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1 Executive Summary

- This report represents the second deliverable from CERTO Work Package 6 (WP6), focused on the development of indicators. It is an annual progress report of the work carried in WP6 during the year two of the project noting that work is ongoing, in addition due to the 9 month no cost extension. The general objective of Task 6.1 was to analyse the list of User requirements in order to define a list of useful indicators to be included in the CERTO prototype or to be provided as a downstream service. Task 6.2 is focused on the planning and management of indicators for industry and local authorities and Task 6.3 is focused on supporting EU Policy through the development of harmonised indicators. Finally, Task 6.4 pertains to the development of a higher-level, more complex index which incorporates outputs from the previous tasks.

- This deliverable provides an overview of the context of the work and presents the main indicators that WP6 has focused on in response to the analysis of User requirements. A brief overview of the initial User requirements is also given (Section 3).
- Four main indicators are described in response to the User requirements analysis, including two indicators based on total suspended matter (TSM) and/or turbidity (TUR), one indicator based on Chlorophyll concentration (CHL P90), and another based on phytoplankton bloom phenology (Section 4). Additionally, the more complex Socio-Ecological System Vulnerability Index (SESVI) is also presented.
- The indicators being produced are described in detail, including their development and origin, and an in-depth description of their methodology. The preliminary results for the indicators currently under development are also presented as a report on the scientific progress of CERTO. While the results presented in this deliverable are still preliminary, some initial conclusions can already be drawn and will be used for further developments.
- Future plans for the development of WP6 indicators, as well as next steps for the integration in the prototype, are presented in Sections 5 and 6.

2 Introduction

CERTO Work Package 6 is focused on the development of Indicators that Users can take advantage of more effectively to integrate data and observations into their analysis and daily work. The first step to achieve this objective was to analyse the needs of several Users interested in CERTO's products, which was done through a series of interviews conducted in 2020 under WP2. The information collected during these interviews was analysed and enabled the identification of a list of indicators and relevant products for Users and stakeholders from industry (e.g., shipping and aquaculture), local authorities (e.g., port authorities) and regulators (e.g., environmental agencies) in charge of reporting on the European Union (EU) Water Framework Directive (WFD) and Marine Strategy Framework Directive (MSFD), as previously stated in CERTO Deliverable D6.1. Moreover, the Socio-Ecological System Vulnerability Index (SESVI) is being developed, as planned in the original proposal, with the aim of assessing the overall vulnerability of a certain socio-ecological system to external changes and pressures. Indicators are a key part of the CERTO project since they are important in demonstrating the added value of the harmonised products resulting from the project. SESVI also aims to demonstrate the additional benefit obtained from using different global data sources, including several Copernicus services.

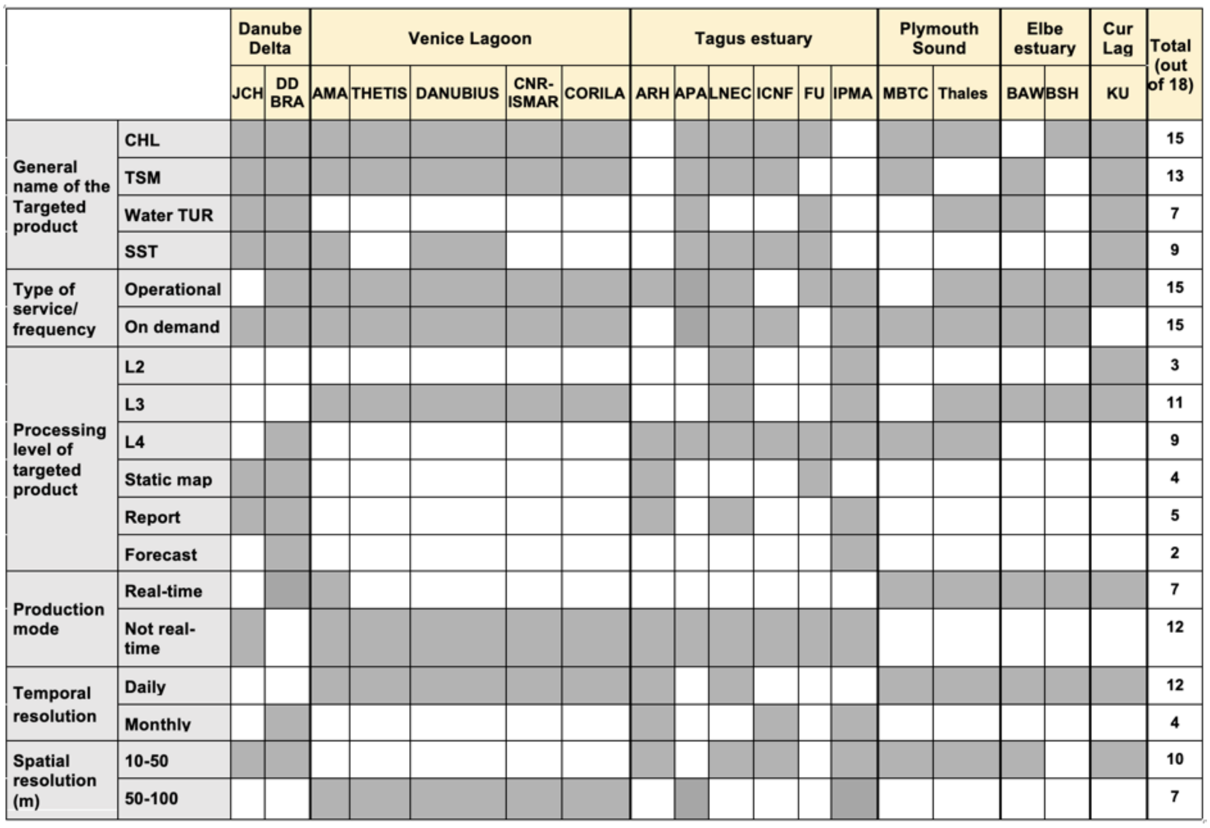
Following the first interviews with Users, a second round of interviews was performed in the final trimester of 2021, providing Users with an update on CERTO's progress and to obtain further information on how the indicators would be most effective for them. Engaging with Users is key during the development phase to perform necessary adjustments before the Demonstration Phase starts later in 2022. The results of those interviews are presented and analysed in depth in CERTO Deliverable D2.3 but are considered herein for future developments on indicators. Demonstration of the proposed indicators will be done under WP8, where indicators will be tested against 'real life' situations and exposed to service providers and end-users.

Deliverable D6.2 presents the progress in the development of indicators that has taken place in the last 12 months of the project, from January to December 2021. The Deliverable consists of four main sections: i) Section 3 provides the arguments used to reach the final list of indicators to be developed within WP6; ii) Section 4 gives an overview on indicator development, including a detailed description of methodology and preliminary results; iii) Section 5 integrates feedback from Users obtained during the second round of interviews in autumn-winter 2021 and proposes a plan for the adapted development of these indicators based on this new feedback; and iv) Section 6 describes the main steps for prototype integration.

3 Indicators selected from the analysis of User Requirements

Users of the six CERTO case study sites were interviewed in 2020 regarding their needs and expectations for water quality monitoring in their respective regions. Due to covid-related restrictions, the interviews were mostly conducted via teleconference and involved local Users and stakeholders that had expressed interest in exploiting CERTO products. A full description of the interview results can be found in Deliverable D2.1. Table 3.1 is a summary of the Users' needs (a comprehensive summary of the User Requirements Analysis can be found in D6.1).

Table 1 - ***Summary of the main specific requirements needed for CERTO's case studies (Danube Delta, Venice Lagoon, Tagus estuary, Plymouth Sound, Elbe estuary and Curonian Lagoon). (Adapted from CERTO Deliverable D6.1).***



		Danube Delta		Venice Lagoon					Tagus estuary						Plymouth Sound		Elbe estuary		Cur Lag	Total (out of 18)
		JCH	DD BRA	AMA	THETIS	DANUBIUS	CNR-ISMAR	CORILA	ARH	APA	LNEC	ICNF	FU	IPMA	MBTC	Thales	BAW	BSH	KU	
General name of the Targeted product	CHL	■	■	■	■	■	■	■		■	■	■	■		■	■		■	■	15
	TSM	■	■	■	■	■	■	■		■	■	■			■		■		■	13
	Water TUR	■	■							■			■			■	■		■	7
	SST	■	■	■		■				■	■	■	■						■	9
Type of service/ frequency	Operational		■	■	■	■	■	■	■	■	■		■	■		■	■	■	■	15
	On demand	■	■	■	■	■	■	■		■	■	■		■	■	■	■	■		15
Processing level of targeted product	L2										■			■					■	3
	L3			■	■	■	■	■			■			■		■	■	■	■	11
	L4		■						■	■	■	■	■	■	■	■				9
	Static map	■	■						■				■							4
	Report	■	■						■		■			■						5
	Forecast		■											■						2
Production mode	Real-time		■	■											■	■	■	■	■	7
	Not real-time	■		■	■	■	■	■	■	■	■	■	■	■						12
Temporal resolution	Daily			■	■	■	■	■	■		■				■	■	■	■	■	12
	Monthly		■						■			■		■						4
Spatial resolution (m)	10-50	■	■						■		■	■		■	■	■	■		■	10
	50-100			■	■	■	■	■		■				■						7

The results of the interviews indicated that CERTO Users are interested in the monitoring of Marine and Transitional waters, requiring several indicators relevant to the biological structure, composition, and overall quality of the water. Total Suspended Matter (TSM), Chlorophyll Concentration (CHL) and Sea Surface Temperature (SST) are the parameters required by most of the Users for all case studies. Turbidity (Water TUR) was also of high importance to several Users. Currently, the ability of satellite products to provide accurate data that can represent the spatial and temporal variability of these water quality parameters in these waters is limited which highlights the need to provide high quality products for transitional regions.

The favoured format for receiving the data is as high-level processed data (Level 3 or Level 4) or in the form of static maps summarising the data characteristics. The preference is for little or no additional processing being required, except for those Users directly involved in academic research. Research-oriented institutions (such as LNEC, IPMA and KU) have additionally requested the availability of low-level processing data (L2) for the purposes of forecasting, research, or modelling. Users suggested that data could be reported in the form of publications or reports addressing EU Directives, such as the WFD and the MSFD.

In addition, Users were also expecting to receive products with the highest temporal and spatial resolutions that work for the whole water continuum. Integration of information, in the form of percentiles, anomalies and trend analyses, were also requested as some of the Users do not have the resources to analyse large amounts of data.

Almost all Users tended to prefer finer temporal and spatial scales, especially for spatial resolution where datasets are desired in the 10-100 m range. On the question of whether data should be provided as *near-real time* or *operational*, Users were evenly split.

From this analysis, four indicators were selected for further development: i) two are being developed under Task 6.2 and are focused on the identification of turbidity maximum zones and dredging areas; and ii) two more are being developed under Task 6.3 based on the CHL product and focused on the analysis of phytoplankton dynamics, more specifically the CHL 90th percentile (CHL P90) and the bloom phenology metrics. In addition, the more complex Socio-Ecological System Vulnerability Index (SESVI) is the focus of Task 6.4. As previously acknowledged, these indicators seem crucial to support Users in their local responsibilities, such as decision-making, licensing and EU Directives reporting. Moreover, the importance of SESVI was highlighted in the CERTO year 1 review.

Following the 2020 interviews, a second round of interviews with the same Users were undertaken in the last part of 2021, in an effort to update the Users with recent developments following the first round of interviews. These meetings were essential to present progress on indicator development and to receive continued feedback from the users, which is key to making adjustments during this development phase, promoting improvement of the final set of indicators. The results of those interviews are presented and analysed in depth in CERTO Deliverable D2.3.

4 Development of Indicators

The development of WP6 Indicators is presented in three sections: i) Planning and management indicators for industry and local authorities (section 4.1); ii) Indicators to support EU policy (section 4.2); and iii) Social-Ecological system Vulnerability Index (SESVI; section 4.3). The description of each indicator, methodology developments and preliminary results are then presented for each section. The preliminary results are based on interim or preliminary satellite data produced specifically for indicator testing: hence, the results should not be considered "final" for CERTO since the indicators will be run over the final CERTO data production from WP7. It is important to note that changes and adjustments might be required during the second part of the development phase. In fact, section 5 already considers some future developments of indicators, based on the feedback collected from Users during the second round of interviews.

4.1 Planning and management indicators for industry and local authorities

4.1.1 Description of indicator to be developed

The indicators envisaged in Task 6.2 will focus on the influence of sediments and will be based mainly on EO products Total Suspended Matter (TSM) and/or Turbidity (TUR), which can already be considered as primary indicators. The User requirements collected in CERTO confirm that the concentration of sediments in areas of interest is highly relevant. Having that in mind, the indicator work done during 2021 has been focused on two main points: i) Indicator for maximum turbidity zone/high loads zone; and ii) detection of dredging activities.

4.1.2 Method development

Detection of the maximum turbidity zone

The main objectives of the indicators for detecting the maximum turbidity zone are to: i) analyse trends (height and width) by comparing daily/weekly/monthly maps to see shifts and seasonal trends, and ii) take tides into account (inflow/outflow) to see their impacts. This may also be interesting when looking at less tide-influenced zones.

To best characterise the turbidity zone, we first need to list and analyse the possible causes of the existence of the zone, and then assess the possible influences on the shift of the turbidity zone. As such, we first listed the potential causes of the turbidity zone based on an in-depth analysis of the Elbe River tidal system:

- Accumulation of suspended matter
- Transport towards the open sea/out of the estuary is smaller than the transport coming from the upper river for a longer period, so that:
    - Less surface runoff → turbidity zone increases and tends to shift upstream
    - Flooding event → turbidity zone decreases; most of the suspended matter gets washed out into the North Sea

Causes may vary depending on each site and are mainly relevant for interpretation, not necessarily for method application. The possible influences on the shift of the turbidity zone that are more relevant to the method are:

- Tides
- River morphology

- Surface run-off
- Composition of suspended matter
- Anthropogenic causes, e.g., dredges
- Bacterial and algal influence on structure/ formation of suspended matter
- Salt level gradient influences transport of sediments, leading to vertical circulation

Depending on what data is available, it may not be possible to properly assess all influences, so the first steps were to use data types mostly available everywhere, which are tide information and river run-off.

The first step was to define the area of interest. Global shapefiles representing one polygon of each area were gathered and then subdivided into 1km long sub-regions along the river line. The segmented 1-km wide polygons were created using the QGIS software.

An example is provided below (Figure 1) for the Tagus area.

