session and I would have liked it to be longer…it has been very good, particularly Lauren Biermann's presentation.

5 Discussion

Based on attendance numbers, the range of topics covered, the sectors and countries represented, levels of engagement and delegate feedback, the workshop certainly achieved its aim of raising awareness of Copernicus data, products and services for water quality monitoring. Delegate feedback also suggests that the workshop is likely to contribute to the wider project aim of increasing uptake of Copernicus data, products and services.

Some challenges arose from delivering the workshop online, as outlined in the delegate feedback. However, the overall benefits of online delivery, notably the calibre of speakers and the wider reach of the event, outweighed any disadvantages. Constructive comments by delegates will help to improve future events, ensuring clearer pre-event communication, scheduling more time for questions and discussion, and possibly integrating networking sessions.

The workshop did not reach any conclusions on the priority applications for water quality monitoring to meet policy requirements and what research and development is needed to make them operational. Although participants were asked these specific questions, the main issues submitted as discussion topics or raised during Q&A sessions were around knowledge sharing and supporting data access. The issues identified and recommendations arising from the workshop can be summarised as follows:

<u>Issues</u>
- Potential impact of **EU exit** on UK organisations who provide Copernicus products and services, and on the UK's ability to influence future Copernicus developments.
- Lack of **institutional capacity** can be barrier to uptake of EO.
- The proliferation of **different algorithms** for processing optical data for aquatic applications can be confusing to non-EO specialists.
- There is a need for better understanding of the **relationship between EO-derived measurements and ecosystem condition** e.g. 'good environmental status'.
- There is a need for better understanding of **uncertainty**, and of how best to **communicate uncertainty** to end-users.
- There is a need for more and better ***in situ* data**, including data at higher spatial resolution.
- Some attendees felt the data and products were **not easily accessible / easy to use** for non-EO specialists and were disappointed by the reliance on *in situ* monitoring.

<u>Recommendations</u>
- Provide more **training, information and support** on accessing and using data and services, particularly off-the-shelf products.
- Facilitate **knowledge-exchange and sharing of case studies**. In the UK, the Defra EO Centre of Excellence (EOCoE) Implementation Group, currently funded by the Caroline Herschel Framework Partnership Agreement on Copernicus User Uptake,

provides a good framework for knowledge transfer and collaboration, particularly for public sector organisations.
- Continue to explore innovative use of **citizen science** and **new sensor technology** to generate *in situ* data and share successful examples so these can be replicated and scaled up.
- Explore potential for **analysis-ready data** for aquatic applications.
- Consider developing a tool in the style of JNCC's Crick Framework covering the use of EO for water quality monitoring, i.e. a framework that tells users what can be monitored using EO and which data / technique to use.
- Seek to **harmonise and standardise** EO-derived water quality products, instead of different groups producing different products for the same parameter. The CERTO project is likely to make important progress in this area.

6 Conclusions

The workshop on Using Earth Observation for Water Quality Monitoring was a great success. Attended by 174 delegates from 20 countries, the event brought together representatives from government, public and private sector organisations, academia, research institutions and environmental NGOs. Feedback from participants was overwhelmingly positive, with delegates commenting on the high quality of the presentations, the wide range of topics, the useful focus on practical case studies, and how expertly the speakers handled the questions.

Statistics from social media and web analytics showed a high level of engagement with the workshop content and resources, both before, during and after the event. The videos, presentation slides and other resources from the workshop and training sessions have been made publicly available, increasing the potential reach and ongoing impact of the event.

The workshop identified and documented a number of issues and recommendations, largely focussing on the need for knowledge transfer and support for data access and use. These were presented and discussed at a meeting held by the Defra EOCoE on 26 November 2020, which aimed to understand the direction of water quality policy, explore the current fit of EO solutions to policy delivery, and help EOCoE consider how emerging technologies might support policy ambitions.

We therefore conclude that the workshop achieved its aim of raising awareness of the use of EO for water quality monitoring and is likely to have made an important contribution to the wider project aim of increasing uptake of Copernicus data, products and services.

