Changes of water colour in the aquaculture zone of the Ebro Delta, NW Mediterranean - pilot site for citizen observatory

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SUMMARY

Changes in water colour are linked to a number of processes of concern to society, including algal blooms. In order to motivate citizens to get engaged in environmental monitoring and to improve their environmental science capacity, bio-optical measurement tools for citizens are developed within the EU project "Citclops" (Citizens' observatory for Coast and Ocean Optical Monitoring). Key parameter is an assessment of water colour by comparison to the Forel Ule (FU) colour scale. In one of the two Citclops test areas, the Ebro Delta, NW Mediterranean, measurements of water colour with the FU scale along weekly transects from May – June 2011 revealed colour changes over short distances and time frames, indicative of fast dynamics of phytoplankton in the area. The typical seasonal pattern of phytoplankton proliferations was reflected well by FU colours as retrieved from satellite data (Medium Resolution Imaging Spectrometer (MERIS) full resolution 300m data). The results show that a simplified classifications natural waters by its colour enhances our understanding of spatio-temporal dynamics in the Ebro Delta. Hence, such measurements can complement more accurate in-situ observations that allow the identification of harmful algal taxa and phycotoxins. Thereby, Citclops observations support phytoplankton surveillance for human health and food safety. Direct links to environmental issues strongly motivate the general public to engage in environmental surveillance and stewardship, and to support local monitoring efforts.

INTRODUCTION

Changes in water colour are directly linked to alterations in water composition, in particular phytoplankton biomass and community assembly. These relate to a number of processes of concern to society like algal blooms. In order to measure these parameters, and improve the environmental science capacity of citizens, the importance of their active involvement is gaining increased recognition. The impact of public participation in the best case leads to a conservation of the environment by forming knowledge and identity of individuals, providing a basis for relationships and legislation of social-ecological systems and scientific data to answer scientific questions as overlapping outcomes, see Fig. 1 (*1*).

Within the EU project Citclops both aspects are addressed. The overall aim is to equip citizens with tools by transfer of bio-optical measurements to smartphone apps, and to improve their general knowledge of the environment. In order to motivate citizens and enable their participation, they need to know what, how, and why to measure.

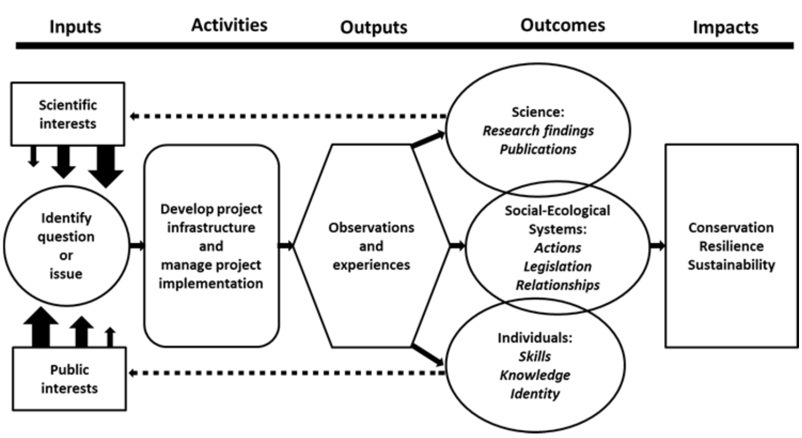
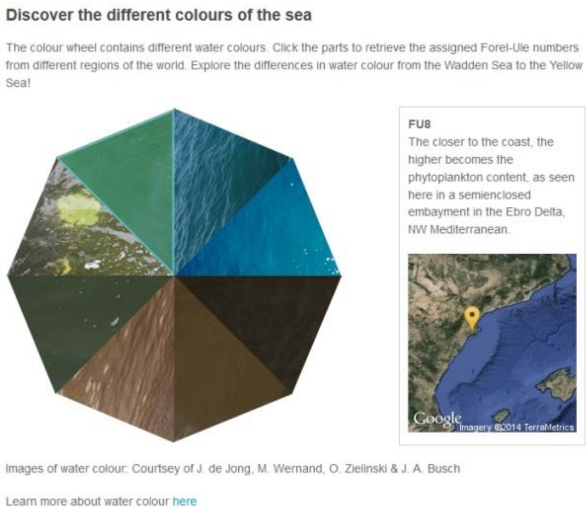


Fig. 1: Scheme of public participation in scientific research project, including feedback arrows. Balanced input from scientific and public interest, negotiated differently by each project are visualised, as well as different overlapping outcomes for science, social-ecological systems and individuals (Use of figure courtesy J. Shirk).