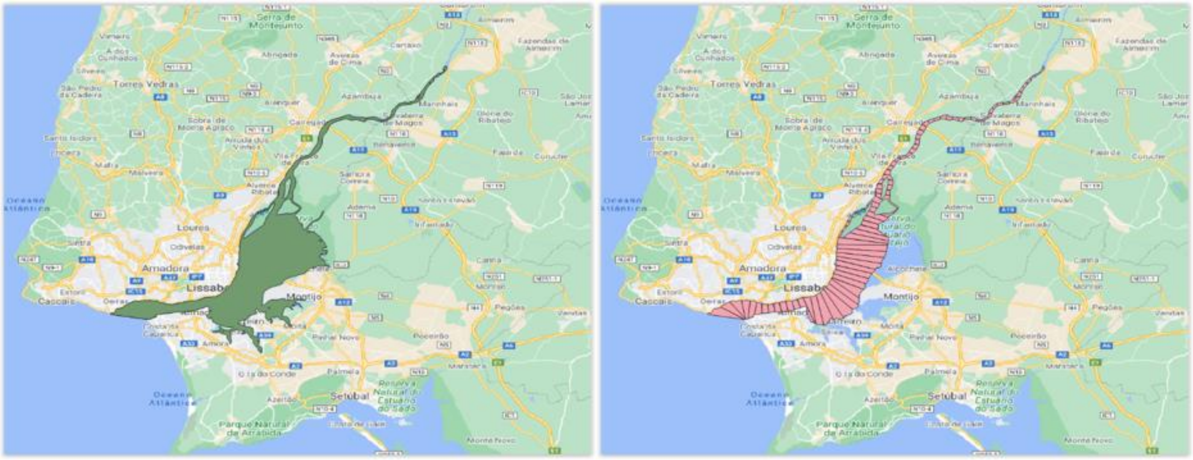


Figure 1 - Tagus shapefiles - left whole region of interest, right 1km long sub regions along the river flow.

Once the subregion division is complete, this shapefile is used to compute the turbidity zone statistics on the CERTO Turbidity products for each given day. We used turbidity (computed using the Nechad algorithm at 865nm).

The method developed for this indicator during the last reporting period is as follows:

1- Calculate the averaged turbidity for each km segment.

2- Compute the quantile value (Qxx) of turbidity for the current date and create (all segments considered) a list which indicates if the turbidity average of a 1 km segment matches this value or not.

3- Loop over this list and find all potential turbidity zones for the current date.

i) Initialise a start- and an end-pointer and an exception counter (explained below).

ii) Case 1: If the current river segment is tagged as valid (>= Qxx), start or continue the count of the current zone and add this km segment.

iii) Case 2: If the current river segment is tagged as invalid (< Qxx) and the exception count isn't exceeded, increase the exception count by one and remember the position of the exception. The exception counts correspond to the number of segments with turbidity values below Qxx or without data (NaN) that are located between two segments with high turbidity levels (identified as (>= Qxx). This can happen due to errors in TUR retrieval or due a non-realistic spatial average due to low number of valid pixels in the segment. When the number of exception counts reach a certain threshold, the algorithm stops looking for the maximum zone and writes the results.

iv) Case 3: If the current river segment is tagged as invalid and the exception count is exceeded, compute the length of the current zone and reduce it by exception counts which occur at the end of it. Save the detected zone to a list of all potential zones for the current date and reset all pointers and counters.

4- Choose the longest potential zone for the current date as maximum turbidity zone and apply the criteria of the minimum zone length and the minimum turbidity value.

Some aspects of the method need to be parameterised to be adapted to a specific region. The default values were derived for the Elbe estuary after a detailed analysis of the parameter interactions for a given year and then applied as is for the other years:

- minimum pixel count for a km segment which needs to be reached, otherwise the median of the current segment is set to NaN – the default is set to 50
- quantile value Qxx – the default is set to 0.65
- minimum turbidity value of Q0.65 – the default is 10.0
- threshold of exception values of the turbidity zone which are allowed to be 'NaN' or '<Qxx' – the default is set to 7
- minimum length (km) of a turbidity zone to be considered – the default is set to 20.

Several weaknesses have already been identified and may need to be revised before the final version is used:

- a lot of thresholds are not tied to the actual dataset
- zone detection at the edges might be interrupted before the actual end of the transect; this might be a problem because in the later analyses the zone middle is used
- by using a quantile-value as threshold, the maximum zone length is already defined
- Absolute threshold (TUR/TSM value) may not be enough to characterise, and we may need to normalise to check the expansion/decrease of the zones.

Once the location of the turbidity zone has been properly identified, and its maximum well defined, we use a regression correlation between location and potential influencers (such as tide or river runoff as was mentioned earlier).

Detection of dredging activities and impacts

The main questions related to this indicator work were to (i) assess whether dredging events were (reliably) detectable and, if so, (ii) whether dredging lead to higher TSM concentrations in the region considered or if sediments are swept away by the currents.

For now (bearing in mind this task is ongoing) work on this indicator has not progressed very far and the analysis only started in a visual manner, first to see in RGB images whether these events were visible or not. The principle of the method is to analyse TUR concentrations before and after a dredging event to see their potential impact on the system. The method will first look through images to detect dredging events. Once an event has been identified, it takes the two time-concurrent images (before and after) to assess the impact. Depending on revisit time and system dynamics, this may however prove difficult when looking at Sentinel-2 data and, in the end, only a dredging event detection indicator may come out of this work.

4.1.3 Preliminary Results

The maximum zone turbidity indicators may be presented to Users in different forms, depending on their interests. First, turbidity maps may be displayed, relaying information at a given time in the Case Study Area. This allows for quick visual comparisons between the observed days. Figure 2 shows an example for the Elbe region, where the turbidity zone is clearly visible in March 2018 (top part of the picture) at the beginning of spring and is not as clearly visible in November of the same year (bottom part of the picture). Figure 3 shows an example for the Tagus region, where the turbidity zone is seen to be shifted from South to North between the two dates, one in January 2019 and one in May 2019.

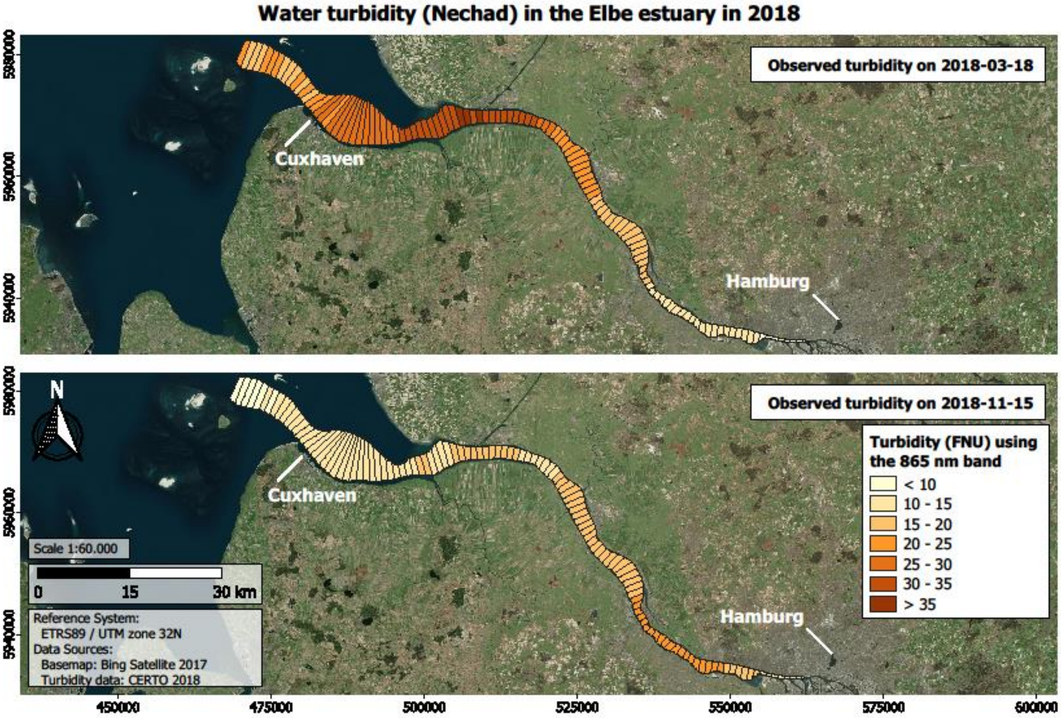


Figure 2 - Turbidity Map of the Elbe for 2018-03-18 (top) and 2018-11-15 (bottom).

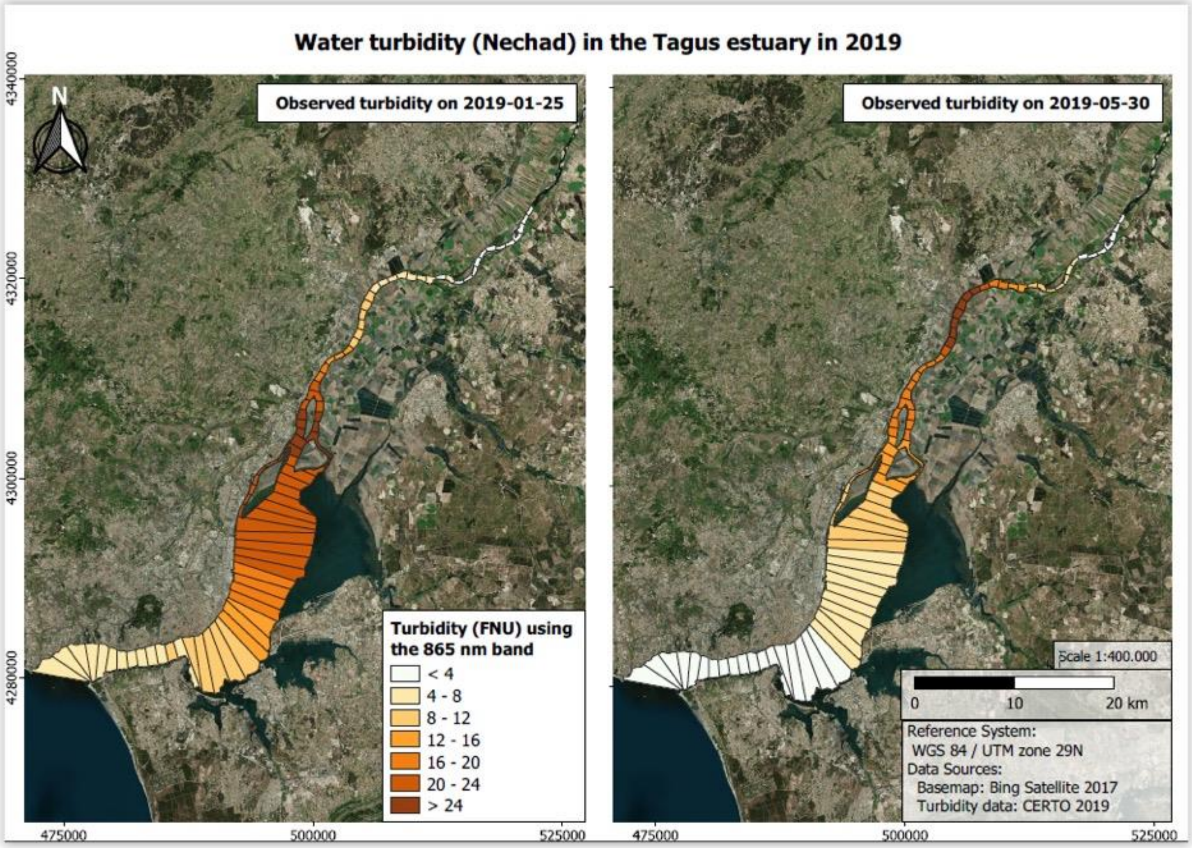


Figure 3 - Turbidity map of the Tagus for 2019-01-25 (left) and 2019-05-30 (right), where the South-North shift of the maximum turbidity zone (dark brown) is visible.

The turbidity information can also be plotted along the river line (Figure 4), from upstream (region with no or barely any tidal influence) to river mouth / estuary opening. Figure 4 shows the same information as Figure 2 but in another format, depending on User needs.

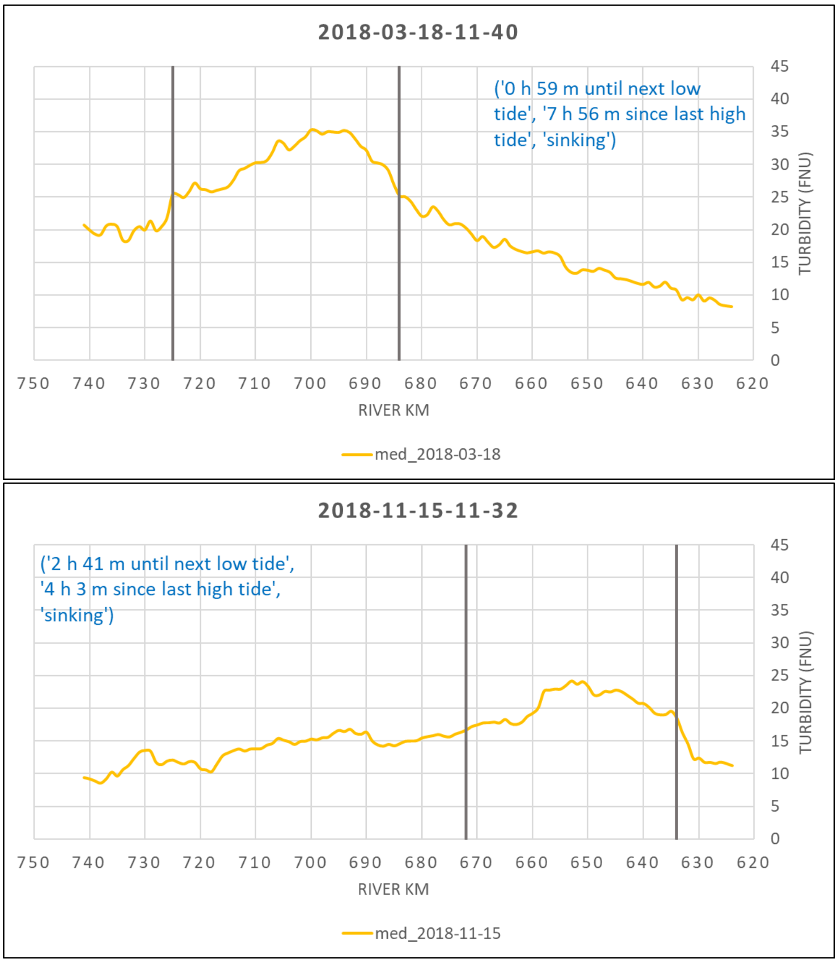


Figure 4 - Turbidity zone detection along the Elbe River line from upstream (right - km 620) to river mouth (left - km740). The tide information at the time of the overpass is also displayed. The vertical lines define the maximum turbidity zone as explained in Section 4.1.2.

The different regression plots can then help define which parameter most influences the turbidity zone location. For now, only the regression along the river discharge is implemented (Figure 5). For the Elbe region, river runoff appears to be the main driver of the maximum turbidity location. On the contrary, it seems that the river runoff is not as important for the turbidity zone position in the Tagus, as can be seen on Figure 6, with a regression coefficient < 0.2 compared to > 0.8 for the Elbe Case Study.