Appendix 1: Country of residence of workshop participants

Country	Number of participants
Algeria	1
Argentina	1
Finland	2
France	7
Germany	6
Ghana	1
Greece	3
Ireland	4
Italy	1
Kenya	1
Libya	1
Philippines	1
Portugal	1
Qatar	1
Romania	1
Singapore	1
Spain	4
Ukraine	3
United Kingdom	109
United States	5
Unknown	20

Appendix 2: Organisations represented by workshop participants

Organisation	Number of participants
AECOM	1
ARGANS	5
British Antarctic Survey	2
Brockmann Consult	3
Cardiff University	1
Centre for Ecology and Hydrology	4
Centre for Environment, Fisheries and Aquaculture Science (Cefas)	12
Centre for Research and Technology, Hellas (CERTH)	1
CNES - French Space Agency	1
Compass Informatics, Ireland	3
Cranfield University	1
Department for Environment, Food and Rural Affairs (Defra)	4
Department of Agriculture, Environment and Rural Affairs (NI)	5
Environment Agency	6
Environment Systems Ltd	1
Geological Survey of Finland	1
GeoSmartDecisions	1
Ghana Space Science and Technology Institute	1
Higher Institute of Water Affairs	1
Hochschule Rhein-Waal	1
Ifremer - French National Institute for Ocean Science	1
IGB Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin	1
Institute for Research in Astronomy and Astrophysics, Argentina	1
Instituto de Ciencias Marinas de Andalucia-CSIC	1
Iowa Tribe of Oklahoma	1
Joint Nature Conservation Committee	13
Land Quality Management Ltd	1
Mediterranean Agronomic Institute of Chania	2
Meteo Romania	1
Ministry of Defence	1
Ministry of Municipality and Environment	1
National Centre for Geocomputation, Maynooth University	1
National Trust	1
Natural England	15

Natural Environment Research Council	1
Natural Resources Wales	6
Newcastle University	6
Odessa National University I.I. Mechnikova	3
Office for National Statistics	1
Ordnance Survey Northern Ireland	2
Pixalytics	1
Plymouth Marine Laboratory	7
QUASAR Science Resources, S.L.	2
Scottish Environment Protection Agency (SEPA)	5
Servicios Mineros de Andalucía S.L.	1
Singapore Space & Technology Ltd	1
Stirling University	2
Thames21	1
The Rivers Trust	1
U.S. Environmental Protection Agency	2
Université du Littoral Côte d'Opale	2
University Akli Mohand Oulhadj of Bouira	1
University of Goettingen	1
University of Lisbon	1
University of Modena and Reggio Emilia	1
University of Nottingham	1
University of Plymouth	2
University of Reading	1
University of the Philippines	1
University of Wisconsin-Madison	1
University of Worcester	1
University of York	1
Unknown	22

Appendix 3: Questions asked during the workshop

Day 1:

Votes	Answered	Question	Post workshop comment
Christine Maggs, Joint Nature Conservation Committee			
4	yes	For Christine: Are all these policies and protections effective in sustaining our aquatic and marine environments?	
3	yes	For Christine - where do you think satellite Earth Observation could make the biggest impact in JNCC's marine/freshwater work?	
3	yes	For Christine - I think you said Planet data was used (as well as Landsat and Sentinel-2) for detecting green algal blooms in Ireland. Was this because high spatial and/or temporal resolution was needed? Or did freely available Landsat / Sentinel-2 data give similarly useful results?	
Carsten Brockmann, Brockmann Consult			
6	yes	For Carsten: Will Sentinel-2 Level 2 products for water applications become available in the future?	[Carsten Brockmann] ESA is seriously thinking about a water atmospheric correction for S2, which would lead to a S2-L2A product (water reflectances), eventually.
3	yes	For Carsten: Do you know how many people currently use the Copernicus Services?	
6	yes	For Carsten: Are the Copernicus products and services used widely within the public sector? Or are they mostly used for research?	[Carsten Brockmann] They are used for both, public and research. For example, UNEP is using it for SDG6.1 reporting (result is here: https://www.sdg661.app/map)
5	no	For Carsten - is access to the Copernicus products and services you described affected by whether or not the user is a member of the EU? Will there be any impact on UK's access when we leave the EU?	[Carsten Brockmann] No. Access to Copernicus Data is free and open for everyone.
6	yes	For Carsten - How is suspended sediment distinguished from shallow muddy banks? The area between Essex and Denmark is very shallow and the bottom of the ocean often shows in the imagery. I can imagine there would be quite a lot of confusion between the two.	[Carsten Brockmann] Algorithms usually make assumptions, if they see the bottom or not, and base their calculations on this assumption. Most algorithms assume not seeing the bottom but mask out areas where it is the case.

