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REVIEWS

The scientific strategy needed to promote a regional ecosystem-based approach to fisheries in the Mediterranean and Black Seas

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Abstract This manuscript is an outcome of the workshop entitled "Scientific Strategy for a Global Approach to Promote Regional Ecosystem-based Approach to Fisheries (EAF) in the Mediterranean and Black Seas" held in Sète (France) in July 2012. The workshop was organized by Work-Package 6 of the coordination action "Coordinating Research in Support to Application of Ecosystem Approach to Fisheries and Management Advice in the Mediterranean and Black Seas" (CREAM), funded by the EU Seventh Framework Programme. The main aim of the workshop was to discuss what is needed to advance on a robust scientific strategy to promote EAF in the Mediterranean and Black Seas. Participants discussed a series of scientific recommendations for promoting the coordination of initiatives with the aim of contributing to an operational EAF. Discussion was carried out on (i) what can be learnt from case studies that promote EAF worldwide, (ii) how a scientific strategy for EAF can be built, and (iii) which are the future scientific networking activities to promote EAF. Here we summarize the discussions and conclusions of the workshop, and we present the recommendations and future initiatives proposed to advance EAF in the

Refer to the ''Appendix'' section for the complete list of "participants to the workshop" authors.

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Mediterranean and Black Seas region. Participants to the workshop agreed that the achievement of a common vision regarding the Mediterranean and Black Seas region should be one of the first and most important elements towards a successful EAF. A common vision should recognise the need to promote the reconciliation of conservation and exploitation, and to aim for a good socioeconomic and ecological status. The vision should also promote the recovery of ecosystems and rebuilding of marine commercial stocks and predator species. EAF initiatives, carried out worldwide, illustrated that whilst the development of relevant science is essential to render the EAF process operational, the involvement of stakeholders is the key factor that characterises successful initiatives. This is especially important in the Mediterranean and Black Sea context, where many stakeholders show conflicting interests and associated trade-offs. During the workshop, it became clear that numerous overlapping and poorly coordinated initiatives for EAF exist in the region. The group discussed the integration of the existing initiatives in a coordinated manner and arrived to the conclusion that a scientific network to promote coordinated and operational EAF initiatives created by the scientific community is needed. Ultimately, the discussion was focused on how to build such a scientific network and how to proceed to consolidate the regional scientific vision, with a clear scientific strategy and roadmap, including a diversified toolbox. In the short term, the proposed EAF scientific network should (i) document and coordinate scientific initiatives, (ii) promote the sharing of scientific information and capabilities, (iii) promote data availability, integration, harmonization, and interoperability, (iv) promote training capabilities and capacity building of the scientific community and stakeholders, (v) establish mechanisms to disseminate knowledge, and communicate EAF benefits, and (vi) promote concrete regional scientific initiatives. In the long run, the network should promote scientific advice on EAF to inform adaptive management, and promote EAF implementation at different geographical scales (from local to regional) using a transversal approach. The ultimate goal of the network should be to link management advice to good scientific information providing useful advice to address management objectives (i.e. present the trade-offs), and creating a knowledge-based management approach.

Keywords Ecosystem-based approach to fisheries (EAF) · Mediterranean and Black Seas · Scientific strategy · Scientific network · Roadmap · Toolbox · Coordination · Transversal approach

Background

The need to consider natural changes as well as human activities when analysing and managing marine resources highlights the need to adopt an integrated view of complex ecosystems. Since the productivity of marine resources depends on the ecological state of

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ecosystems, not only the dynamics of target species, but also the dynamics of non-target organisms, trophic relationships and energy flows, environmental factors and human impacts have to be considered to manage our seas and oceans properly (Botsford et al. 1997; Cury et al. 2003; Duda and Sherman 2002; Cury et al. 2008). This can only be achieved through an Ecosystem-based Approach to marine resources Management (EAM), or when dealing specifically with fishing activities, the Ecosystem-based Approach to Fisheries (EAF) (Costanza et al. 1998; Pauly et al. 2002; Pikitch et al. 2004; Link 2011; Christensen and Maclean 2011).

Several national and international governmental bodies are actively promoting the sustainable management of marine resources, and the adoption of the EAF in order to address increasing amounts of anthropogenic pressures on marine environments and conflicts between multiple users competing for space and resources (FAO 2003; Garcia et al. 2003; Garcia and Cochrane 2005; Shannon et al. 2010; Smith et al. 2007; Link et al. 2011). International conventions, treaties and other legal instruments, such as the United Nations Convention on the Law of the Sea (UNCLOS), the Convention on Biological Diversity (CBD), the Agenda 21 of the United Nations, and the FAO Code of Conduct for Responsible Fisheries, promote EAF worldwide. At the European level, the promotion of a sustainable marine environment is now in the agenda of several on-going policies, such as the new Common Fisheries Policy (CFP) and the Marine Strategy Framework Directive (MSFD), which aims at achieving a Good Environmental Status (GES) in EU marine waters by 2020, at the latest (EC 2008).

Making progress towards the EAF is also a timely issue in the Mediterranean and Black Seas region (GFCM-SAC 2005; Cochrane and de Young 2002; Cochrane and de Young 2008; UNEP 2009). The Mediterranean basin is a complex region with high biological diversity and a long history of human activity (Blondel and Aronson 2005; Lotze et al. 2011). The landmasses surrounding this sea are heavily populated. The basin currently includes 21 modern countries with very different (and sometimes conflicting) socioeconomic and cultural traits, and some of the most renowned marine tourist destinations in the world. As a result of this complex socio-economic and ecological context, the management of Mediterranean and Black Sea resources is seldom coordinated and proactive, and actions are usually taken only after problems have appeared.

To move towards a sustainable use of marine resources, substantial effort and funding is going towards initiatives guided by EAF principles, which are aiming at contributing to the implementation of an EAF in the region. A relevant initiative to promote EAF is the coordination action CREAM ("Coordinating Research in Support to Application of Ecosystem Approach to Fisheries and Management Advice in the Mediterranean and Black Seas"), funded by the EU Seventh Framework Programme (http://www.cream-fp7.eu/). CREAM aims at:

(i) Establishing guidelines for the application of the EAF in the Mediterranean and Black Seas;
(ii) Creating an effective collaboration network among key players in fisheries research and management;
(iii) Developing training and capacity building activities regarding data collection, and methodologies used in fisheries assessment and management.

