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The French initial assessment of the Marine Strategy Framework Directive (MSFD) highlighted the lack of reliable data concerning offshore areas. During the planning of the monitoring programmes, the scientists therefore proposed to partially cover this gap by using existing fisheries research vessel surveys deployed for the purposes of the Common Fisheries Policy (CFP). This paper describes ways of improving the effectiveness of these surveys and making them better suited to delivering the information needed for the MSFD. The process took two years and became operational at the beginning of the year 2016. Testing phases from October 2013 to August 2015 had to be organized to fit within the ongoing fisheries tasks without significantly increasing the workload in terms of both time and human resources. Six fisheries research surveys henceforth collect new data, with or without additional sampling techniques. Specific examples are given with litter and hydrological data which will be used to assess the environmental status of French marine waters. The paper also identifies certain limitations regarding this approach. This French experiment enabled more efficient and effective use of current data collection efforts, while optimising vessel time and implementing an ecosystem approach in collecting data for fisheries management.

1. Introduction

The EU Marine Strategy Framework Directive (MSFD, 2008/56/EC) establishes a framework within which EU Member States shall take action to achieve or maintain good environmental status (GES) of their marine waters by 2020 [1]. GES is based on 11 qualitative descriptors, as listed in Annex I of the MSFD. The first stage of this marine strategy was for all Member States to carry out an initial assessment of the current status of their seas. The 2012 French initial assessment highlighted that there was a significant lack of data concerning offshore areas (beyond the 20 m isobath) in comparison with coastal and transitional waters monitored for the Water Framework Directive (WFD; [2]) [3–6]. Crise *et al.* [7] came to the same conclusions for southern European seas under the Perseus experiment, where data availability was poor in open sea for most of the descriptors. Teixeira *et al.* [8] noted that the number of indicators decreased noticeably from shallow to deep waters, due among other factors to the lack of sampling. The general conclusions of technical assessment reports highlighted for all French marine sub-regions the lack of standardized and accessible observational data for offshore areas [9]. These knowledge gaps remain an issue for the computation of operational indicators to assess correctly the state of the marine environment that have emerged from recent legislative commitments [10]. In order to collect information on anthropogenic disturbances and their impact on the environment and to develop a proper scientific and technical basis for the implementation of actions aimed at improving the quality of the marine environment, it is necessary to conduct regular surveys, collect data and analyse their results.

Creating new surveys entirely dedicated to MSFD would be very time consuming and costly, probably resulting in insufficient spatial or temporal coverage. A better strategy would be to adapt and optimize existing surveys. Monitoring programmes (MP) could be efficiently developed by using survey downtimes for additional sampling. In particular, fisheries surveys could play an important role in MSFD monitoring programmes [11,12], as they are the only surveys that sample the EU offshore and coastal marine waters each year. The French

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Research Institute for the Exploitation of the Sea (Ifremer) has been carrying out standardised fisheries surveys every year for the last three decades in the seas surrounding France. These surveys use either bottom trawls or a combination of fisheries acoustics and pelagic trawl sampling. Additional sampling techniques (*e.g.* floating-manta trawl, WP2 plankton net, *etc.*) are used in some cases. The various different - but compatible - existing monitoring methods need to be adapted and standardized to take into account regional differences. When planning monitoring schemes, care should be given to ensure suitable spatial and temporal scales. Sampling protocols in Europe are currently available for the assessment of certain indicators (see *e.g.* ICES Survey Protocols, http://www.ices.dk/publications/our-publications/Pages/Survey-Protocols.aspx - Accessed 05 January 2018), but should be adapted to MSFD requirements and standardized for compatibility with other regions.

This is the aim of the Joint Monitoring Programmes (JMP), that examine how much and what type of sampling is needed, at a minimum, in order to achieve quality standards and how these data could be collected most efficiently [11,13]. Pioneering integrated surveys [12] and pilot projects (*e.g.* De Boois and van Hal [14]) have demonstrated that indicators of other ecosystem component states could be measured alongside routine biological sampling conducted for fish stock assessments during fisheries surveys in the Regional Sea Conventions (RCS) areas (*e.g.* International Bottom Trawl Surveys (IBTS) under the Barcelona Convention for the Mediterranean; the Bucharest Convention for the Black Sea; the Oslo-Paris Convention (OSPAR) for the NE Atlantic, and the Helsinki Convention (HELCOM) for the Baltic). However, sampling activities cannot be extended endlessly without compromising data quality [11]. Ecosystem sampling should indeed be optimised in a coordinated and adaptive way, to ensure that the addition of new sampling protocols does not compromise the quality of standard data collection, and to optimize the utility of the sampling programme. If interesting studies have provided general principles [11,15], few practical examples of the optimisation of data collection programmes for ecosystem sampling are to be found in the literature (but see *e.g.* [12]).

The aim of this paper is to bridge this gap by presenting a practical example of the optimisation of a data collection programme to meet MSFD ecosystem monitoring requirements. The article describes how French fisheries surveys were optimised to move on from single-species stock assessment toward MSFD compliant ecosystem monitoring.

2. Material and Methods

2.1. French monitoring programmes

The second stage of the marine strategy was to establish and implement monitoring programmes to measure progress towards GES. The very wide scope covered by MSFD requires additional monitoring in areas where it was not previously required by EU law [13]. In France, the definition of the MP lasted from 2012 to 2015 under the supervision of the Ministry of Environment, and coordinated by the Marine Protected Areas Agency (AAMP) and Ifremer. Scientists designated for each of the 11 descriptors undertook the design of these MP (a complete survey programme for each descriptor, including terrestrial, aerial and nautical means). In 2012, each of them suggested that vessel-based surveys should collect data for MSFD. On this occasion, they identified existing observation platforms provided by research vessels (R/V) which were mainly involved in fisheries stock assessment, as a potential way of providing additional means of monitoring. The MSFD coordination team from Ifremer therefore proposed to explore the possibilities of adding MSFD monitoring to existing vessel surveys.