Votes	Answered	Question	Post workshop comment
2	no	For Carsten - Can you provide me with information on which normalization formula was used to produce the normalized water-leaving reflectance layers?	[Carsten Brockmann] 1) Clear water: Morel, A. and Gentili, B. (1996). Diffuse reflectance of oceanic waters. III. Implication of bidirectionality for the remote-sensing problem. Appl. Optics, 35: 4850-4862. 2) turbid water: Young-Je Park and Kevin Ruddick, "Model of remote-sensing reflectance including bidirectional effects for case 1 and case 2 waters," Appl. Opt. 44, 1236-1249 (2005)
4	no	I would like to know the water bodies covered by the "Copernicus Global Inland Water Service" in Algeria, and how can an independent researcher get involved in the Copernicus activities over Algeria?	[Carsten Brockmann] You can check-out the water bodies included by Copernicus Land Service here: https://land.copernicus.eu/global/sites/cgls.vito.be/files/products/CGLOPS_sites_list_20170112.zip
2	no	For Carsten- How TOA images impact EO time series analysis, for example in a time series analysis of Ocean colour?	[Carsten Brockmann] TOA images are the source for any subsequent analysis. These are the source measurements.
6	yes	For Carsten - The River Elbe work was fascinating. Many UK rivers are rather smaller than the Elbe: Is there a limit to monitoring of rivers that are below 10m width? Will this improve in the future (with presumably a high-res less than 10 m)?	[Carsten Brockmann] It can't be done with Sentinel 2. Even 10m is challenging given that some bands used are measured at 20 and 60m. There are commercial satellites are higher spatial results, but at the costs of lower radiometric quality. Water quality is sometimes possible, but it comes with additional costs for the data and higher uncertainty.
4	yes	For Carsten - What variables are likely to be available in the 100x100m coastal products you mentioned for release next year?	[Carsten Brockmann] Reflectances, TUR, SPM, Chl, bb
2	yes	For Carsten: Are there any future products or services that may revolutionise the use of EO for water quality monitoring?	[Carsten Brockmann] Yes. Scientists are working on higher level products, such as PFTs, and hyperspectral sensors will allow us to better quality and quantify water constituents.
3	yes	For Carsten - is any new ground data collection planned to complement the new Copernicus satellite missions? i.e. to aid validation and interpretation of the data?	[Carsten Brockmann] In H2020 there are (at least) two relevant projects: MONOCLE and Hypernets. Ideally these should be sustained. Stefan Simis (PI of MONOCLE) might know more. [Stefan Simis] To add to Carsten's mention of relevant projects, it may be useful to point out that these are R&D projects and not (yet) rolling out sensor networks at the desired scale. So some investment push is needed and we would be looking at Copernicus, Space Agencies as well as national bodies (env. ministries, EA) to reach the required capacity.

Votes	Answered	Question	Post workshop comment
3	no	for anyone: maybe a basic question but how accessible is data from Copernicus? If I want to consult SST or Chlorophyll data for instance, can I? Or would I need to hire a specific service to get access to the data and get it treated and delivered?	
Mickael Vasquez, Ifremer			
4	yes	For Mickael or Christine: what type of EO data was used in the UKSEAMAP (or EUSeaMap), could you share with us the techniques applied and the software used	
2	yes	For Mickael - are the EO products used as input data in EUSeaMap equally reliable in all water depths i.e. in open seas and in shallow coastal waters?	
Lauren Biermann, Plymouth Marine Laboratory			
4	yes	For Lauren: Is bottom reflectance an issue because the water's quite shallow and clear? In more turbid waters, would the suspended particles be an issue too I am guessing?	
7	yes	For Lauren: Why Acolite was chosen for Atmospheric correction. How its quality was evaluated for indexes compare to L2A Sentinel data for Sen2Cor?	
4	yes	For Lauren: What would you say are the next steps in expanding this approach to a global level?	
6	yes	for Lauren - what is the smallest detectable size of marine plastic able to be identified with Sentinel 2?	
4	no	For Lauren: how do you construct your training dataset for the ML?	
3	no	Lauren, you mentioned the Maia camera, is that the one with the same spectral wavelengths as Sentinel-2 (which can also be used on drones)?	
6	yes	Lauren - In addition to index is the classification take plastic debris shape in account?	
2	no	for Lauren - can you visually identify marine plastic in a sentinel image? What would this look like to the eye?	
4	yes	Lauren: what is the ratio of plastic at the surface over plastics in the water column? Is there a chance to detect also plastic not floating at the surface?	