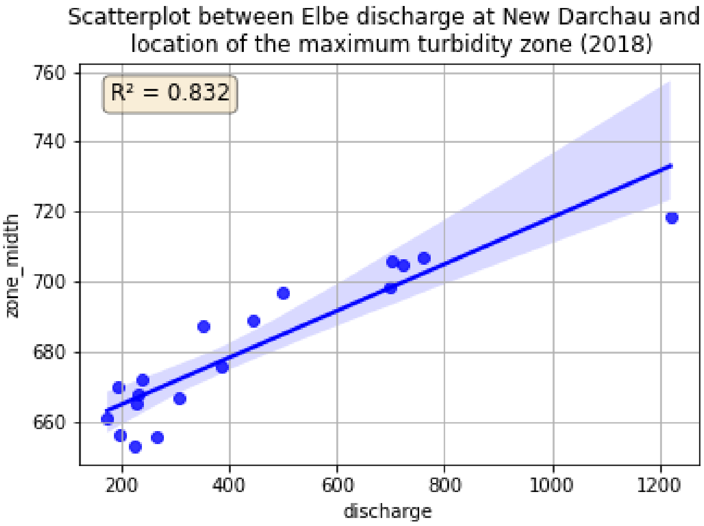


Figure 5 - Regression plot between maximum turbidity zone location and river discharge for the Elbe Case Study Site.

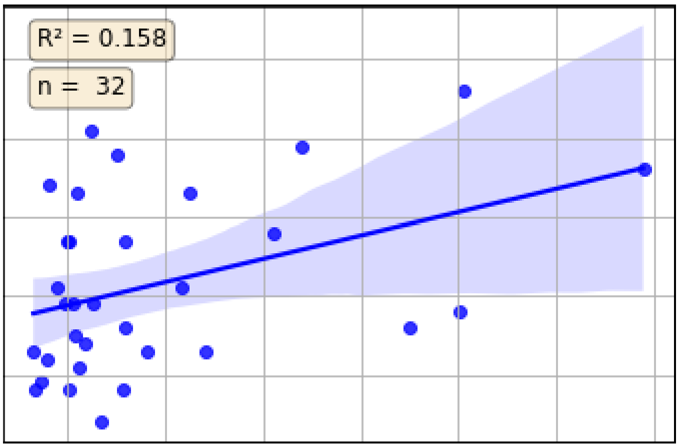


Figure 6 - Regression plot between turbidity zone location and river discharge for the Tagus Case Study Site.

4.2 Indicators to support EU policy

4.2.1 Description of indicator to be developed

EU Member States need to comply with several EU Directives, such as the WFD and the MSFD. Some of the Users included in CERTO are entities that hold the responsibility of conducting and reporting assessments on water and ecological quality. High-level processed data for transitional waters fulfils important needs of most users, especially when aggregated data are provided. The indicators provided should allow for evaluation of specific metrics of the Directives (i.e., CHL P90) and provide information on ecosystem health through the analysis of phenological metrics used to study the dynamics of phytoplankton blooms. Thus, two sets of common indicators were developed for six user-case areas:

- Chlorophyll-a 90th percentile (CHL P90), calculated using continuous remote sensing datasets over the growing season (e.g., Brito et al., 2012; Devlin et al., 2007; Revilla et al., 2009, 2010).

- Phytoplankton bloom phenology metrics (e.g., Koeler et al. 2009; Racault et al. 2012; Ferreira et al. 2021). Phenologically-important aspects of the phytoplankton growth are determined by: (1) the time of bloom initiation, peak, and end, (2) the main bloom duration, (3) the number of blooms, and (4) the bloom amplitude and area.

4.2.2 Method development

Spatial subsets (Table 2) of data cuboids were downloaded from the CERTO data catalogue (https://engage.certo-project.org/thredds/catalog.html) through THREDDS data server NetCDF (Network Common Data Format) Subset Service. The processing of raw S2 Multi-Spectral Instrument (MSI) data (i.e., atmospheric correction and CHL bio-optical algorithm) was performed by Plymouth Marine Laboratory (PML). The data archive of the variable of interest (CHL), with spatial resolution of 60 m, was accessed for the dates between January 2017 and December 2020. The downloaded NetCDF cuboids for each case study area were imported to the Scientific Development Environment (Spyder 3.3.6) of Python (version 3.7) where data processing and analyses were performed.

Table 2 - Spatial extent of ROIs.

	Coordinates			
Curonian lagoon	55.73°N	54.89°S	21.29°E	20.52°W
Elbe estuary	54.42°N	53.63°S	9.21°E	8.21°W
Razelm-Sinoe lagoon system	45.05°N	44.46°S	29.18°E	28.73°W
Tagus estuary	38.88°N	38.58°S	-8.92°E	-9.34°W
Tamar estuary	50.53°N	50.15°S	-3.88°E	-4.42°W
Venice lagoon	45.60°N	45.00°S	12.60°E	12.00°W

The data cuboids for each case study area contain three CHL products generated by different algorithms (OC2, Gilerson and Gons05). Briefly, the three algorithms are characterised as follows:

- The OC2 algorithm (O’Reilly et al., 1998) is used for clear waters, specifically where CHL < 10 mg m^{-3} and Total Suspended Matter (TSM) is minimal (using a cut-off of 0.5 FNU). It makes use of the blue-green wavelength ratio to estimate the CHL content.
- The Gilerson algorithm (Gilerson et al., 2010) is designed for more turbid waters. This algorithm is a generalised near-infrared-red wavelength ratio algorithm and is suitable for waters with moderate to high CHL content (2 < CHL < 200 mg m^{-3}) and, as it uses the red bands, should cope with higher TSM.
- Gons05 (Gons et al., 2002; Gons et al., 2005) is a semi-analytic algorithm that uses the same near-infrared-red ratio as Gilerson but also brings in a term related to CHL absorption, water absorption and the backscattering coefficient. Again, this is expected to perform better in moderate to high CHL waters (2 < CHL < 200 mg m^{-3}) and correct for wider variation in detritus.

The suitability of the CHL product depends on the regional characteristics of each area. For each case study area, the remote-sensing-derived CHL values (in space and time) were compared to in-situ data (when available). Then, data distribution histograms, time series analyses, matchups and statistical analyses were performed to evaluate its capacity to represent natural conditions and dynamics. Table 3 shows the algorithms that were used for each area. These were the most appropriate at this point.

It is important to note that within the scope of the CERTO project, bio-optical algorithms will be regionally refined based on the assessment of optical water types. Thus, the CHL products used here are intended to serve the purpose of method development only. Once the final and improved CHL product from CERTO is available, indicators will be computed again, and results will be derived.

Table 3 - Selected algorithms for each case study area and CHL range.

	Algorithm	***RS CHL range (mg m^{-3})***
Curonian lagoon	Gilerson	25 – 150
Elbe estuary	Gons05	0 – 50
Razelm-Sinoe lagoon system	Gilerson	25 – 150
Tagus estuary	Gons05	0 – 50
Tamar estuary	OC2	0 – 10
Venice lagoon	Gons05	0 – 50

Regarding the CHL P90 indicator, climatological and annual per-pixel computations were undertaken (Figure 7) once the most suitable CHL product was selected for each case study area. The per-pixel CHL average, CHL percentile 90, CHL variance and number of valid pixels were then computed. The productive period considered ranged from March until October for all case study areas, apart from the Tagus estuary, where the growing season is longer, spanning from February until October. Data from 2017 until 2020 were considered for the climatological computations. In theory, a period of five years should be considered, but this was not possible in this case as data were not available. For annual computations, only data from 2018 onwards were used due to the limited number of images available for 2017, when only Sentinel-2A was available.

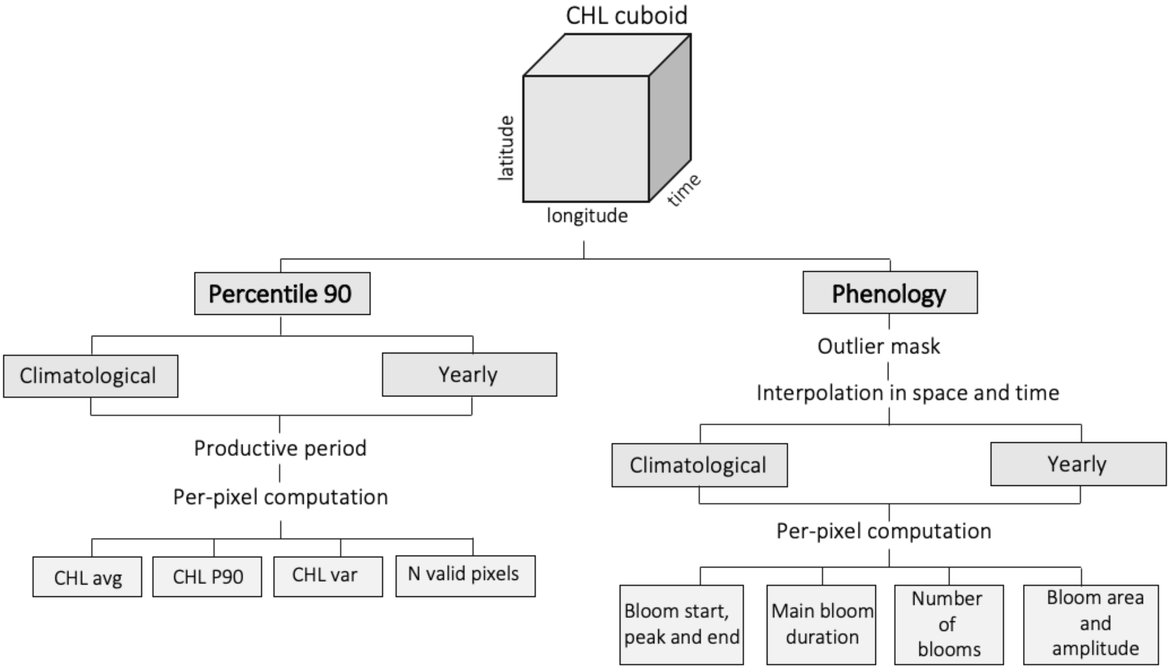


Figure 7 - Overview of indicator computations.

For the phytoplankton bloom phenology computations (Figure 7), the initial CHL data cuboid was pre-processed to reduce missing data, since the estimation of bloom phenology metrics may be impacted by missing data (Racault et al. 2012). First, an outlier mask that removed data deviating more than three times the (per-pixel) standard deviation from the mean was applied. Then, data were spatially smoothed by interpolating three pixels along the latitude and longitude axes. Daily and weekly bins were created, and a 2-week centred moving average was used to smooth the CHL signal, helping fill remaining gaps, following Ferreira et al. (2014).

Climatological (2018-2020) were obtained, as well as annual metrics due to the high interannual variability of transitional water systems. For climatological and annual computations, daily and weekly binned data were used, respectively. For both cases, a CHL 14-day moving average was considered.

For each pixel, the following phenological metrics were estimated (Figure 8): 1) CHL mean (mg m^{-3}); 2) CHL maximum (mg m^{-3}); 3) amplitude of the bloom (mg m^{-3}); 4) day/week of bloom initiation; 5) day/week of bloom peak; 6) day/week of bloom termination; 7) duration of bloom in days/weeks; 8) area of the bloom (mg m^{-3}). The main bloom of the year was selected as the bloom with the biggest area, after numerically integrating the area of the geographical representation of CHL during the period of the bloom, using Simpson's rule. Blooms were identified using two criteria (e.g., Ferreira et al. 2021): 1) CHL must surpass a threshold of 5% of the annual CHL median, and 2) this condition must be maintained for a minimum of 15 days. Bloom duration was calculated as the difference in days/weeks between initiation and termination of the bloom, while the amplitude corresponds to the difference between the annual maximum and mean.

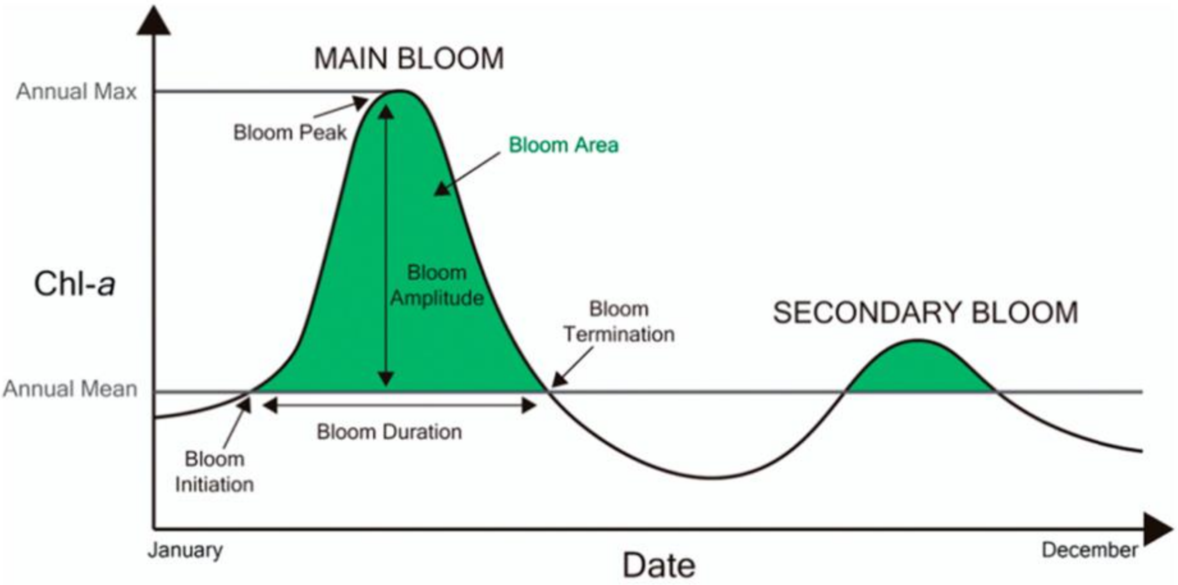


Figure 8 - Representation of phytoplankton bloom phenology metrics calculated: CHL mean, CHL max, bloom amplitude, days of bloom initiation and termination, bloom duration, day of bloom peak, and bloom area (green). Source: Ferreira et al. 2021.

4.2.3 Preliminary Results

Curonian Lagoon

The climatological CHL average and P90 for the productive period (March until October) in the Curonian Lagoon are shown in Figure 9. The northern region of the lagoon is connected to the Baltic Sea and showed lower CHL concentrations. The central/southern region of the lagoon is characterised by a poor water renewal regime and showed higher CHL and CHL P90. Figure 10 shows the annual CHL P90 for the years 2018 until 2020. The northern region of the lagoon showed lower CHL P90 values than the central and southern regions. This was a common feature observed for all years sampled. Of the years sampled, 2020 was the least productive year during the growing season.

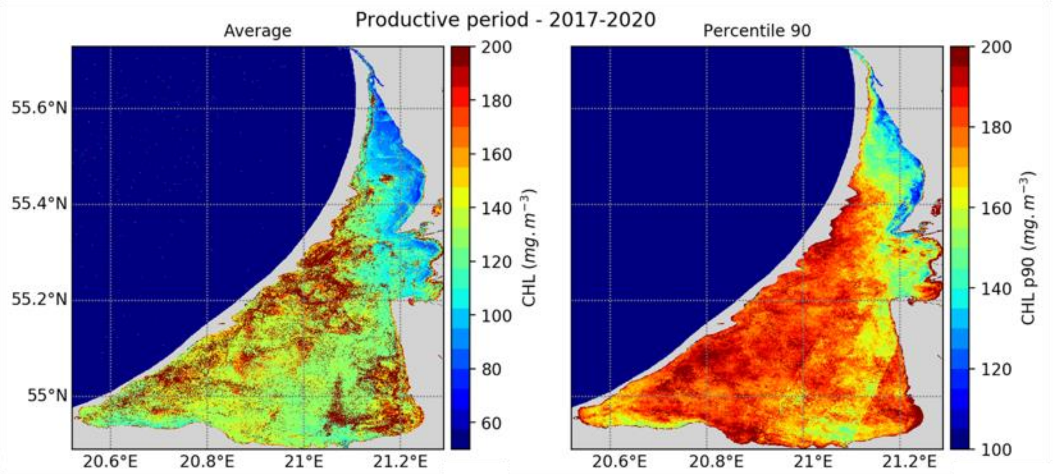


Figure 9 - Climatological average (2017-2020) of chlorophyll-a concentration (left) and 90th percentile (right) during the productive period (March until October), in mg m^{-3}.

