SAFI

Support to Aquaculture and the Fishery Industry

Grant Agreement No. 607155

Final Publishable Summary

Grant Agreement number:.... 607155

Project acronym: .... SAFI

Project title: .... Support to Aquaculture and the Fishery Industry

Type of funding scheme: ....Collaborative Project - small or medium-scale focused research project

Date of latest version of Annex I against which the assessment will be made: 07/09/2015

Final Report

Period covered ....01/10/2013 – 30/09/2016 (36 months)

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SEVENTH FRAMEWORK PROGRAMME

European Commission

Revision Records

Issue	Date	Updates	Authors
v1.0	29/11/2016	Creation	SAFI Consortium

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Period covered by the whole project: 01/10/2013 – 30/09/2016 (36 months)

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The definition of the acronyms used in this document is provided hereafter:

AB -- Algal Bloom
ACF-- Auto-Correlation Function, Statistics
AD -- Applicable Document
AMJ --- April, May, June months
BBP-- Backscattering coefficient of Particles
C-TEP --- Coastal Thematic Exploitation Platform, European Space Agency project
CC -- Carrying Capacity
CDM --- Absorption coefficient of the Coloured Dissolved Materials
CHL, CHLa --------------------------------------- Chlorophyll-a concentration
CI -- Condition Index
CMEMS --- Copernicus Marine Environment Monitoring Service
CRTS -- Centre Royal de Télédétection Spatiale (National Space Center), Morocco
DOMMRS--- Daithi O'Murchu Marine Research Station (Partner #6)
DOW-- Description Of Work (Annex I of the Grant Agreement)
EC -- European Commission
ECMWF --- European Centre for Medium-Range Weather Forecasts
EO -- Earth Observation
ESA --- European Space Agency
ESA-DUE --- ESA Data User Element
EU -- European Union
FAO --- Food and Agriculture Organisation, UN
FP7 --- Framework Programme 7
FTE --- Full Time Equivalent
GA -- Grant Agreement
GIS --- Geographical Information System
GI, GSI --- Gonadal index, Gonado-Somatic Index
GSM --- Garver, Siegel, Maritorena algorithm (cf. Maritorena & Siegel, 2005)
HAB --- Harmful Algal Bloom
ICES -- International Council for the Exploration of the Sea
IFAPA --- Instituto Andaluz de Investigación y Formación Agraria, Pesquera, Alimentaria y de la Producción Ecológica (Partner #5)
IOCCG --- International Ocean Colour Coordinating Group
IPCC--- International Panel on Climate Change
IPMA--- Instituto Portugues do Mar e da Atmosfera IP (Partner #4)
IP, IPR --- Intellectual Property (Rules)
IT -- Information Technology
JAS --- July, August, September months
JFM --- January, February, March months

KO	Kick-Off meeting, milestone MS1
LDA	Linear Discriminant Analysis
LOICZ	Land-Ocean Interactions in the Coastal Zone network
M#	Month number # since start date (01/10/2013)
MFI	Mesenteric Fat Index
MRT	Multi-Regression Tree
MSD	Marine Strategy Directive
MSPD	Marine Spatial Planning Directive
NASA	National Aeronautics and Space Administration, USA
NOAA	National Oceanic and Atmospheric Administration, USA
NRT	Near Real Time
O#	Objective number #
OBIS	Ocean Biogeographic Information System
OLCI	Ocean and Land Colour Instrument, on-board Sentinel-3 (ESA)
OND	October, November, December months
PFT	Phytoplankton Functional Types
PM#	Progress Meeting #
PNAB	IPMA's National Biological Sampling Programme
PP	Primary Productivity
PR1	Periodic Review 1, milestone MS5
PUDF	Plan for Use and Dissemination of the Foreground
RE	Reports Dissemination level: Restricted to the Commission
REA	Research Executive Agency
RTD	Research and Technical Development activities
S2, S3	Sentinel-2, Sentinel-3 (ESA satellites)
SAFI	Support for Aquaculture and Fishery Industries
SGR	Specific Growth Rate
SMART	ESA project, Sustainable Management of Aquaculture through Remote sensing Technology
SME	Small and Medium Enterprises
SST	Sea Surface Temperature
TR	Final End User and Training Meeting
UB	User Board
UCC	University College Cork (Partner #2)
UK	United Kingdom
VIF	Variance Inflation Factor
WP	Work Package
WW3, WWIII	WAVEWATCH-III (wave model)

2 Final Publishable Summary Report

2.1 Executive Summary

From its design, the FP7-SAFI project was intended to **promote the use of spatial data as support to marine aquaculture and fishery activities.** The motivation of this project came from the conjunction of several elements that were considered, at the time of the proposal, as many positive signals that would help the SAFI consortium to set up an economical sustainable service at the end of the project. These positive elements were:

1. ***The Observational context***: many "projects" were conducted in the past to demonstrate the benefit of Earth Observation (EO) for the aquaculture and fisheries sectors. Although quite conclusive, these projects were not transformed into operational service for mainly two reasons:
   a. the potential lack of maturity and genericity of the derived-products (often linked to one problematic on one area), and, more important
   b. the uncertainty in the sustainability of the EO offer that was refraining the willingness to setup and promote an operational service.

   EU-Copernicus program shall solve the second point, while, with respect to first point, SAFI proposed strategy was to evaluate the genericity of environmental indicators (at global scale) and, with help of scientific partners to improve their transferability.
2. ***The Market context***: there was still a low willingness to introduce EO data in the end-users activities because of a number of barriers ranging from communication, but also transfer of from EO to real professional needs of the industry. Often, there is breach in the value added chain that prevents any penetration of the market, simply by lack of understanding and expertise on both side offer-demand. The very good relationship and working methodology developed through SAFI partners (mainly SMEs) during past projects have been felt has a positive answer to this weakness in market understating and penetration.

The present document is the synthesis of the three-year adventure of SAFI project and describes how things have been set up and organised to prepare the ground for the deployment of a SAFI service based on realistic business considerations. In particular, all scientific developments are synthetized in the following: development, validation and test on exportability outside Europe of 5 families of environmental indicators for fisheries and of 3 families of indicators for marine aquaculture. Also rules for dissemination and exploitation of results are presented.

All together, we can state that assumptions made at the start of SAFI are valid; Copernicus is progressively entering into full operation and is starting to serve SAFI services. Thanks to large span of partnership expertise, a large number of users have been consulted (65) and are willing to support SAFI in the near future. Lastly and thanks to all construction and elaboration done within SAFI-project (and listed in the present document), the next main objective of the SMEs partners is then to set up a cluster of SMEs (starting from the SAFI SMEs) to set up the commercial offer of the SAFI services.

2.2 SUMMARY DESCRIPTION OF PROJECT CONTEXT AND OBJECTIVES

2.2.1 SAFI Context

Optimising production through the daily control of aquaculture farms operations, identifying places where suitable conditions for marine life are fulfilled, monitoring fish stocks to exploit them in a sustainable manner, estimating effects of climate change on fish habitats; monitoring water quality; all these activities require a good knowledge of the environmental characteristic of the oceans. Based on field data, the knowledge on ocean expends, and indicators on the state and health of the environment become available but also require input data.

In parallel to these growing needs for information, techniques for the remote sensing of the Earth and Oceans are consolidated and international strategies like Copernicus in Europe plan huge efforts to ensure continuous and sustainable availability of such data.

However, there are still too few interactions between the remote sensing community and marine stakeholders.

SAFI project aimed at **promoting the use of spatial data as support to marine aquaculture and fishery activities**, taking the advantage of the very latest satellite sensors being launched, and the expertise of the project teams to exploit these to produce understandable indicators adapted to the activities of the marine actors, in support to aquaculture and fisheries.

The specific objectives of the SAFI initiative are developed below:

- **Objective 1 - To develop a service to assist marine aquaculture** deployment (optimization of cages location w.r.t. to environmental and ecological context) and environmental monitoring during operations
- **Objective 2 - To develop a service to support fishery** by providing indicators of recruitments, abundances and shell/fish locations
- **Objective 3 - To set up a network of SMEs** at different levels of expertise (and EO awareness) required by the service – and to build a consistent and marketable offer.
- **Objective 4 - To evaluate the capacity of exportation, acceptance, and sustainability of this service**
- **Objective 5 - To foster the use of sentinel 2 and sentinel 3 data**

These objectives, as they were at the beginning of the project, are more explicitly described in the following section.

2.2.2 SAFI Objectives

Objective 1 - To develop a service to assist marine aquaculture deployment (optimization of cages location w.r.t. to environmental and ecological context) and environmental monitoring during operations

i) **Support to optimal cages location**: The environmental parameters that are necessary to optimize the location of cages are well known. Some of them are directly quantified by Sentinel-3 (or existing Ocean Colour missions) or by Sentinel-2 (or existing high resolution optical missions), or by models or combinations of sensors.

SAFI aims to provide relevant environmental information through online tools to supply advice for fish cages locations.

ii) **Support to water quality monitoring**: During the last decade, a large number of projects have been carried out for the detection of red (or green) tides and more generally Algal Bloom (AB) and more specifically Harmful algal Blooms (HAB). Two main techniques are co-existing: First is the detection of a departure from an average situation in Chlorophyll fields. This presents the problem of the definition of the reference state itself (i.e. if there is a regular bloom at one place, the bloom will then sticks to the reference state and will never be detectable). The second technique is the identification of specific spectral signatures in the observed reflectances – this is possible for only few species and required good atmospheric correction (i.e. good water signal). Another one which is recently explored is to track temporal anomaly at given location (so AB is searched as a sudden change in the Chlorophyll concentration evolution). Lastly, new methods are under development, which try to make the statistical link between bloom occurrences and external forcing (i.e. rainfall provoking high discharge of humic material at sea, lack of wind that helps stratification …).

SAFI aims to co-apply these methods to check whether their capability to detect blooms are similar or not and if there is means to merge these methods to qualify the robustness of the detection (to give a confidence level in the detection) for the monitoring of fish farming plants. In addition, all the other environmental information is to be made available for marine actors to monitor in near-real time the status of the marine environment around existing farms.

Objective 2 - To develop a service to support fishery by providing indicators of recruitments, abundances and shell/fish locations

SAFI aims to make some significant contributions to these objectives:

i) **Support to determination of bivalve abundance and maturity:** The maintenance of the populations of these species requires effective recruitment and post-settlement survival through juvenile phases. Therefore, to implement more-effective management systems it is of utmost importance to increase our understanding on the environmental factors that affect recruitment. The ability to track and predict the spatial dynamics of invertebrate species using key environmental parameters will likely become increasingly important as climate change alters geographical distribution patterns of many marine populations.

SAFI aims at examining the potential of using environmental data derived from Satellite Remote Sensing observations to explain the yearly abundance fluctuations observed and to predict future trends in the abundance of the bivalve commercial species at a relatively fine spatial scale in order to include them in management plans. The results achieved on Portuguese coasts will be transposed to areas with similar conditions and where bivalve fisheries are undertaken, such as in south Spain and Morocco (see section on Objective 4 below for further details on test sites and indicators).

ii) **Support to fishery indicators for abundance, location and recruitment of small pelagic**: Abundance strongly depends on recruitment and year-to-year biomass variability of small pelagic stocks. Long term periodic fluctuations can appear when environmental conditions overlap anthropogenic effects.

SAFI aims to develop statistical models to estimate environmental dependence of small pelagic fish abundance and recruitment and to use ecological niche models for fish location as a function of environmental evolution (climate change). Few species shall be studied such as anchovy or sardine. Accessible historical data of fisheries and scientific cruises are to be used. Relevant environmental parameters will be selected to be correlated with abundance of fishes (Chlorophyll-a, turbidity, temperature, salinity, dissolved oxygen, wind, waves, stratification, current, tide, river plumes…), using historical *in situ* data, satellite imagery, and model results.

Objective 3 - To set up a network of SMEs at different levels of expertise (and EO awareness) required by the service – and to build a consistent and marketable offer.