A similar choice was also made by most Member States, which decided for cost-efficiency reasons to develop their MP by extending existing monitoring activities [11]. Moreover, previous management strategies focusing on specific human impacts or individual species have been judged insufficient for the implementation of the ecosystem approach called for by new regulations such as MSFD [15]. In France, the PELGAS survey [16] followed an ecosystemic approach by monitoring hydrology, phytoplankton, zooplankton as well as birds and mammals, in addition to its fish stock assessment role, from 2000 in the Bay of Biscay. This survey demonstrated the potential of fisheries surveys for ecosystem monitoring [12,17].

2.2. Feasibility study for optimisation of the French fisheries surveys

Following the proposals made in 2012, the optimisation of vessel surveys in France was considered a priority because it offered the means to obtain suitable offshore data at moderate cost. It was pointed out that the MP should be able to provide data for the calculation of the indicators set by the Commission Decision (*e.g.* [13]). The data to be collected were consequently related to the requirements of the MSFD, and particularly information on indicators of several quantitative descriptors selected by the European Commission [18]. French research scientists selected the following criteria for good environmental status relevant to the descriptors of MSFD: (i) biodiversity: distributional range, pattern and area covered by the species; population abundance, demography and genetic structure; condition of typical species and composition of species; (ii) habitat: physical, hydrological and chemical conditions; (iii) productivity: performance of key predator species using their production per unit biomass; (iv) eutrophication: nutrients, dissolved oxygen, water transparency, chlorophyll concentrations and phytoplankton community composition; (v) contaminants: concentration of contaminants measured in biota; (vi) marine litter: amount of floating litter (including micro-particles) and litter deposited on the seafloor; and (vii) energy: distribution of underwater noise. They are used for the requirements of descriptors 1 Diversity (i/ii), 4 Food webs (iii), 5 Eutrophication (iv), 8 Contaminants (v), 9 Contaminants in fish and seafood (v), 10 Litter (vi), 11 Energy and noise (vii). These descriptors were selected because they could be collected during fisheries surveys to compensate for the lack of French data in offshore areas [3–6].

A feasibility study was launched in October 2013 to assess the compatibility between the proposals made by the scientists, linked to the previous data, and the fisheries stock assessment operations. This preliminary stage was developed with the help of vessel-based survey coordinators. The MSFD coordination team from Ifremer sent a questionnaire concerning new protocols to implement for the requirements of the directive. The main topics in the questionnaire were: additional monitoring and parameters to be recorded, vessel survey concerned, sampling strategy, operational protocol onboard and logistic. This was applicable to all vessel surveys (coastal and off-shore) implemented by Ifremer for fisheries stock assessments. The aim was to make a first selection among the various proposals taking into account the logistical limits to the amount of work that can be done in a single survey, and the priority given to the primary survey objectives defined by the funding provider [11]. The preliminary indications from the questionnaire lead the MSFD coordination team to exclude the vessels and surveys that were not appropriate to conduct the proposed monitoring operations (*e.g.* irrelevant survey areas, vessel too small…). In February 2014, an analysis of the results of this questionnaire was conducted. Six vessel surveys were chosen on the basis of four major criteria: the possibility of having more people onboard, of working on a continuous basis (day / night), of loading and deploying more sampling equipment, and the areas covered by the French surveys. These fisheries surveys are conducted with two R/V, *Thalassa* in the Atlantic region and *L'Europe* in the Mediterranean sea (see Table 1 for a presentation of their main characteristics).

As a result, the second step involved the deployment of near-operational field tests between September 2014 and August 2015 [19]. In addition to already known operations (*e.g.* seafloor litter, water nutrients, mammals and birds, *etc.*), two new protocols for routinely monitoring fisheries surveys were tested. The first was devoted to the

Table 1
Main characteristics of R/V *Thalassa* and *L'Europe*.

Vessel	*Thalassa*	*L'Europe*
Main missions	Fisheries research Physical oceanography Underwater systems deployment	Fisheries research Coastal environment
Length overall	73.65 m	29.60 m
Overall breadth	14.90 m	10.60 m
Draught	6.10 m	3.45 m
Year of construction	1996	1993
On-board staff	Crew: 25 Scientists: 25	Crew: 8 Scientists: 8
Internet link	http://flotte.ifremer.fr/fleet/Presentation-of-the-fleet/Vessels/Deep-sea-vessels/Thalassa Accessed 02 February 2018	http://flotte.ifremer.fr/fleet/Presentation-of-the-fleet/Vessels/Coastal-vessels/L-Europe Accessed 02 February 2018

collection of organisms for contaminant and food web monitoring [20]. On the basis of trawling carried out by Cefas (Centre for Environment Fisheries and Aquaculture Science - UK) and by Ifremer (France), a new protocol for gelatinous zooplankton has also been tested since 2012 and 2014, respectively [21]. The aim of these different tests (more regular and using new protocols) was to make sure of the compatibility between suggested protocols and those from the fisheries stock assessments. If they proved to be so, MSFD protocols were adapted in order to be fully operational for the monitoring programmes. The study ended in October 2015 and a synopsis was sent to the partners to inform them of the possibility of implementing the different MSFD protocols [22]. Fig. 1 shows the main steps of the French experimentation.

