Brussels, 24 March 2020

COST 010/20

DECISION

Subject: **Memorandum of Understanding for the implementation of the COST Action "Unifying Approaches to Marine Connectivity for improved Resource Management for the Seas" (SEA-UNICORN) CA19107**

The COST Member Countries and/or the COST Cooperating State will find attached the Memorandum of Understanding for the COST Action Unifying Approaches to Marine Connectivity for improved Resource Management for the Seas approved by the Committee of Senior Officials through written procedure on 24 March 2020.

MEMORANDUM OF UNDERSTANDING

For the implementation of a COST Action designated as

COST Action CA19107
UNIFYING APPROACHES TO MARINE CONNECTIVITY FOR IMPROVED RESOURCE MANAGEMENT FOR THE SEAS (SEA-UNICORN)

The COST Member Countries and/or the COST Cooperating State, accepting the present Memorandum of Understanding (MoU) wish to undertake joint activities of mutual interest and declare their common intention to participate in the COST Action (the Action), referred to above and described in the Technical Annex of this MoU.

The Action will be carried out in accordance with the set of COST Implementation Rules approved by the Committee of Senior Officials (CSO), or any new document amending or replacing them:

a. "Rules for Participation in and Implementation of COST Activities" (COST 132/14 REV2);
b. "COST Action Proposal Submission, Evaluation, Selection and Approval" (COST 133/14 REV);
c. "COST Action Management, Monitoring and Final Assessment" (COST 134/14 REV2);
d. "COST International Cooperation and Specific Organisations Participation" (COST 135/14 REV).

The main aim and objective of the Action is to The aim of SEA-UNICORN is to help improving policies for Sustainable Development by fostering interactions among the varied research communities that study Marine Functional Connectivity (MFC), the modelers that predict its ecological and economic consequences and the stakeholders involved in environmental governance and sustainable exploitation for the seas.. This will be achieved through the specific objectives detailed in the Technical Annex.

The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 88 million in 2019.

The MoU will enter into force once at least seven (7) COST Member Countries and/or COST Cooperating State have accepted it, and the corresponding Management Committee Members have been appointed, as described in the CSO Decision COST 134/14 REV2.

The COST Action will start from the date of the first Management Committee meeting and shall be implemented for a period of four (4) years, unless an extension is approved by the CSO following the procedure described in the CSO Decision COST 134/14 REV2.

TECHNICAL ANNEX

OVERVIEW

Summary

In a human-altered marine environment, fragmented and subjected to unprecedented climate change, planning sustainable strategies for development requires to understand the distribution of marine biodiversity and how its variations impact ecosystem functioning and the evolution of species. Functional Connectivity characterizes the migratory flows of organisms in the landscape. As such, it determines the ecological and evolutionary interdependency of populations, and ultimately the fate of species and ecosystems. Gathering effective knowledge on Marine Functional Connectivity (MFC) can therefore improve predictions of environmental change impacts and help refine management and conservation strategies for the Seas. This is challenging though, because marine ecosystems are particularly difficult to access and survey. Currently, >50 institutions investigate MFC in Europe, by using complementary methods from multiple research fields to describe the ecology and genetics of marine species. SEA-UNICORN aims at coordinating their research to unify the varied approaches to MFC and integrate them under a common conceptual and analytical framework for improved management of marine resources and ecosystems. For this, it will bring together a diverse group of scientists in order to collate existing MFC data, identify knowledge gaps, reduce overlap among disciplines, and devise common approaches to MFC. It will promote their interaction with connectivity theoreticians and ecosystem modelers, to facilitate the incorporation of MFC data into the projection models used to identify priorities for marine conservation. Lastly, it will forge strong working links between scientists, policy-makers and stakeholders to promote the integration of MFC knowledge into decision support tools for marine management and environmental policies.