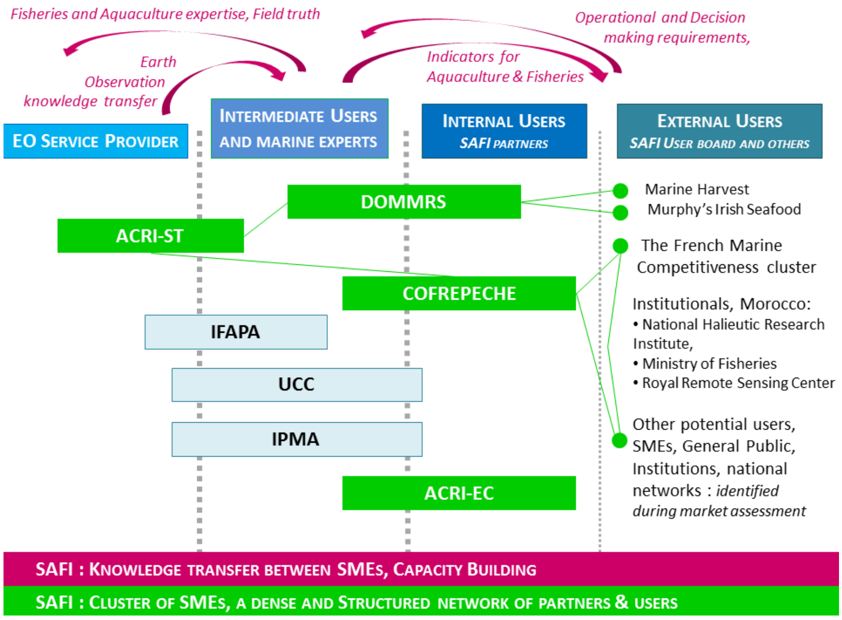


Figure 1: Expertise chaining within SAFI, relying on SMEs and institutions experts and non-experts in EO

On the figure above are indicated the partners of the SAFI project (SMEs are in green and institutional partners are in light blue) as well as a schematization of their expertise from the Earth Observation on the left to the Aquaculture and Fishery Thematic on the right. The objective of SAFI is to make the link between the two sides of the figure (from EO to end users) by establishing the necessary chain of expertise within SMEs, helped by R&D institutions. On top of the figure, transfer and exchange of expertise during the project are figured with pink arrow. The significant level of exchange is to be noticed. At the end of the project, the market will be assessed with consultation of end users through demonstration and training. The business model will then be established and the business plan built.

Objective 4 - To evaluate the capacity of exportation, acceptance, and sustainability of this service

The state of the art in indicators derivation for aquaculture and fishery is that often these indicators are derived for one site – presenting specific hydrodynamics, meteorology and biogeochemistry.
Therefore, beyond the previous objectives of SAFI, it is of course of prime importance to evaluate the capacity of these indicators to be generalized to others sites (or to assess the efforts that shall be put in place to adapt them to a new area). As such, this transportability evaluation is an entire component of the business model of SAFI.
To answer to this objective, SAFI develops two successive approaches:

Internal validation: once elaborated on one site, the indicators are tested on another European site (choice of the other site is conducted by the presence of same species and, more strongly, by the availability of *in situ* data to evaluate the relevance of indicators). Each of them will be deployed based on EO and model data, and confronted on a consistent period of time to *in situ* measurements provided by the end-users involved in the case study, or by local authorities or other local sources.

Demonstration on site outside Europe: This second step is fundamental as the SAFI SME partners intend to promote this activity internationally. Because of a very favourable context (Halieutis strategy deployment, very important fishery industry and strong willingness of aquaculture development), Morocco has been chosen as a very relevant partner for these demonstration. Halieutis Strategy has been put in place in 2009 to promote fisheries and aquaculture in the Kingdom. Expectations towards 2020 are very strong: pass from the annual fish catch from 1M tons to 1.6M tons, from less than 500 tons to 200.000 tons of yearly aquaculture production, increase species under quota from 5% to 95% with the uppermost objective of ensuring sustainability of the natural resources. In such context, SAFI clearly aimed to bring strong assistance to the deployment of this strategy and others elsewhere in the world.

Whatever the results of these two phases, the objective of such evaluations is to report and document the exportation/transferability and sustainability of the SAFI services for a better acceptance by its users.

Objective 5 - To foster the use of sentinel 2 and sentinel 3 data

Several benefits are expected from the launch of Sentinel 2 and 3 satellites (as part of the Copernicus Programme):

- Better spatial coverage,
- Better temporal revisit,
- Better sensors characteristics than precursors,
- Availability of multi-sensors observation (coincidence of observations of SST, Ocean Colour and altimetry products),
- Availability of coincidence of Sentinel 1, 2 and 3 observations allowing data fusion and Bayesian combination of data sources.
- These new capabilities will be largely considered especially for the joint availability of Ocean Colour, Sea Surface Temperature (SST) and Sea Surface Height

SAFI planned to take full advantage of these new satellite data being made available by the Copernicus Programme during the years of the SAFI project.

2.3 MAIN SCIENCE AND TECHNOLOGY RESULTS AND FOREGROUND

2.3.1 Main results overview

SAFI main results consist in:

- Derivation of new indicators for aquaculture and fishery management
- Development of new tools to support marine aquaculture and fishery activities
- Development of new services, business models and an SME network for the operation, maintenance and upgrade of SAFI services
- Development and maintenance of a users' community to better shape the SAFI services, products and tools, to collect feedback and assess the market for the preparation of SAFI commercial exploitation

2.3.2 SAFI R&D – the indicators developed

Introduction to indicators' setup: data collection and validation

One of the innovative aspects of SAFI project is to exploit the latest Earth Observation and model based information available around the globe to assess the state of the oceans.

During the first phase of the project, all the available environmental data (models, *in situ* and satellite) were analysed, and the most relevant parameters required to setup novel indicators and services were collected (see Figure 2).

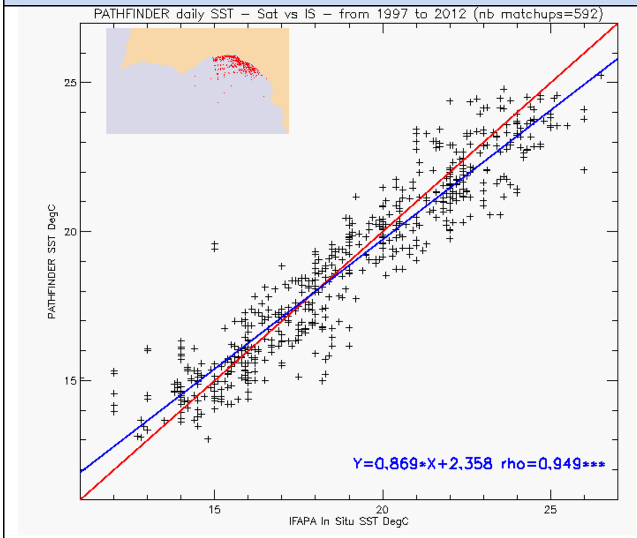
Environmental data from models and Earth Observation were also validated and the datasets with the highest quality were finally chosen for use in indicators setup and publication into SAFI Services.

A special focus was given on the results of the quality analysis for sea surface temperature (SST) and the chlorophyll-a datasets.

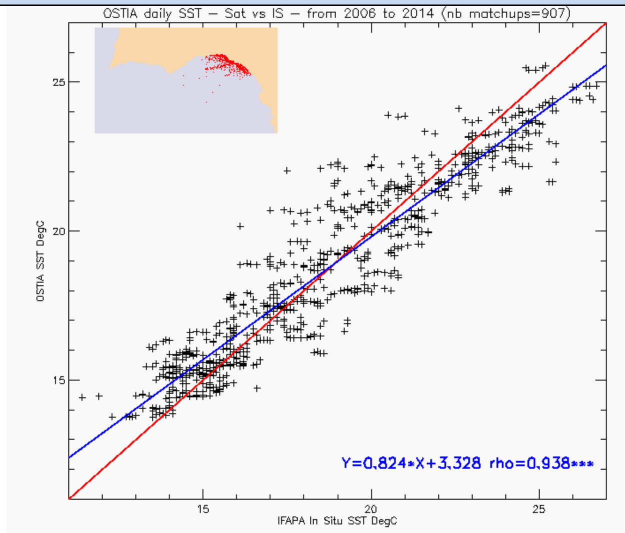
Analyses exploited time series of historical database collected by SAFI partners in the Huelva (Spain) and Algarve (Portugal) Regions, and the corresponding data from various models and Earth observation sources; For SST, the PATHFINDER, OSTIA, GHRSST MUR and ODYSSEA datasets were analysed (Figure 3). For chlorophyll-a, OC5 algorithm with MODIS data, and Globcolour GSM_CHL1 datasets were studied.

Figure 2: List of the environmental EO and model datasets exploited in SAFI and collected (more details in D7.2 document).

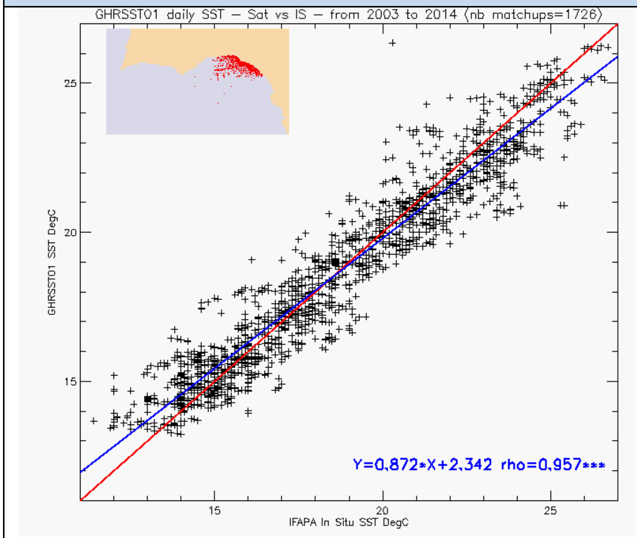
PATHFINDER



OSTIA



GHRSST MUR



ODYSSEA

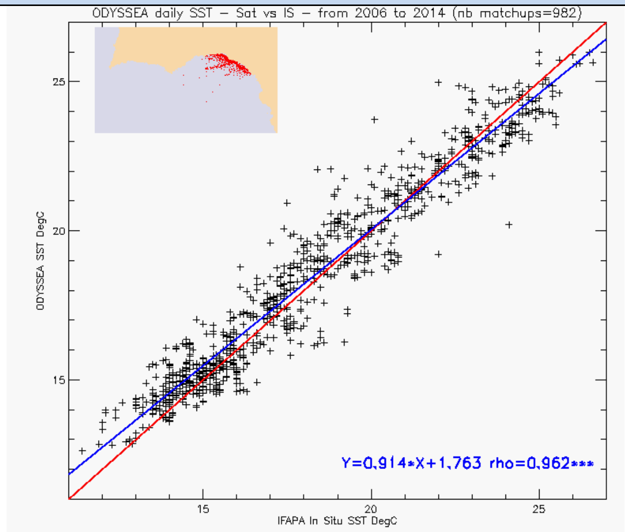


Figure 3: Correlation analysis of EO SST datasets versus IFAPA temperature in situ *measurements in Huelva region (Spain)*

All the satellite measurements of sea surface temperature have a very good correlation with the *in situ* measurements (Spearman rho ranging from 0.93 to 0.97).

For **chlorophyll-a concentrations** performed, OC5-MODIS showed slightly better results than GlobColour GSM-CHL1. When considering offshore waters only, the OC5 and GSM algorithms provided quite similar results (Spearman rho=0.74 and 0.78, respectively).

These datasets were then used to develop novel indicators or apply existing ones to SAFI areas and species of interest. Hereafter are presented the main results for each indicator developed.

Fishery of small pelagic finfish: Sardine abundance & recruitment indicators

To setup this indicator of the abundance (low/high) of recruits (sardines <16 cm in length), a linear regression method was first applied and was statistically significant yet it had a poor predictive power. Thus, a linear discriminant analysis (LDA) was successfully applied to improve the predictive power of the indicator, namely the capacity of the environmental and biological variables from the previous spawning season to discriminate between high and low abundance of recruits (< 16 cm). This analysis was done separately for the three areas considered to be recruitment ”hotspots” for the Atlanto-Iberian sardine stock: the Western Iberia, the Gulf of Cadiz and the Bay of Biscay, since the environmental stressors are area-specific.