The testing phase successfully demonstrated the suitability of most of them, in a cost-effective way. Gridded maps were drawn up, based on feasibility studies data, using a spatial interpolation method, the block averaging procedure (BAP; [23]). BAP enables to rapid processing of large amounts of ecosystem data, collected according to different sampling schemes, while avoiding edge effects [12]. Gridded maps were produced using a reasonably fine (0.25° x 0.25°) common grid, using the R package EchoR [24].

3. Results

The French monitoring programmes were adopted at the beginning of June 2015 by the authorities coordinating each marine sub-region. Building on the success of the feasibility study (2014–2015; Fig. 1), they all recommended the collection of the necessary data for MSFD monitoring by optimising time from vessel fisheries management surveys. Marine mammals, birds, marine litter (floating litter, sea-floor litter, micro-particles), gelatinous zooplankton, contaminants, food webs, underwater noise and hydrology were to be monitored in offshore areas [25–28]. Because of the significant cost of lab analyses, organisms (cephalopods and fishes catches) are sampled for contaminants and food webs analyses only when funding is available. Following the submission of the French monitoring strategies, additional sampling for MSFD became official at the beginning of 2016 [29], starting with the IBTS survey. Examples of potential indicators calculated from the data collected by the PELGAS ecosystem survey can be found in Doray *et al.* [12,30]. Today, most of the European vessel surveys try to collect data on human pressures and ecosystem state, in response to different requirements such as CFP, MSFD and other legislation or international agreements [11]. The following sections present the vessel surveys used in France and the new information obtained from them. Subsequently, examples are given with litter and hydrological data collected for MSFD requirements and which will be used to assess the environmental status of the French marine waters. Those case studies have been chosen as (i) litter is an emerging topic, specifically covered by MSFD; (ii) hydrological data were collected using an integrated system (Pocket Ferry Box), which allowed to provide high resolution data that could complement low resolution sampling strategies generally used.

3.1. *Shipborne fisheries surveys*

Six shipborne surveys, related to the requirements of the European data collection framework (DCF), are used for the purposes of the MSFD French legislation: IBTS [31], PELGAS [16], MEDITS [32], PELMED [33], CGFS [34] and EVHOE [35]. Five of them are mandatory according to Table 10 of the Annex of the EU-MAP Commission implementing decision EU/2016/1251 [36]. Table 2 presents their main characteristics and Fig. 2 the areas covered by the fisheries surveys. From 2015 onwards, the CGFS survey was carried out on another scientific vessel. In order to ensure the continuity of the time series, an inter-calibration between the two vessels (R/V *Thalassa* and R/V *Gwen Drez*) was realized in October 2014 [37]. MSFD field tests began with the CAMANOC survey [38] on R/V *Thalassa* during this intercalibration exercise in the Western English Channel (Fig. 1).

Since the surveys maintain long-term series, the DCF protocols

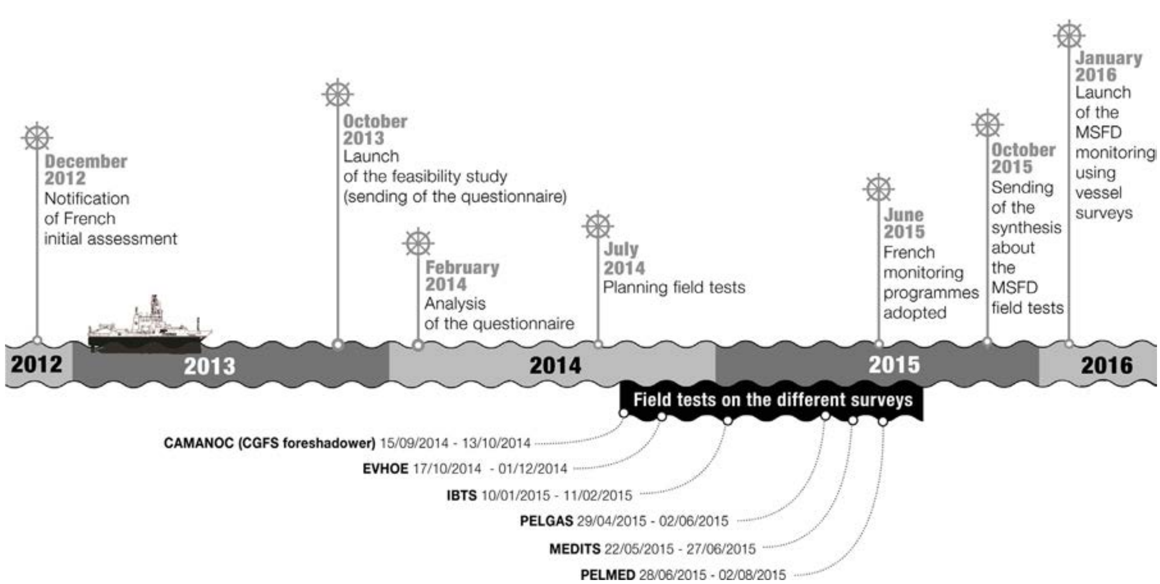

Fig. 1. Main steps of the French experimentation.

Table 2
Main characteristics of IBTS, CGFS, EVHOE, PELGAS, MEDITS and PELMED fisheries surveys.