Participants in CREAM include 22 national research institutes from 17 countries of the Mediterranean and Black Sea with a background in fisheries research, which provide advice to national, regional and international fisheries management organisms. CREAM includes eight European Union member states (Bulgaria, Cyprus, France, Greece, Italy, Malta, Romania, and Spain) and nine non-European countries (Croatia, Egypt, Georgia, Lebanon, Morocco, Russia, Tunisia, Turkey, and Ukraine) (Fig. 1). The project also includes one intergovernmental organisation, the International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM), and seeks the active collaboration of five regional and international fisheries management organisms as external participants in order to identify gaps (in terms of data, knowledge, training, coordination). External participants to the project are the Food and Agriculture Organization of the United Nations (FAO), the General Fisheries Commission for the Mediterranean (GFCM), the Commission on the Protection of the Black Sea Against Pollution (BSC), the International Commission for the Conservation of Atlantic Tunas (ICCAT), and the Regional Activity Centre for Specially Protected Areas of the Mediterranean Action Plan of the United Nations Environmental Programme (UNEP RAC/SPA).

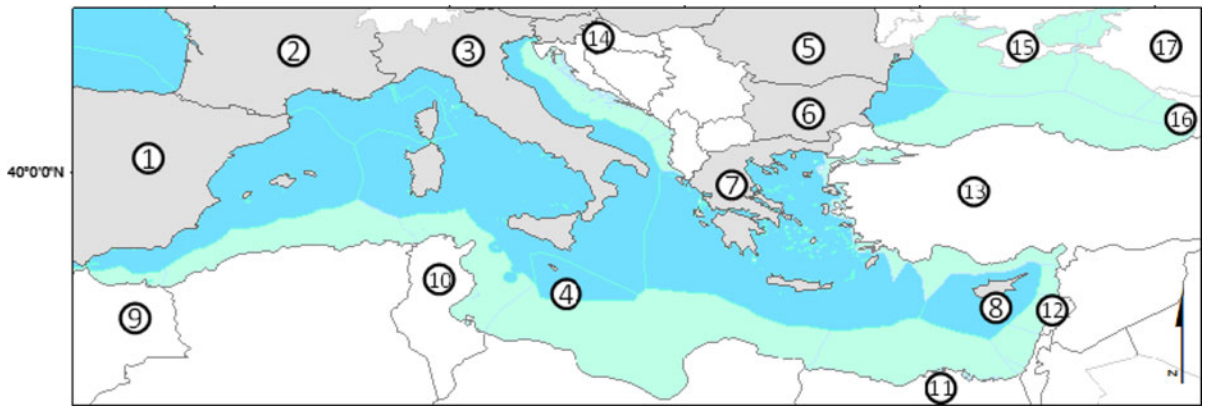

Fig. 1 The Mediterranean and Black Seas region, and countries participating in the coordination action CREAM. Countries of the European Union (EU) are highlighted in grey and the EU waters are highlighted in dark blue. Non-EU countries are in white and non-EU waters are in pale blue. CREAM countries are numbered *1* Spain, *2* France, *3* Italy, *4* Malta, *5* Romania, *6* Bulgaria, *7* Greece, *8* Cyprus, *9* Morocco, *10* Tunisia, *11* Egypt, *12* Lebanon, *13* Turkey, *14* Croatia, *15* Ukraine, *16* Georgia, *17* Russia

CREAM is organized in six work-packages, with Work-Package 6 aiming at:

(i) Strengthening the scientific basis for building a generic framework to implement EAF in the Mediterranean and Black Seas;
(ii) Establishing a network that will coordinate scientific research to make EAF operational.

CREAM Work-Package 6 organised its first workshop on the 3rd and 4th of July 2012 in Sète, France. The workshop topic was the "Scientific Strategy for a Global Approach to Promote Regional EAF", and was attended by 30 participants.

Participants to the workshop included CREAM partners and a series of recognised experts external to the project, who were invited to enrich the discussion and present interesting initiatives at a regional or international level (the full list of participants is provided in Appendix 1).

The attendees to the workshop learned from, reflected on and discussed about:

(i) What can be learnt from case studies dedicated to promote EAF around the world?
(ii) How a scientific strategy for an operational EAF in the Mediterranean and Black Seas can be built?
(iii) What are the future scientific networking activities to promote?

To facilitate discussion and participation, three questions were posed in advance to the experts attending the workshop:

(i) What are the existing and key scientific initiatives and tools that can contribute to EAF in the Mediterranean and Black Sea?
(ii) What are the scientific gaps that need to be addressed to advance EAF?
(iii) How do you envisage a scientific network for an operational EAF and who would be the key players?

Below we summarize the discussion, topics and conclusions of the workshop, and we present its recommendations, as well as proposed future initiatives to advance towards an operational EAF in the Mediterranean and Black Seas region.

The workshop

The workshop was organised in a series of sessions that included presentations dealing with key topics, followed by discussions. Following a review of EAF principles and objectives (FAO 2003, 2008; Pikitch et al. 2004; Sissenwine and Murawski 2004), the participants reflected on the need of a worldwide scientific EAF strategy, and its importance in the Mediterranean and Black Sea context, in particular. Additional presentations dealt with what could be learnt from worldwide case studies, and which international and regional initiatives and methods may be useful to contribute to EAF in the region. Special emphasis was placed on important topics in the Mediterranean and Black Seas

context, such as the quantification of the impacts of fishing (Tudela 2004), the spread and associated impact of non-indigenous species (Bariche et al. 2004; Azzurro et al. 2011), the multiple stressors and interactions of human activities (Coll et al. 2012; Claudet and Fraschetti 2010; Oczkowskia et al. 2009), the evaluation of ecosystem services (Katsanevakis et al. 2011; Salomidi et al. 2012), and the need to move towards a spatially-based analysis of human activities (Giakoumi et al. 2012; Stelzenmuller et al. 2012).