On the project website (www.citclops.eu) and in dedicated citizen training events, fundamental bio-optical principles and the resulting relation of water colour to constituents, such as phytoplankton, suspended solids and coloured dissolved organic material (CDOM) is transferred to the public, e.g. with a colour wheel (Fig. 2). Water colour measurement in Citclops is simplified to a comparison with 21 colours (blue to brown) on the Forel Ule (FU) colour scale (compare *2*). The assignment of colours by citizens is performed either with a plastic scale above water, or by a digital scale above a photo in the Citclops smart phone app. Information on how to measure are provided on website and directly in the app. In development are a quality control procedure for images (*3*) and a seasonal fit with background images of typical regional FU colours for the two Citclops core regions Wadden Sea and Ebro Delta. For this purpose, a data extraction service for MERIS full resolution satellite data has been developed, based on version 2 of the DUE coastcolour project (www. coastcolour.org).

Fig. 2: Citclops colour wheel for citizen´s education: Different water colours from around the world are assigned to corresponding Forel Ule values. A change of colour and FU numeral equals a change of water constituents.
Source: http://citclops.eu/education/colour-wheel--water-colours-explained



The Ebro Delta is a touristic area and is known for seafood, fisheries and leisure activities in two semi-enclosed embayments Alfacs and Fangar (Fig. 3). Hydrodynamics in both bays are influenced by the surrounding Mediterranean Sea and seasonally by freshwater inflow through channels from an irrigation system for rice agriculture. Such changes in water regimes can influence the presence of algal species including taxa which are capable to produce potent phycotoxins. This is by simple transport of algal blooms from the Mediterranean, provision of good conditions for already present species in the bay´s zones with long retention times (*4*), or by providing favourable environmental conditions, e.g. by nutrient inflow from terrestrial activities via irrigation canals (*5*). Typically, algal biomass (by proxy of the algal pigment chlorophyll *a* (Chl *a*)) follows a pattern of increase towards end of summer/autumn in both embayments, with earlier start in Fangar Bay (*6*). Three major potentially noxious algal genera are known for high biomass production in the bays: dinoflagellate *Karlodinium* spp., diatom *Pseudo-nitzschia* spp. (*7-8*) and occasionally the raphidophyte *Chattonella* spp. (M. Fernández-Tejedor, pers. comm.).

In this study we present the first results of a direct comparison of in-situ and satellite colour data in both Alfacs and Fangar bay for the year 2011 in order to test compatibility, strengths and weaknesses of both methods and the information shown by colour monitoring.

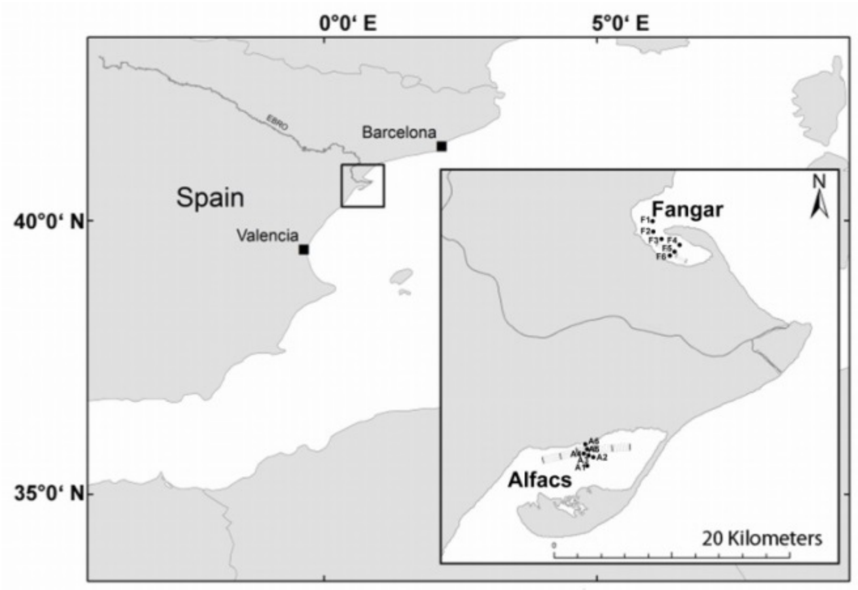


Fig. 3: The two semi-enclosed embayments Alfacs Bay and Fangar Bay are in the Ebro Delta natural park on the NW Mediterranean coast. Forel Ule (FU) water colour was measured and modelled at six stations in both bays (dots), A1-A6 in Alfacs Bay, F1-F6 in Fangar Bay, including positions at the centre of the bays and close to the aquaculture facilities (black pattern).

METHODS

Water colour was measured at six stations along transects during nine cruises in Alfacs Bay and five cruises in Fangar Bay, in May and June 2011 (Fig. 3). Water colour above a submerged white Secchi disk at half Secchi depth was assigned colour standards of a LaMotte colour scale (LaMOTTE COMPANY, Maryland, USA) and assigned to the matching FU numeral (1-21).