Acronym	Full name	Main sampling gear	Area	Period (quarter)	Time series	References
IBTS	International bottom trawl survey in the North Sea	Bottom trawl	South North Sea / Eastern Channel	I	1978 - cont. / 2007 - cont.	[31]
CGFS	Channel Ground Fish Surveys	Bottom trawl	Eastern Channel	II	1988 - cont.	[34]
EVHOE	*Evaluation des ressources halieutiques de l'ouest européen*	Bottom trawl	Bay of Biscay and Celtic Sea	IV	1987 - cont.	[35]
PELGAS	*Petits pélagiques Gascogne*	Acoustic & Pelagic trawl	Bay of Biscay	II	2000 - cont.	[16]
MEDITS	International bottom trawl surveys in the Mediterranean	Bottom trawl	Gulf of Lions and East Corsica	III	1994 - cont.	[32]
PELMED	*Petits pélagiques Méditerranée*	Acoustic & Pelagic trawl	Gulf of Lions	III	1993 - cont.	[33]

(sampling plan, fishing gear, catch analysis protocol) are often standard (or lightly amended) and are repeated from one year to the next. Before the implementation of the feasibility study, these surveys were already multi-disciplinary. Additional activities considered for MSFD were: (i) collecting other information from the catch (marine litter, jellyfish, biota for analysis); (ii) automated and high spatio-temporal resolution sampling (Pocket Ferry Box, Automatic Identification System (AIS)); (iii) deployment of equipment (floating-manta trawl, WP2 plankton net, Niskin bottle); (iv) observations (birds, mammals, floating litter). Some of these protocols were carried out before implementation of the MSFD but most were done on a more or less regular and/or coordinated basis. MSFD MP made it possible to harmonize the protocols for all the surveys. Today, the opportunistic use of French fisheries surveys provides the only large-scale spatio-temporal sampling tool for various data, such as sea-floor litter [39] or gelatinous zooplankton [21], and at low cost. Table 3 shows for each survey what has been added for the requirements of the MSFD, distinguishing operational and strategic changes. Descriptors concerned by all of these data are highlighted as well.

3.2. Marine litter

Litter on the sea floor, floating litter and microplastics were assessed using the MSFD protocols as defined by GES technical group [40,41] and enshrined in trawl survey manuals for both MEDITS [42] and IBTS [43] cruises. Experiments for floating litter and microplastics were launched more recently on pelagic surveys (PELGAS, PELMED).

Marine litter abundance at sea can be estimated either by direct observations of large debris items (*e.g.* ROVs), by shipbased and aerial observations for debris floating at the sea surface, by large-scale imagery applications and net trawls. Net-based assessment surveys are the most widespread and effective methods to date [39], using a similar approach to the methodology for monitoring benthic species on the sea floor or surface organisms for floating litter. Results from trawl surveys indicated efficient sampling and results for sea floor litter and floating litter, with possible time trends assessment. The approach has been extended in the past few years to the evaluation of floating microplastics, with common approaches and in a standardized manner covering all MSFD requirements [44,45]. Typically, results from the first

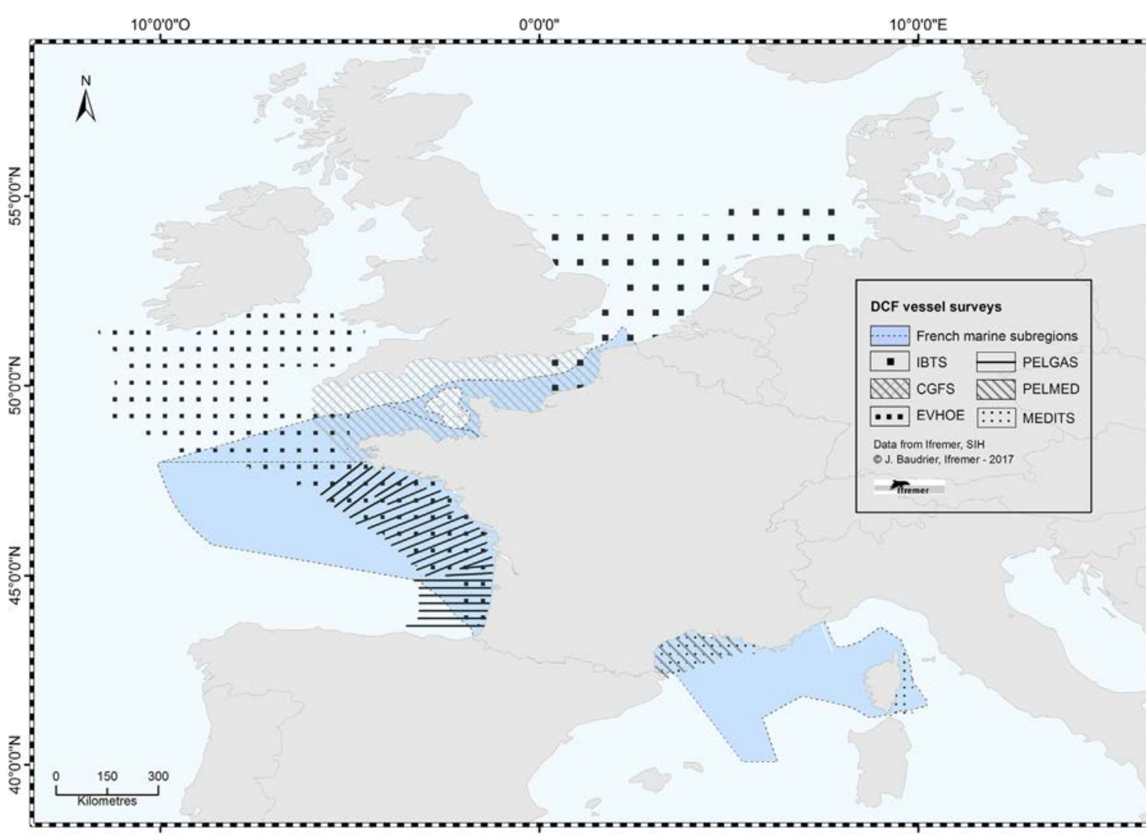

Fig. 2. Main areas covered by the French standardised fisheries surveys (data from Ifremer).