Areas of Expertise Relevant for the Action	Keywords
● Biological sciences: Population biology, population dynamics, population genetics, plant-animal interactions ● Biological sciences: Conservation biology, ecology, genetics ● Earth and related Environmental sciences: Biological oceanography ● Earth and related Environmental sciences: Biogeochemistry, biogeochemical cycles	● Marine connectivity ● Marine resources ● Metapopulations ● Metahabitats ● Migrations

Specific Objectives

To achieve the main objective described in this MoU, the following specific objectives shall be accomplished:

Research Coordination

● Synthesizing existing knowledge on MFC and its past and present drivers and overcoming disciplinary fragmentation to detect knowledge gaps, identify the taxa and geographic areas for which substantial information is already available and highlight where coordinated research efforts would produce the most significant advances.

● Comparing and improving MFC assessments among laboratories and disciplines and promoting research integration for addressing theoretical and technical limitations and building on recent advances in analytical, statistical and modeling tools to co-create universal frameworks allowing the integration of multi-disciplinary MFC concepts and datasets, in a statistically rigorous way.

● Bridging gaps between MFC and complementary research disciplines (e.g. functional ecology, ecological stoichiometry, socio-ecology) to produce MFC data that can be combined with information on the functional roles played by the organisms in the various habitats/ecosystems they inhabit during their life.

● Bridging the gap between MFC scientists, policy makers, managers and end-users to optimize the format and quality of MFC data for decision-making in policy and management for the sustainable exploitation of the seas and catalyse the implementation of MFC research-based policies, in Europe and beyond.

● Disseminating MFC knowledge to a wide audience (including scientists, stakeholders and the wider public) to promote global awareness on its ecological and economic importance.

Capacity Building

● Gathering and sharing multidisciplinary scientific and methodological expertise among the varied scientists currently involved in the empirical evaluation of MFC.
● Triggering interdisciplinary interactions among the scientists involved in the evaluation of MFC and those investigating its causes, its evolution and its ecological or economic consequences.
● Strengthening Europe's research and innovation capacities by creating a pan-European network of MFC experts with sufficient critical mass and complementary skills to drive international scientific and technical progress in MFC research.
● Promoting geographical, age and gender balance in the MFC scientists community by equally involving female and male participants, especially ECIs and participants from ITCs, in the Action leadership positions and in the joint writing of the Action's review articles and reports.
● Facilitating international cooperation and spreading scientific excellence in the field of MFC in Europe (and beyond) by providing new training and collaboration opportunities, including through ex-change of scientists (especially ECIs) and methodologies.
● Contributing to the emergence of the 'next generation' of MFC scientists, with robust expertise in varied (yet complementary) disciplines to allow more comprehensive and useful assessment of in-terconnections among populations, communities or ecosystems.
● Initiating MFC scientists to the specific needs of policy makers, regulatory bodies and decision makers to provide relevant MFC knowledge for the sustainable management of the seas, in Europe and beyond.
● Familiarizing marine stakeholders and the public with the central role played by MFC in the resilience of marine biodiversity and with the urgent need to incorporate MFC knowledge into management strategies for the seas, thereby catalyzing environmental protection.