Corresponding to FU measurements at station A4 in Alfacs Bay, remote sensing reflectance spectra were collected from a set of three Ramses spectrometers that measured the water-leaving radiance, matching sky radiance and downward irradiation (*9*). These were assigned to FU numbers by means of conversion to chromaticity coordinates and matched to FU coordinates following Wernand *et al*. (*10*) and Novoa *et al*. (*2*).

MERIS scenes of the Ebro Delta area for the year 2011 were downloaded from the coastcolour ftp site, extracted and projected on a standard lat-lon grid. Based on the L2R products, the information of band 1-9 (412-708 nm) was converted to FU values by means of the FUME algorithm (*10*). At the position of all 12 ground stations, the nearest nine pixels were selected to test the variability in information near the stations and give some means for data quality control. The MERIS overpass is always in the morning (between 9:53 and 10:53 UTC) and 142 scenes are available in 2011. From the available pixels (142 times 9) at station A4 near 45% contained no data due to clouds or failure in the processing to L2R products. Only in 24% of the cases all 9 pixels contained reliable data.

RESULTS

Water colour as measured with the LaMotte scale, as well as derived by reflectance data from the A4 platform station and MERIS ranged from blue-green to brownish green during the respective study time. Measured FU values are in quite similar for the Alfacs station, but not for the Fangar station (Table 1). A closer inspection revealed that for the Fangar station only scenes with 1, 2 or 3 good pixels per scene were available, due to proximity of land and bottom reflection. Highest FU values – towards brown water- were, however, derived at station 2 in Fangar Bay (FU 16). Such high FU values (above 10) were, however, all observed in scenes with only 1 pixel available and could not be confirmed by independent match-up ground measurements.

Table: Minimum and maximum FU water colour values over the year 2011 at six stations in Alfacs and Fangar bays. Comparison of reflectance systems and traditional measurements at station 4 in Alfacs Bay are set in bold.

	Alfacs station (central to interior)						**Fangar station (exterior to central)**					
	1	2	3	4	5	6	1	2	3	4	5	6
Jan-Dec FU min MERIS	7	6	6	**6**	6	7	6	7	8	7	7	7
Jan-Dec FU max MERIS	9	9	9	**9**	9	9	13	16	13	13	13	13
May-July FU min platform	-	-	-	**8**	-	-	-	-	-	-	-	-
May-July FU max platform	-	-	-	**10**	-	-	-	-	-	-	-	-
May-July FU min LaMotte	7	7	7	**7**	7	7	6	7	6	8	8	7
May-July FU max LaMotte	9	9	10	**10**	10	9	8	14	9	9	8	8

Weekly in-situ measured FU colour from May to July reveal a general greening of water in both bays over time. Naturally, water at stations towards the outside Mediterranean- especially station 1 in Fangar Bay, has by trend lower -meaning more blue- FU colours. Especially in Fangar Bay, water colour changes over short distances and time scales are visible (Fig. 4), with highest FU values at station 2 (see 2011-05-19, Fig. 4).

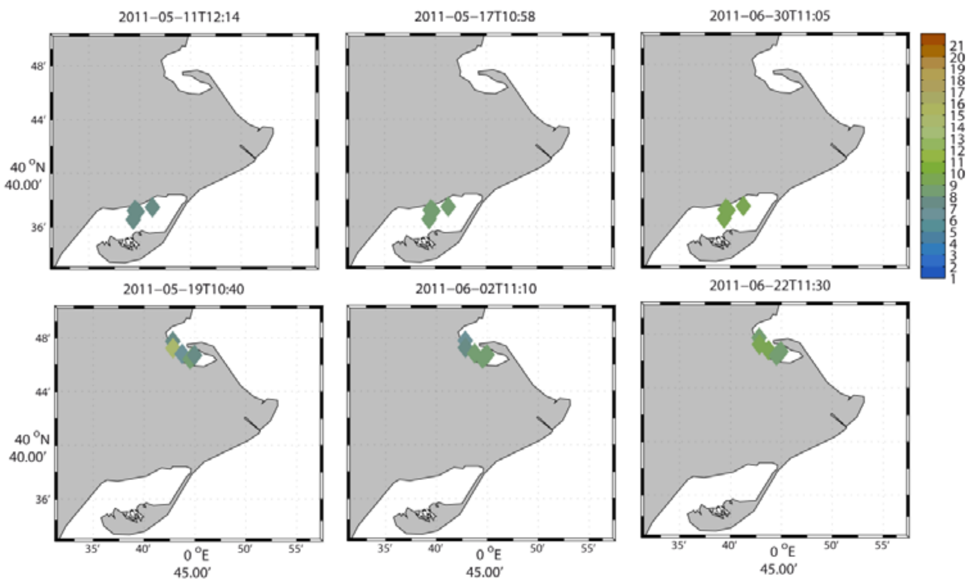


Fig. 4: Variations of measured FU values at selected dates between May and July 2011 in Alfacs & Fangar bays along transects.