The discriminant function correctly classified 80% of the observations in the three areas when using all the environmental and biological variables. When using only Sea surface Temperature (SST) and chlorophyll-a concentrations (CHLa), the correctness of the classification increased to 92% in the west coast area but decreased to 67% in the Gulf of Cadiz. The correctness of the classification decreases for all the areas when only SST is used as predictor.

In general, higher abundance of recruits was associated to high food availability (CHLa) and to low SST, although there were differences of the most important variables according to the areas under study. Years of high abundance of recruits in the Western Coast and in the Gulf of Cadiz were mostly related to high CHLa, particularly during the last quarter of the previous year. In the Bay of Biscay, in contrast to the other two areas, higher temperatures were associated to higher abundance of recruits but this is a consequence of mean SST in this area was below the optimal range for sardine larval development. Overall, the abundance of adults was the least important variable for the discrimination between groups.

The same analysis was done using ICES time series of recruitment strength and spawning stock biomass estimated for the all Atlanto-Iberian Sardine Stock. The linear discriminant analysis (LDA) was able to correctly classify 79% of the observations by cross-validation when using all the environmental and biological predictors or only SST and CHLa, but the accuracy decrease to 73% of correct classification when using only SST to discriminate between the two recruitment groups.

In general, years of high recruitment strength were associated to lower SST and higher CHLa during the last quarter of the previous year but also to the abundance of spawners (spawning stock biomass) of the previous year. This is in accordance of the hypothesis that the most important variables in explaining the separation of high and low recruitment years are optimal temperature (ranging between 13 and 17 °C) and high food availability (higher values of CHLa) occurring during the spawning season.

These promising results evidence that satellite-derived SST and CHLa can be used as indicators of the level of recruitment of sardines populations living in Atlanto-Iberian and Bay of Biscay regions. Due to satellite operability and observations in adequate scales, using derived SST and CHLa to predict high or low recruitment conditions with several months in advance and with a high percentage of correctness would be an important support to fisheries management.

The sardine abundance and recruitment indicators were also adapted to the Morocco region based on the same methodology, and could correctly classify 100% of the acoustic data observations by cross-validation, and 80% for the catch data, using SST and CHLa as predictors. The data used for these analyses were acoustic abundance of recruits data, north and south of Cape Blanc and catch data in fishing Zone C (south of Cape Boujdor, North West Africa).

Fishery of small pelagic finfish: ecological niche and species mobility indicator

To identify the ecological niches for sardine and anchovy, all the available matchups (spatio-temporal concordance between *in situ* data from OBIS and Fishbase fish presence and the environmental measurements from satellite) in the "EUROPE" zone were used.

The following maps show the seasonal potential habitat of sardine and the significance of observations for the 5 geographical areas studied: Biscay (-12/1°E,43/49°N), Baltic (10/25°E, 54/60°N), North Sea (-3/10°E, 51/65°N), Ireland (-12/-3°E, 50/60°N) and Mediterranean (Medit: -1/37°E, 30/45°N). Regional observations were considered significant when they are higher than 15% of the total of seasonal observations. In green: areas with significant number of observations, in red the others.

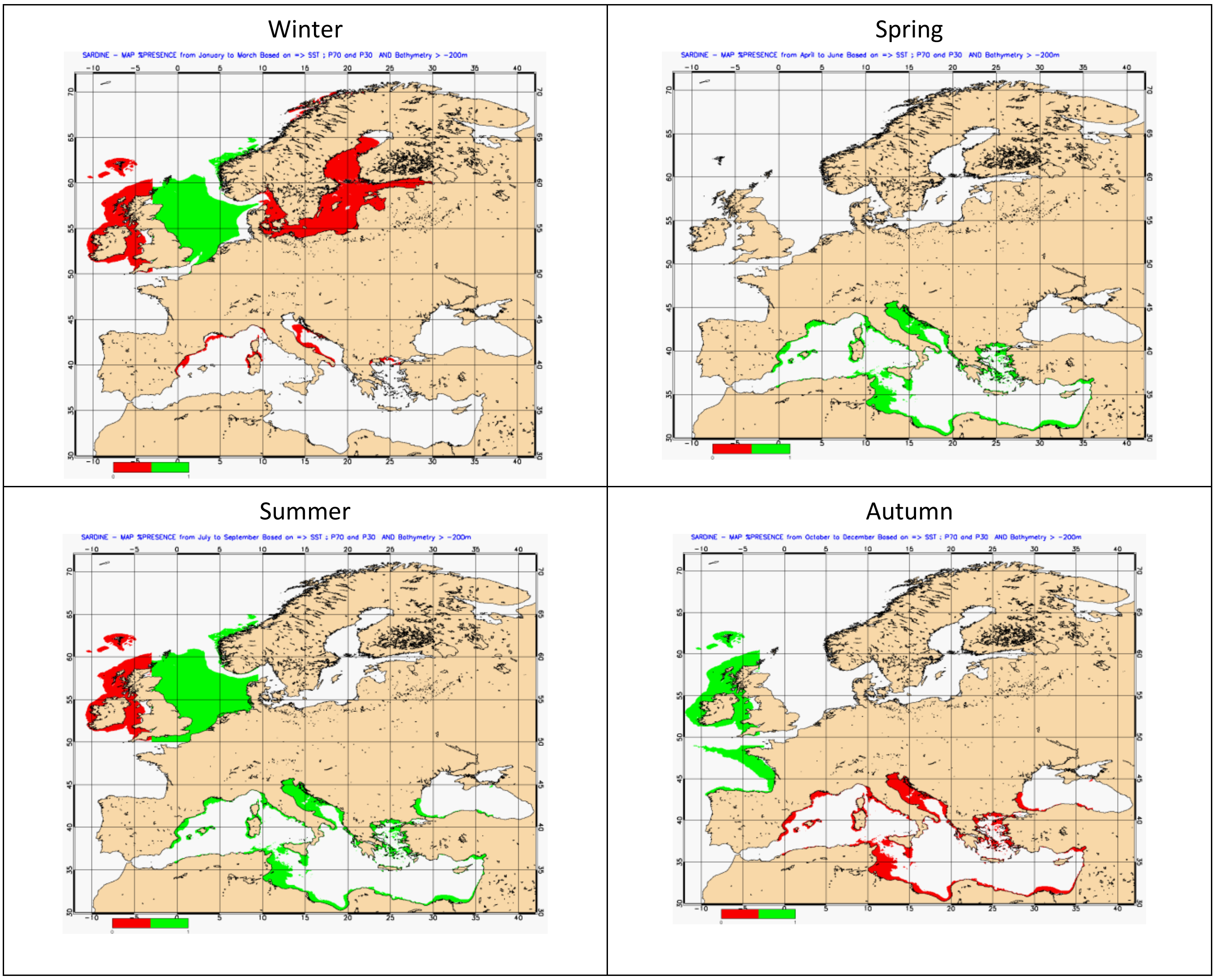


Figure 4: Seasonal evolution of the sardine habitat location in Europe throughout a year, derived from OBIS sardine observations recorded.

Similar maps could be produced for anchovies (detailed in report D10.2). In winter, the potential habitat of anchovy is limited to the North of Europe, with significant observations recorded in the North Sea and the Baltic Sea. In spring, potential habitat of anchovy is limited to the Mediterranean Sea where the quasi-totality of observations is recorded. During summer, the potential habitat is in the North Sea, the Baltic Sea and the

Mediterranean Sea, with significant observations recorded in the North Sea and the Baltic Sea. During autumn, significant observations were recorded in the Baltic Sea, the Bay of Biscay and around Ireland.

The methodology has then been adapted to Morocco for sardine niche indicator deployment, using *in situ* data of daily sardine landings (in kg) from Atlantic Moroccan fishing ports (period 2003-2014). Not enough *in situ* data was available for anchovy indicator deployment outside Europe.

Fishery of small pelagic finfish: maturation index for sardine and anchovies

The **sardine maturation algorithms** linking the morphometric condition factors **with SST** from EO gave the following models (by linear regression): i) a Gonadosomatic index (GSI); ii) a Gonadal index (GI); and iii) a Mesenteric fat index (MFI).

Sardine is mainly a zooplankton feeder, with an additional feeding on phytoplankton. This fact, could explain the weak correlation found between sardine GSI and satellite derived **chlorophyll-a concentrations** (R^2=0.28). A correlation test (Spearman rho) between GSI and **phytoplankton size classes** showed that the only significant positive correlation was with micro-phytoplankton (diatoms, dinoflagellates) supporting the hypothesis of the limited filtration capabilities of sardine for small food particles. Furthermore, those results could explain the poor correlation found between GSI and total chlorophyll-a, since the medium and smaller fractions of the phytoplankton communities cannot be captured by the sardines.

A quality evaluation test of the purposed sardine maturation index was performed comparing real GI data with estimated GI derived from the GI algorithm. The agreement between the simulated and real GI data is high with the exception of Oct-Nov 2015 when the first maturation cycle happens, suggesting that for areas with more than one maturation cycles per year should need a specific algorithm for each maturation cycle.

The applicability of the proposed indices should be presented in the scientific paper: "*Approaching to small pelagic fisheries management using SST remote sensing data: A case study in the Gulf of Cadiz (SW Spain)"* to be submitted to Marine Policy.

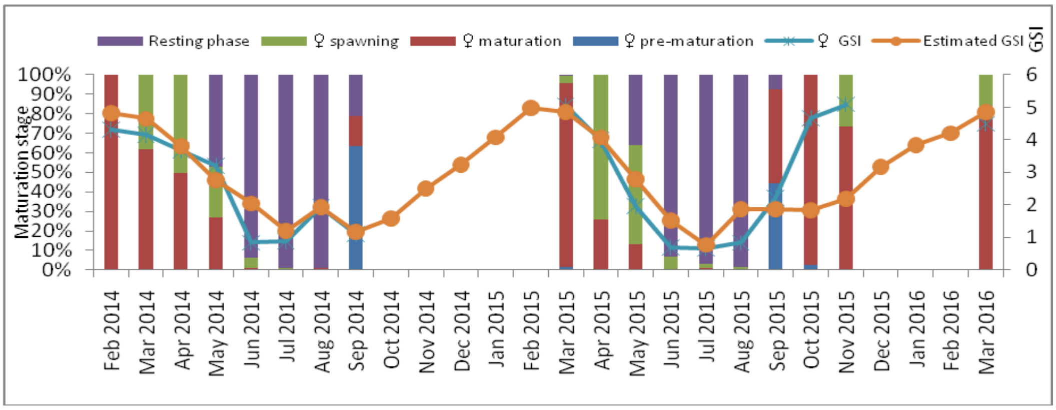


Figure 5: Evolution of observed and estimated Gonadal Index of sardine during the study period

Mesenteric fat is crucial energy storage for the reproductive activity of the individuals, and could be considered as a raw forecast tool of offspring quality. Consequently, higher MFI values should mean higher quality of offspring, but this hypothesis must be validated by an inter-annual comparative recruitment analysis.

MFI is positively correlated with the increase of SST, late spring and summer in the Gulf of Cadiz, i.e. the resting phase of the full annual reproductive cycle of the species.

The tests performed for sardine were also deployed for anchovy, obtaining only weak correlations between the condition and maturation factors and the environmental variables (SST, chlorophyll a). The quality of the results was unsuitable to purpose the resulting algorithms as an operational tool for the dynamic management of the legal biological closure of this species in the Gulf of Cadiz.

Fishery of bivalves: biomass indicator

Three sets of indicators were produced to forecast future bivalve biomass of the main commercial species in the South of Portugal. As input, all these indicators use IPMA's regular bivalve fisheries surveys, i.e. historical data sets of bivalve biomass from 1986 towards 2012 and the assembled historical sets of the environmental variables.

a) Indicators using the environmental variables with largest time span available (i.e. meteorological data, climatic indices and SST from satellite). This selection of variables aimed to optimise the number of samples used in the modelling procedure. To estimate this indicator, a model selection procedure (optimised stepwise procedure) was used in variable selection. Then, the indicator was estimated with a general linear model approach and the respective assumptions tested. Residuals were tested for temporal autocorrelation using ACF and Durbin-Watson Test. Collinearity among explanatory variables was tested using Variance Inflation Factor (VIF).
The indicator produced for *Chamelea gallina* included Summer wind intensity, Summer maximum wind intensity and Spring rain amount. The linear model showed no signs of collinearity (VIF values <1.5) or temporal autocorrelation (D-W=2, p-value= 0.36) and explained 75% of *Chamelea gallina* variability of the following year. The three variables were highly significant, similar to the overall model. This species would thus be favoured by summers with high peaks of intense wind (maximum wind) altered with relatively low intensity of winds on average for the same season and rainy springs, all on the previous year.