During the workshop, novel initiatives at the European or international level were presented. These initiatives could contribute to the EAF application in the region by complementing the available toolbox. Initiatives presented included new research to promote ecological scientific knowledge for EAF (Cury et al. 2011; Lotze and Worm 2009; Pikitch et al. 2012), the incorporation of single species assessment in an EAF context (Colloca et al. 2012), and initiatives on ecological indicators and ecosystem assessments (such as the European MSFD and GES initiative, the STECF (Scientific, Technical and Economic Committee for Fisheries) expert working group on EAF management, and the IndiSeas project, EC 2008; Gascuel et al. 2012; Shin et al. 2012; Cardoso et al. 2010). Global modelling initiatives and scenario building (such as the NEREUS project and the new IPBES United Nations initiative, NEREUS 2012; IPBES 2012) were also introduced.

Relevant science is essential, but not enough

The group discussed worldwide initiatives towards EAF (including examples from Canada, South Africa, Australia, New Zealand and United States of America) (Shannon et al. 2010; Smith et al. 2007; Fletcher et al. 2010; Link et al. 2011; Curran et al. 2011; Lester et al. 2010). A comprehensive presentation reviewing what can be learnt from leading case studies, and the suitability of these initiatives to be applied in the study area was discussed. The revision looked at what science is actually used to do EAF in key case studies (what is proposed, what is done). Main elements analysed were the topics included in the EAF approach, the scientific toolbox deployed, what has been successful or challenging, and the main external factors conditioning EAF implementation (in a positive or negative way).

Case studies provided clear inspiration to advance EAF, but it was also clear that Mediterranean and Black Sea socioeconomic realities differed considerably. South Africa was identified as the region with the most similarities to the Mediterranean and Black Sea circumstances due to some socio-economic features shared by both areas, in addition to some ecological ones (such as the importance of small pelagic fish in their fisheries). Therefore, both regions shared some similarities considering the topics included in the EAF approach, the toolbox and the external factors conditioning EAF. Other international or European initiatives that were presented, such as initiatives on ecological indicators like those mentioned above, and ecological modelling approaches (for example, applications of Ecopath with Ecosim, Atlantis, and Osmose models, Christensen and Walters 2011; Fulton 2010; Travers et al. 2007), were presented and positively valued by the group. Several applications of ecological models and indicators (Coll and Libralato 2012) have been developed or are being developed in the region and these will be important contributions to EAF. Links to these initiatives should be made explicit while developing a scientific strategy for EAF in the region (Fig. 2).

EAF case studies and initiatives illustrated that the development of relevant science based on a clear roadmap, utilizing a diverse toolbox, and with the capacity to adapt the tools and approaches as EAF is implemented, is essential if the EAF process is to succeed. However, the case studies also illustrated that relevant scientific basis is not enough. In fact, the key factor that characterises successful initiatives worldwide is the involvement of stakeholders in the EAF process (Shannon et al. 2010; Smith et al. 2007; Link 2011). Stakeholders need to be engaged throughout the process, from the development of methods, to the application of the science, i.e. the link of science to management, to the implementation of adaptive management measures, and the subsequent monitoring and assessment of the measures. This could be better achieved through coordination with multi-stakeholder co-management committees overseeing geographically delineated fishing grounds or particular fisheries therein. The group argued this territorial-based co-management is even more important in the Mediterranean and Black Seas context (Fig. 2), where many stakeholders exist and interact (commercial and recreational fishers, industry, non-governmental and governmental organizations, general public, etc.), exhibiting sometimes conflicting interests and trade-offs.

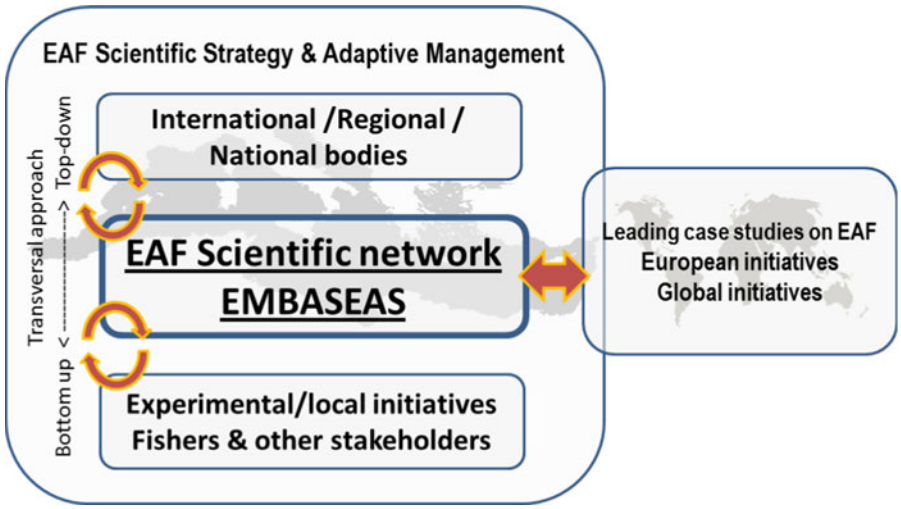

Fig. 2 The Ecosystem Approach to Fisheries (EAF) scientific strategy and links to promote adaptive management in the Mediterranean and Black Seas region envisaged by the group

In fact, early in the discussion, the group recognised that establishing the link between science and the implementation of adaptive management schemes is one of the most difficult issues to ensure the success of EAF. Although this is a key topic worldwide (Link 2011), few experiences show clear success in how to link scientific initiatives at local and regional scales to the societal needs of implementing management actions based on scientific advice in an adaptive manner. The documentation of examples and initiatives that advance towards the implementation of adaptive management and how to translate EAF general principles into concrete management activities is thus of outstanding importance. Unfortunately, successful initiatives in the Mediterranean and Black Seas are few, but the ones that exist set the examples on how to proceed (for example, pioneer case studies through the Mediterranean artisanal fishing platform, www.medartnet.org, and through the Network of Managers of Marine Protected Areas of the Mediterranean Sea, www.medpan.org). The group highlighted that one of the first tasks to pursue in the Mediterranean and Black Seas region should be to identify, document, and promote these successful case studies.