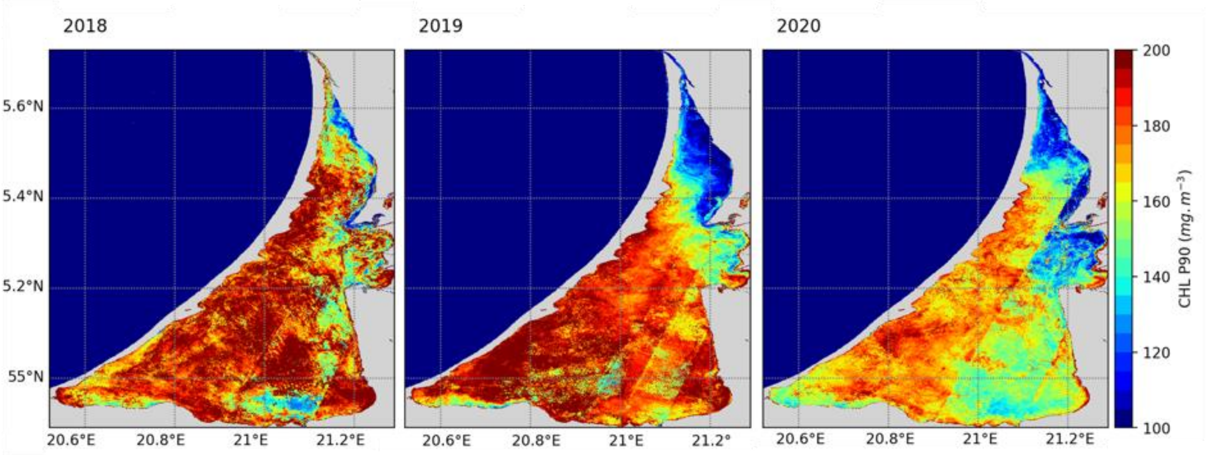


Figure 10 - Annual chlorophyll-a percentile 90 (mg m^{-3}) during the productive period (March until October) for the years 2018, 2019 and 2020.

The phytoplankton bloom phenology in the Curonian lagoon (Figure 11) showed a consistency in the timing of blooms over the entire lagoon. In most of the lagoon, blooms typically started in June/July, peaked in September/October, and ended in October. In the northernmost region, the bloom phenology seemed to be influenced by coastal dynamics, yielding a similar pattern, with blooms starting during winter (February), peaking in March, and ending in April. Commonly, 1-3 blooms occurred and lasted between 6 to 16 weeks.

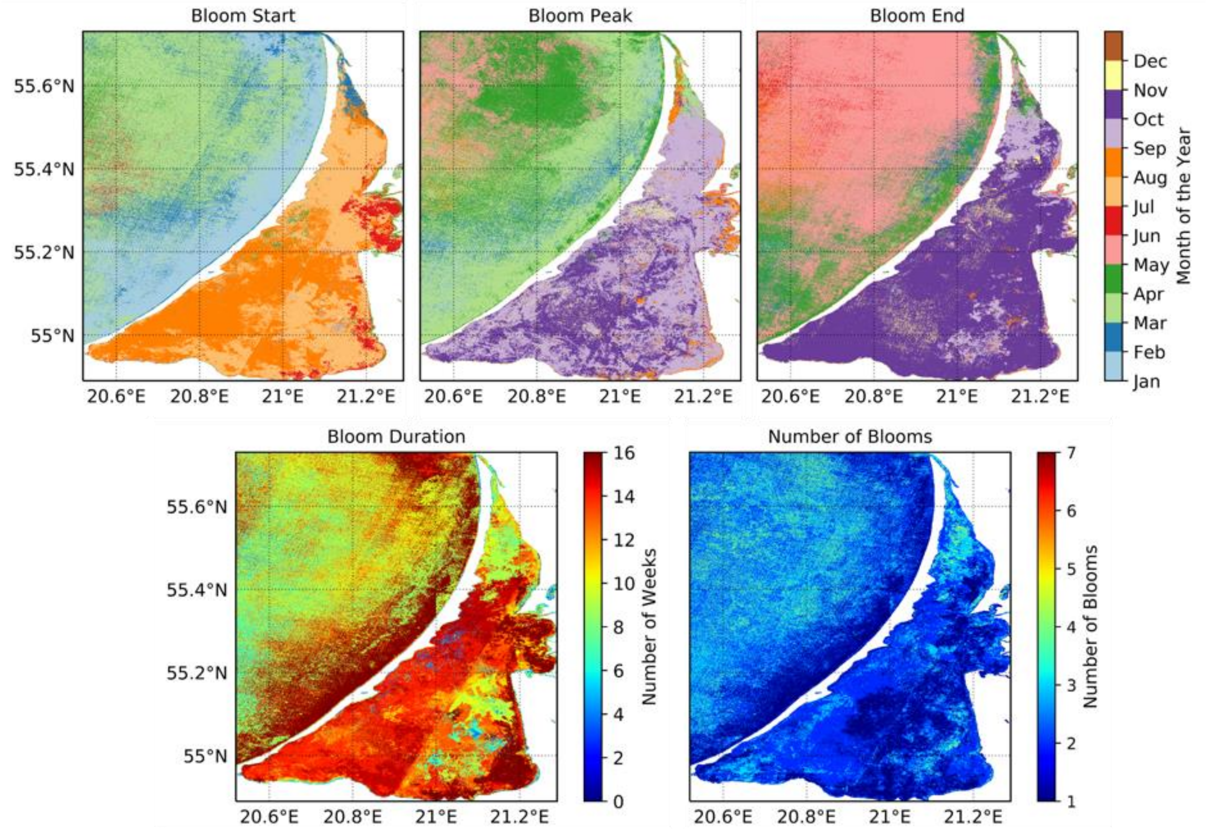


Figure 11 - Bloom start, peak, end, and duration (weeks) and per-pixel number of blooms.

Elbe Estuary

In the Elbe estuary region, the climatological CHL average and CHL P90 for the productive period (March until October) are shown in Figure 12. An offshore-coast gradient of CHL can be seen, with higher CHL along the coast and estuary than in offshore waters. The CHL P90 followed this CHL gradient. Figure 13 shows the annual per-pixel CHL P90 for the years 2018 until 2020. The CHL pattern is consistent throughout the years.

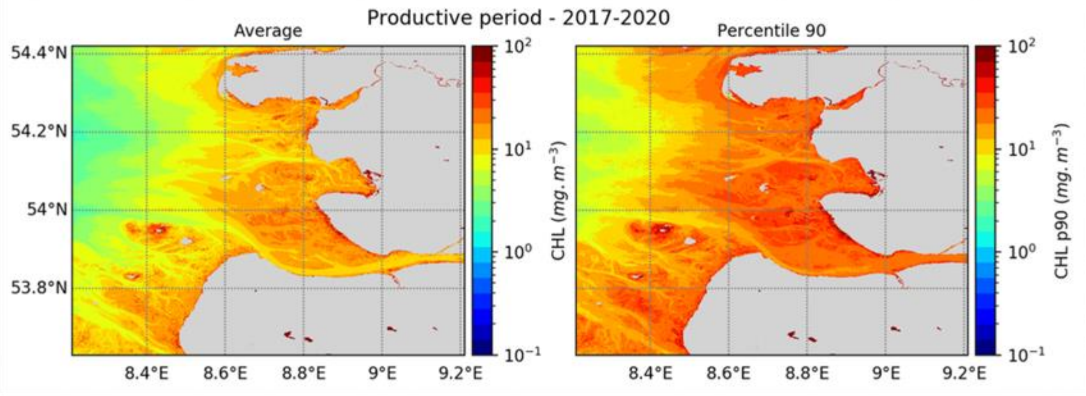


Figure 12 - Climatological average (2017-2020) of chlorophyll-a concentration (left) and 90th percentile (right) during the productive period (March until October), in mg m^{-3}.

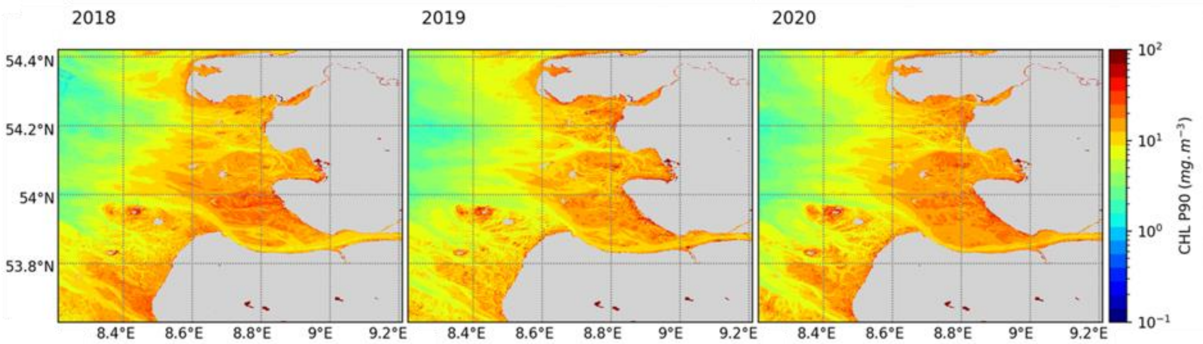


Figure 13 - Annual chlorophyll-a percentile 90 (mg m^{-3}) during the productive period (March until October) for the years 2018, 2019 and 2020.

In the Elbe estuary, the blooms started mostly in winter and spring (February to April) and ended in June (Figure 14). Generally, 1-2 blooms occurred per year and lasted up to 16 weeks.

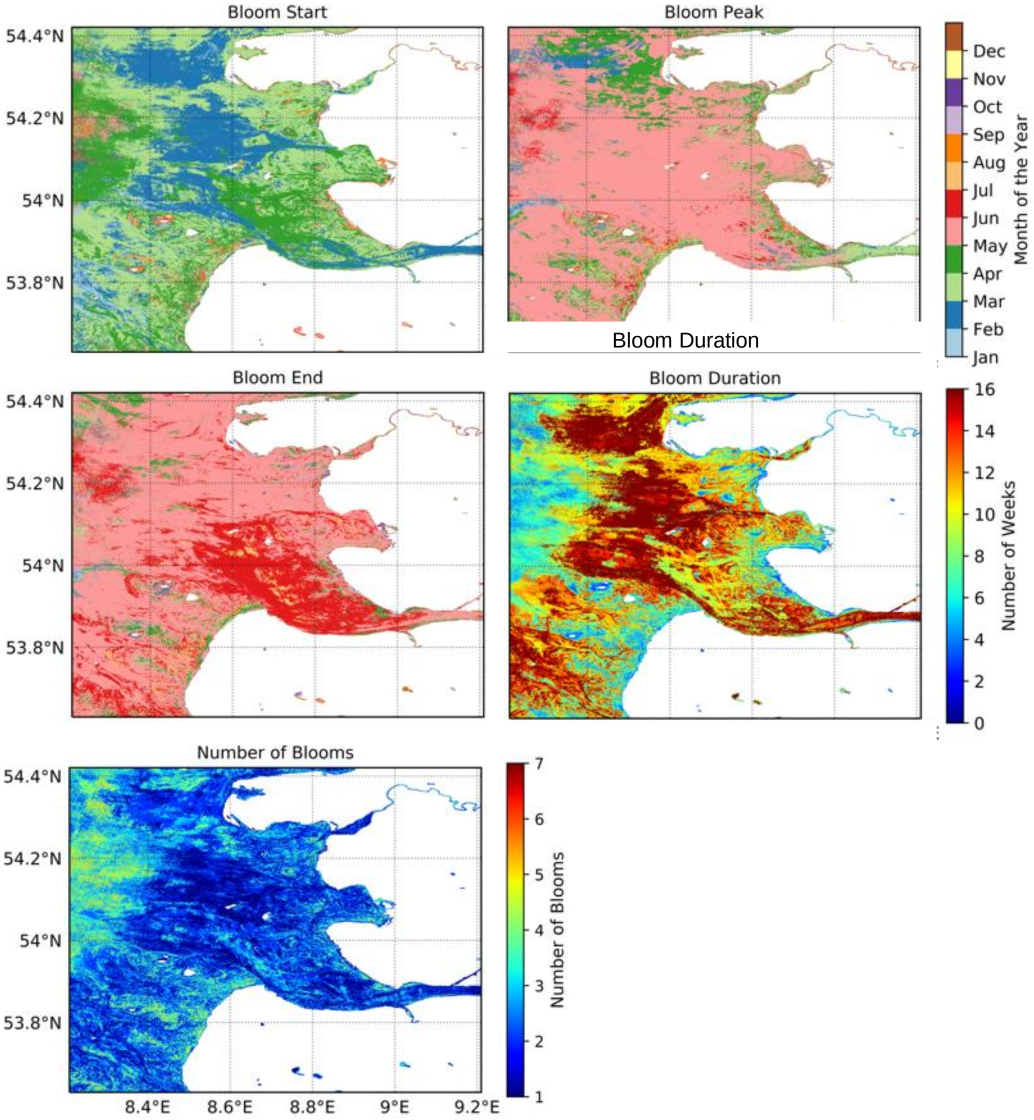


Figure 14 - Bloom start, peak, end, and duration (weeks) and per-pixel number of blooms.

Razelm-Sinoe Lagoon system

In the Razelm-Sinoe lagoon system, the climatological CHL average and CHL P90 for the productive period (March until October) are shown in Figure 15. The Razelm-Sinoe system behaves like a large lake, with only one connection to sea in the southern part (Sinoe lagoon). The CHL average in the Razelm lagoon was higher in the south than in the northern region, which showed similar concentrations to the Sinoe lagoon. The CHL P90 was lower in the Sinoe than in the Razelm lagoon. Figure 16 shows the annual CHL P90 for the years 2018 until 2020. CHL P90 increased from 2018 until 2020, which was the most productive of the 3 years.

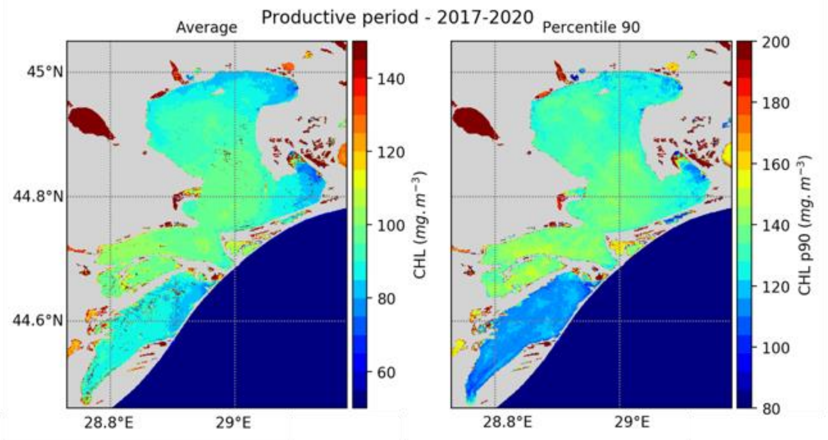


Figure 15 - Climatological average (2017-2020) of chlorophyll-a concentration (left) and 90th percentile (right) during the productive period (March until October), in mg m^{-3}.