TECHNICAL ANNEX

1 S&T EXCELLENCE

1.1 SOUNDNESS OF THE CHALLENGE

1.1.1 DESCRIPTION OF THE STATE-OF-THE-ART

Oceans cover 71% of the Earth, host almost every major phyla, and deliver multiple ecosystem services, many of which (e.g. food provision and climate regulation) shape human societies today. Marine assets represent the 7th largest economy in the world, estimated to be worth at least US$ 24 trillion. Sustainable management of the seas is therefore essential, in Europe and worldwide. Over the last century, marine ecosystems have been substantially altered: 90% of top oceanic predators have disappeared and many habitats have been lost or severely degraded. As a result, only 13% of the world's oceans today have relatively intact ecosystems. Because the ocean is immense and many marine species are yet to be discovered, extinction rates at sea are still poorly resolved. However, current estimates compare with the terrestrial extinction rates observed prior to the Industrial Revolution, which increased dramatically afterward. Without careful management of marine biodiversity, it too could soon face a similarly rapid, catastrophic collapse. Because species diversity loss compromises ecosystem function and resilience to change, human dependency on marine wildlife and the linked fate of marine and continental ecosystems necessitate that we act quickly to halt this unprecedented degradation. Recent findings showed that marine ecosystems are highly vulnerable to anthropogenic pressures, and most experience multiple, concurrent threats (e.g. overfishing, temperature rise, hypoxia). This is particularly true for European seas, where fishing, oil and gas exploitation, biological invasions and tourism have had major impacts on biodiversity and ecosystem function. Yet, the protection of the seas lags far behind that of continental habitats. For example, Aichi targets (www.cbd.int/sp/targets) set only 10% of marine areas as an objective for ocean conservation by 2020 compared with 17% for terrestrial systems.

Effective marine conservation is currently stymied by dynamic ecosystem-level changes that are poorly understood. Improving knowledge on connectivity is a crucial first step to understand them and promote species and habitat resilience to global change. In ecology, connectivity refers to how the movement of organisms and the flow of nutrients and materials are facilitated (or not) by the landscape. Therefore, connectivity assessments allow understanding relationships between the individuals, species or communities and the habitats or regions they inhabit. Over the last decade, developments in theoretical ecology have divided the broad concept of 'connectivity' into two inter-twined components: 'structural connectivity', a notion related to the physical characteristics of the landscape, and 'functional connectivity', which represents the response of organisms to environmental heterogeneity and structuring, encompassing their movements and exchanges between habitat patches. While human activities often result in changes in structural connectivity, functional connectivity determines the demographic, ecological and evolutionary interdependency of populations and communities, as well as the flow of energy and organic matter amongst sites. Hence, it modulates the ecological effects of environmental change, and ultimately seals the fate of species, ecosystems and the services that they provide.

In order to predict how marine ecosystems will respond to future climate change, and to design effective conservation and management strategies, it is critical to build a more quantitative understanding of marine 'functional connectivity' (MFC). Yet, MFC knowledge is challenging to obtain because, in the ocean, movements occur in three dimensions and few organisms remain sedentary over their entire lifetime. Most marine species have at least one phase of important dispersal during their life span, typically at the propagule stage, but sometimes also at the juvenile or adult stages. Describing their dispersive strategies is particularly challenging because of (i) limited access to the marine environment, (ii) typically small size of dispersers, (iii) large population sizes, and (iv) substantial dispersal distances, with no clear a priori relationship between life-history traits and dispersal potential. As a result, a diversity of methods and tools (e.g. telemetry, genetics, biophysical modeling), have been developed from a range of disciplines to predict, reconstruct or directly track individual movements among populations or habitats. Each technique has strengths and weaknesses that affect the accuracy of the MFC estimates, which in turn affects the potential of such data to inform management. For example, genetic or other natural tags provide evidence of connectivity, but their inference of connectivity levels is limited by the assumptions underlying their interpretation. Biophysical modeling can provide highly realistic scenarios for dispersal at large spatial scales, but typically lacks empirical validation. Finally, telemetry (physical tagging) can unambiguously identify individual movements, but is often limited to large-sized organisms and provide only limited information on lifetime dispersal.