The indicator produced for *Donax trunculus* included Summer to Winter average maximum wind intensity. The linear model showed no signs of collinearity (VIF values <4) and there was no evidence of temporal autocorrelation in the residuals (D-W= 2.178, p-value= 0.866). The final model explained 88% of *Donax trunculus* variability of the following year. The three variables were highly significant, similar to the overall model. This species would thus be favoured by summer to winter with high peaks of intense wind altered with relatively low winds on average, on the previous year.

The indicator produced for *Spisula solida* included Summer Wind maximum intensity and SST and Winter amount of rainfall. Still, model selection eliminated two of those variables, indicating that only the Summer Wind maximum intensity was significant to predict species biomass on the following year. Thus a new model was done using only this variable. There was no evidence of temporal autocorrelation in the residuals (D-W= 2.1, p-value= 0.96). The final model explained 74% of *Spisula solida* variability of the following year. The model was highly significant.

b) Indicators using the environmental variables available by satellite only. This implied lower number of samples used, as most variables are only available recently. The procedure to develop these indicators started with a variable selection carried out by raw data graphical analysis. In spite of the low number of samples, some relationships are promising and should be explored in the future, perhaps taking into account the spatial variability to increase the number of samples.

An indicator was produced using *Chamelea gallina* biomass in function Spring PICO-PSD, explaining 30% of the bivalve variability on the following year.

An indicator was produced using *Donax trunculus* biomass in function of winter CDM (absorption coefficient, which is a proxy of salinity), explaining 36% of the bivalve variability on the following year.

An indicator was produced using *Spisula solida* biomass in function of summer particulate back scattering coefficient (a proxy of concentration of suspended matter), explaining 63% of the bivalve variability on the following year.

c) Indicators using seasonal averaged SST data from satellite to forecast bivalve biomass. These were estimated using multivariate regression trees analysis, applied on seasonal satellite SST, which is the EO variable that has greater available temporal span. Multivariate regression trees analysis (MRT), is a method that finds the best partition of the variance, using the explanatory variables. This indicator provides a clear cut-off value of the seasonal SST of the previous year, to forecast bivalve's biomass.

Using only three splits (cuts) in the Spring and Autumn SST, MRT was able to accurately estimate 78% of the variability of *Chamelea gallina* biomass in the following year. In fact, higher biomasses are predictable with only the first two splits, as it is shown in the predictions plot. The classification only failed on 1996 out of 25, i.e. 96% accuracy (1995, on the lagged biomass).

High biomass of the bivalve *Donax trunculus* was predicted by average Spring SST greater than 17.23°C. This explains 44% of the variability of bivalve biomass, and failed only on three years over the complete series of 25 years. Similar to *Chamelea gallina*, monthly data could not improve this result.

The biomass of the bivalve *Spisula solida* could not be successfully predicted using seasonal SST. The best solution (good year: SST.JAS < 21.42°C) only explained 26% of the variability and failed on almost half of the samples. This model was thus not considered for brevity. Monthly data, similar to the other species did not show a substantial improve on this predictions.

Fishery of bivalves: maturity indicators

- **Gonadal index (GI)**

After an initial positive correlation between the GI and the SST from EO, the goal was to look for a forecasting tool for the management of the biological closures of bivalves in the Huelva's region. The highest correlation was obtained between GI and SST from 60 days before (SST60) for both species.

The interpretation of the Gonadal Index (GI) values in relation to the gonadal maturation stage of the species is summarized in the following table:

Table 1: Relationships between GI values and gonad maturation stages

Maturation stage	Gonadal Index (GI)	
	Striped venus	Wedge Shell
Resting	< 2	< 1.2
Maturation	2.2 – 3.3	1.3 – 2.7
Ripe and beginning spawning	>3.3	> 2.7

The quality evaluation of the proposed GI algorithms was tested for the whole sampling period until June 2016 using the SST 8 days product from 60 days before the sampling data (see Figure below).

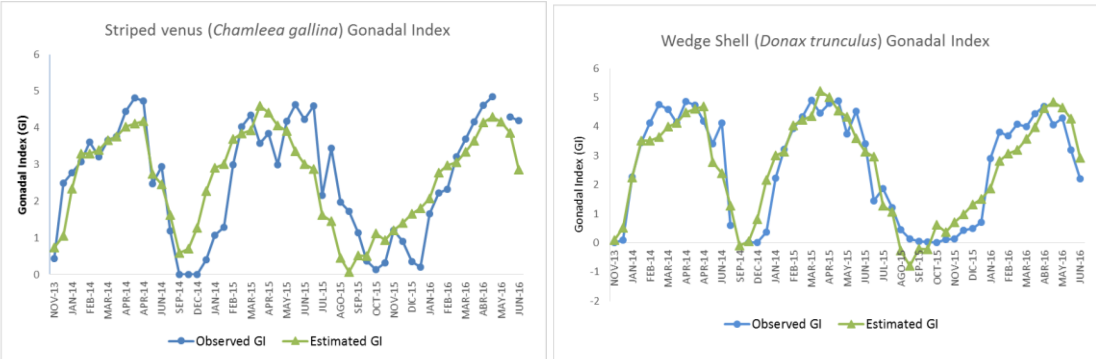


Figure 6: Evolution of measured and estimated GI for striped venus & wedge shell during the study period

These graphs show a good correspondence between these models and the observed results. Models were demonstrated to be a useful and easy tool to forecast maturity stage in the Gulf of Cádiz for *C. gallina* and *D. trunculus*. Thus, the biological closure periods could be chosen by fishery managers several weeks in advance allowing a best strategy in the management of both striped venus and wedge shell bivalve populations.

- **Condition index (CI)**

The final model of *Chamelea gallina* condition index included the interaction between SST and month and the CHLa (51% of the total deviance is explained by the model, where CHLa only represents about 10% of the deviance). The predicted condition index was greatest in April-June, just after the SST showed its lowest values and started increasing. The final model for *Donax trunculus* included SST interacting with month and CHLa (this model explained 56% of the deviance). This species showed greatest condition index slightly latter than *Chamelea gallina*, with an optimal temperature of 16-18°C. Overall, both species showed higher conditions in colder temperatures.

Condition index can be predicted using SST, month and CHLa from satellite data, both for *Chamelea gallina* and *Donax trunculus*. These indicators produced and validated using spatial predictions over an area and data from another geographic zone (Huelva) can be now used in a fisheries context.

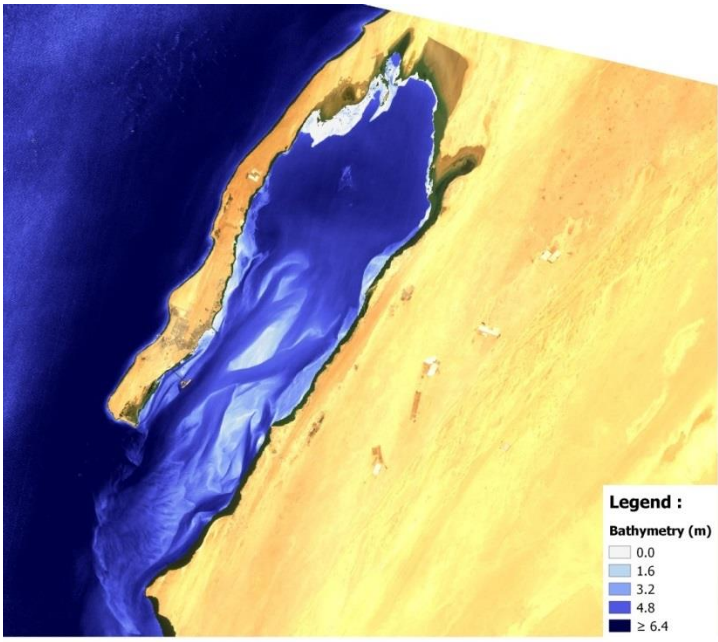
- **Oocytes diameter**

Oocyte diameter also reflects gonad maturation and it is known to increase during maturation towards spawning. Afterwards, oocyte diameter decreases as spawning occurs. This parameter was only estimated for animals from the Algarve. The variation throughout the year of the oocyte diameter measurements is rather similar for the two analysis methods used (smear and histology), although oocyte diameter measured by histological techniques was more accurate and provided better results during the procedure than smear techniques. *Chamelea gallina*'s oocytes reached larger sizes than the ones from *Donax trunculus*.

Oocyte diameter can be estimated by SST interacting with month and CHLa on *Chamelea gallina* (R^2=48%), whereas for *Donax trunculus* no clear relationship was found (R^2=12%). The absence of a good relatioship of oocytes diameter in *Donax trunculus* can be related to a greater fragility of those strutures for the latter species, that often get danified during the analytical procedure. The condition index is a better indicator of the maturation period than oocyte diameter, if we are predicting it using satellite variables.

Aquaculture site optimization: seabed mapping for shallow waters

A relatively simple method (Pennucci *et al.,* 2007[1]) is used for bathymetric retrieval from EO high resolution products (Sentinel-2 and Landsat-8) under two assumptions: i) the sea floor albedo is constant and ii) several *in situ* truth are known in order to derive the parameters used to link the blue and green reflectance's with the depth. Despite its limitations, this method is used to provide a first guess (e.g. for depth) for the more complete methods. This method was deployed in the bay of Dakhla, south of Morocco. Earth observation images from USGS' Landsat 8 (30m spatial resolution) were exploited to derive a bathymetry for year 2014 (Figure 7, left). Then, the same methodology was deployed using a Sentinel-2 image (Figure 7, right).



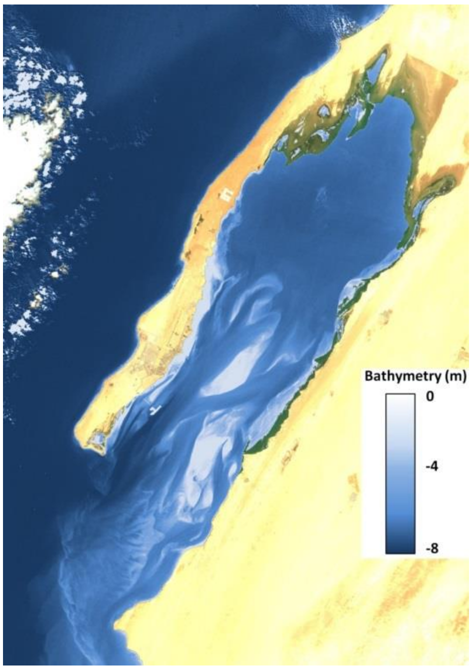


Figure 7: Bathymetry estimates in the bay of Dakhla (South of Morocco) from (left) Landsat 8 over year 2014, and (right) Sentinel-2 (ESA) on 16/09/2015.

Year 2002's bathymetry was also produced with Landsat 7, and compared to the 2014 bathymetry to assess sedimentary evolution through the years.

Finally, the method was applied to another site in North West Ireland (Mulroy bay, Co. Donegal, see Figure 8).

[1] Pennucci G., R. Grasso, C. Trees, "Bathymetry estimation from high-resolution satellite images," Poster contribution at NURC REA Conf., 25-27 September 2007, Lerici, Italy

Figure 8: Mulroy Bay (Donegal, Ireland): (left) ESA Sentinel-2 image on 29/05/2016, and (right) the corresponding shallow water bathymetry derived.

In the frame of SAFI, simple bathymetry products were developed to support the extrapolation of existing punctual data in space and over the years to follow bathymetry evolution (as in Dakhla where sedimentary processes are important). To continue beyond SAFI, the indicators developed here can be further consolidated with the indicators under research developed in particular in the frame of the Co-ReSyF project (EU H2020, 2016-2019). The results from this project could later complement the SAFI catalogue offer in terms of bathymetry estimates in shallow waters and associated confidence intervals.