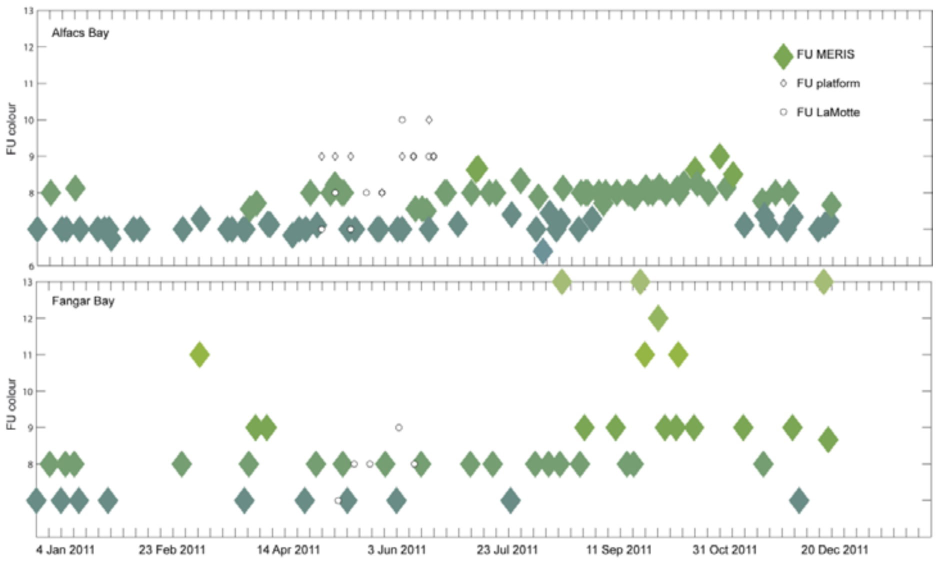


Fig. 5: Temporal dynamics of water colour changes at key station 4 in Alfacs and Fangar bays in 2011. From January – December, FU as derived by conversion of MERIS reflectance data (diamonds, colour corresponds to FU colour) is plotted over time, from May – July, FU colour derived from a radiometric system on a platform (open diamonds), and as measured with LaMotte scale (open circles) are shown.

DISCUSSION

FU colour conversions of reflectance data from a radiometric system installed on a platform, as well as from MERIS are in the same ranges as FU classifications by the traditional method. Direct comparison was often impeded by lack of MERIS scenes due to cloud coverage and a relative high fraction of pixels without information. Nevertheless, it is clear that MERIS achieves a high spatial and temporal coverage. From the limited set of measurements that were obtained in the same period, there is some indication of bias between in-situ and MERIS colour. This might originate in a difference in spectral resolution between the MERIS sensor (9 bands in 300 nm) and the Ramses sensor (90 bands in 300 nm) or systematic offset in the MERIS atmospheric correction, resulting in a bluer spectrum.

The Citclops MERIS FU-colour conversion and extraction service for the Ebro Delta delivered a good overview on water colour changes over the year. It is an indication of what we might expect the Citclops App would deliver in these bays. These citizens' observations will not nicely cover a standard grid, but will be mainly positioned along the shore line. But that is exactly where the MERIS data are most corrupted and so the two sources are complementary. Also the in situ dataset of measured FU values, which represent a type of Citclops measurements by citizens, revealed more details than the MERIS data. Changes over short distances and time frames are indicative of fast dynamics of phytoplankton in the area, which were also observed over depth at the same time (*8*).

First inspection of the data indicate a higher occurrence of green water, which matches the expected seasonal pattern described by Llebot *et al*. (*6*), with higher plankton proliferations towards autumn. Different water masses were clearly distinguished by FU colours, especially at station 2 in Fangar Bay, which is close to an inflow of a freshwater canal from rice fields. Such high FU values with yellow/brown hues correspond to this source of dissolved and suspended organic material inflow to the bay.

Thereby, even such simple measurements of 21 hues of water colour aid to complete our understanding of spatio-temporal dynamics. They also complement more accurate in-situ observations that allow the identification of harmful taxa and phycotoxins. Hence, Citclops observations have a potential to support phytoplankton surveillance for human health and food safety. Both, citizen´s knowledge about the system and about effects of their measurements raise identity and awareness. This provides a strong motivation for the general public to get engaged in environmental observation and stewardship.

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