During the last decade, technological developments across these disciplines have generated major advances in MFC knowledge. MFC data are now available for a broad range of aquatic organisms (from viruses to whales) and across all marine eco-regions. However, a significant bias exists towards organisms and areas that are important to society. For example, studies focusing on fish are ~3 times more prevalent than those on the next most commonly studied taxa (shrimps and lobsters). Likewise, dispersal of some shallow-water habitat-forming organisms (e.g. corals and kelps) has been studied extensively, whereas other species of ecological importance (e.g. invasive species and most pathogens) have received limited attention. Study locations are also more concentrated around Europe, North America and Australia, compared to Asia, Africa, and the Pacific. These taxonomic and geographic biases hamper our ability to understand connectivity at a global scale. However, an even greater impediment to broad scale MFC knowledge synthesis is the current lack of method integration. Indeed, most MFC studies (88%) used a single methodology, principally genetics (48%) or bio-physical modelling (24%). Direct observation studies represent only ~19% of the literature, and tagging studies even less (~17%). Because, these methods differ in their underlying hypotheses and assumptions and/or the geographical or temporal scales, integrating them could lead to major scientific breakthroughs in marine research and policy. However, among the few attempts to integrate methods, only a subset were typically combined, usually genetics (an inferential technique) with either natural tags (e.g. otolith composition, i.e. another inferential technique) or particle drift models (i.e. a predictive method). In contrast, predictive methods (like niche or behavioral modeling) have never been integrated with empirical ones (such as tagging). Because of this methodological bias, most of the published MFC knowledge relates solely to larval dispersal (60%), which has primarily been investigated to assess population structure (~48%). Only a small fraction of papers (0.5%) is dedicated to higher-level ecological processes (e.g. material fluxes) and ecosystem services.

Integrating methods should lead to a far more accurate image of overall MFC. However, because organisms with a similar ecology or geographical distribution may have different population structure, this will also require consolidated knowledge for a wide range of taxa, regions and habitats. For this, MFC research needs to balance gaining in-depth knowledge in some systems and extrapolating it to unstudied systems. Valuable but undocumented information on the functioning of our planet is also embedded in the diversity of habitats frequented by particular species over their lifetime and the ecological implications of the connectivity between them. Therefore, obtaining insights into MFC trends across some specific types of taxa or species can particularly improve decision making in management and policy. A typical case is that of microorganisms: although they have substantial economic impact on society (e.g. as human or animal pathogens, or through their role in carbon cycling), knowledge on their dispersal and distribution is still very limited. Another example is the transfer of energy and matter between the continental and marine realms via the migrations of diadromous fishes. Improving MFC knowledge of these species will help understand the spatial and temporal dynamics of coastal ecosystem services, allowing managers to optimize conservation actions both at sea and on land. Fortunately, it is now within reach of MFC scientists to identify the processes that shape the microbial seascape and connectivity, especially as new methods such as metagenomics are available. Theoretical frameworks and analytical tools to investigate connectivity within and among realms have also recently been developed, along with approaches allowing for integrated prioritization of conservation measures. By building on these new frameworks and methodologies, we can shed new light on important ecological and economical linkages, and provide mechanisms to incorporate this knowledge into management and policy.

1.1.2 DESCRIPTION OF THE CHALLENGE (MAIN AIM)

Current global initiatives for sustainable development, such as the Strategic Plan for Biodiversity 2011-2020 (Aichi targets) and the UN Sustainable Development Goal for 2030 n°14 “Life below water”, all require a comprehensive understanding of MFC and its drivers in order to anticipate environmental changes and their socio-ecological consequences. Indeed, accurate MFC knowledge is needed not only to conserve vulnerable species or ecosystems (Aichi targets 10 & 12), control the spread of invasive species, pathogens or aquaculture escapees (Aichi targets 7 & 9), and determine networks of protected areas (Aichi target 11), but also to ensure sustainable fisheries management (Aichi target 6) and enhance the benefits derived from biodiversity and ecosystem services (Aichi targets 14, 15 & 16). A number of prominent advisory marine management organizations (e.g. ICES, ICSU, IOC) agree on this need, as reflected by the adoption of the Marine Strategy Framework Directive (2008/56/EC), the Framework Directive for Maritime Spatial Planning (2014/89/EU) and other international ecosystem-based management frameworks (e.g. EU Blue Growth strategy 2017). The EU member states have been mandated to establish and implement EU maritime spatial plans by 2021. Fit-for-purpose ocean science and data are also urgently needed to inform policies in support of the sustainable development goals for a well-functioning ocean described in the 2030 Agenda of the UN Decade of Ocean Science for Sustainable Development.