Votes	Answered	Question	Post workshop comment
3	yes	For Lauren - interesting and tricky problem you mentioned about detecting different types of plastics. Do colours of plastics as well as type play an issue? E.g. do you have to train your algorithms separately for opaque vs transparent items?	
3	no	For Lauren: Do you take into consideration the contribution of water constituents such as cdom and chla to the signal when training the machine learning?	
2	no	Lauren: Has there been consideration to take data of known plastic hotspots or areas of high concentrations of ghost fishing nets recognised through satellites and compare with known cetacean hotspots?	
2	no	@Lauren: Do waves and viewing angles affect macroplastics detection?	
1	no	For Lauren: For Acolite, what path reflectance (fixed/tiled) do you prefer for plastic detection? and do you prefer doing sun glint correction also? If so, which masks did you find better, I mean L2W masking?	
Andrey Kurekin, Plymouth Marine Laboratory			
4	yes	Andrey - How did you manage to mitigate geometrical distortion from side-looking acquisition mode of SAR? e.g. Ascending vs descending acquisition, or are you using just one mode?	
5	yes	@Andrey - Which type of S1 data format are you using? Is the dataset for training open or proprietary? How are you validating your results?	
4	yes	Andrey how does sea state (i.e. rough vs calm waters) affect the ability to detect oil slicks? How about currents disrupting the sea surface, do they have an effect?	
4	yes	For Andrey: Are there plans to use the method of detecting oil spill for legal enforcement purposes to discourage ships from releasing oil in their bilge water for example.	
2	yes	Andrey - can you say a bit more about what sort of natural features can look like oil spills?	
1	no	For Andrey - Do you correlate the oil slicks with any weather data or other types of ancillary dataset?	

Votes	Answered	Question	Post workshop comment
1	no	For Andrey: Why you choose to extend this service in west Africa particularly? Is it an area with high risk?	
Keith Cooper, Cefas			
4	yes	Keith - are sediment plumes as you showed a factor in approval for wind farm placement?	
2	yes	Keith - would the different industries you mentioned prefer to receive information from satellites as images or in other formats?	
Shubha Sathyendranath, Plymouth Marine Laboratory			
2	yes	For Shubha or anyone else: Could you talk a bit more about the round-robin comparison to identify the best atmospheric correction algorithm? Thank you.	[Shubha Sathyendranath] There are three papers that describe the methods we developed in some detail. They are: Brewin et al.: https://www.sciencedirect.com/science/article/pii/S0034425713003519 Muller et al. (a): http://dx.doi.org/10.1016/j.rse.2015.01.033 Muller et al. (b): http://dx.doi.org/10.1016/j.rse.2013.11.026
1	no	Shubha - are there larger biases in some regions or time periods than others? Is sparse data for validation/calibration an issue in developing algorithms?	[Shubha Sathyendranath] Yes, the distribution of biases is a complex problem. But briefly, the uncertainties tend to be higher in turbid coastal waters. Not having sufficient high quality in situ data for all types of waters is indeed a problem when we try to characterise uncertainties in products. For further details on how we approached the problem using an optical classification, please see paper by Jackson et al. (2017): doi:10.1016/j.rse.2017.03.036.