A coordinated scientific EAF initiative is needed

During the workshop, several initiatives, datasets, methods, as well as past and present projects that aim at directly or indirectly contributing to EAF in the Mediterranean and Black Seas region were reviewed and discussed. Scientific initiatives included projects from national research institutions, collaborative bilateral projects and European programmes, initiatives of other regional bodies (such as FAO, GFCM, BSC, ICCAT, UNEP RAC/SPA, or the Mediterranean Scientific Commission CIESM), international projects on indicators and modelling, local and regional pilot studies, and non-governmental organizations activities (e.g., WWF, Oceana). A *status quo* revision is one of the aims of CREAM Work-Packages 2 and 3, which will serve to illustrate that several interesting efforts and initiatives are currently in place, although they are highly heterogeneous (CREAM-WP2 2012).

In fact, at an early stage of the workshop it became clear that numerous local and regional initiatives exist, which have highly overlapping themes and are poorly coordinated. As a consequence, final results may be undermined by redundancy and by creating confusion amongst end users and policy makers. Thus, the group discussed the need to promote the integration of these existing initiatives in a coordinated manner. It was recognized that substantial funding through European projects and national calls is being invested in promoting EAF, but that achievements are still modest due to the limited coordination and the lack of a regional common vision. Therefore, there is a real need to integrate what has been done and is being done, what has been achieved, with what is needed in the future in order to advance the application of EAF.

To progress towards this coordinated regional initiative, the group identified the need to achieve a clear and strong common regional scientific vision on what marine ecosystems in the region should be, according to specific criteria. The Mediterranean and Black Seas are dominated by a human landscape with conflicting interests; therefore the achievement of a common vision is one of the first and most important elements of a successful EAF. The group argued that the vision should recognise the need to promote the reconciliation of conservation and exploitation and to aim for a good socioeconomic and ecological status. Maintaining marine ecosystems in a healthy, productive and resilient condition will ultimately serve to sustain human uses and provide goods and services (Katsanevakis et al. 2011). Since the status of marine resources and ecosystems in the region is poor (Coll et al. 2010, 2012; Lotze et al. 2011; Abdul Malak et al. 2011; EC 2012), the vision should also promote the recovery of ecosystems, in general, and the rebuilding of marine commercial stocks and predator species, in particular.

A significant part of the Mediterranean and Black Seas region is located within European Union waters (Fig. 1). Therefore, the group discussed the need to synchronize the vision and the strategy towards EAF with what is being developed at the European level. Current and future policy developments of the new Common Fisheries Policy (CFP) and the Marine Strategy Framework Directive (MSFD) (EC 2008) will strongly influence the whole region. In addition, the application of the Barcelona Convention, the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (initiated in 1976), will not only affect European countries. The new European policy will also lead to the implementation of new targets in fish stock in order to reach abundances ensuring the maximum sustainable yield target by 2020 and to the monitoring of indicators related to the GES targets. Therefore, linking activities at the European level to the regional reality of the Mediterranean and Black Seas is vital, although likely to be challenging.

For an EAF to be successful at the Mediterranean and Black Sea level, the group also emphasized the importance of integrating different visions at different geographic scales, from local to regional levels. This notion promoted an interesting discussion about the geographic scale (or territorial management unit) appropriate for science to be applied in order to better influence management of marine resources. The group suggested that science in the region should be developed with a transversal approach, where both bottom-up and top-down processes between science and management are needed to promote a scientific strategy integrating different geographical scales. Therefore, scientific initiatives should be able to respond to both local and regional issues using appropriate management units. The transversal view should aim at integrating these two approaches through consultation and cooperation. Science for EAF should be proactive and should establish numerous partnerships with both local and regional institutions, as well as strong links with international initiatives (Fig. 2).

Scientific achievements and obstacles in the road to EAF

To date, topics analysed in the Mediterranean and Black Seas region using an EAF approach included: (i) the impact of fishing on commercial species (Colloca et al. 2012), (ii) the impact of intense exploitation of small pelagic fish (Palomera et al. 2007), (iii) reduction of predators and ecosystem changes (Lotze et al. 2011), (iv) selectivity of fishing (Sardà et al. 2006), and by-catch and discarding issues in relation to EAF (Bellido et al. 2011), (v) endangered species (Tsounis et al. 2007), (vi) the modification of benthic habitats and habitat losses and degradation (Claudet and Fraschetti 2010), (vii) the impact of climate change and climate variability (Lloret et al. 2004; Sabatés et al. 2006), (viii) the impact of invasive species (Galil 2009, 2007), (ix) multiple impacts of human activities (including impacts of land-based activities) (Coll et al. 2012), (x) the biodiversity conservation and fisheries benefits of marine protected areas (Garcıa-Charton et al. 2008), and (ix) the socio-economic impacts of fisheries mismanagement and food security (Merino et al. 2007). These topics were in fact similar to topics identified in leading worldwide case studies.

The scientific toolbox used to tackle these issues included: (i) monitoring (mainly in EU countries), as well as stock assessment analyses and models, (ii) ecological and bio-economic models, (iii) data-based and model-based indicators, (iv) fleet-based approaches to assess both the ecological impacts and the socio-economic performances of fleets; (v) spatial datasets

and analysis of diversity, threats, and management proposals, and (vi) knowledge from expert judgement and local ecological knowledge. These initiatives have contributed to the advancement of EAF in the region by providing: (i) ecosystem analyses at local and sub-regional scales, (ii) integrated knowledge on the status of several commercial species, (iii) knowledge on ecosystem effects of fishing and ecosystem functioning at local/regional scales, (iv) a set of available ecological models and indicators to use, (v) knowledge on temporal and spatial patterns, and (vi) large potential of expert knowledge to inform EAF.

However, on-going results of CREAM work packages have illustrated that the capacity to address EAF issues in the region is generally low or medium depending on the areas and topics (CREAM-WP2 2012). During the workshop, the group identified and discussed general topics that need to be tackled to advance EAF in the region in the future. Important scientific challenges identified by the group include:

- Lack of long-term data and spatial datasets, since data on several topics and areas are missing and there are data accessibility issues;
- Lack of data quality measures and uncertainty analyses;
- Limited knowledge on human impacts related to fisheries aside from direct fishing impacts (invasive species, aquaculture, habitat destruction, litter pollution from fishing vessels), as well as other human impacts (including land-based activities), the impact of climate change, and how they interact and accumulate;
- Lack of methods to integrate knowledge and ecosystem research results in management processes, such as risk assessments methods, marine strategy evaluation procedures, or harvest strategy rules integrated in adaptive management procedures.