Table 3
Additional activities considered for MSFD monitoring on the 6 French vessel surveys.

Activity MSFD descriptor related to	IBTS	PELGAS	MEDITS	PELMED	CGFS	EVHOE
Observers for mammals and birds D1, D4	Sustainable funding	Sustainable funding	No observers (no possibility of having one more person onboard)	Sustainable funding and protocol harmonisation	New MSFD protocol	Sustainable funding
Observers for floating litter D10	New MSFD protocol	New MSFD protocol	No observers (no possibility of having one more person onboard)	New MSFD protocol	New MSFD protocol	New MSFD protocol
Physics and chemistry of the water column (CTD[a]) D1, D4, D5, D7	Equipment upgrade to standardize and increase the number of sensors	Equipment upgrade to standardize and increase the number of sensors	Equipment upgrade to standardize and increase the number of sensors	Equipment upgrade to standardize and increase the number of sensors	Equipment upgrade to standardize and increase the number of sensors	Equipment upgrade to standardize and increase the number of sensors
Physics and chemistry of subsurface water (Hight Frequency Ferry Box / Pocket Ferry Box) D1, D4, D5, D7	New MSFD equipment	New MSFD equipment	New MSFD equipment	New MSFD equipment	New MSFD equipment	New MSFD equipment
Seafloor litter D10	Sustainable funding	Not possible (pelagic trawl)	Sustainable funding	Not possible (pelagic trawl)	Sustainable funding	Sustainable funding
Microplastics D10	New MSFD protocol	Not possible (no time available)	Not possible (no time available)	New MSFD protocol	New MSFD protocol	New MSFD protocol
Gelatinous zooplankton D1, D2, D4, D5	New MSFD protocol	New MSFD protocol	New MSFD protocol	New MSFD protocol	New MSFD protocol	New MSFD protocol
Organism collection for contaminants and food web[b] D4, D8, D9	New MSFD protocol	New MSFD protocol	New MSFD protocol	New MSFD protocol	New MSFD protocol	New MSFD protocol
Station water nutrient samples D5	Sustainable funding	Sustainable funding	Not possible (no time available)	New MSFD protocol	Sustainable funding	New MSFD protocol
Station phytoplankton samples D1, D4, D5	Sustainable funding	Sustainable funding	Not possible (no time available)	Sustainable funding	Sustainable funding	Sustainable funding
Station zooplankton samples D1, D4	Sustainable funding	Sustainable funding	New MSFD protocol	Sustainable funding	Sustainable funding	New MSFD protocol
Automatic Identification System (AIS) D11	New MSFD protocol	New MSFD protocol	New MSFD protocol	New MSFD protocol	New MSFD protocol	New MSFD protocol

[a] Measurements: conductivity, temperature, pressure, pH, dissolved oxygen, fluorescence and turbidity.
[b] Not every year.