Aquaculture site optimization: mapping of optimized site location

In the case of **salmons, mussels, seabass and seabream**, a first literature review has allowed partner to find out the main parameters ruling the living conditions of the fishes, as well as an optimal range of values. From salmons, discussion with Murphy's Irish Seafood farmers led to even more detailed ranges of values for the fish habitats, as well as optimal conditions for operation of the type of farm used to breed salmons. From these characteristics, SAFI used archives of Earth observation and model datasets to identify the areas statistically corresponding to such values. Depending on the species, influencing parameters varied. Optimal site location maps were thus produced over Europe, and (when relevant, i.e. not for salmon) applied in Morocco.

Then, the work on optimized site location focused on the deployment of the indicators on other various areas of interest as well as their **validation**. The following Figure 9 compares the location of the seabass and seabream farms in Spain in 2004 (image on the left, source European Commission Report "Study of the market for aquaculture produced seabass and seabream species", 2004, with hatcheries in red, and farms in green), with SAFI results from the optimal site location indicator based on 2005-2015 environmental data (right). The quasi totality of the Mediterranean Spanish and Balearic Islands (but the northern coast of Menorca) coasts show optimal environmental conditions for seabass and seabream farming (right map). It agrees with the farms location reported by the European Commission in 2004 (left map).

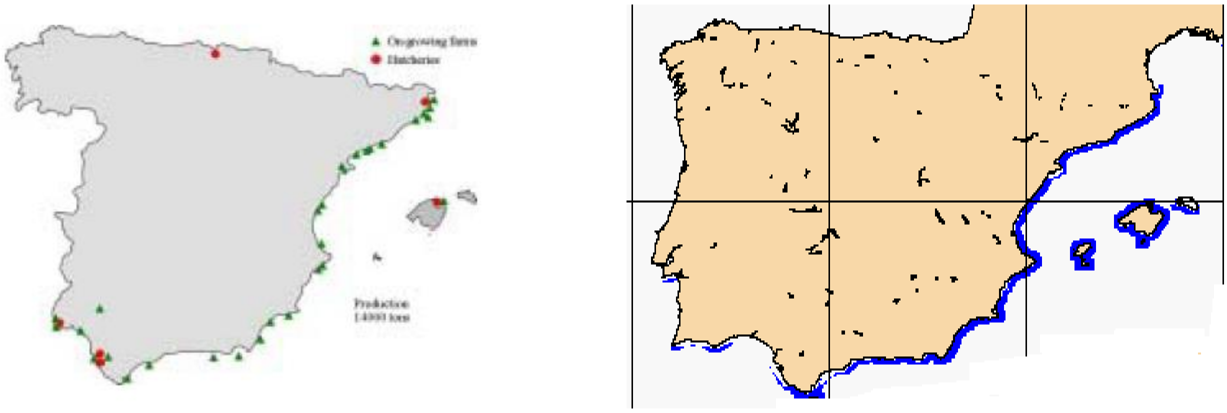


Figure 9: Comparison of the SAFI optimal site location indicator for seabass and seabream with actual farms location in Spain.

In addition, at the end of the project, a specific analysis was made in views of a **changing climate**. The analysis focused on salmon farming suitability which is particularly of interest for Irish farmers and farming authorities as Ireland is at the breeding limit for salmon in terms of water temperature.

Due to the high degree of uncertainty in the quantification of the sea surface temperature at regional scale by 2100, this kind of indicator is to take with caution. This gives however an idea of the possible impact of climate evolution on the site suitability for the species actually farmed, and could help farmers to anticipate evolution of farming at medium to long term.

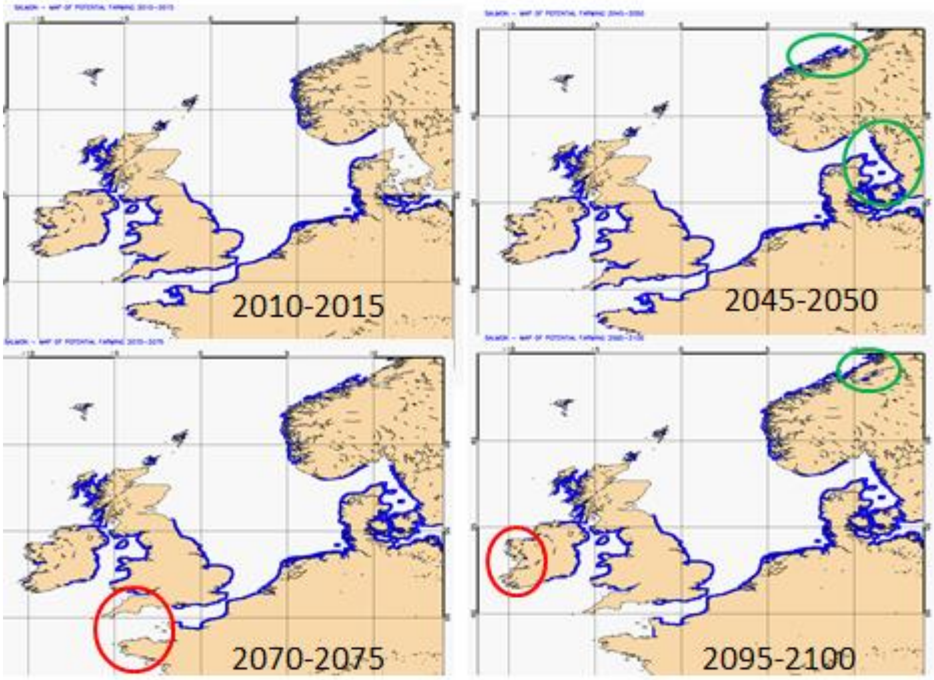
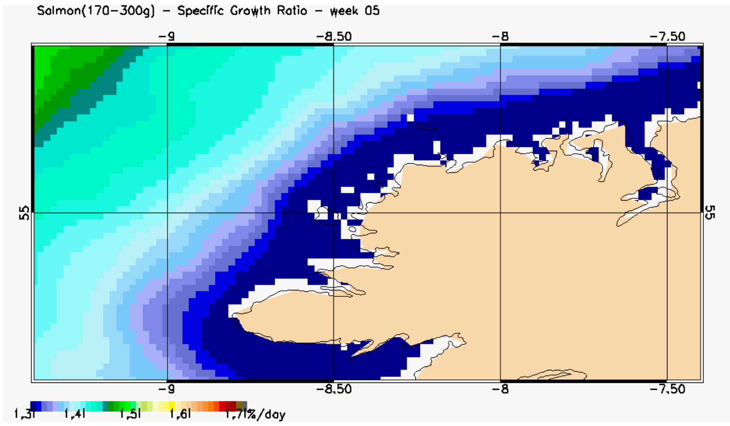


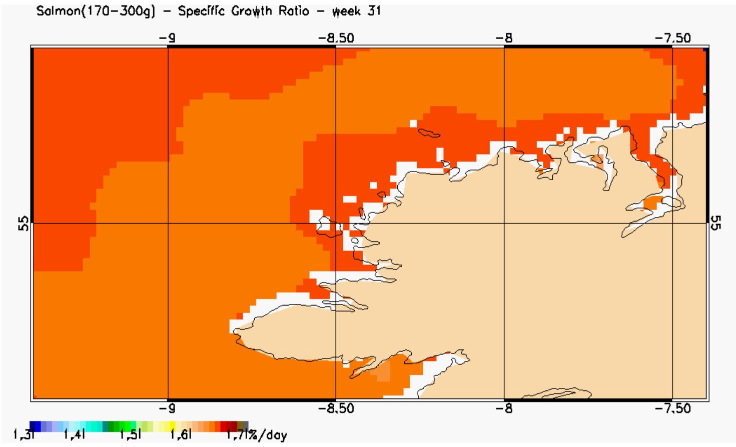
Figure 10: Evolution of the salmon optimal sites location in North-West Europe between now and 2100; estimations are based on the IPCC moderate evolution scenario (A1B) for sea surface temperature evolution.

Growth indicators for mussels were also tested using Thomas *et al.* model (2006)[1]. The growth rate product generated from this model was presented to stakeholders from the Gulf of Cadiz, and the results obtained there were found reasonable. Cooperation with users is the key to the validation process. SAFI counts on new users' willingness to participate in the adaptation and validation of the new indicators applied to their species of interest to further derive robust products.

Finally, in addition to the optimal site validation, activities targeted the development/deployment of novel indicators to strengthen the growth indicator support. A model developed by Handeland (2008)[2] for Norway was deployed in Ireland to estimate the **Specific Growth Rate (SGR) of salmon post-smolts** of two different size groups (70–150g and 150–300g). The SGR corresponds to the percentage of increase in weight per day. The following figure shows the salmon post-smolts SGR expected for post-smolts of 170-300g in winter and summer, computed from the ODYSSEA sea surface temperatures (source Ifremer CERSAT). This result can be useful to estimate qualitatively the suitability of sea surface temperature for smolts' growth but could not be validated in the frame of the project.



Winter:



Summer:

Figure 11: Weekly Specific Growth Rate for the 170g-300g salmon post smolts in North West Ireland in winter 2016 (top, 1-7 February 2016) and summer 2016 (bottom, 1-7 August 2016).

[1] Thomas, Y., J. Mazurié, S. Pouvreau, C. Bacher, F. Gohin, J. Bouget, C. Struski, and P. Mao. 2006. Modélisation de la croissance de la moule Mytilus edulis (L.) par couplage d'un budget énergétique dynamique et de données environnementales satellitaires. rapport IFREMER.

[2] Handeland, S.O., Imsland A.K., Stefansson, S.O., 2008. The effect of temperature and fish size on growth, feed intake, food conversion ef fi ciency and stomach evacuation rate of Atlantic salmon post-smolts. Aquaculture 283, 36–42

Aquaculture: near real time environmental monitoring of farms

In the first half of the project, the main functionalities for environmental information publication were put in place. Then, the remaining 18 months consisted mainly in their consolidation and in the validation of the Harmful Algal Blooms (HAB) detection products: green HAB with *Lepidodinium chlorophorum*, and Red HAB with *Karenia Mikimotoi* microalgae (based on a method developed by Ifremer and described in Sourisseau et al 2016[1]). These HAB detections were deployed in Near-real time and made available for the SAFI users through the monitoring tools. A validation analysis was also made with in particular a nice bloom confirmation in south west Ireland during summer 2015 (see Figure 12).

A toxic bloom of *Karenia mikimotoï* was detected by SAFI in the offshore waters on 19/08/2015, two days before its coastal observations (the 21/08/2015) by the "Marine Institute".

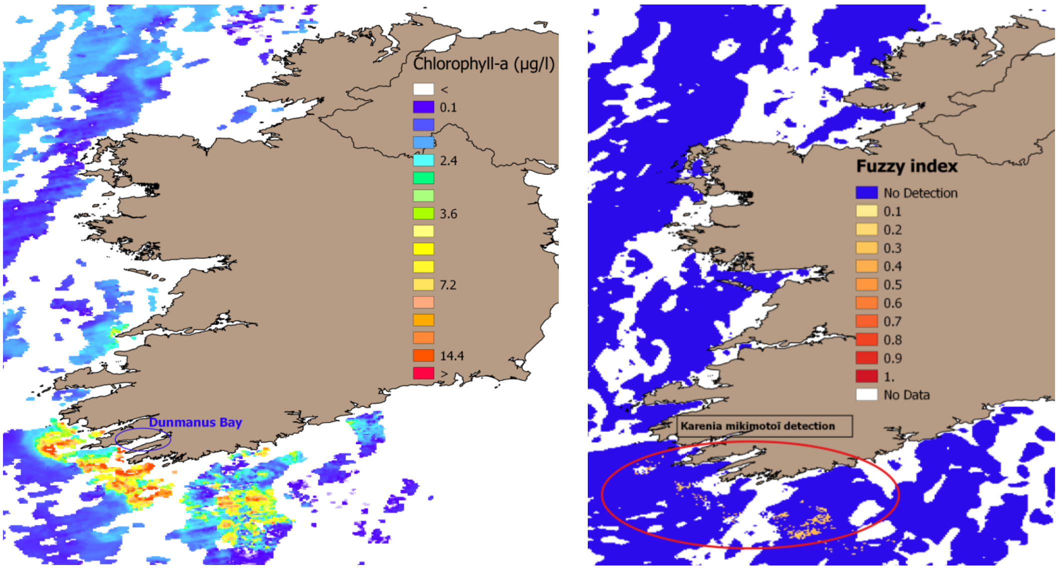


Figure 12: Chlorophyll-a concentration observed from space on the 19/08/2015 (source GSM Globcolour), and corresponding K. mikimotoi *HAB detection product. The detection of the species and the presence of toxins were confirmed by Marine Institute two days after this remote detection.*

In each case, the availability of new data from the Copernicus programme (Sentinel2, Sentinel3) were considered, exploited when made possible (for Sentinel-2 data) and new opportunities were documented in *D8.1 – Adaptation to Sentinel-2 and Sentinel-3 data*.