Votes	Answered	Question	Post workshop comment
1	yes	Shubha, how might the Ocean Colour product be used in relation to fisheries research?	[Shubha Sathyendranath] There are many papers that have explored the use of satellite data in fisheries. One approach that has yielded rich dividends is to explore the relationship between phytoplankton phenology and recruitment of fish larvae (testing the Hjort-Cushing match-mismatch hypothesis). Others have looked at climate variability (El Nino - La Nina), impact on phytoplankton and implications for fisheries yield. For these types of applications, the special issue in the ICES Journal of Marine Science on remote sensing and fisheries provides many examples. Most of the applications in the special issue deal with the use of remote sensing for ecosystem-based management and related topics. From a commercial point of view, a number of countries provide potential fishing zone advisories (e.g. India, Japan) to fishermen, on the basis of satellite data.
Mike Best, Environment Agency			
2	yes	For Mike: From EUROHAB so far, can we see any increasing trends in the occurrence of blooms? Or do they appear relatively constant?	
3	no	Mike: would the web-based alert system show the users that satellite images i.e. like a weather report for spatial differences?	
2	no	Mike: How chlorophyll can be used as an indicator for HAB species such as Dinophysis that are toxic in low abundances?	
2	no	Mike: are the measurements and lab data, used to develop your algorithm, publicly available?	
2	no	For Mike Best: Has there been any consideration of the impact from chemical pollution on algal speciation changes?	
1	no	For Mike: From which depth (surface or integrated from the whole water column) in-situ data on Chlorophyll a do you use to calibrate space-born products?	

Day 2:

Votes	Answered	Question	Post workshop comment
Andrew Tyler, University of Stirling			
4	yes	Andrew Tyler - do you think the 13 Optical Water Types are representative of all lakes globally, or might you find more than 13 types as you do more sampling?	
3	yes	Question for Andrew - what was it that made POLYMER better than other atmospheric correction algorithms?	[Stefan Simis] In addition to answers provided in the session, we can add that while none of the processors showed ideal performance, POLYMER showed the most consistent response compared to in situ observations, particularly in green to near infra-red bands. We suspect that POLYMER underestimates the reflectance, such that downstream algorithms for Chl-a or Turbidity need to correct this effect.
2	no	Andrew - It looked as if lakes which are improving, worsening or had little change in terms of chl-1 were fairly randomly distributed across the world, is that correct or were there particular geographic areas where lakes were getting better or getting worse?	
2	no	Andrew- In terms of lake management and the factors influencing deteriorating lake quality, how do you account for internal loading of nutrients?	
1	no	Andrew - Interesting that deeper lakes are responding more to temperature changes, I would have thought they would be more resistant to change.	
Vagelis Spyrakos, University of Stirling			
7	yes	Vagelis - how should members of the public report cyanobacteria blooms (other than in the meeting Chat!!) e.g. in England would we report to the Environment Agency? Is there any kind of citizen science app for reporting changes in inland water quality that walkers / kayakers etc might notice?	
3	yes	Vagelis - that table summarising suitability and cost of different sensors for chl-a and phycocyanin detection looked very useful! Is that published anywhere? and if so, could it be kept updated as new sensors become operational?	
2	no	Vagelis- What is the potential for using EO to monitor algal blooms in rivers?	
1	no	to Vagelis, are water dams included in your project?	
1	no	Vagelis - How have the 933 uk lakes been chosen to be included on the website? Are these lakes that are	

Votes	Answered	Question	Post workshop comment
		already surveyed by traditional methods to check accuracy or are these currently unmonitored lakes? Also, what happens after the 12-month trial will this be the end of this data being made available or will it be available long term to inform our assessments of lake condition.	
Claire Neil, SEPA			
3	no	Claire, how comparable are determinations of good environmental status based on in situ AND remote sensing data, with GES determinations based on remote sensing alone (e.g. because the water body isn't accessible to ground survey)? Is remote sensing likely to over-estimate or underestimate water quality compared to ground survey?	
2	no	Claire- Is it likely to be possible to improve the recording of coordinates of ground truth data in future, to help matching points with pixels?	[Tiago Silva] This should be very feasible on the ground, given that smartphones can give accurate positioning without added cost. However, existing databases would need to be updated and this might prove laboursome.
4	yes	To Claire: Do you account the depth of inland water bodies (lakes, rivers), which may vary from 20 cm to 3 m, at calibration of S2 data for Chlorophyll concentration? If so, then how do you address that? What is the optimal depth for in-situ water sampling to identify Chlorophyll concentration to further calibrate/ compare with S2 data?	
6	yes	Claire, How you take on account the depths of water bodies? As for water body with depth 1 m and for water body with depth 10 m it will be different signals from body to sensor	
4	no	Claire - Can you distinguish influence of floating and emergent plants on results. Equally is there a potential application in terms of monitoring macrophytes?	
2	No	Claire - Have you published your work if it is please provide the link.	