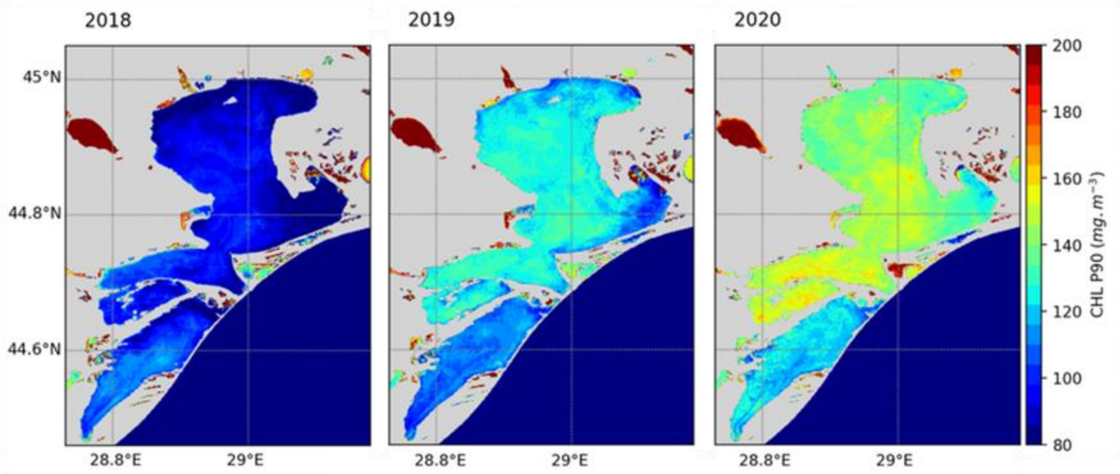


Figure 16 - Annual chlorophyll-a percentile 90 (mg m^{-3}) during the productive period (March until October) for the years 2018, 2019 and 2020.

The climatological phenology metrics (Figure 17) showed that the main blooms commonly occurred in late summer and ended in autumn. These lasted up to 14 weeks. Moreover, 1-4 blooms occur per year. The years 2018, 2019 and 2020 yielded the same climatological pattern (figure not shown).

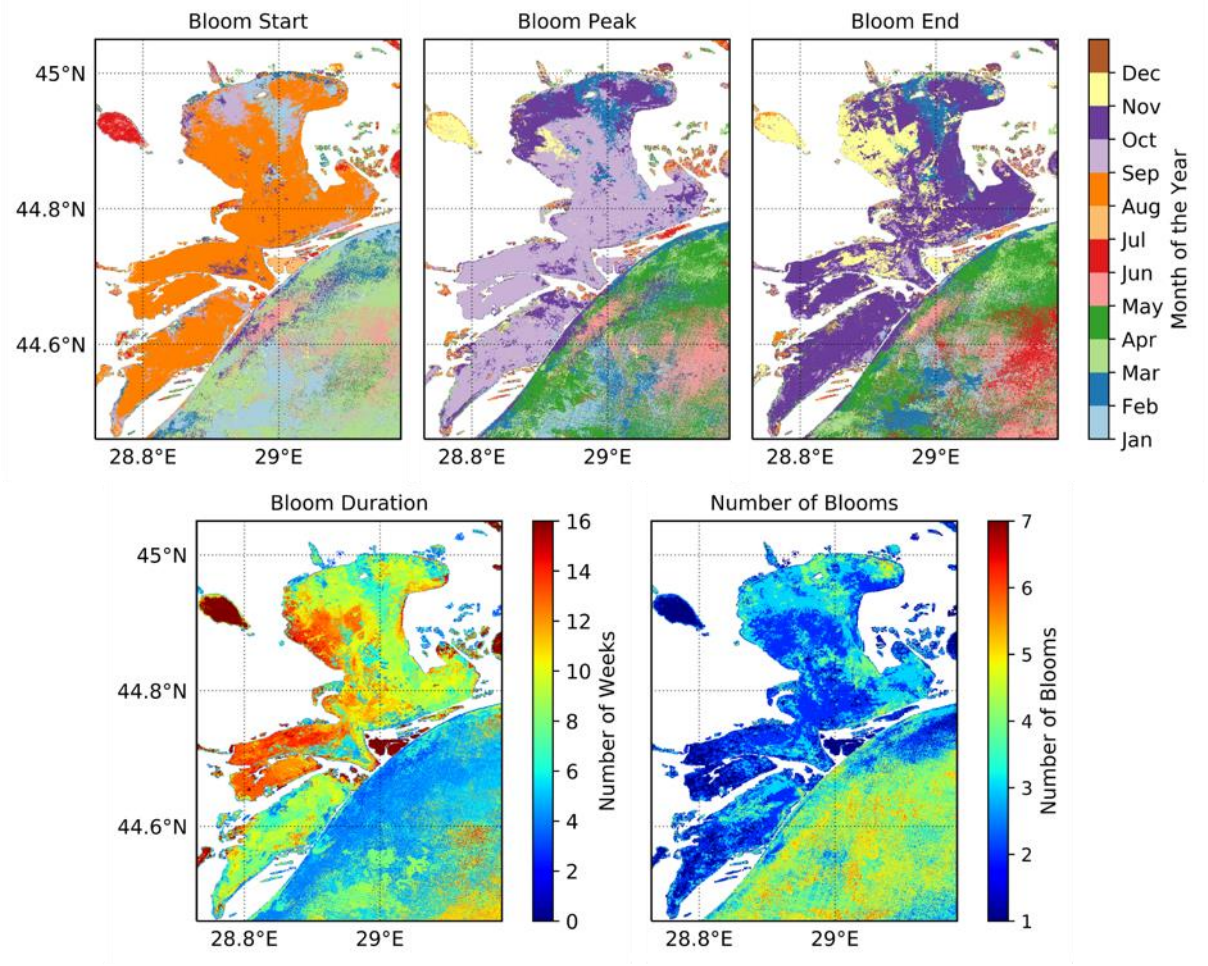


Figure 17 - Bloom start, peak, end, and duration (weeks) and per-pixel number of blooms.

Tagus Estuary

The climatological CHL average and P90 for the productive period (February until October) in the Tagus estuary are shown in Figure 18. A clear spatial pattern following the estuary depth can be verified, with higher CHL and CHL P90 (and CHL variance, plot not shown) in the upstream intertidal regions. Figure 19 shows the annual CHL P90 for the years 2018 to 2020.

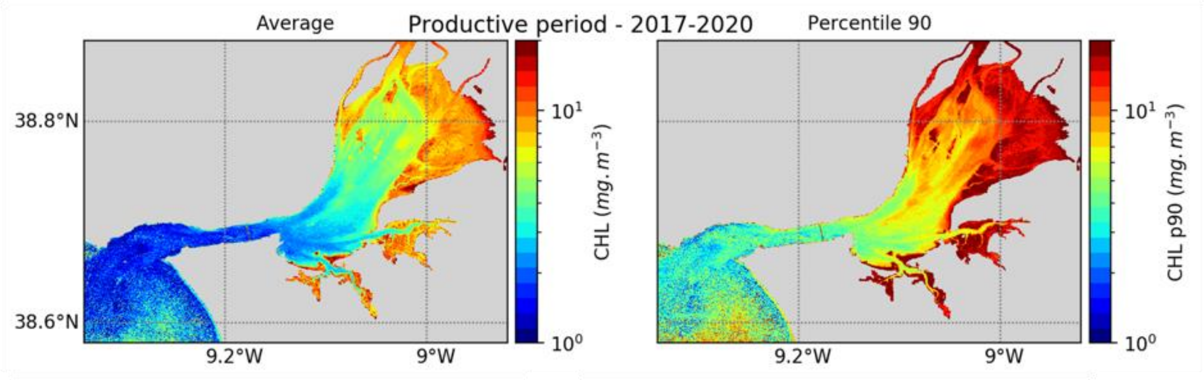


Figure 18 - Climatological average (2017-2020) of chlorophyll-a concentration (left) and 90th percentile (right) during the productive period (March until October), in mg m^{-3}.

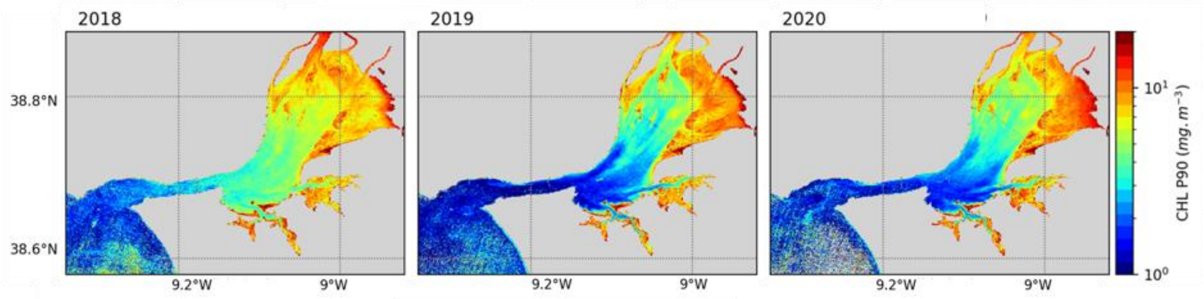


Figure 19 - Annual chlorophyll-a 90th percentile (mg m^{-3}) during the productive period (March until October) for the years 2018, 2019 and 2020.

The estimated climatological phytoplankton bloom phenology metrics (Figure 20) showed high heterogeneity along the estuary. In the south-eastern region of the estuary the main blooms started mostly in October. In the north-eastern region most blooms started in January, March and April. On the other hand, in the central areas of the estuary and northern margins, blooms tended to start in February. The estimated duration of these blooms varied from 5 to 9 weeks. Closer to the estuary margins the blooms showed more heterogeneity in terms of timing and tended to last less time.

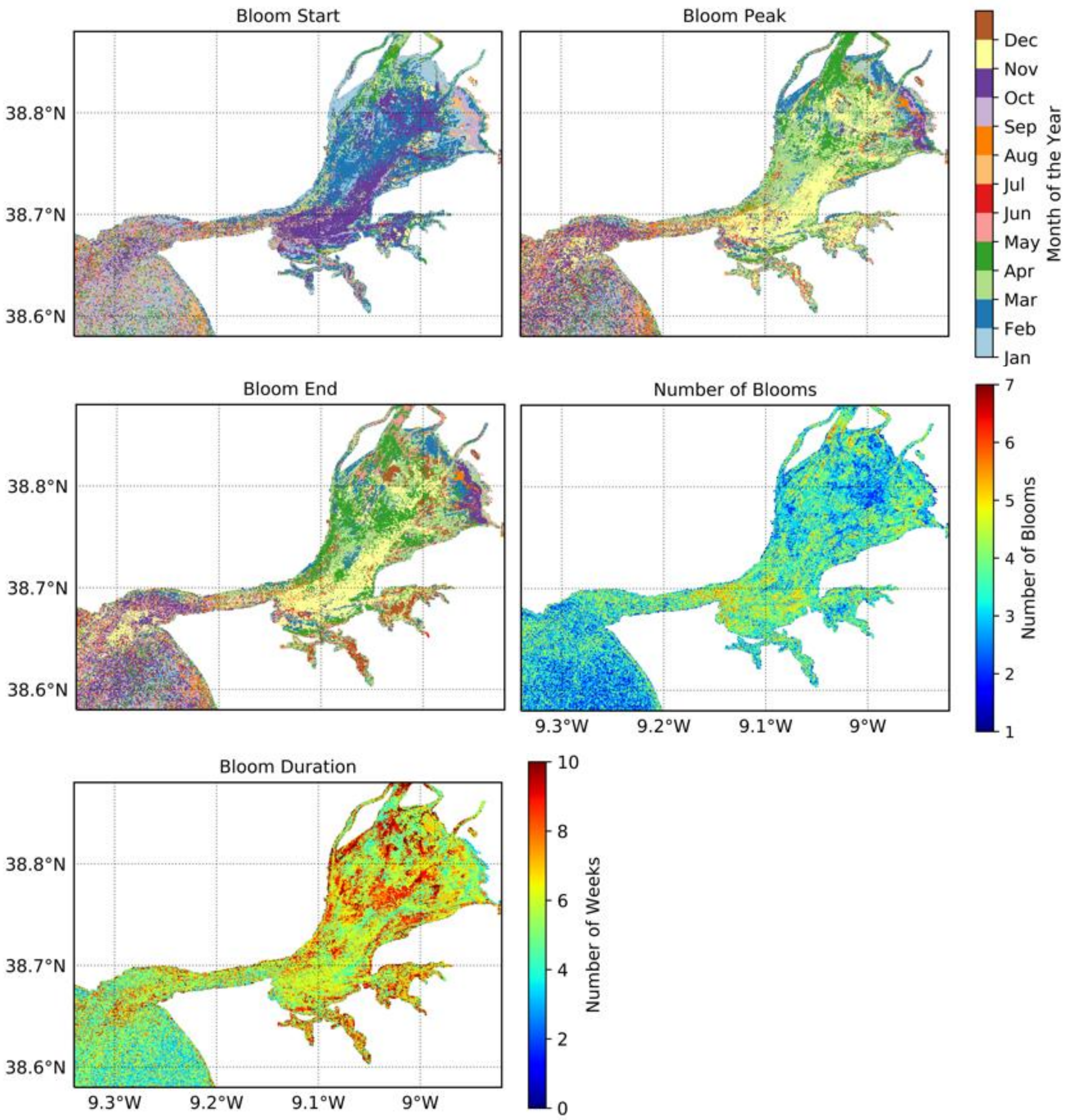


Figure 20 - Bloom start, peak, end, and duration (weeks) and per-pixel number of blooms.

Tamar Estuary

In the Tamar estuary region, the CHL average and P90 climatologies for the productive period (March until October) showed higher concentrations in the estuary, decreasing towards coastal waters (Figure 21). In the estuary, higher CHL averages and P90 were reached in the central part of the estuary. CHL variance was higher in the upstream regions of the estuary. Figure 22 shows the annual per-pixel CHL P90 for the years 2018 until 2020. These results show low interannual CHL P90 variability.