At the end of the project all indicators quality were assessed, and when of good quality, ingested into the SAFI tools for publication to the SAFI users.

[1] Sourisseau M; K. Jegou , M. Lunven , J. Quere, F. Gohin a , P. Bryere (2016). Distribution and dynamics of two Dinophyceae producing high biomass blooms over the French Atlantic Shelf. HARALG-1197; No. of Pages 11.

2.3.3 SAFI tools developed

The first SAFI tool targeting intermediate users to be developed was the SAFI Web-GIS. An additional tool was also created, further to end-users' request for a simpler interface and functionalities: the SAFI Mini-Web tool.

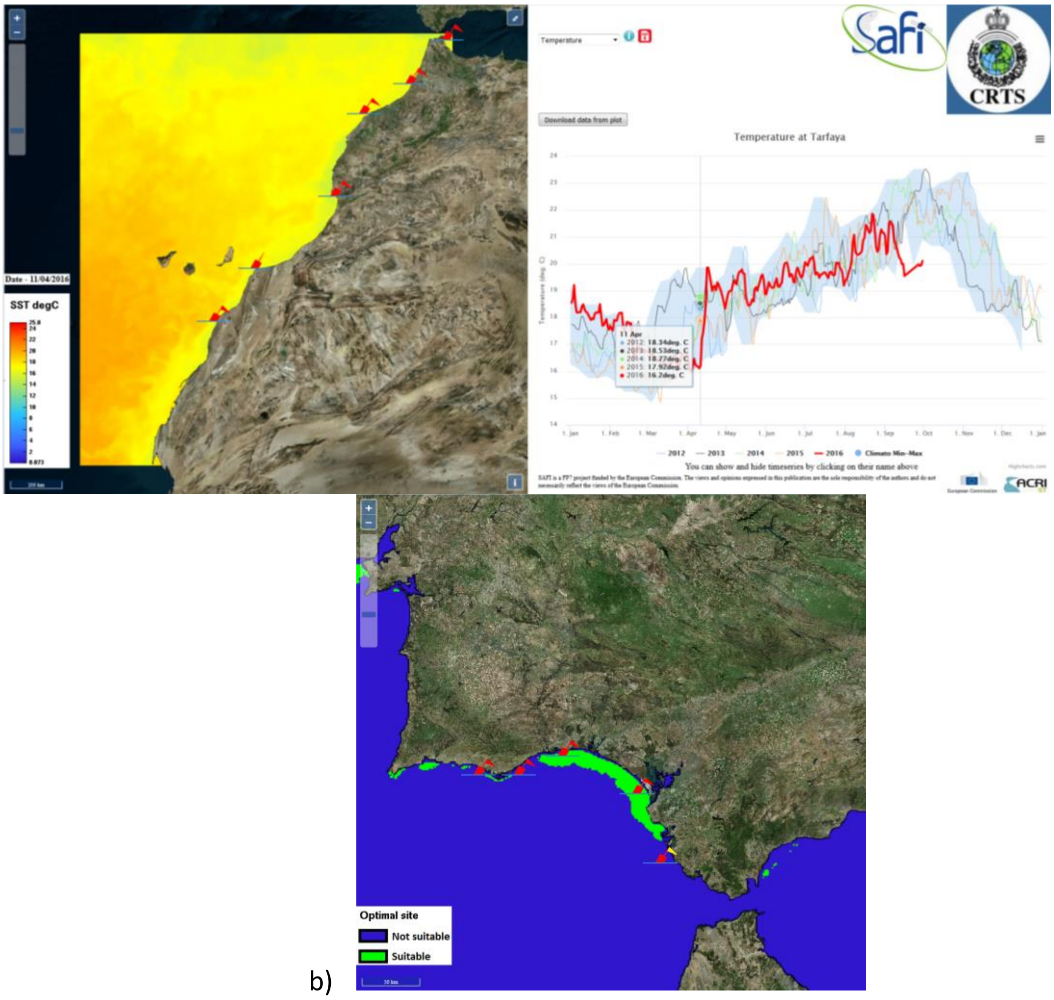
Both tools are relying on an extensive environmental database (EO and model) collected or generated by SAFI partners (Figure 13).

Figure 13: Overview of the SAFI database for environmental parameters.

The SAFI Mini-Web tool provides a comprehensive set of functionalities including:

- Access to the SAFI environmental database including historic and near-real-time data;
- Access to the SAFI designed indicators relevant to the activity;
- Maps presented over customised areas of interest;
- Time series extraction over users' locations of interest, with access to reference information from the climatology.

An overview of the data presented in Mini-Web tool is shown on Figure 14. This tool has been deployed on 6 areas: Morocco, Gulf of Cadiz, Madagascar, Ireland x2 (South West and North) and Tunisia.



a) b)

Figure 14: Overview of the SAFI Mini-Web tools: a) sea surface temperature in Moroccan waters; b) Mussels optimal site location over Southern Spain/Portugal (green=suitable areas). Demonstrations are available on www.acri-he.fr/projects/safi

To go further in the data and SAFI products handling, the user can use the SAFI Web-GIS tool, which provides:

- in-depth access to the SAFI database including historic and near-real-time marine environmental data (from Earth Observation and models);
- remote data processing capabilities for individual research needs;
- time series extraction;
- statistical analysis capabilities and
- site identification based on user-specified criteria.

A strong synergy was made here with the Coastal Thematic Exploitation Platform (C-TEP), developed by ACRI and partners on behalf of the European Space Agency, to allow users to order heavy processing on archives of increased volume of environmental data coming principally from Copernicus. The SAFI user can thus create his/her own layers and process SAFI databases with:

- Time-series extraction,
- Statistics over space,
- Statistics over time,
- Mask generation.

An example of the Web-GIS tool interface to launch extraction of time series in a point of interest is shown on the following figure.

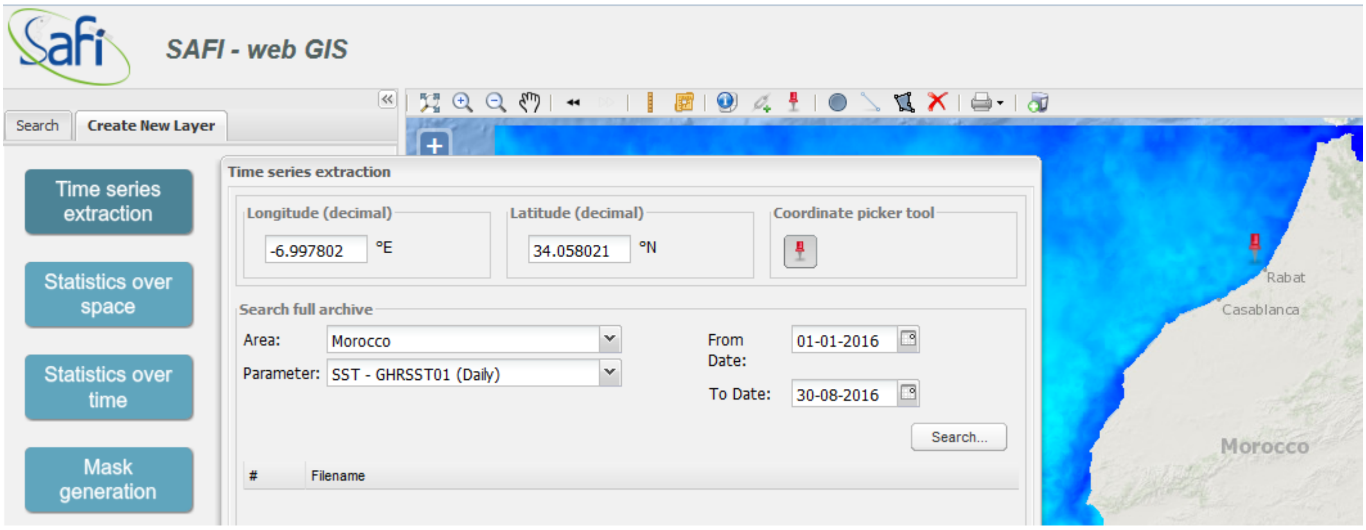


Figure 15: overview of the prototype of the SAFI Web-GIS tool proposing to extract time series over a point of interest, www.safiservices.ucc.ie/webgis2

The analysis of compliance between the specification of the SAFI system as a whole (database, Mini-Web, and Web-GIS tools) showed that the implementation activities correspond very well to the activities planned at the beginning of the project.

These tools and functionalities were implemented considering the exploitation plans built, and user iterations from the dissemination and training activities organised. They were found very relevant by the users consulted so far, and particularly those attending the Rabat end-users final meeting (see deliverable on Users' feedback D6.2).

2.3.4 SAFI services defined and commercial exploitation foreseen

The market, the threat and concurrency were analysed as well as stakeholders' expectations and acceptance of the services.

The following activities were fulfilled:

- Analysis of the targeted markets gathering qualitative and quantitative information to define an objective and get as complete as possible views on the potential of development for the SAFI Company;
- Analysis of the industrial existing context, to highlight opportunities and threats, and inform strategic decision for the future deployment of SAFI as a business;
- Definition of the priority markets for the SAFI company, based on deeper analysis of the needs during the SAFI project, users' feedback, and level of readiness and market demand for the SAFI tools developed: initial targets for the SAFI company are: finfish and shellfish aquaculture companies (SMEs and larger businesses), consultancies/ services companies working in relation with aquaculture;
- Definition of a business model,
- Establishment of the pricing strategy and of financial projection showing the potential for SAFI Company to be financially sustainable in its third year of activity;
- Definition of potential additional features to the SAFI company that could enhance its commercial potential, and assessment of the investments/ financial support needs.

The commercial exploitation of SAFI services will thus be ensured by a core network composed of SAFI SMEs companies, and further expended to service providers and promoters depending on arising opportunities.

2.3.5 The SAFI stakeholders' community

Partners participated in numerous communication activities to publicize the project results (website update, brochure, newsletters and conferences presentations).

Throughout the developments and deployments phases, consultations were also organised with aquaculture and fishery stakeholders (and with the Userboard in particular) to collect feedback and plan the future commercial exploitation of the service. At the end of the project, 65 stakeholders were consulted and provided advice on the tools and products. The project ended with a major consultation of Moroccan stakeholders with a 2-days workshop (27-28/09/2016 in Rabat, Morocco, see Figure 16) where SAFI teams presented the tools and products and detailed the science behind these indicators.

Figure 16: Audience of the SAFI end-user meeting in Rabat, Morocco (27-28/09/2016)

There, the successful integration of the SAFI demonstrations into the lectures given at this Rabat Training event demonstrated how SAFI project learnings and targeted regional studies could have an impact on teaching and learning, and capacity building of new entrants into the aquaculture and fisheries sector. The demonstrations and their showcasing at the 3rd Userboard Meeting and Rabat event also highlighted the Services potential to build capacity in the existing sector with targeted deployment as an affordable commercial service.

The demonstrations highlighted a number of promising aspects, such as:

- the potential to reduce the costs of identifying the best sites for aquaculture-based farming of commercial species,
- the potential, and mechanisms to use, to conduct regional assessments at higher latitudes where persistent cloud cover is often an issue
- the potential for the SAFI service options to be deployed on a range of global locations, the potential for Service deployment adapt to the need to acquire different datasets than those developed for European test sites,
- how algorithms can be exported from the Case Study sites in which they were developed to new regions,
- the capability for algorithms developed through SAFI can be deployed on high volumes of data,
- the good acceptance of the notion of paying for quality, and of proposed SAFI service deployment.