Votes	Answered	Question	Post workshop comment
Stefan Simis, Plymouth Marine Laboratory			
3	no	Stefan - you identify possible lack of institutional capacity as a barrier to the uptake of remote sensing for WFD monitoring - can you say more about this and how it might be addressed?	[Stefan Simis] Our aim should be to fully exploit the information value of the satellite products, now and in future. We should build capacity both with regard to using satellite products in data workflows (e.g. providing training to GIS experts) and to build a common understanding of the workflow used to generate satellite products, their uncertainty estimates and the inherent assumptions of these methods.
2	no	Stefan- Please can we have a DOI or link to Papathasopolous et al 2019 (from Stefan). The text on the slide was too small to read properly	[Stefan Simis] https://doi.org/10.5281 /zenodo.3463050
4	yes	Stefan - How can users of EO Water Quality products find the correct ones for their needs? For example, how to know which product would perform well for a specific lake?	[Stefan Simis] There is no single marketplace for EO services, and I would advise prospective users to ask for a consultation from as independent an expert as can be found. Organisations such as EARSC may be able to connect client-demand to suitable suppliers. Ultimately, EO products should be accompanied with validation statistics and uncertainty information so that the user can judge for themselves whether a product is suitable for their needs. However, with scarcity in in situ validation data such statistics should also be scrutinized.
2	no	Stefan in your slide about drones you showed the MICASENSE RedEdge camera - is that compatible with satellite spectral bands?	[Stefan Simis] This camera has narrower bands than Sentinel-2 MSI and more similar to ocean colour sensors such as MERIS and OLCI. It has bands in the Red, Green, Blue, far-Red and infrared but not the short-wave infrared. Ultimately, for comparison with current and future satellites it is preferably to fly hyperspectral instruments. We also experiment with those but in the low-cost segment these are not imaging cameras but nadir-pointing.

Votes	Answered	Question	Post workshop comment
Christopher Merchant, University of Reading			
3	yes	Christopher - can EO data provide an 'early warning system' if a lake seems likely to stop mixing and become stratified? And if so, can anything be done?	[Stefan Simis] Yes, this is a great idea and yes it could be done by linking the lake modelling to a seasonal to decadal prediction system. Probably locations that are already marginally mixing and have societal importance would be the first lakes to consider.
1	no	Apologies, I missed mechanism why lakes under warming more under climate change will mix less? ie is it that the differential between colder and warmer seasons will lessen?	[Stefan Simis] In summer lakes warm from the surface, more or less, since the sunlight is absorbed in the top 10s of metres and the air is warm. Warm water is more buoyant. If the cooling season of the lake doesn't erode the warm layer enough because of climate change, the wind will no longer mix the water all the way down the lake depth.
1	no	Chris - what are the prospects for higher resolution SST EO long-term analysis, e.g. is Landsat good enough?	[Stefan Simis] Landsat8 is reasonable for patterns of temperature a high resolution (with some stripy artefacts) but not absolute accuracy of lake temperature. One option is to use Landsat for spatial detail in conjunction with other data that fix the temperature biases. The future Copernicus mission LTSM should be great for temperature for small lakes. And maybe the calibration of the next Landsat will also be improved.
Steve Greb, Geo AquaWatch			
2	yes	Steve Greb - Analysis Ready Data sounds like it would really reduce barriers to uptake, but given what we've heard about all the different atmospheric correction methods suitable for different sensors and applications, how easy would it be to get consensus on what constitutes aquatic 'ARD'?	
3	no	Steve Greb - Generating Data for GEE is interesting, but what is the accuracy of the data? By adding it to GEE, many GEE users may use this data as ground truth but as we saw so far in the workshop, global products for water quality are not performing well so far. How can AQUAWATCH provide this data at GEE but in the same time assure the quality of the data?	