The aim of SEA-UNICORN (Fig. 1) is to start fulfilling this need, by (i) fostering multidisciplinary interactions among the varied research communities involved in the study of MFC (e.g. geneticists, behavioral ecologists) and the modelers that predict its ecological and economic consequences (e.g. fishery, conservation and social-ecological systems scientists), and (ii) consolidating their interactions with the stakeholders involved in environmental governance and sustainable exploitation for the seas, in Europe and beyond.

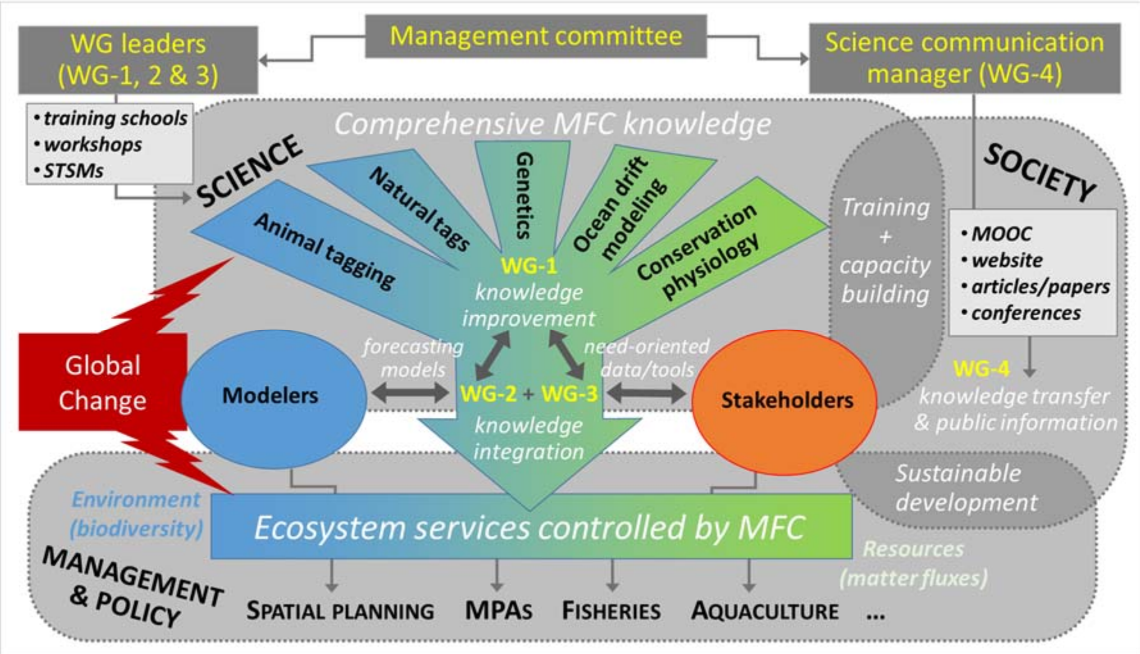

Fig.1 - Structure and expected outputs of the SEA-UNICORN Action. WG = Working Groups of the Action (see 4.1.1).

In doing so, we aim to start tackling the three major Scientific Challenges (SC) listed below:

SC 1 - Gathering operational MFC (and associated) data for protecting marine biodiversity - Given the spatio-temporal heterogeneity across marine habitats, MFC knowledge is mandatory for making decisions about where, when, and how to protect marine communities. Marine biodiversity conservation typically relies on information about population size and structure, and spatio-temporal dynamics of linkages among populations. However, important knowledge gaps on MFC need to be filled before these factors can be integrated into conservation decision-making. For example, whilst most marine populations could be connected by extensive propagule dispersal, recent research identified self-recruitment as far more important than previously thought. Similarly, life-history diversity within marine populations has been poorly studied (even for exploited species) so its ecological and evolutionary consequences are consistently overlooked in marine management. Yet, recent research has showed that this variability is more common and complex than previously understood. It affects individual fitness and local population dynamics (e.g. via trophic interactions) which, in turn, may affect evolutionary trajectories and modulate biodiversity at local and global scales.