Overall, the demonstrations undertaken under the remit of Work Package 12 highlight the potential utility of the products, services, and expertise that have developed under the FP7 funding. This has been demonstrated in terms of:

- The potential to enable European and non-European Aquaculture and fisheries strategy implementers,
- The potential to provide regional- and national-scale environmental quality information to monitors and responsible agencies
- The potential to provide decision support to developers and industry, streamlining applications and ensuring the sites are better located, in the most effective area,
- The potential to provide both the next generation of aquaculture and fisheries experts and operators with the capabilities to harness the potential of Earth Observation data

In looking beyond the FP7-funded phase of SAFI service development, it is important to remember that these success stories form a core component of the SAFI story. They serve to highlight not only the rigorous science undertaken to develop the SAFI products, but also the wide range of applications which the service can have, and the global potential for Service deployment. It is also important to note that these demonstrations, their development, and deployment, have enabled the SAFI team to respond to the SAFI community's requests, in particular those of the Userboard.

2.4 POTENTIAL IMPACT (INCLUDING SOCIO ECONOMICS AND WIDER SOCIETAL IMPLICATIONS OF THE PROJECT SO FAR) AND MAIN DISSEMINATION ACTIVITIES AND EXPLOITATION RESULTS

2.4.1 Potential Impact

The potential impact of the SAFI project results are here presented per each of the key aspects highlighted in the SAFI call for proposal (recalled in blue in the following).

***Impact on SMEs**: The results of research in this topic should clearly be of interest and potential benefit to SMEs. A strong participation of SMEs in the project itself should help contribute to the realisation of that benefit.*

Projects are expected to promote the number of SMEs involved in the development of space activities, by initiating and/or reinforcing links between SMEs (not necessarily from the space sector) and other traditional actors in the space sector. SMEs are expected to be fully integrated into the value added chain in a sustainable way through the provision of their core expertise.

The SAFI consortium has been built to capitalise on a chain of SMEs expertise (from EO experts to thematic experts). It is the synergy gained by combining SMEs with this different expertise which will allow each to further build its experience and enhance its operations thereby increasing their competitiveness.

Spatial Earth Observation is not yet used operationally neither in aquaculture nor in fishery monitoring. In this context, the SAFI cluster of SMEs had a real competitive advantage compared to the current situation where there is an almost complete disconnect between those with the EO expertise and those with the need for better information in the thematic application area.

Intermediate users (internal or external to the consortium) were involved since the beginning of the project in the definition of the SAFI tools and products specification to ensure a perfect fit-for-purpose SAFI service. These users have an appreciation of the value of remotely sensed derived information within the aquaculture and fisheries industry, yet do not have sufficient know-how and capabilities to work with the EO data themselves – however they are perfectly placed to ensure that that the service offering is the appropriate one. This intermediate solution was very important as interviews at the beginning of the project showed that aqua & fishery end-users (administrations, farmers, fishermen) were quite reluctant to use EO products, due in particular to their apparent complexity. This project also reinforced and deepened the intermediate-users knowledge of EO capabilities, so that the y can act as promoters of the SAFI tools towards end-users.

The market for SAFI is promising, as shown by the results of the business analyses. Especially for SMEs, the SAFI Services arm them with a competitive advantage either providing them with easy access to indicators, and products from EO and models to support their activities (targeting farmers & fishermen), or to provide processing capacities and huge database availability to setup their own analyses (for consultancy).

Some SMEs are already involved with the SAFI partners to continue the exploitation of the SAFI tools in support to their own business after the end of the SAFI EU-FP7 project.

Impact on innovation: There is a determined focus on fostering new ideas, supporting world class teams tackling significant societal challenges, and on ensuring that the fruits of our investments can be properly exploited.

The SMEs and other organisations involved in SAFI are at the forefront of their respective fields within Europe as experts in information management and applications and the fisheries/aquaculture industry. By bringing them together, SAFI built new collaborations and facilitated in a very practical way the uptake of EO derived information in the fisheries/aquaculture industry. This is a very real demonstration of how Europe's investment in a world-class EO infrastructure is being uptake in order to support and develop European SMEs and expert organisations.

Ensuring food security is a major societal challenge recognised by organisations including the FAO and the EU. Indeed agriculture including fish production is also one of the GEOSS societal benefit areas. A strategic objective of GEOSS is to "improve the utilization of Earth Observation and expanded application capabilities to advance sustainable agriculture, aquaculture [and] fisheries". This project addressed this requirement in a practical way, creating novel indicators for fishery management and aquaculture development worldwide. It also reached out beyond Europe to demonstrate the expertise of the European SMEs and their capability to help in addressing the area of food security. Moreover, the capacity building aspects of the project demonstrated European expertise but also helped the wider world to take ownership of the technologies and knowhow that will be required in addressing national food security needs.

Impact on Copernicus uptake: Compliance with GMES strategy and implementation, especially in the view of upcoming sentinel missions

SAFI is fully compliant with the GMES/Copernicus Programme strategy, especially as the consortium has a number of partners who are active in EO use and algorithm definition. Moreover, partner are and were also involved all along SAFI as partners and co-ordinators in both Copernicus core and downstream service provision projects (e.g. MyOcean, OSS2015, Aquamar, ASIMUTH) as well as related activities funded by ESA (e.g ESurge, SMART, C-TEP), and at the national level. They also took direct contact with Copernicus actors, and its Marine Environment Monitoring Service (CMEMS) in particular, publicizing the uptake of the data per downstream services as those setup in the frame of SAFI. SAFI partners finally also contributed to European working groups on the Copernicus value chain, and the role of industries and downstream services.

Capacity Building on Earth Observation outside Europe: The participation of […] third countries included under the ICPC list, is particularly welcome. The use of space applications can contribute to their economic and social development and support environmental protection.

A Moroccan actor (third party involved in the project) was particularly engaged in SAFI in order to:

- Demonstrate SAFI capabilities elsewhere than in Europe and ensure its transferability and internationality
- Do capacity building,
- Contribute to social development and support environmental protection.

Beyond Morocco, the SAFI project also demonstrated their services in other African countries: Tunisia, Algeria, Madagascar.

The final user meeting was organised in Rabat, Morocco and allowed all SAFI stakeholders consulted to meet, gathering people from Europe and Africa.

2.4.2 Outreach Achieved

SAFI's outreach activities and the methodology of implementing them have been described in *Deliverable 4.4 – The Plan for User and Dissemination of Foreground.* In brief, activities involved establishing a communications infrastructure, and the use of this infrastructure to disseminate information out to target audiences (outreach), and conduct two-way information exchange activities gathering feedback and guidance from target stakeholder audiences (stakeholder engagement). A third aspect of communication (1 way information flow to educate) was also implemented, but to a far lesser degree.

The communications infrastructure established consisted of three core elements:

- The physical infrastructure (Printed brochures, newsletters and SAFI outcomes documents)
- The digital infrastructure (digital versions of brochures and newsletters, the SAFI website incorporating the Twitter feed, the online press releases using Alpha Galileo, online trade article, presentations/posters available for download, presentation templates and the SAFI brand).
- The professional networks infrastructure of professional person-to-person connections built over the course of the project (through the Userboard established).

Each of these elements was established over the course of the SAFI project. With the professional networks, the pre-existing contacts of each of the partners formed the basis for creating a hub in the network at the first Userboard Meeting. However, as the project progresses, and outreach opportunities seized, this network expanded as expected. SAFI's treatment of the Userboard as being "part-of-the-team" was a crucial aspect in developing the Userboard into "Champion Users" by the end of the SAFI project. This is described in more detail in *D6.2 – the SAFI Service Feedback Report.*

The infrastructure was used to implement all the SAFI communications activities. For example, with regard to outreach, templates supported partners in distilling their research into a recognisable SAFI presentation. Presentations made were uploaded onto the Sharepoint hosted at ACRI-ST, enabling partners across Europe to draw from the pool of collective results and perspectives that was accumulating. These presentations were given to a wide variety of audiences, in a wide variety of locations. Overall, SAFI team members participated in over 76 events, not including press release activities (Figure 17). Audiences sizes varied, but were mostly in the 50 – 1000 number of participants (Figure 18). Whilst formal briefings to between 1 and 10 individuals was important, it was key to spread the SAFI message to wider audiences using conferences and larger events (with between 100 and 1000 participants), whilst ensuring that SAFI research had a more real impact through participation in workshops, and shaping workshop discussions with learnings from SAFI (smaller audiences of between 10 and 50 people). A crucial element in outreach concerned regional awareness raising. Small national symposia, regional workshops, and sectoral workshops and conferences were targeted here, adding to the number of events attended with audiences between 50 and 100 persons.

In many cases, integration of SAFI dissemination material was facilitated by the provision of the brand, and content in a central location. This made it more efficient for SAFI team members to integrate elements of SAFI material into presentations, and seize non-SAFI-funded event attendance opportunities to disseminate SAFI findings in addition to that of the funding projects. With UCC for example, it enabled them to effectively double the number of events where SAFI (and SAFI branded) foreground was being disseminated, allowing for integration into presentations to industry (e.g. the Irish Space Industry Day), schools (Science Week 2015), societal education for a (Sea for Society Think Tank) etc. The provision of printable brochures and newsletters provided follow on material to conversations at these events, ensuring that new contacts were able to take some SAFI with them after the conversation ended.

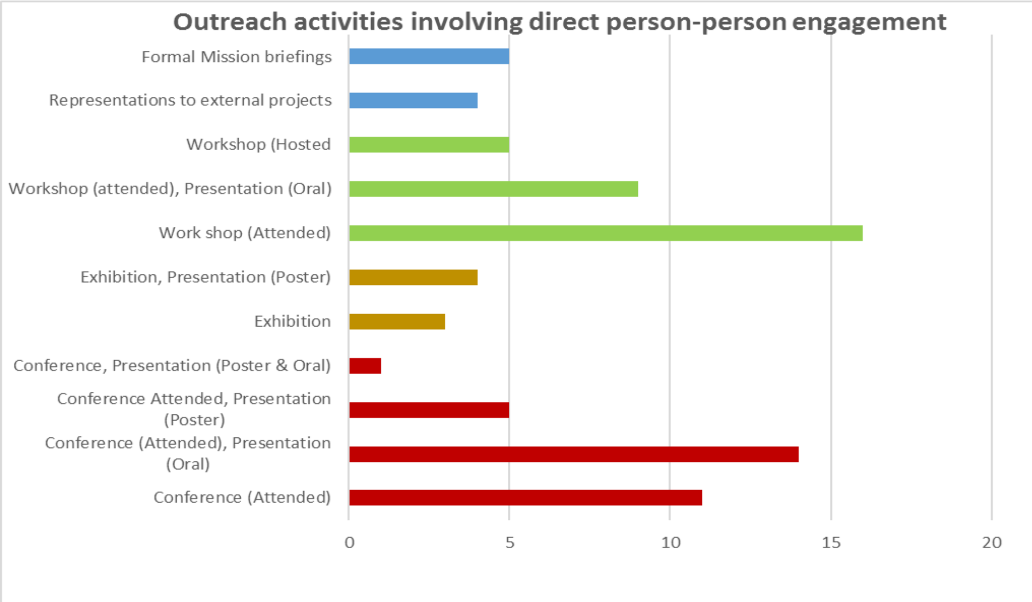


Figure 17: Outreach opportunities taken by SAFI collaborators in terms of small-scale briefings to external audiences (blue), workshops (green), exhibition opportunities taken (orange), and conferences (red). This figure does not include press releases, and is based on SAFI activity records gathered from all partners over the duration of SAFI (1st October 2013 – 30th September 2016).