The group listed basic scientific knowledge that is lacking in the process to advance EAF in the region. The outcome was a long list of issues and topics, evidencing the fact that basic gaps of knowledge from the region can be found in all topics, from physical-oceanography and ecological topics, to social and economic issues. These topics include:

(i) The description of basic ecological processes and patterns: such as abundance and distribution of marine resources, natural refuges and habitats, migration of species, information on the stock structure and stock connectivity in relation to fisheries management and the location of MPAs, location of nursery and spawning areas, basic ecology of predators and their ecological needs (e.g., minimum prey needed), basic data on taxa indirectly affected by fishing (sharks, seabirds, marine mammals), basic data on the ecology of small pelagic fish and invertebrates (prey of predators), invasive species, endangered species and data deficient species, and data on ecosystem functioning and biodiversity patterns at the community level (mainly species, phylogenetic and functional diversity);

(ii) The effect of anthropogenic pressures and the interaction of stressors and drivers: such as the effects of multiple stressors including their synergies, the effects of environmental variability, the impact of aquaculture on capture fisheries, and land-based human pressures on marine fisheries, the ecological impact of management plans and MPAs, and the potential for recovery of resources and ecosystems;

(iii) Socio-economic subjects: such as the quantification of ecosystem services, total catch and by-catch, real fishing effort, economic evaluations (including true cost of fisheries mismanagement, non-market costs, the sensitivity of ecosystems to public policies, and market/non-market incentives), fishing fleet behaviour, and how to combine socioeconomic and ecological evaluations in a fleet-based approach.

Gaps are also found in methodologies and tools needed to complement the toolbox for EAF. In this regard, the group discussed several methods that are already applied worldwide that could be adapted to be used in the Mediterranean and Black Seas region. The need for an improvement of scientific methods includes: (i) further standardization of stock assessment methods and harmonization of methods and data, (ii) the extension of indicators and definition of reference points, directions and targets (both limits and thresholds), including the development of indicators of stock status in data poor situations, (iii) the further development of modelling capabilities and scenarios including key human drivers to join global efforts in predicting the future of the oceans, and (iv)

the creation or adaptation of tools to incorporate ecosystem research results into the management process. This requires the promotion of a regional toolbox with new and adapted methodologies to span the whole range of approaches needed (Fig. 3), including monitoring, evaluation, and adaptive management.

Whilst it is evident that the scientific community has the obligation to fill the identified scientific gaps and to develop the required toolbox, a pragmatic approach is clearly required. The group acknowledged that while it is essential to reduce gaps of data and methods, it should be recognised that there will always be gaps in the knowledge and information required to contribute to EAF. Nevertheless, policy makers need to make the best decision they can using the available information. This calls for a pragmatic combination of the precautionary approach, especially when data on basic elements and processes is very limited, with the use of those tools and data which are readily available to provide the best possible scientific advice. Therefore, in addition to promoting the completion of important scientific gaps, the group recognised that it is essential to:

(i) Promote low cost practices for collecting data and developing tools;
(ii) Promote collaborative efforts and improve coordination;
(iii) Complement but avoid repeating existing scientific initiatives;
(iv) Deal with limited financial means and allocation of funds with an effective use of resources.

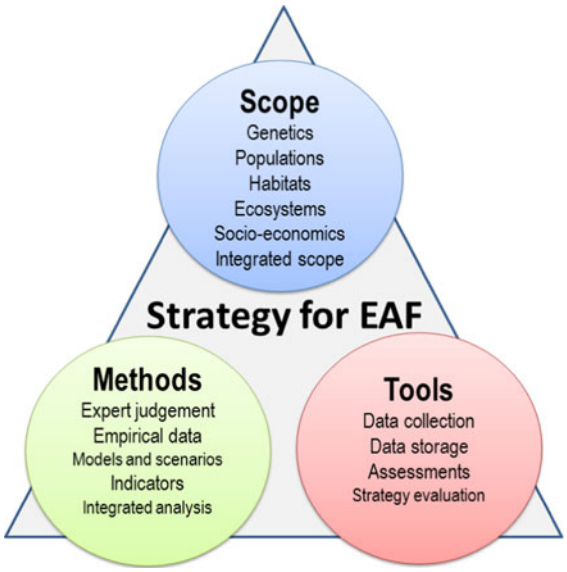

Fig. 3 The toolbox needed to advance a regional scientific strategy for Ecosystem Approach to Fisheries (EAF) in the Mediterranean and Black Seas region (adapted fromSmith et al. 2007)

Data-poor and data-poor access regions: our Achilles' heel

Data access (both availability to new data and access to existing one) is a hindrance to scientific inputs for EAF. The CREAM work packages dealing with initiatives and data that contribute to the EAF are in the process of identifying several regions where data are less abundant (CREAM-WP2 2012). Although countries that are included in the EU Data Collection Framework are more prone to be in the possession of fisheries data, it is clear that basic data regarding abundance, biodiversity, and other relevant parameters is still highly heterogeneous in the region. CREAM is mapping the available resources in order to identify areas and topics that need special attention. This will be a substantial contribution to the delineation of a scientific roadmap, and ultimately to generate some of this lacking data.

However, a large amounts of knowledge are already available, including data collected through the Data Collection Framework Initiative of the EU (such as fisheries independent data from the MEDITS and MEDIAS demersal and pelagic surveys, respectively), national projects, regional bodies, other scientific initiatives (such as initiatives from CIESM, IUCN, FAO regional projects and ICCAT), and large-scale initiatives to collate and integrate datasets (such as GEOBON, http://www.earthobservations.org/geobon.shtml, the European contribution to databases for Biodiversity, ECOSCOPE, http://www.ecoscopebc.ird.fr, knowledge based on exploited marine ecosystems, and Marine Knowledge 2020 EU initiative, http://ec.europa.eu/maritimeaffairs/policy/marine_knowledge_2020/index_en.htm). Despite these initiatives, most of these data are not available to the scientific community at large. Therefore, an additional problem to the data-poor situation in the Mediterranean and Black Seas is the limited accessibility to datasets by end users. In fact, it has been recognised that the region is suffering from an endemic problem of data ownership and accessibility. This issue highlights a serious problem of efficiency when developing

science to contribute to EAF, impairs the ability to calibrate oceanographic and ecological models, prevents the calculation and standardization of indicators, and overall provides a negative image of the scientific community.