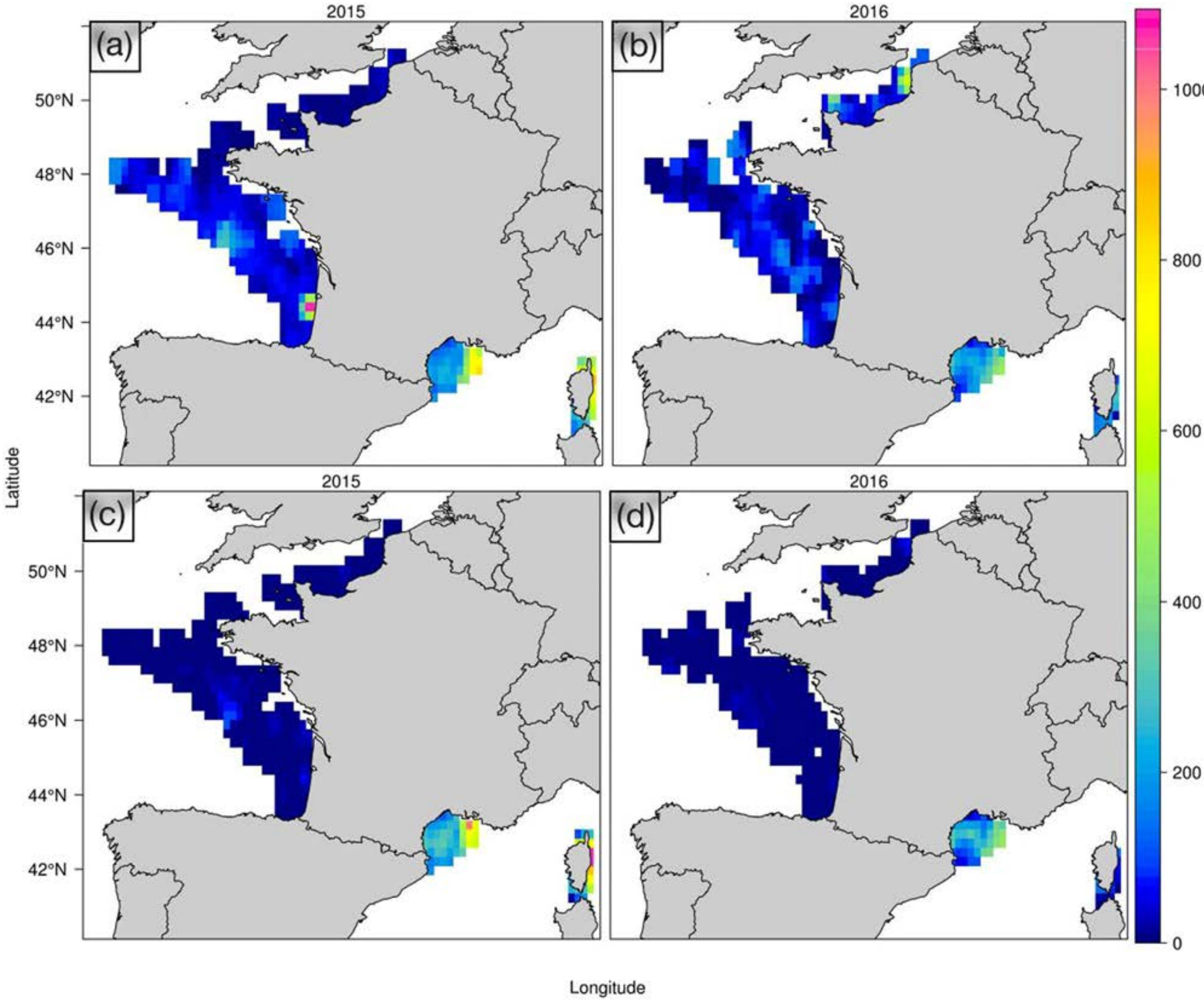

Fig. 3. Gridded maps of average densities of bottom (a-b) total litter and (c-d) plastic sheets and bags collected in 2015 and 2016 during the MSFD optimised French fisheries surveys (data from Ifremer).

experiments held in 2015 and 2016 showed the potential of such an approach for assessment of annual variations in both total litter and specific items, the latter approach being critical when considering reduction measures that are dedicated to a specific type of litter. For example, the ban on non-degradable plastic bags, as decided in France in July 2016, will require a suitable tool to assess the effectiveness of the measures. Monitoring plastic sheets and bags on the sea floor is a suitable approach for this purpose, providing consistent data on quantities, distribution and time trends (Fig. 3). Gridded maps of average densities of total litter and plastic sheets and bags as measured in bottom-trawl surveys are presented. Data were obtained during MSFD optimised French fisheries surveys in 2015 and 2016, following the Guidance for monitoring marine litter in European seas [41] as a standardized protocol. Highest litter densities (600–1000 litter per square meter) were found in the main river plumes (Seine, Gironde, Rhône) and around Corsica island.

3.3. Hydrology

The literature highlights that in general, the observation and monitoring of highly dynamic systems such as marine waters requires dense sampling in space and time in order to detect short-term events which might have a strong impact on the ecosystem [46]. Focusing on the MSFD sub-regions, existing observation and monitoring programmes lack the high spatio-temporal resolution coverage required to determine the status of the marine environment and changes therein. Most of the regular and year-round observations and monitoring programmes only cover the very near coastal zone. Numbers of stations drastically decline or are non-existent offshore (beyond the 20 m isobath).

Considering the need for MSFD monitoring programmes for Eutrophication and Pelagic Habitats, the fact is that processes involved in phytoplankton bloom dynamics cover a wide range of spatio-temporal scales [47,48], and that bloom events could last only a few days but with strong direct and indirect effects on ecosystems. The responsiveness of phytoplankton to environmental changes and the ecosystem goods and services associated with this compartment explain why phytoplankton is widely used as an indicator for the development of environmental quality assessment systems [1,2,49].

Consequently, since ecological studies and overall ecological assessments need to integrate physical, chemical and biological information in order to achieve a comprehensive view of the states and dynamics of the ecosystems, but also need to be in phase with its main spatial and temporal controlling scales [47,50], it was relevant to test the added value of the implementation of an integrated, autonomous system called Pocket Ferry Box (PFB, 4H-JENA), the particularity of which is to be coupled with a multiple-fixed-wavelength spectral fluorometer (Algae Online Analyser, AOA, bbe Moldaenke [51]). The aim is