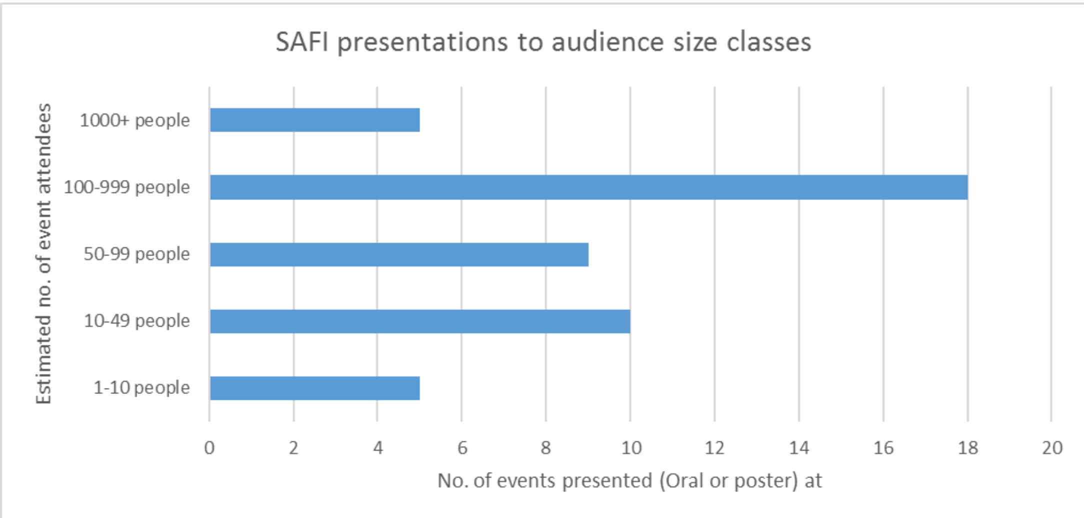


Figure 18: Estimated audience sizes to which SAFI foreground was disseminated

The effects of outreach can be evident when we look at the website statistics outside of the United States, SAFI partner countries (France, Spain, Portugal, Ireland, and Morocco) spawned the highest number of website hits. In contrast web statistics on the % of new sessions indicates that SAFI partner countries have a reduced % of new sessions in comparison to non-SAFI partner countries (with the exception of Russia). This could be an indication that audience saturation was being achieved in the SAFI-partner countries, with new markets engaged spawning a higher proportion of new sessions. In looking at the Geographical spread, the distribution of African countries engaging with the website is coastal in nature, evidence that the project is being disseminated to stakeholders with an interest in coastal regions, a key target audience of the SAFI project (Figure 19).

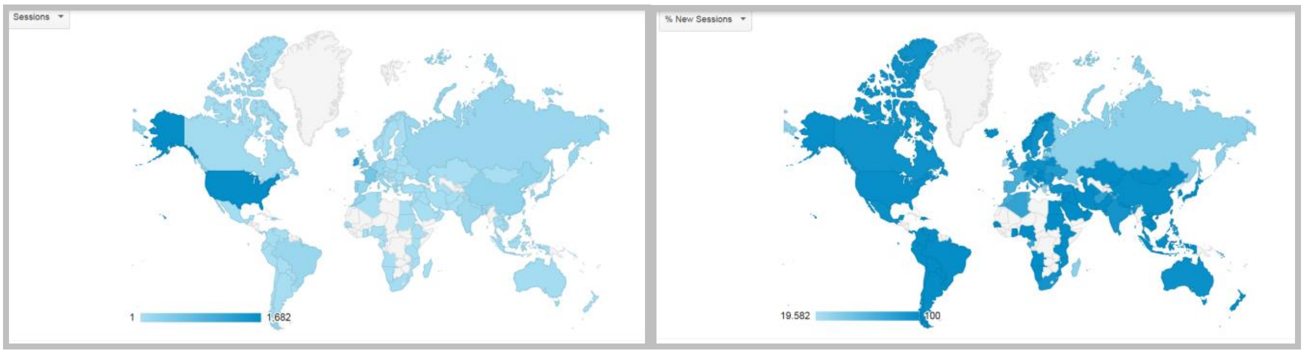


Figure 19: Total number of sessions which are identifiable by geographical area (left), and the proportion per country of sessions being "New sessions".

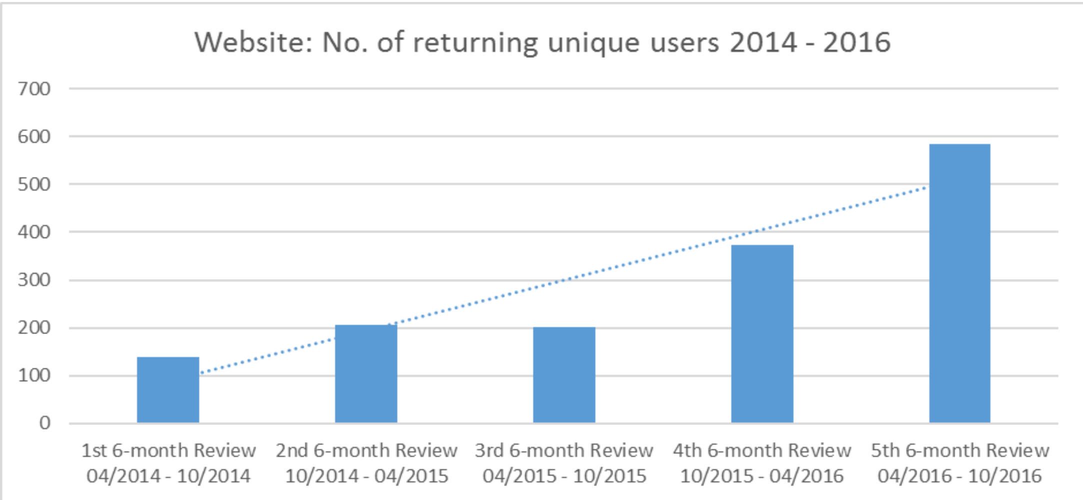


Figure 20: Growth in the SAFI online Community. Results of an exploratory analysis into the Website User statistics obtained every six months since the website launch. Vertical axis shows the number of unique returning users, representing those encounters with the website, who return later to the SAFI service website after ending their initial session.

As outlined in SAFI's users' feedback document, the SAFI team has delivered a positively received Service, series of products, and scientific studies. It also supports the view that Users, when trained, are confident in the science underpinning the products and services, whilst at the same time overwhelmingly wish development of the service to continue. The feedback also highlighted the value of investing strongly in a stakeholder engagement and "champion" user development approach, preparing the market for release of the commercial product with a strong supporting User community. This effectively maximises the integration potential of the commercial service, as user-stories and accounts accompany the product and service releases. Essentially, SAFI has started the conversation with potential consumers, before the product is even released, preparing them to receive it.

With the development of 2 different types of Services, underpinned by the same science and expertise, the project has demonstrated Service flexibility and Service capability to target different parts of the aquaculture and fisheries decision chains. Evidence of the tailoring potential has also been shown through the implementation of 9 different demonstration studies, testing the transferability of the science, processing and visualisation capabilities to different species, regions, user requirements, and target market groups (researchers, operators, and advisors).

In doing so, the demonstration activities give us a flavour of SAFI Service potential to contribute to, for example:

- Site assessment and optimal site identification – enabling developers to streamline development applications targeting regions with greater returns, and less environmental impact
- Environmental monitoring – enabling operators and responsible agencies to monitor the environmental quality performance of a site, identify deviations from acceptable standards and their root causes, and implement corrective measures
- Maritime Spatial Planning – providing a more cost-effective solution to gather baseline environmental data at regional, national, or even international scales.
- Fisheries environment monitoring – providing near real time assessments of the environmental conditions within which commercial and keystone species are reproducing and maturing, highlighting deviations from the norm, and enabling corrective measures in terms of precautionary quota adjustments to be implemented.
- Fostering more economically resilient coastal fishing communities – through the provision of monitoring of commercial species environments, SAFI Services can also contribute to fore-warning them about potential deviations in the catch stocks. This would give them more time to adapt their planned fishing season to account for lower catches in key species, improving their resiliency to environmentally-driven shocks to commercial supplies. Such improved resiliency extends beyond the producers, but could also aid processors, and onwards along the supply chain to adapt to, and mitigate excessive deviations in species stocks.

The potential for SAFI-developed products, services, and expertise to contribute to education, and enabling new entrants to the aquaculture and fisheries sector was also shown. Demonstration studies, the underpinning science, and the Services themselves were integrated into a series of lectures delivered at the Training Event and Showcase in Rabat, proving the potential utility for education and research using SAFI as a foundation block, and the opportunities for this to continue. Integration of expertise into education also occurred with primary- and secondary-level audiences through participation in Ireland's Science Week. This highlighted the transdisciplinary nature of SAFI-developed expertise, which can be combined with the latest non-SAFI visualisation tools, to support teaching of core scientific and social concepts (Climate Change and the impact on Earths food supplies).

The survey also revealed some unexpected indications of SAFI project success, namely the fostering of productive, and potentially long-lasting collaborative relationships within the consortium partnership, and indications that this was created within a strong project community base. This community base is of great benefit to the early stages of the Services development as a commercial endeavour, providing not only the pool of future "champion" users, but also the strong trans-sectoral links needed to enable Earth Observation specialists, IT specialists, biologists and business developers to meet the needs of Europe's aquaculture and fisheries sectors (and beyond). Lastly with education, SAFI enabled a team member to become part of Ireland's Ocean Literacy Network, ensuring that the lessons and learnings of SAFI have a secure way into public education within Ireland, and demonstrating the value of similar opportunities being seized in other regions.

The final impact which the SAFI team wish to highlight arises from the demonstration of linking the SAFI Web-GIS tool to the ESA-funded Coastal Thematic Exploitation Platforms' Big Data processing engine. Effectively this provides users of a data visualisation tool, with the capability to extract and visualise their own defined analyses conducted on vast volumes of data. It does so by providing a simple, understandable process launching tool, integrated into the SAFI information exploration area. User's do not need to know about the functioning of the Coastal-TEP, nor the details of processing data, nor are fisheries and aquaculture users concerned with the challenges of processing Earth Observation data. In integrating this launching tool, and establishing the link between the SAFI Web-GIS and the Coastal-TEP, the Service provides them with what they want – an easy-to-use, understandable means to get the information they need (in a language they understand).

SAFI has demonstrated a number of potential avenues for future development. Opportunities such as new species, new areas (markets), new applications of the technology links, new ventures in education and capacity building, all provide perspectives on how SAFI could have an impact beyond the FP7-funded phase of SAFI service development. This impact is not only on the fisheries and aquaculture sector, but beyond in the IT sector, education sector, and Space sector amongst others. Socio-economically, the developed Services offer the promise of cost efficiencies and resiliency development for our aquaculture and fisheries communities (respectively), monitoring and area assessment capabilities for our Environmental monitoring agencies, and planning coordinators, and commercialisation of research founded on synergies between *in situ* biological and environmental data, and data derived from Europe's Earth Observation infrastructure. From the societal perspective, SAFI can have, and is having, an impact on Europe's pool of scientific knowledge in ocean biology and ecology research, Europe's Information Technology arena through proof of concepts such as the SAFI-Coastal-TEP link, and lastly, on international cooperation and collaboration. The final point on cooperation and collaboration is not only evident in the success of the Userboard, and in engaged audiences, but also the team behind SAFI itself, people from European and non-European nations who have been part of this international, multi-disciplinary venture, and who have worked and learned together over three years of SAFI activities.

Figure 21: SAFI team at a project meeting in Huelva, Spain.

2.5 Project Website

The SAFI public website is accessible at www.safiservices.eu.

The Mini-Web tool demonstration is publicly available at: www.acri-he.fr/projects/safi; and the latest version of the Web-GIS tool is accessible at http://safiservices.ucc.ie/webgis2 (login needed).

2.6 Project logo & promoting illustrations

2.6.1 Project logo

2.6.2 Illustrations

Project logo, diagrams or photographs illustrating and promoting the work of the project, as well as the list of all beneficiaries with the corresponding contact names can be used provided the citation of the source (namely the SAFI project) and the project website (www.safiservices.eu).

2.7 List of partners & associated abbreviations

- ACRI-ST, France (Coordinator) and its subsidiary in Morocco, ACRI-EC.
- University College Cork – National University of Ireland (UCC), Ireland
- COFREPECHE, France
- IPMA (Instituto Portugues do Mar e da Atmosfera), Portugal
- IFAPA (Instituto Andaluz de Investigación y Formación Agraria, Pesquera, Alimentaria y de la Producción Ecológica), Spain
- DOMMRS (Daithi O'Murchu Marine Research Station), Ireland

Contact: contact@safiservices.eu

- End of Document -