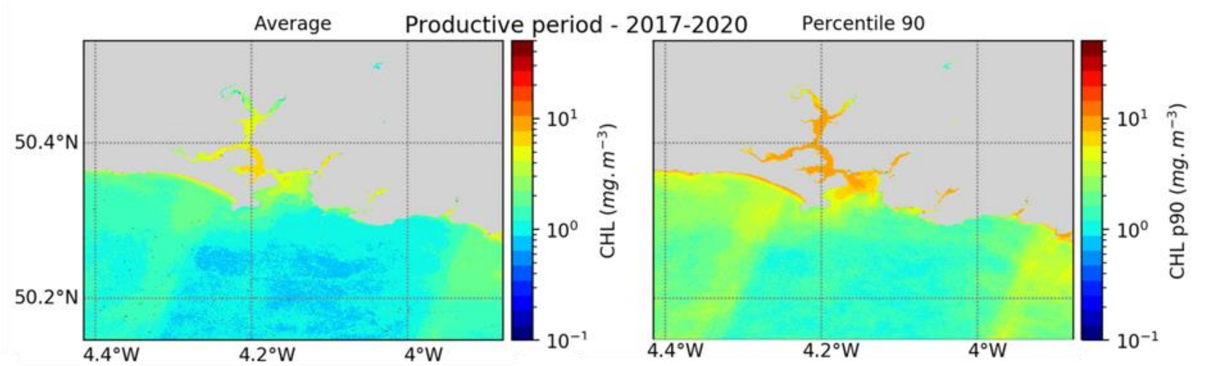


Figure 21 - Climatological average (2017-2020) of chlorophyll-a concentration (left) and 90th percentile (right) during the productive period (March until October), in mg m^{-3}.

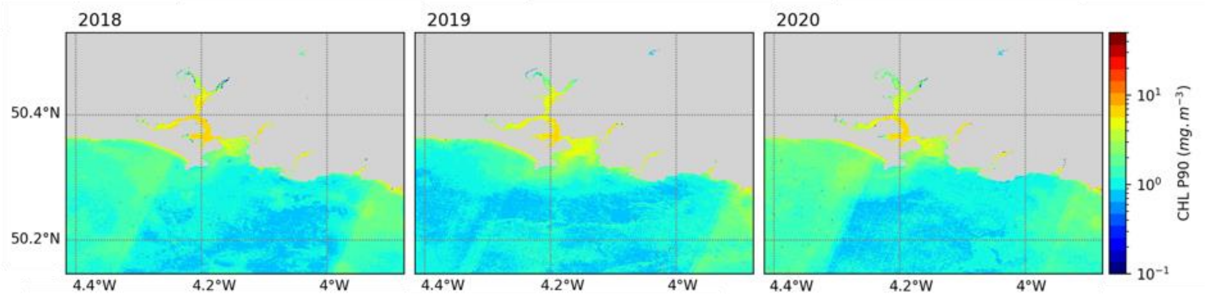


Figure 22 - Annual chlorophyll-a percentile 90 (mg m^{-3}) during the productive period (March until October) for the years 2018, 2019 and 2020.

The preliminary results of the climatological bloom phenology indicate high spatial variability in the Tamar estuary (Figure 23) and adjacent oceanic regions. In the estuary upstream areas, blooms tended to start, peak and end during spring and summer. In the estuary mouth, blooms started, peaked, and ended during autumn and winter. The number of blooms varied between 1 and 5 per year and lasted more than 10 weeks.

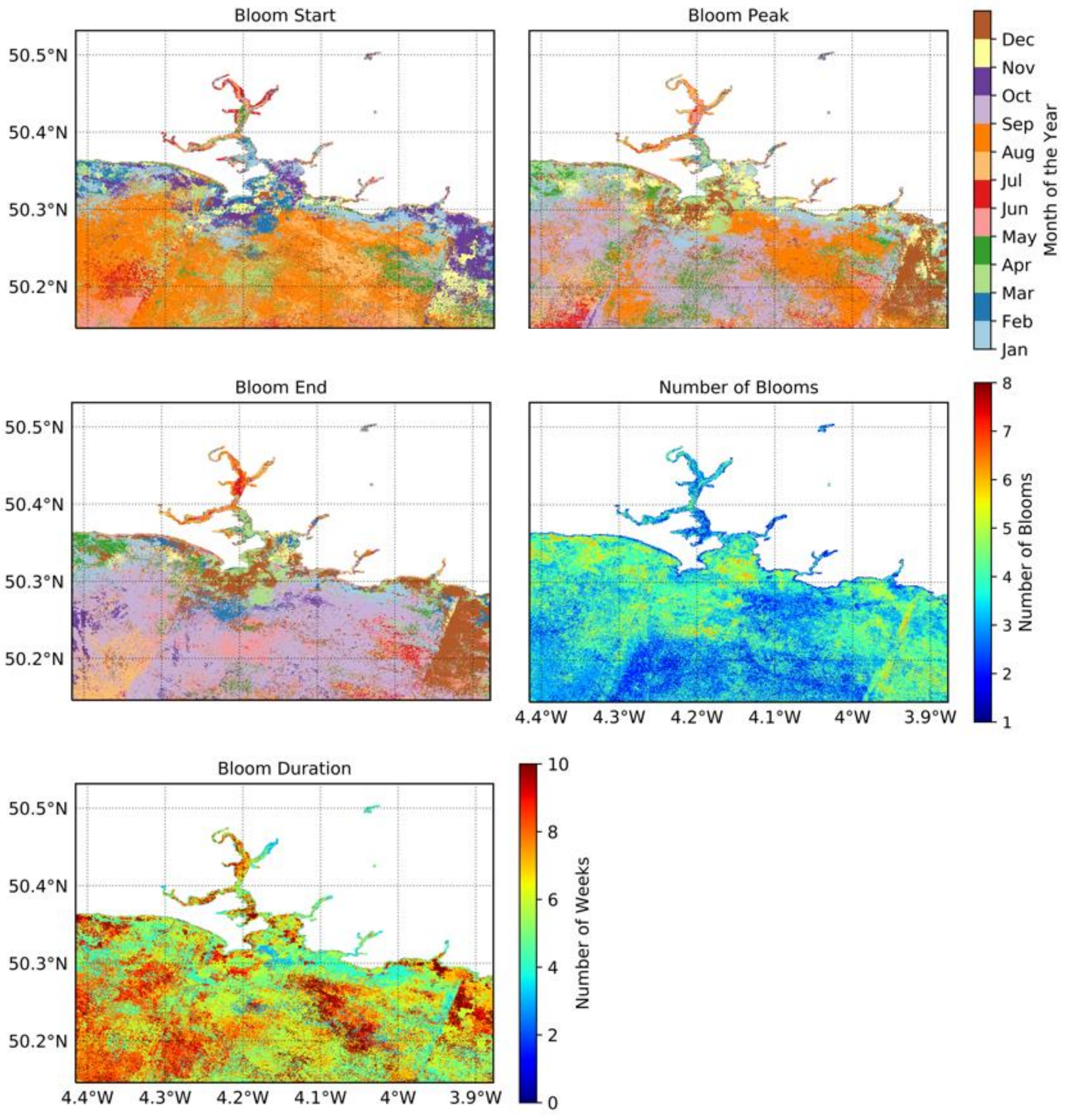


Figure 23 - Bloom start, peak, end, and duration (weeks) and per-pixel number of blooms.

Venice lagoon

The climatological CHL average (Figure 24) for the productive period (March until October) shows higher CHL in the intertidal areas than in the deeper central area of the lagoon. The CHL P90 followed the same pattern. Figure 25 shows the annual per-pixel CHL P90 for the years 2018 until 2020. These results showed low interannual CHL P90 variability.

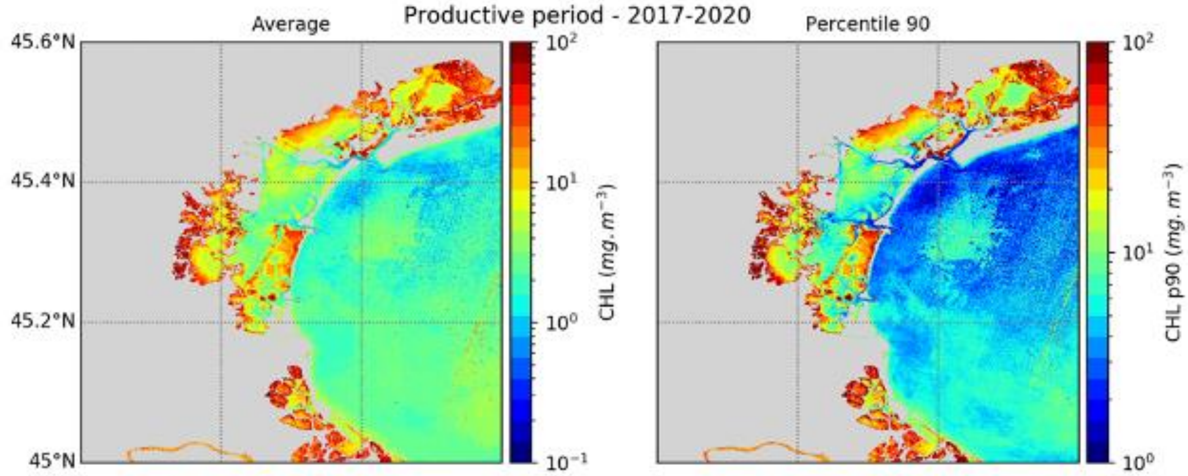


Figure 24 - Climatological average (2017-2020) of chlorophyll-a concentration (left) and 90th percentile (right) during the productive period (March until October), in mg m^{-3}.

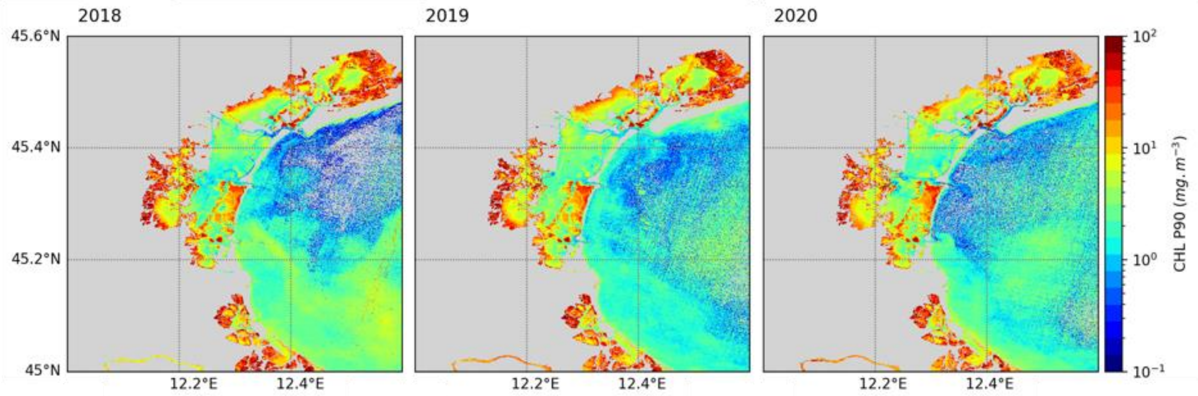


Figure 25 - Annual chlorophyll-a percentile 90 (mg m^{-3}) during the productive period (March until October) for the years 2018, 2019 and 2020.

The climatological bloom phenology indicated high spatial variability in the Venice lagoon (Figure 26) and adjacent coastal/oceanic regions. The main blooms in the lagoon started typically in winter and summer months and ended in the spring and autumn months. The number of blooms varied between 1 and 4. In some regions, the main bloom lasted more than 16 weeks.

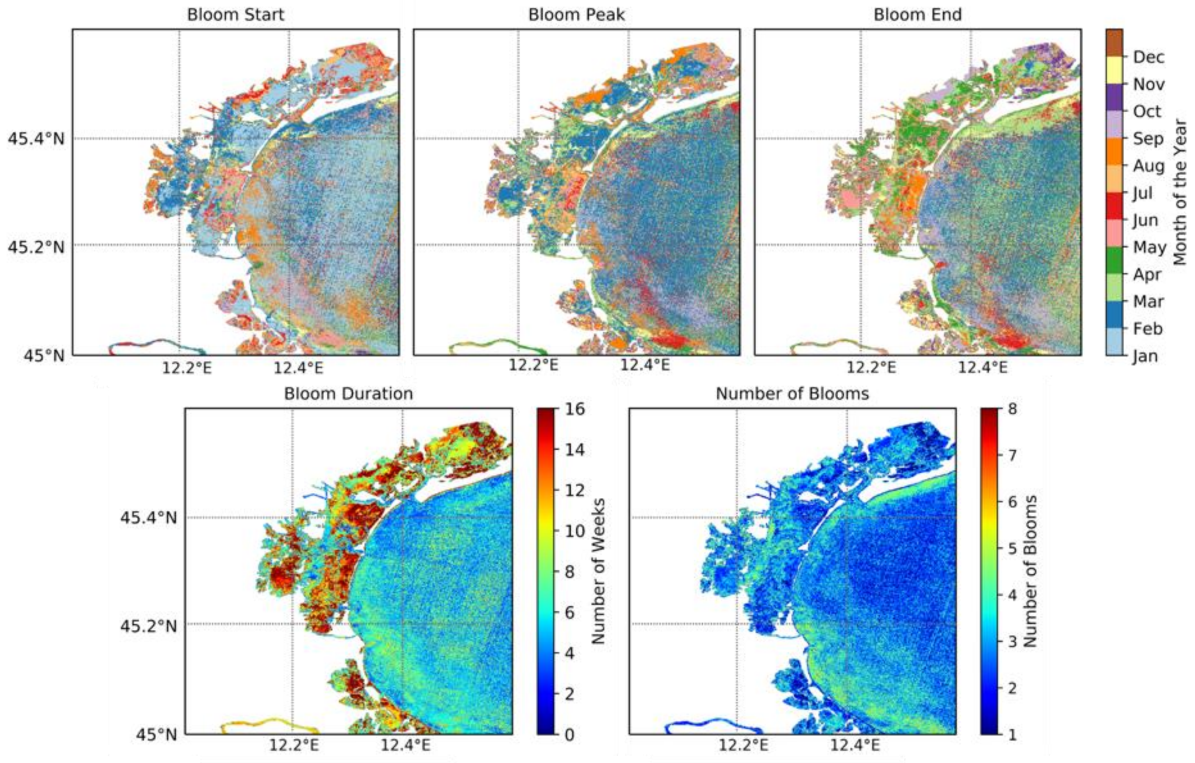


Figure 26 - Bloom start, peak, end, and duration (weeks) and per-pixel number of blooms.

4.3 Social-Ecological System Vulnerability Index (SESVI)

4.3.1 Description of indicator to be developed

For Users wanting an overview of their local or national water bodies, to create summary reports, compare different sites, identify hotspots across a wider region and/or assess how different factors may affect the social and/or ecological system in different ways, or which of those factors are the most critical in any given site, the Social-Ecological System Vulnerability Index (SESVI) is an excellent solution. SESVI is being developed in CERTO for lagoon systems and estuaries and provides an indication on how vulnerable a water body system is to pressure and change, based on its socioeconomic and environmental characteristics. Given that SESVI is being developed as a framework concept, vulnerability can be defined on a case-by-case basis to suit User needs and SESVI may be tailored to a specific site or defined universally with SESVI applied “globally” for comparison across multiple sites. As a snapshot in time, SESVI can help policy managers and decision-makers quickly identify vulnerability hotspots in their region. By incorporating time-series data, SESVI includes a direction and magnitude of change that further informs the degree of vulnerability. It can, therefore, be used to reveal the most relevant pressure factors in a water body. SESVI, in CERTO, provides an exemplar of a more complex index that would typically be operated by a specialist downstream-service provider with local expertise and customers by contrast to a standard product that could be supplied by the upstream Copernicus service.