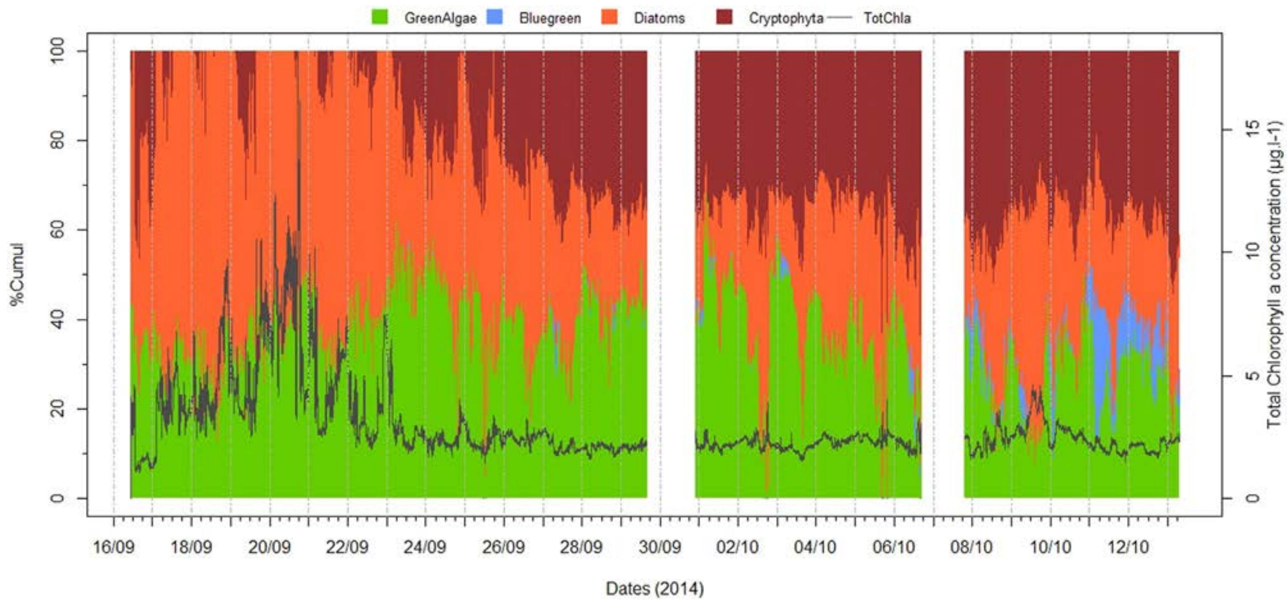

Fig. 4. Change in the total phytoplankton biomass (dark line) and in the relative proportion of the phytoplankton spectral groups (Green-algae, Blue-green algae, Cryptophyta and Diatoms) during the CAMANOC 16th September – 13th October 2014 cruise on board the R/V Thalassa (data from Ifremer).

to gain further knowledge on high-resolution events in order to be able to explain why some parameters (or MSFD criteria) could downgrade or upgrade Good Environmental Status assessment results, mainly on the basis of low resolution sampling strategies. Moreover, high resolution data could contribute to validation and calibration steps when using satellite remote sensing and hydrodynamic-hydrological modelling derived products. All parameters were recorded at a frequency of once per minute and geographical coordinates were provided by an external GPS receiver. The system used during this trial was assembled with sensors for salinity and temperature (AANDERA conductivity sensor 3919), pH (Meinsberg MV 3010), oxygen concentration (AANDERA oxygen optode 3835), CDOM (AANDERA Cyclops 7 sensor) and spectral groups of phytoplankton using an Algae Online Analyser (bbe Moldaenke).

The implementation of high resolution *in situ* measurements with a Pocket Ferry Box, coupled to a spectral fluorometer and associated with optimised unsupervised spectral classifier data processing [52,53], offers the means to provide an environmental state-specific and synoptic view of the main hydrological parameters, phytoplankton biomass and spectral groups in a MSFD marine sub-region for a given period (Fig. 4). During the MSFD cruises, this system also allows a near real-time adaptive sampling strategy to capture the main hydrological and biological changes. This will contribute to the definition of eco-hydrological regions in order to focus low resolution conventional sampling strategy in these areas and consequently to optimize the costs of laboratory analysis on a lighter set of *in situ* samples.

4. Discussion

The paper presents a case-study of integrated fisheries surveys developed in France from 2013 for the needs of MSFD. The discussion focuses essentially on the strength and limitations of this approach.

4.1. Improving international partnerships

Fisheries surveys conducted within the EU Data Collection Framework have been coordinated at international level within the ICES survey planning groups since the early 2000s (*e.g.* Working Group on Acoustic and Egg Surveys - WGACEGG, 2004) and earlier (*e.g.* International Bottom Trawl Survey Working Group - IBTSWG, 1992), or at Mediterranean scale (*e.g.* MEDITS and MEDIAS survey groups). Despite the implementation of multi-disciplinary surveys which are sometimes international, the lack of coordination of monitoring programmes on other ecosystem components has often been highlighted (*e.g.* [54]). For better integration and international collaboration with regard to monitoring activities, Joint Monitoring Programmes are necessary [11]. The pilot action “Multi-use of Infrastructure for Monitoring in the North Sea” proposed in 2012, was aimed at achieving this goal during various IBTS cruises in 2014 [14]. Similarly, the Working Group on Integrating Surveys for the Ecosystem Approach (WGISUR) explores the possibility of developing integrated surveys, which means joint monitoring cruises using similar protocols and instrumentation to collect data [13]. All these experiments should be developed further. For example, English and French trials on gelatinous zooplankton resulted in the successful implementation of the observation protocol in the French MSFD monitoring programme that will hopefully inspire other EU coastal Member States [21].

An interesting illustration is given by marine litter. Large scale trawl surveys on the seabed began long before strong support for monitoring was provided [39]. Monitoring is successful when the results can be used directly as a basis for effective management decisions [55]. At present, trawl surveys provide adequate means to achieve both criteria 10DC1 (composition, amount and spatial distribution of litter on the coastline, in the surface layer of the water column, and on the seabed) and 10DC2 (same with micro-litter), with standardized protocols at RSC levels, enabling assessment of sea floor litter and both floating debris and microplastics. The use of nets in most surveys (IBTS, CGFS, EVHOE and MEDITS) gives satisfactory results in terms of sampling, but, because these gears are crafted for collecting nectobenthic rather than benthic species, they probably underestimate the quantities present. They do however provide consistent results in terms of trend assessment, location of accumulation hot spots and composition of litter (Fig. 3), and are thus in phase with MSFD requirements in terms of monitoring of both litter and the impact of reduction measures. In addition, routines are under development for the automatic calculation of indicators / criteria, prior to reporting or scientific analysis. As an integrated tool, fish stock surveys provide a powerful means to simplify, standardize and report on the basis of D10 criteria, enabling further aggregation and analysis of GES. The inclusion of standardized protocols in the manuals of the different surveys from a given marine region would be a way to provide common indicators at European level. This example illustrates the use of "operational" indicators which have well-understood relationships between natural state and specified anthropogenic pressures, necessary to define environmental targets and decide on management measures [56]. To gain an accurate and meaningful assessment of plastics and their influence, large-scale and long-term monitoring is needed across countries and environments. In this case, monitoring could also provide information on the efficiency of implementation of measures decided for mitigating marine pollution and deterioration [57].