The issues of data availability and access are two major problems that need to be solved in harmony. If public data ownership and data accessibility is not ensured in the future, forthcoming data acquisition initiatives will have limited applicability and contribution to the EAF process in the region. This issue needs to be solved quickly, especially in the current context of limited resources. This requires a major effort from scientists and policy makers to ensure that existing data are accessible with good metadata after being harmonised, standardized, and checked for quality. In the "global information era", ensuring data availability, interoperability, and quality should be a compulsory requirement accompanying any publicly-funded initiative.

Novel topics and initiatives with added value

Five important topics that add value to the need for a coordinated scientific EAF initiative in the Mediterranean and Black Seas region at a regional scale were highlighted. These topics include: (i) the issue of quantifying the real impact of fisheries by integrating knowledge on different fishing fleet segments and from different areas, (ii) the need to deal with the accelerating non-indigenous species spreads and impacts, (iii) the complexity of considering multiple human impacts, their cumulative effects and interactions, and how they impact productivity patterns, (iv) the need to consider spatial planning and integrated coastal zone management in future analyses moving towards an ecosystem-based spatial approach, and (v) the need to advance our capability to fully quantify ecosystem services and to accurately inform policy makers and society.

Quantification of the real impact of fishing

Access to data and information on the different fishing fleets operating in the region is difficult. In most cases, data available only covers official landing statistics that do not consider discards, catch that is sold on the black market or is used for consumption of fishers and relatives, and illegal catches, all components of IUU (Illegal, Unregulated and Unreported catches). IUU catches are caused by a lack of control by countries and regional organizations on fishing activities, due to inappropriate or insufficient operational plans and disciplinary measures for those not following the rules, and due to lack of political will (Zeller and Pauly 2007). IUU practices impair the correct assessment of exploited marine species, and complicate or even defeat the development of suitable management actions. They can also have important socio-economic impacts due to conflicts with legal activities, and especially with artisanal and subsistence fishing. This is a fundamental issue in the Mediterranean and Black Seas region where IUU activities are large (Tsikliras et al. 2007; Le Manach et al. 2011).

Despite IUU, official landing statistics aggregated at country level have limited information value since they give no indication of regional landing statistics, and hence can usually not be matched to stock units for stock assessment purposes. The only regional dataset freely available is the GFCM capture production dataset for the region, released in 2010 (http://www.fao.org/fishery/statistics/software/fishstat/en). Biological stock related variables are required in order to carry out stock assessments and to calculate the vast majority of indicators based on fisheries dependent data. Such data is only collected in sufficient detail for a limited number of species at present. In addition, different countries and regional bodies use different data collection protocols and levels of data aggregations, creating additional challenges for scientists attempting to combine data and perform the analyses at the relevant regional scale for shared stocks. Moreover, data on fishing effort is either not available or very difficult to access. In Europe, high resolution fishing effort data is in fact being collected by national authorities since the introduction of the Vessel Monitoring System (VMS), but such data remains unavailable to scientists (Hinz et al. 2012). Moreover, recreational and artisanal fisheries, which are of high importance in the region, are frequently not included in official statistics by country (Tudela 2004).

In addition to these limitations associated with the calculation of single species target reference points, the multi-gear and multi-species nature of Mediterranean and Black Sea fisheries remains a further stumbling block to quantifying the real impact of fishing. In the region, fishers routinely set out with a number of gears, catching a multitude of species in a

single fishing trip (Caddy 2009). The quantification of the real impact of fishing should take into account the multi-gear nature of fisheries, and the resulting high interaction between gears and fleet segments since most of the main target species are exploited by more than one fishing technique or strategy, each often concentrating on individuals of different sizes during different seasons. This poses a considerable challenge with regards to the collection of accurate fisheries data.

Multispecies stock assessments require a vast amount of detailed data, including information on predation mortality rates, and diet data to take into account trophic relationships when calculating species interactions (Magnusson 1995). For the region, such data is not always available and methods to combine the results of single species stock assessment remain in their early stages (Maravelias et al. 2011).

Until the quality of data on fishing activities improves, the capacity to properly evaluate fishing impact on commercial stocks through multi-species reference and target indicators such as the maximum sustainable yield and the side effect of gear selectivity, as well as the impact on non-commercial species, habitats and ecosystems, will be very limited. A coordinated scientific EAF initiative at a regional scale could play an important role at promoting practical measures such as setting up a regional database for fisheries data, as well as integrative studies that deal with the real quantification of seasonal catch and fishing mortality rates, and the impact of multi-species fishing by gear segment.

Non-indigenous species spreads and impacts

The Mediterranean and Black Seas region are not only important hot spots of marine biodiversity, but also hot spots of xeno-diversity. So far, 660 multicellular non-indigenous species have been recorded (Galil 2009), and this number can be as high as 1,000 species when unicellular taxa and Atlantic migrants are considered (Zenetos 2010). Non-indigenous species (NIS) can have different origins and impacts and they may arrive using different pathways (such as canals, mariculture and aquaculture, shipping, etc.). Some NIS can establish large population, replace indigenous species, and attain commercial importance. Due to the increasing speed and dimension of this phenomenon (Galil 2009; Zenetos et al. 2010), which is probably being exacerbated by climate change (Lejeusne et al. 2010; Bianchi 2007; Azzurro 2008), there is an urgent need to collect basic information on the biology and ecology of NIS.