4.3.2 Method development

SESVI aims to offer a holistic assessment of the water body system, looking at both its social and ecological parts (Figure 27). It takes into account the inherent characteristics of the system and the external forces that may affect its ecological functions and, by extent, its ecosystem services functions. A long list of suitable socioeconomic and environmental indicators from existing local and global datasets are being compiled to assess both parts (Figure 27) and produce the overall vulnerability assessment (SESVI score).

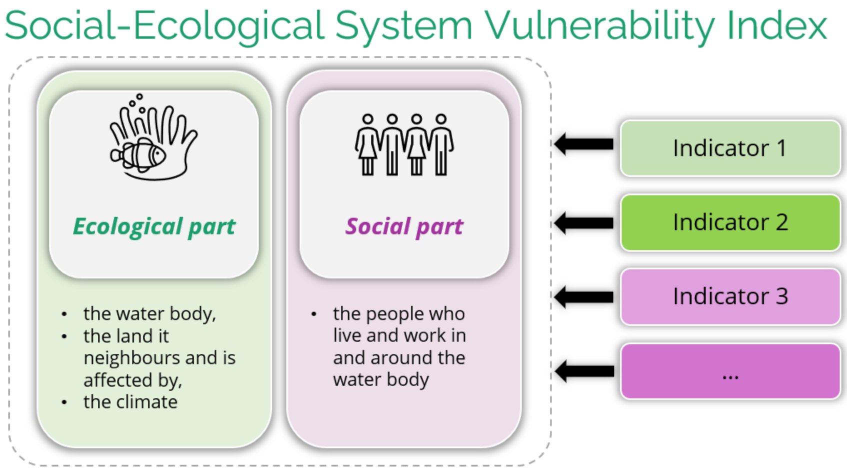


Figure 27 - SESVI addresses both parts of the water body system: the ecological and the social part, using indicators to describe both.

Depending on what they describe, these indicators can be grouped under one of the main three vulnerability assessment components: (1) exposure, (2) sensitivity, and (3) adaptive capacity (Figure 28). In the case of SESVI, *exposure* refers to external forcing due to climate change, environmental change and/or human activities; *sensitivity* refers to the inherent degree of resilience of the ecological system to external forcing, and *adaptive capacity* indicates the social system's degree of resilience and measures of adaptation to change.

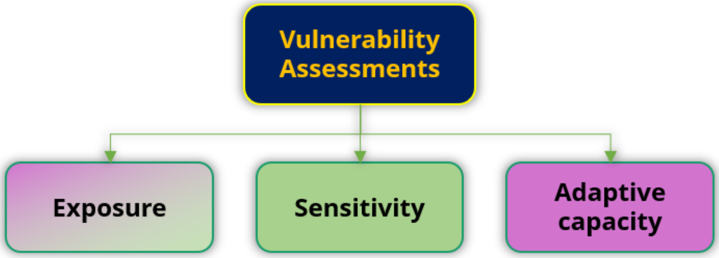


Figure 28 - Vulnerability assessments contain three main components: exposure, sensitivity and adaptive capacity of the (social and/or ecological) system under investigation.

The development of SESVI heavily relies on a good *a-priori* understanding of the water system under investigation and the main pressures that affect it now or in the future. Based on this understanding, SESVI is then developed to explore, assess and identify critical aspects of the water system that may require attention. Even though the final output of SESVI is intuitive and visually easy to interpret, SESVI is a relatively complex index to produce because it is built using several different datasets that are carefully chosen amongst a plethora of available datasets for each CERTO Case Study. Figure 29 summarises the main steps that we are following to develop SESVI.

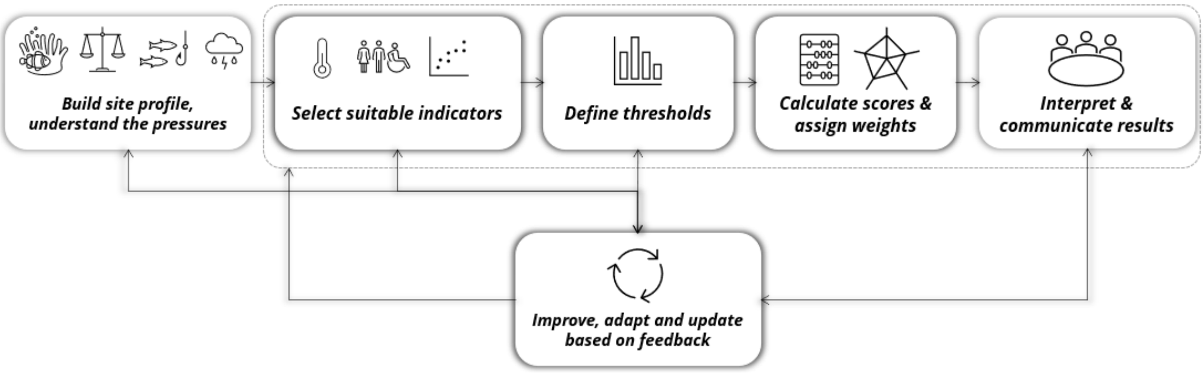


Figure 29 - Main steps followed to develop the SESVI framework.

The main effort for SESVI concentrates on the selecting, sourcing, and processing of suitable variables/indicators/descriptors which are dependent on the type of water body of interest (e.g., can differ between rivers and lagoons), the main pressures acting on it, and the scientific question in mind. As a result, a considerable amount of work has gone into this preparatory phase and is still ongoing at the time of writing. During this phase:

1. Areas were characterised in consultation with the local Case Study teams, due to their in-depth knowledge of the site.

2. Once the main pressures in the site were identified (Step (1) above), suitable datasets and indicators to describe the sites and pressures were selected and are being sourced. These include *in-situ*, modelled and satellite data, which are being extracted using GIS software at catchment and water body level (for spatial data such as population density grid, land cover, elevation) and in the form of Excel tables (for temporal non-spatial data such as fertiliser use, GDP per capita). Table 4 lists the datasets sourced and processed to date. The entire list of indicators is shown in Figure 31.

3. Suitable thresholds are being defined based on various criteria (e.g., world means, national averages or maxima/minima, percentiles and other suitable statistical measures) which are tailored to each indicator used. Effort is made to create these thresholds applicable across Europe so that they can be applied to all six CERTO Case Studies and produce comparable results. This step requires review of existing bibliography, of other similar approaches, as well as consultation with the local Users and Case Study teams, who hold extensive local knowledge of the six CERTO sites.

4. Once all thresholds are defined (currently, an ongoing task), these are applied, and each variable/indicator is assigned a score for the Case Study. If the indicator is a time-series, the magnitude of change is also used to assign a weight based on the level of increase or decrease over a certain time. Preliminary results for those datasets processed already are shown in chapter 4.3.3 of this report.

5. The combination of all individual scores in each Case Study makes up the sub-total per each of the three SESVI components: (a) exposure, (b) sensitivity, and (c) adaptive capacity. Further combination of all component scorings produces the total SESVI score

for the entire Case Study or (sub)region of application. This final step requires that all datasets identified in Step (2) are analysed and processed (Steps (2) through (4)) and is scheduled for completion in autumn 2022, in time for the Demonstration phase (WP8).

Table 4 - Datasets sourced and processed to date for SESVI. Datasets not sourced yet are not listed (see Figure 31 for the full list of datasets under consideration at this stage).

Data type	Dataset name/Data source	Dataset version
Population density	Gridded Population of the World, Version 4 (GPWv4): Population Count and Density, Revision 11	4.11
Fertilisers	FAOSTAT Fertilisers (Agricultural use)	(Accessed: Summer 2021)
Elevation	Shuttle Radar Topography Mission 1 Arc-Second Global	3
River basins	HydroBASINS 15s	(Accessed: Summer 2021)
River network	HydroRIVERS 15s	(Accessed: Summer 2021)
Land Cover	Copernicus Land Monitoring Service (CLMS) Global CORINE Land Cover	3.0.1
IPCC Sea Level Rise projections	Projected Sea-Level Rise Under Different SSP Scenarios	(Accessed: October 2021)
Mean tidal amplitude (range)	European Atlas of the Seas	(Accessed: October 2021)
Extreme precipitation	Number of precipitation days exceeding 20mm	1
Employment in marine fisheries, aquaculture & processing	European Atlas of the Seas; DG Mare Employment in marine sectors	(Accessed: October 2021)
Employment in coastal tourism	European Atlas of the Seas; DG Mare Employment in marine sectors	(Accessed: October 2021)
Employment in maritime transport	European Atlas of the Seas; DG Mare Employment in marine sectors	(Accessed: October 2021)
Employment in ports, warehousing and water projects	European Atlas of the Seas; DG Mare Employment in marine sectors	(Accessed: October 2021)
(Marine) Natura 2000 sites	European Atlas of the Seas	(Accessed: October 2021)
Population aged 65 years and more (urban region)	European Atlas of the Seas; Eurostat	(Accessed: October 2021)
Median age at national level	Eurostat – Median age at national level	(Accessed: October 2021)
Ageing population	Eurostat – Increase in the share of the population aged 65 years or over between 2010 and 2020	(Accessed: October 2021)

Figure 30 presents how the above steps feed into the SESVI implementation framework. First, we interact with experts (such as local Case Study CERTO teams and local stakeholders) to understand the sites and create site profiles. Then, identification of suitable indicators and sourcing of datasets from the CERTO prototype and multiple other sources feed into the development of a large GIS and auxiliary database in which spatiotemporal datasets are processed, extracted, calculated and thresholds applied to calculate scores for each indicator used. Continuous user interaction is necessary to ensure the datasets used and thresholds applied are relevant to stakeholders. All these individual scores are then integrated into a total SESVI score for each region of interest, following which we go through another round of user interaction to demonstrate and interpret the results, and receive feedback for potential improvements.

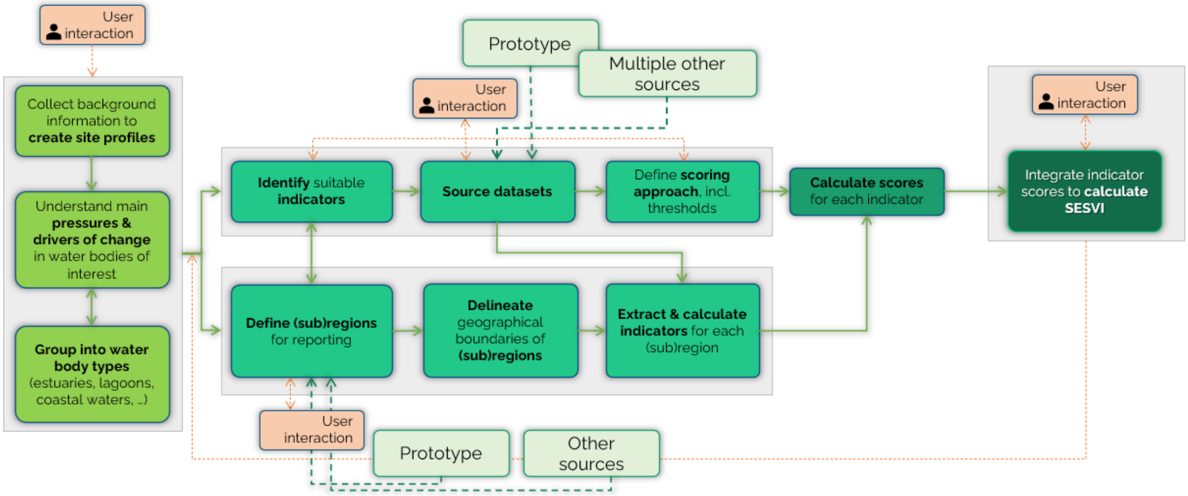


Figure 30 - Overall approach of the SESVI implementation framework.

The final output of the approach is a “SESVI wheel” (Figure 31), which has the three levels. Starting from the outer circle of the wheel, we have the individual indicators and their own scores based on thresholds. Each indicator belongs to one of the three SESVI components (exposure, sensitivity and adaptive capacity). The combination of the individual indicator scores makes up the (sub)total of each SESVI component and the combination of those three scores makes up the total SESVI score in the innermost circle of the wheel.

Figure 31 - The SESVI wheel summarises in an intuitive visual way the different levels of scoring applied during the application of SESVI. Once applied, a 4-colour traffic-light approach (blue, green, yellow, and red) is used to assign colours to each indicator, component and the SESVI score itself.

4.3.3 Preliminary Results

A 4-colour traffic-light approach (blue, green, yellow, and red) is used to assign colours to each indicator, component and the SESVI score itself, indicating their respective score based on individual criteria. For time series data, + and – signs further indicate the magnitude of change. An example is shown in Table 5 for the *population trend* indicator.

Table 5 - Values and magnitudes of change for the population trend indicator used in SESVI (exposure component).

	Value in a single year (2020)			**Magnitude of change (2000-2020)**		
	Category name	**Category symbol**	**Criterion**	**Category name**	**Category symbol**	**Criterion**
Population trend (based on population density data, persons per sq. km of land area)	Low	🟦	≤16	Slow	+ / -	≤5%
	Medium	🟩	>16 and ≤87	Medium fast	++ / --	6-29%
	High	🟨	>87 and ≤421	Fast	+++ / ---	30-80%
	Very high	🟥	>421	Very fast	++++ / ----	>80%

Because of its nature, SESVI can only be fully applied when all datasets are ready and processed. When there are gaps in the outer circle, the inner two circles cannot be calculated. At implementation stage, all data gaps appear grey. Preliminary results for the Tagus Estuary are shown here for the outer circle of the SESVI wheel to demonstrate how SESVI works. The same datasets have been extracted for the other 5 sites too but are not presented in this report.