Votes	Answered	Question	Post workshop comment
3	no	for Steve Greb:It was very heartening to hear all the work that GEOAQUAWATCH are doing. On a global scale and using lakes as an example, is the plan to use the satellite data along with in situ monitoring to help inform the setting up of a surveillance list of lakes of different types (e.g optical water types) around the world, that should be used for climate change observations so that funds could then be targeted to ensure those lakes would have more intense in situ monitoring for data validation purposes. Which in turn would help public and government confidence in the climate data trends observed.	
Tiago Silva, Cefas			
3	yes	Tiago - how can data cubes be used to analyse sea surface temperature data? Are they being used / considered for Cefas's project researching 'hot spots' and 'cold spots'?	[Tiago Silva] Our datacubes have both OSTIA 4 km SST, and 100 m LANDSAT, which could be used depending on the spatial scales of interest. Thanks for the suggestion, I have passed it to the team working on that project.
2	no	Tiago - does 'xcube' do more than the 'xarray' module in Python, or will the latter become a standard for handling data cubes?	[Tiago Silva] The xarray classes are used in xcube, but there is a lot more to it: a server to serve data and image requests, a datacube generator, a web viewer, etc... xarray is popular library in datacube software but there are also some notable exceptions, such as Rasdaman.
1	no	Tiago - for the work on southern North Sea, how did the Chl concentrations compare when using the different algorithms? Is the CMEMS algorithm reasonable, or did you find that something more specific is needed?	[Tiago Silva] The CMEMS regional algorithm gives a first order approximation but it breaks down in areas of high turbidity and regions of freshwater influence. That is why locally fitted algorithms, and water class dynamic algorithms are preferred.
Steve Groom, Plymouth Marine Laboratory			
2	yes	Steve Groom - is it feasible / desirable to group transitional waters into optical water types as was described earlier for lakes? Or is that not possible in transitional waters, they are too different and dynamic?	

Appendix 4: Discussion topics raised during the workshop

Discussion topic	Votes	Discussed
QUESTION - how can we facilitate ongoing knowledge-sharing between UK public sector bodies about how they are using 'off-the-shelf' Copernicus products and services for water quality monitoring? This workshop is a good start!	8	Yes
QUESTION - will the UK's departure from the EU have any impact at all on our ability to (a) access and use Copernicus data and services for water quality monitoring applications and (b) influence future developments in data and service provision in this area?	8	Yes
QUESTION / R&D PRIORITY - it seems we need more and better in situ reference data to get a better understanding of uncertainty across all products and applications - is that correct? How might we address this? And how best to communicate uncertainty to end users and other stakeholders?	6	Yes
APPLICATION PRIORITY - freshwater nature conservation. R&D PRIORITY - we need research on the relationship between Chlorophyll-a measurements and habitat condition in freshwater environments.	5	Yes
R&D PRIORITY - would it be useful to have more research / more sharing of findings on the subject of which atmospheric correction algorithm is most suitable for particular applications and particular sensors?	4	No
What could Copernicus do to improve water quality products and services: Requirements/ideas for next generation Sentinels? Improvements/new Copernicus Services? Research Questions /support actions in the R&D programme?	3	No
APPLICATION PRIORITY - monitoring condition of Marine Protected Areas in the UK's overseas territories. R&D PRIORITY - we need a better understanding of how products derived from EO can be a proxy for impacts and pressures on these ecosystems and can therefore give us insight into MPA condition.	3	No
QUESTION: Is it possible to provide a standard product of water quality instead of having different groups producing a different product for the same parameter?	3	No
One important thing to develop is the monitoring of HAB based on the estimation of phycocyanin from satellite imagery. We need sensors with a higher spatial resolution and spectral bands that are appropriate.	2	No
QUESTION for DISCUSSION - is there an equivalent to JNCC's 'Crick Framework' for using EO for water quality monitoring? Would this be useful? i.e. a user-friendly framework that tells you how well EO techniques can monitor different aspects of water quality, and which product/s to use?	2	No
APPLICATION PRIORITY - seabed mapping in temperate waters. R&D PRIORITY - we need more and better *in situ* data for validation of light attenuation and light availability products for use in seabed mapping.	1	No