However, detailed information on what the effects of NIS on fisheries and other human activities are is missing. We do not know what effects fisheries have on the establishment of NIS populations, and we do not have a complete view of the changes provoked by NIS on natural habitats and ecosystems. For this reasons, it is difficult to estimate the true cost of NIS. As a matter of fact, past opportunities of monitoring and tracking the consequences of NIS in a coordinated way were lost, but, due to cooperation between scientists and local populations, the use of Local Ecological Knowledge (LEK) has recently illustrated new possibilities to retrieve historical data (Azzurro et al. 2011). Therefore, a coordinated scientific EAF initiative in the region in collaboration with current efforts (such as CIESM Tropical Signals Program, http://www.ciesm.org/marine/programs/tropicalization.htm) could help promote the monitoring and coordinated collection of data. Questions such as how marine biodiversity is changing and what are the present and future impacts of NIS that cannot be tackled at local scales without losing the real perspective of the phenomenon. This is of special importance if we want to be able to correctly assess the good environmental status of the region, and improve our knowledge on process-based ecological knowledge. A coordinated EAF initiative could also help increase the awareness of this important topic and the potential associated socioeconomic regional consequences.

Multiple human impacts and interactive effects

The scientific community made substantial progress in the identification and quantification of multiple human threats that impact marine diversity, habitats, and ecosystems in the region (Claudet and Fraschetti 2010; Coll et al. 2010; Lotze et al. 2011; Coll et al. 2012; Giakoumi et al. 2011; Sala et al. 2012, http://globalmarine.nceas.ucsb.edu/mediterranean/). There is currently increasing knowledge on the identification, quantification, and distribution of these multiple stressors. Various EU projects in progress (such as Pegaso, http://www.pegasoproject.eu/, or CoCoNET, http://www.coconet-fp7.eu/) will likely contribute substantially to this knowledge.

However, the way these multiple stressors may interact and combine to impact productivity patterns of marine ecosystems is hardly known (Sala et al. 2000). Multiple impacts may interact and their effects may accumulate, acting synergistically or antagonistically at different ecological levels, from species to community, and ecosystem levels. A comprehensive understanding of these impacts and their interactions is lacking, although it seems that synergistic effects are frequent (Folt et al. 1999; Crain et al. 2008), but see Darling and Côté 2008 for additional discussion (Darling and Côté 2008). Multiple impacts are distributed in a heterogeneous way in the region (Halpern et al. 2008; Coll et al. 2012), and the interaction of these impacts will thus not occur the same way everywhere, and it may affect productivity differently. Moreover, future changes of current human activities (such as climate change, or the invasion of new species), and the appearance and spread of new activities, will likely challenge our current understanding. Additionally, even if some new approaches are currently developed in the frame of the MSFD, the way we can use this knowledge to derive indicators and reference points to inform management remains to be fully explored. A coordinated scientific EAF initiative in the region, in collaboration with existing efforts, could contribute to the documentation of multiple threats data and to the analysis of current and future multiple impacts. Such data is at present frequently scattered and has different spatial and temporal resolutions. This could be achieved by establishing partnerships between data providers and data analysts. To tackle some of these scientific challenges there is a growing need to use and develop novel methodologies of data integration, assimilation and modelling at different scales, taking into account uncertainties in data and processes (Parravicini et al. 2012; Christensen et al. 2012).

Quantification of ecosystem services

To apply the EAF efficiently, there is the need to evaluate and understand socioeconomic costs and benefits of management interventions, in addition to ecological impacts (Katsanevakis et al. 2011). Assigning values to the marine environment allows assessing the management alternatives. Values can be assigned to the economic value of extracted resources, the provision of environmental services, and to marine biodiversity. However, not only market but also non-market values of the environment have to be taken into account, which is not a simple task because not all ecosystem services are traded on markets and have direct monetary values. The alternatives to monetary valuations are non-monetary assessments that attempt to understand the cause, distribution, and strength of socioeconomic values (for example, by developing assessments using other units such as weight to potential areas of conflict and consensus). Nowadays, there are different techniques that can be applied (Katsanevakis et al. 2011), although there are little examples applied to the Mediterranean and Black Seas region. Another difficulty is how to link resources and habitats to different goods and services since data are not always available and comprehensive (but see an attempt to link habitats to services in European seas, Salomidi et al. 2012).

To make progress for an EAF, the full quantification of the impacts of human activities on ecosystem goods and services including the socioeconomic component is a must. This is of particular importance in complex ecosystems such as the Mediterranean and Black Seas, where food security is a crucial aspect of EAF, and there is thus a real need to quantify the risks of mismanagement, and the benefits of good management. A scientific coordinated EAF network in the region could contribute to the development of regional socioeconomic evaluations, and ensure that forecasting ecological models and indicators are linked with policy scenarios including projections of employment, and population trends.

Spatial analyses and management

It is well recognised that the EAF approach needs to take into account the spatial dimension, while bridging regional to local scales (Fig. 2). Spatial management initiatives, including but not limited to MPAs, are useful tools to contribute to the spatial management process (Katsanevakis et al. 2011; Stelzenmuller et al. 2012). In the Mediterranean and Black Seas region, recent years have witnessed an increase in spatial analyses of ecological and socioeconomic data with the aim of contributing to the integrative knowledge that we have on ecosystems and how best to advance towards sustainable management and habitat protection (Maiorano et al. 2009; Giakoumi et al. 2011).

However, spatial analyses in the region have mainly been carried out in the context of MPAs and

no-take zones. Therefore, there is a need to adopt a more integrative view of the spatial dimension by including other areas, taking into account scientific gaps when performing spatial analyses, including information at different scales. New analyses should include the spatial extent of different, and sometimes conflicting, human activities (for example, fishing effort by fishing gear, including in particular the distribution of bottom trawling and other destructive fishing gear, shipping lanes, the location of permanent structures on the seafloor such as pipelines, cables, wind farms, tourist areas, protected areas, etc.), as well as current and future spatial management initiatives to propose an adaptive spatial approach to the management of human activities. Multi-stakeholder co-management on territorial management units would allow for an accurate integration of the spatial dimension in the management of fishing activities therein. This would result in a rational time and area management of fishing effort and technical measures ranging from, for example, no-fishing zones to seasonal and/or geographical gear closures.

A regional scientific EAF initiative could contribute towards the coordination and analyses of data in a spatial framework, and could integrate important lessons from successful local case studies to inform EAF regionally. This should be done in collaboration with initiatives that aim at establishing systems of territorial-based co-management, and promote experiments of EAF application, and co-management at the local scale.