4.2. Limitations

On routine fisheries surveys, the sampling plan was only designed for fisheries stock assessment, and not for other needs such as MSFD monitoring. This priority can result in the deployment of equipment and observations in areas that are of little interest for collecting data for the MSFD. Moreover, vessel space available for scientific work can be an issue. For example, in the western Mediterranean sea, MEDITS and PELMED surveys are performed on the R/V *L'Europe*, which is much smaller than the *Thalassa* used for the other surveys (EVHOE, IBTS, CGFS, PELGAS). There is not room for as many scientists and as much equipment on board as might be hoped for (*e.g.* 8 scientists on board *L'Europe vs.* 25 on board *Thalassa*; see Table 1). This is the main reason for the acceptance of fewer MSFD protocols for the PELMED and MEDITS surveys, and can sometimes be a problem for operating a standardized protocol. However, even on those surveys using a small vessel, protocols could be adapted so to collect important information for MSFD.

Another issue is the scheduling of the surveys: DCF dictates that they are always planned during the same season, not necessarily the best one for certain protocols (for example, phytoplankton samples during the winter period). Weather can often be a major factor disabling a number of potential opportunities for MSFD monitoring, as is the case, for example, with microplastics (floating-manta trawl) or visual observations (birds, mammals, floating litter).

A final difficulty is the fact that responsibility for CFP and MSFD is split between two different ministries in France, as it is at European level (DGMARE and DGENV). The priorities for the two policies are not the same; ways of achieving increased cooperation and coordination should be explored. The challenge is to make our monitoring surveys more efficient and better targeted to deliver all the information needed. While ambitious marine ecosystem management objectives have been adopted in Europe within the MSFD framework, funds made available to implement MSFD Monitoring Programmes have not so far been sufficient to fully achieve the MSFD objectives [11,58]. The EU DCF funding has so far been essential to maintain the fisheries surveys and allow for their optimisation to meet MSFD requirements. The future of MSFD monitoring in Europe will probably depend on the availability of funds for developing suitable Monitoring Programmes to meet the challenge of the MSFD objectives [12]. It will also depend on human resources with the right skills in terms of the methodologies to be developed and implemented for MSFD purposes (examples: plankton taxonomy, innovative technologies, data storage and data processing). In France, new dedicated ship-based ecosystem surveys will still be necessary, to complement existing integrated fisheries surveys mainly in terms of spatial and temporal coverage. For example, new vessel-borne, MSFD hydrological surveys have been conducted in the Eastern and Western English Channel since 2017. They take place in spring and summer to complement the IBTS and CGFS fisheries surveys implemented in fall and winter, respectively. These new hydrological surveys are in the process of been optimised for collecting other MSFD data, following the same approach as for fisheries surveys. The Ministry of Environment currently works on this topic and a dedicated working group has been created (first meeting in March 2018). Likewise, offshore data on benthic communities might be collected during new MSFD hydrological surveys, as the deployment of specific equipment (grab / dredge) was deemed too time consuming to be added to fisheries surveys sampling.

4.3. Beyond DCF and MSFD monitoring strategy

The optimisation of fisheries surveys contributes towards developing a novel set of hydrological and biological observations aimed at achieving further knowledge on plankton community dynamics and structure, supporting the MSFD requirements in particular with regard to pelagic habitat (D1) and eutrophication (D5) issues. The strategy is based on a combination of conventional sampling tools providing data at low spatial and high taxonomic resolution (*e.g.* manual identification of zooplankton net samples up to the plankton species level) and of novel high-resolution sampling tools (Pocket Ferry Box, zooplankton imagery and optical instrumentations, single cell optical and bulk characterizations). Since, however "optimised" the fisheries surveys may be, it will never be possible to cover the full range of spatial and temporal scales characterising the different processes structuring the plankton communities, we also need to consider modelling and satellite derived products. Consequently, *in situ* low and high resolution data series collected during optimised surveys will help scientists to develop, to calibrate and to validate ocean colour algorithms and combine hydrodynamic-biogeochemical models [59,60].

5. Conclusion and future perspectives

To conclude, the strong points of the shipborne surveys are their sustainability, their frequency (annual surveys) and the use of standardized protocols between different countries. Since they maintain long-term series, the protocols have been thoroughly validated and are repeated each year. Furthermore, they are extensively funded by the European Commission in accordance with the Common Fisheries Policy. Therefore, it was pertinent to append new monitoring protocols to meet MSFD requirements because there are real opportunities to collect additional data. Finally, this approach also allows investigation of several ecosystem compartments and MSFD indicators at the same time, rather than developing separate specific data collection for each of the indicators. This should enable a much better understanding of the health of the ecosystem as well as potential interactions between indicators. The French experiment showed that it was less costly than carrying out surveys during a separate cruise, but in either case it does involve additional costs. The implementation of MSFD MP enables the sustainable use of particular cost-effective protocols, the deployment of new ones and the standardisation of some activities (hydrological protocols, data storing, analysis standardisation, *etc.*). It also offers new perspectives.

For example, Doray *et al.* [30] have shown that multiple time series (~15 years long) of potential ecosystem indicators (D1 and D3 related) collected during the PELGAS survey could be jointly analysed to extract the main large-scale trends in the indicator trajectories. This study provided a basis for hypotheses on the main changes undergone by the pelagic ecosystem of the Bay of Biscay, on the main ecological processes driving them and on the potential interactions between ecosystem components. Comparing indicator trends and proxies of external forcing also offers a means to investigate the effects of climate change and fishing on the ecosystem. The analysis of the future time series of data collected by the optimised French fisheries surveys could inform the MSFD and provide similar results over broader spatial (all EU French waters) and ecological (D1, D3, D4, D8, D9, *etc.*) scales, if their standardized collection is maintained over the next 15 years.

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