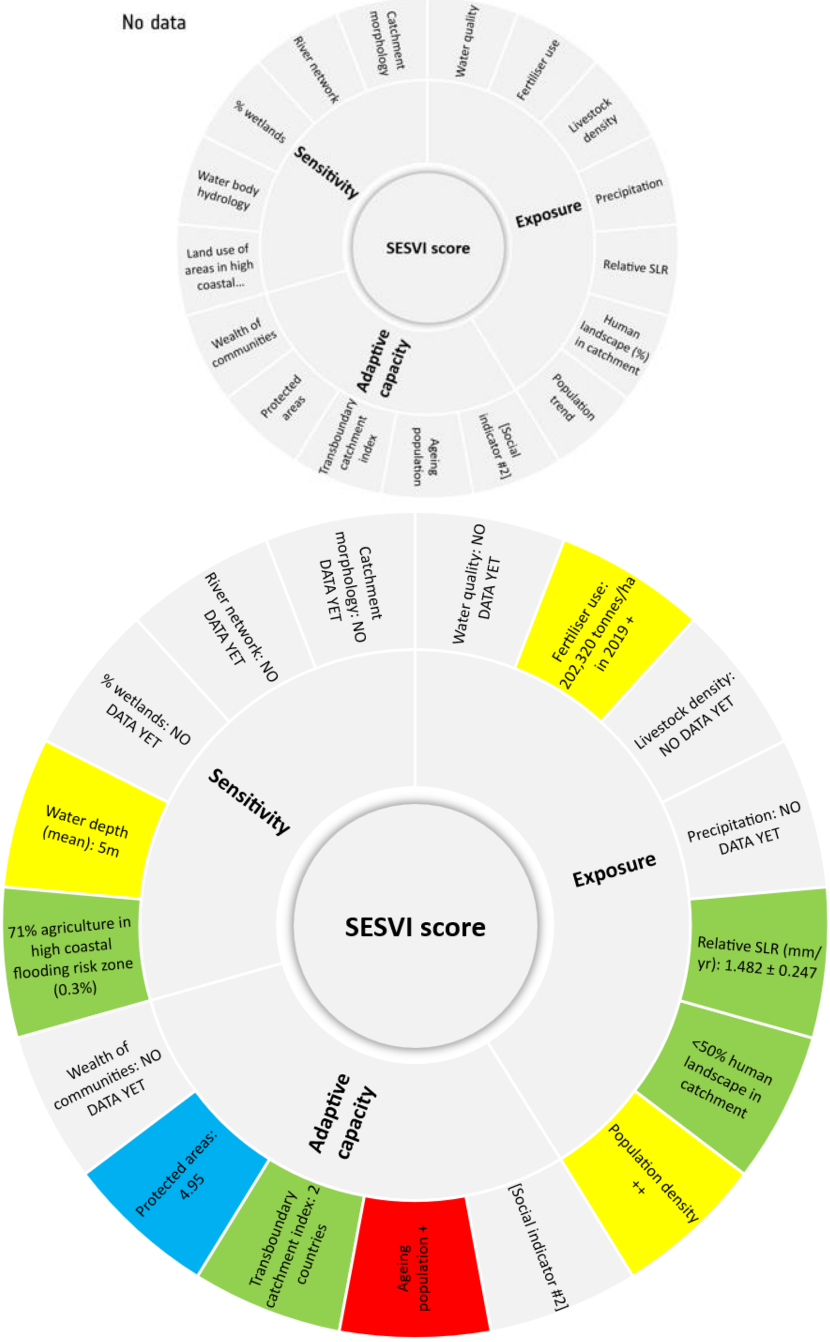


Figure 32 - Starting from an empty SESVI wheel (top panel), as the datasets are being processed, the wheel is being “coloured-in” (bottom panel). At the moment, there are gaps in the outer wheel, which prevent calculation of the scores of the two inner two circles. The results presented are for the Tagus Estuary.

On Figure 32 one can already see that in the Tagus Estuary the population is ageing at quicker rates than in other parts of Europe (red box in ‘adaptive capacity’ component), which can be considered a high risk in terms of the local community’s adaptive capacity to, for example, climate change and extreme weather. While the population trend and fertiliser use in the entire catchment are increasing (yellow boxes in ‘exposure’ component), we see that the relative sea level rise (SLR) is relatively low in comparison to other sites in Europe and the catchment is mainly covered by natural landscapes (trees and uncultivated low vegetation). Finally, even though the low-lying areas at high coastal flooding risk (green box in ‘sensitivity’ component) are mainly covered by agriculture (i.e., risk of high economic loss at extreme storm weather), they cover a very small part of the entire Tagus catchment area.

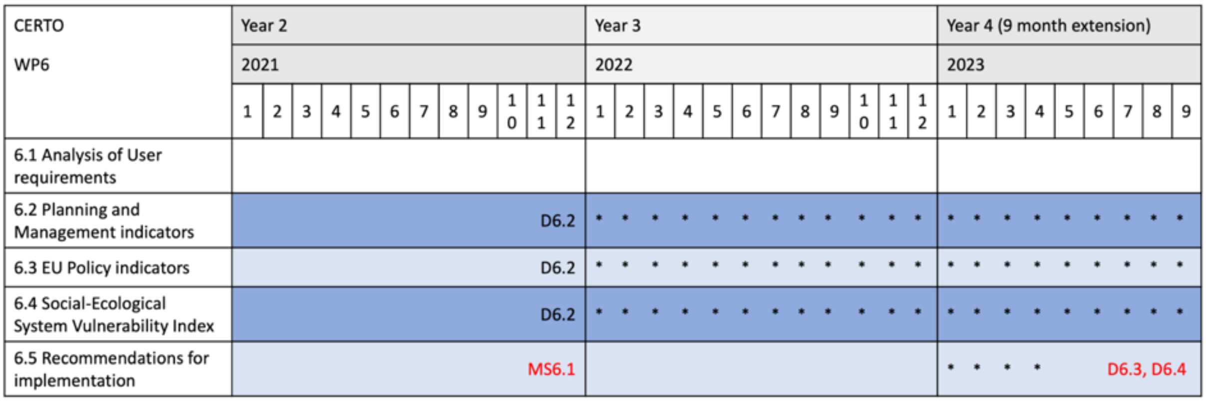
Synthesis of various types of datasets and indicators in one infographic, the SESVI wheel, makes possible the parallel interpretation of various socioeconomic and environmental factors towards better management and holistic assessment of a water body, including its catchment and communities. Even though the results presented herein still have gaps and are preliminary due to the development being ongoing, they help demonstrate the strengths and benefits of SESVI.

5 Future developments on Indicators

The CERTO project is strongly committed to providing indicators that are useful for Users. Thus, WP6 works closely with WP2 to ensure that feedback from Users is incorporated in the development phase. D2.3 reports the reactions and suggestions received by CERTO on indicator development. This will be essential to evaluate further improvements, as described below. Given the 9-month project extension, the adjusted timeline is also provided for WP6 (Section 5.1).

5.1 Adjusted timeline

The CERTO Project received a no-cost 9-month extension due to COVID-19 related issues that mainly prevented field work in 2020 and partially during 2021. This also prevented the development of improved TSM/TUR and CHL products during the year of 2021, which are crucial for final indicator production. Thus, WP6 was also extended until M45, when the final deliverables D6.3 and D6.4 will be submitted, as presented in Figure 33.



CERTO WP6	Year 2 2021	Year 3 2022	Year 4 (9 month extension) 2023
	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9
6.1 Analysis of User requirements			
6.2 Planning and Management indicators	D6.2	• • • • • • • • • • • •	• • • • • • • • •
6.3 EU Policy indicators	D6.2	• • • • • • • • • • • •	• • • • • • • • •
6.4 Social-Ecological System Vulnerability Index	D6.2	• • • • • • • • • • • •	• • • • • • • • •
6.5 Recommendations for implementation	MS6.1		• • • • D6.3, D6.4

* = Task extension

Figure 33 – Adjusted Timeline for WP6.

5.2 Planning and management indicators for industry and local authorities

Maximum Turbidity Zone detection

In general, the plan is to run the scripts for all areas and check with each Case Study Lead whether the parameterisation works adequately for their area. For example, based on the Portuguese users' feedback, we already know that the 1 km segment polygon needs to be adjusted to better reflect the river morphology and the differences in river runoff speed along the river line.

For the indicator(s) of the maximum turbidity zone area, we identified two potential improvements:

- set a threshold for a minimum value range to prevent zone detection in datasets where the values are very close to each other;
- make the exception count dependant on the actual length of the zone (in our current case ~ 1/3 of the transect length).

Based on user feedback, we also plan on providing temporal information of key values, such as Percentile-90, for specific regions. This is relevant, for example, for Water Framework

Directive reporting activities. This can be easily implemented using the (regional) StatisticsOp operator available in SNAP (http://step.esa.int/main/toolboxes/snap/). Statistics can be derived either for each region, shown in Figure 34, or for a selected period for each region (Figure 35). This was not achieved before this report's delivery time but will be done in the near future.

Figure 34- Water Framework Directive defined areas in the Tagus Estuary.

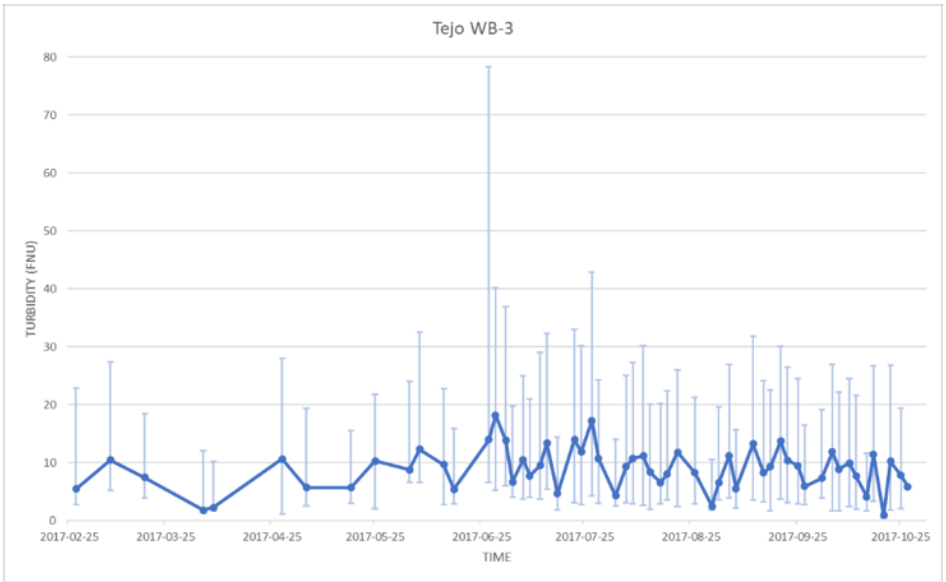


Figure 35 - Timeseries of the Tejo_WB3 area during the growing season (March-October) of 2017. The median (Percentile50) is represented in dark blue, with Percentile 20 as lower error value, and Percentile90 as higher error value.

5.3 Indicators to support EU policy

After the first phase of development and adjustment of methods to compute indicators using remote sensing data, some further developments will be considered. These are derived not only from technical matters, which require the implementation of further detailed improvements, but also from the ongoing engagement with Users during the second round of interviews conducted in late 2021.

In relation to the technical matters, the following aspects will be considered:

i) Transitional water systems are often shallow where the bottom influences the optical signal received by the satellite. This can affect the performance of CHL algorithms in these areas. WP5 has now provided a mask for intertidal regions which can be used to mask out these waters and reduce errors in CHL retrievals.

ii) As stated before, at the moment, the existing CHL products available are not able to represent well the spatial and temporal variation of CHL in these six case study regions. In CERTO, work is being done to improve these satellite products, in terms of their accuracy and precision (WP3, 4 and 5). During 2022-2023, the indicators presented in this document will be recomputed with CERTO's improved CHL products.

In relation to the improvements suggested by CERTO's Users, the following improvements will also be evaluated:

i) Regarding the WFD, reporting to the EU Commission is done at the water body (WB) level. Some of the entities with responsibilities in WFD reporting have limitations in terms of human resources and competences to process these datasets and produce aggregated results. This could severely limit the potential of these indicators. Thus, WB shapefiles for each case study region will be obtained and implemented in order to meet the Users' needs.

ii) To comply with the WFD, it is also necessary to calculate the metrics (e.g., CHL P90) for each salinity class. Although not possible to directly derive salinity for these systems, the CHL P90 can be computed for the same tidal conditions to constrain the salinity range for a certain WB. However, this approach requires detailed knowledge on how tidal conditions affect salinity in the different case study regions. The feasibility of such improvements will be evaluated.

5.4 Social-Ecological System Vulnerability Index (SESVI)

Future SESVI development plans include:

i) Continue data sourcing, extracting, processing and threshold application so that the outer circles of the SESVI wheel can be completed and integrated into the two inner circles (see Figures 5 and 6).

ii) Continue the interaction with interested Users and stakeholders to enable them to better understand how SESVI works and how they could benefit from it. At this stage (see also D2.3), the SESVI concept has been presented to most local stakeholders and some interest was expressed. However, the need for more "applied" results with fewer gaps than what was presented at this stage (see Figure 32) was highlighted as important before stakeholders can decide on the usefulness of SESVI, which is what we are working on, according to the plan.

iii) Continue the interaction with the local CERTO Case Study teams and Users or stakeholders to receive feedback on the methods and discuss the list of selected indicators for SESVI and their respective thresholds.

iv) Use the CERTO Prototype to source harmonised water quality data for the six Case Study sites, including the indicators developed under Tasks 6.2 and 6.3. As these datasets cover relatively short time periods (since the Sentinel-2 and Sentinel-3 satellites were launched a few years ago), we may need to source longer time series of water quality trends from other sources for complementarity.

v) Complete the SESVI implementation and apply it to all six CERTO Case Study sites and demonstrate the results during WP8 demonstrations to the CERTO consortium and external users.

vi) Publish the results in a peer-reviewed publication and present them in at least one international conference.

vii) Identify which aspects of SESVI are potentially commercially exploitable in the Exploitation Plan (D9.2, D9.3), and specify what next steps would bring SME(s) closer to its exploitation as a downstream service, or how it may support other existing or new downstream services.

6 Next steps for integration in the Prototype

One of the main aims of CERTO is to integrate products in its Prototype. Regarding WP6, the interaction with the Prototype will be bidirectional, as improved CERTO datasets (e.g. CHL product) will be used for indicator computation and some of the WP6 indicators will be integrated in the Prototype to be freely available to external communities. Not all indicators developed within WP6 will be available in the Prototype, as some are too complex and tailored to be processed autonomously. This is the case of the SESVI but others may be in the same situation. WP6 and WP7 will discuss this topic in detail to reach a joint decision on the list of indicators to integrate. Given the importance of WB delimitation for WFD reporting purposes, WP6 will provide simple and spatially aggregated indicators for CHL and TSM/TUR data. This will be the first step to integrate indicators in the Prototype.

7 Conclusions

The CERTO project is involved in combining observations and feedback from six different case-study sites in order to harmonise the methodology and results across Europe. The six case-study sites selected for CERTO represent the spectrum of different estuary cases in Europe, and it is expected that in harmonising the scientific approach between these key sites, CERTO will be able to harmonise between other European sites in the future. In this effort, CERTO has worked carefully to achieve a wide variety of feedback from Users and has, therefore, implemented the available feedback into the set of Indicators presented herein. These Indicators are still under development, and the plan is to continue to receive and implement feedback as the development stage progresses through to the end of the project.

This report follows up on the analysis of User requirements presented in CERTO Deliverable D6.1 and presents a first selection and application of the Indicators in response to that User feedback. The indicators presented herein represent the first response to those requirements and what is believed to be the best combination of parameters in order to answer those requirements at this stage. As can be seen from the preliminary results, there is good promise in the Indicators being used, and there is a positive potential for achieving the most critical of User requirements across the board as it stands. The indicators presented seek to achieve all the requirements of Tasks 6.1, 6.2, 6.3 and 6.4. Furthermore, the current set of indicators have been developed while considering the key User feedback from the six case studies. An important distinction is made between Industry-relevant indicators and Directive-relevant indicators so that both aspects of estuary management are considered.

A second round of User interviews was conducted within WP2 in November / December 2021 and involved verifying with Users the suitability of the current set of indicators. The current indicators, as well as a subset of preliminary results, were presented and Users provided new feedback on how the current set can be improved. WP6 will therefore use this further input in the continuation of the project, seeking to implement any additional recommendations and requests that the Users have given. Considering this, while the current set of indicators shows good promise, WP6 is still leaving space for changes and additions to future iterations of its products, depending on the results of user interviews in WP2.

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