To improve our capability to spatially analyse complex topics, there is a need to use and develop novel spatial methodologies, such as marine spatial planning and ocean zoning, and new tools such as remote sensing, spatial quantitative analysis, telemetry, and spatial modelling (Giakoumi et al. 2012; Katsanevakis et al. 2011; Stelzenmuller et al. 2012). Spatial management has obvious links to the other topics and initiatives with the added value mentioned above.

Proposing an EAF new scientific network called EMBASEAS

As a result of the discussion during the workshop, it was clear to the group that a visionary and coordinated scientific network to promote operational EAF initiatives, created by the scientific community (thus following a bottom-up approach) in the Mediterranean and Black Seas, is needed. The proposed network, named **EMBASEAS** (the network aiming at being an ambassador to promote **E**af in the **M**editerranean and **B**l**A**ck **SEAS**), should add value to the current situation. Discussion on how to envisage such a scientific network, and who would be key players in the network, followed.

The network should be independent and individually based, but with clear links to regional bodies such as GFCM, FAO, the EU Joint Research Centre, as well as with non-governmental organizations promoting EAF. Key players of the network should be those interested scientists of different disciplines, participating as independent individuals, rather than as national or institutional representatives. The network should have strong links with local and regional organizations involved in EAF initiatives, and seek the involvement of other stakeholders such as professional and recreational fishers, other users of the marine environment, naturalists, local experts, and policy makers.

The ultimate discussion was centred on how to build such a network with the consolidation of a regional scientific vision, with a clear scientific strategy, and plan (including a diversified toolbox), to promote EAF in the region (Figs. 2, 3). Such a network should have the capability to define a clear, strong, and shared vision for EAF in the region. This could be achieved by gaining a broader view on the EAF implementation strategy, in particular by keeping track of what needs to be pursued to ultimately ensure a good status of the Mediterranean and Black Sea ecosystems. The network should identify key objectives and topics, and establish a road map of coordinated actions to accomplish them. The scientific network should also aim to promote the coordination of scientific activities, to date local or fragmented, in an efficient way, using local initiatives but contributing to the regional vision. This would bridge different geographical scales and promote the use of innovative tools such as models, indicators, scenarios, and other integrative tools. The methodology and manner of linking the initiatives from the local to the regional level can be a considerable challenge for the network.

In the short term, the network could start as a coordinated action of scientists to promote the scientific approach of EAF by coordinating activities, and

improving the capacity of developing science for EAF in the region. The network should promote concrete scientific actions considering available data, tools, and initiatives at different geographic scales to improve process-based ecological knowledge in the area. The group identified several novel topics and initiatives with added value to the network (e.g., the ecology and impact NIS, cumulative impacts, the impacts of specific fishing gear). One of the first tasks of a coordinated scientific initiative would be to identify, document, and promote successful case studies in the region. This could help establish bridges between scientists, policy makers, and other users of the sea, in a transversal way dealing with the best territorial management unit (Fig. 2). Other potential immediate activities include the documentation of initiatives, the sharing of already available information and scientific capabilities, the improvement of the training capabilities, and the capacity building of the scientific community and stakeholders, and the establishment of mechanisms to disseminate knowledge to end users.

In the medium-long term, the network should aim at promoting the implementation of an EAF (from the local to the regional level), and providing scientific advice on EAF to inform adaptive management in the region, where at present only stock assessment advice is taken into account (if at all). Thus, the ultimate goal of the network should be to link management advice to good scientific information providing useful advice to address key management objectives (i.e. present the trade-offs), and creating a knowledge-based management approach. By establishing successful liaisons with local and regional organizations and initiatives, needing scientific advice to promote EAF, the scientific network could contribute to the management of territorial units and provide a stable platform to share successful stories, resources, ideas, and expertise. The network could facilitate the discussion of common problems and possible solutions with local applicability in a coordinated manner and under a common regional vision and strategy. Scientists involved in early practices of EAF could find in the network a suitable platform for networking among themselves to learn tactics on how to implement EAF at the local level, while also building a strategy at the regional level. Such a network would face the challenge of delivering and coordinating at the regional strategic level what can be effectively done at the local tactical level, while influencing the decision making process at different geographic scales (Fig. 2). The ultimate goal should be to link management advice to good scientific information and transform policy strategies and goals into operational objectives. Another important role of the network would be to anticipate the needs of stakeholders—both local communities and managers-and the problems that may occur in the future.

The network should also be used as an opportunity to anticipate the future and invest in tools such as generic and validated models and indicators. In this manner scientists would be able to contribute to initiatives and calls for predicting the dynamics of the ocean, and building scenarios of socio-ecological systems (in cooperation with initiatives such as IPBES, Larigauderine and Mooney 2010). Indeed, it is already clear that in a few years, scientists will have to provide scientific advice on possible future scenarios and the available alternatives to avoid adverse changes in ecosystems and ecosystem services, integrating data on ecology, climate, socioeconomics, and demographics. These tools will enable us to investigate the future of the region, and analyse how to reconcile long-term objectives with local constraints (exploring trade-offs with a suite of socioeconomic and ecological objectives) following the successful initiative of the Intergovernmental Panel on Climate Change. There is thus a clear need to start building on the capability to integrate, modify, improve, innovate, fit and calibrate complex models and frameworks, which will require the promotion of data integration, harmonization, and accessibility. The scientific community has to advance towards building a roadmap of coordinated actions to develop a common strategy and advance towards the future; and the EMBASEAS network may be a good opportunity to achieve this.

Immediate activities and priorities

Finally, the group decided to develop a series of immediate activities to promote EMBASEAS:

(i) The distribution of workshop material and discussions using scientific literature, and the CREAM website (http://www.cream-fp7.eu/);
(ii) The development of a newsletter to promote the activities of the network, and inform EAF initiatives in the Mediterranean and Black Seas region;

(iii) The design of a website to present and promote EMBASEAS;
(iv) The coordination of efforts to answer to future research calls at the European level to fully implement the scientific network envisaged by the group;
(v) The organization of a second meeting during 2013, with the principal aim of discussing ways to operationally build the scientific network EMBASEAS, and expand CREAM objectives.

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