SC 2 - Producing adequate MFC (and associated) knowledge for preserving ecosystem function and services - Linking species geographic distributions and movements across life stages to ecosystem function and services is key to enable sustainable governance of the seas. As organisms disperse or migrate (e.g. to reproduce or forage), they contribute to spatial flows of energy and materials that connect habitats and influence local ecosystem dynamics. Importantly, because biologically mediated ecosystem functions (e.g. respiration and excretion) control most of the marine biogeochemical cycling, changes in species distributions can impact nutrient cycling and sequestration, affecting the overall functioning of the planet. The recognition of this link fostered the recent development of the meta-ecosystem theory, a powerful framework to predict the co-evolution of connected ecosystems. However, empirical research in this field is progressing slowly, mainly because most models consider dispersal as the only type of organismal flows, when many other movements can also connect ecosystems. Variations in biodiversity and in biogeochemical processes are just starting to be integrated into conceptual models (e.g. by modelling ecosystem services) but are crucial to understand and predict energy and material fluxes within and across aquatic ecosystems.

SC 3 - Understanding MFC drivers & forecasting its evolution in the face of Global Change - Developing effective policies for sustainable ocean management requires a comprehensive understanding of present-day MFC and reliable projections of its evolution. This can be done by identifying the past and present drivers of MFC. For example, habitat destruction and fragmentation during the 20th century resulted in significant loss of biodiversity because, when populations and communities become increasingly isolated, connectivity between them decreases. Similarly, changes in climatic conditions have already modified the distribution of many marine species or, by affecting their reproductive or larval biology, led to reduced connectivity and increased self-recruitment. The ultimate consequences of the rapid environmental changes occurring in the oceans will depend on complex interactions between abiotic (e.g. temperature, habitat fragmentation) and biotic (e.g. physiological tolerance, interspecific interactions) parameters, but also on the behavioral responses of resource users. Anticipating these effects relies on modeling, to predict changes in species distribution, ecosystem functioning, and ecosystem services. However, to test hypotheses and improve projections, model parameterization requires high-quality, empirical, and relevant MFC data. Modeling also requires linking MFC metrics with physiological and biological requirements across species and life stages, in order to accurately predict behavioral, genetic, geographic, and demographic responses to environmental change.

1.2 PROGRESS BEYOND THE STATE-OF-THE-ART

1.2.1 APPROACH TO THE CHALLENGE AND PROGRESS BEYOND THE STATE-OF-THE-ART

Connectivity is inherently variable and dynamic, subject to intrinsic and extrinsic factors that affect the movements, dispersal and survival of individuals. Documenting this variability and incorporating it into our understanding of meta-population and meta-ecosystem dynamics is very challenging. To this aim, SEA-UNICORN will innovate by building on pioneering theoretical and methodological advances in varied disciplines, using them to revisit concepts and approaches in MFC research and unify them under a universal and policy-oriented framework. This will significantly improve our understanding of MFC, but also stimulate the emergence of a more systematic and outcome-focused MFC science.

The first innovation will be methodological. Multidisciplinary MFC studies so far essentially involved separate analyses by complementary methods (e.g. tagging and genetic markers in fish) and comparative interpretation of the results. Because of method limitations, such studies have typically been restricted to a single species or taxonomic group (e.g. fish and corals) and inter-specific dependencies in MFC (e.g. the role of macro-organisms in the dispersal and distribution of microbes or parasites) are rarely considered. However, thanks to recent advances in Network Science (e.g. on multi-layer networks), statistical frameworks now exist and allow simultaneous assessment of complementary descriptors, or integration of multiple, separate datasets. SEA-UNICORN will build on these innovations to develop a theoretical and methodological framework allowing effective co-integration of complementary MFC data across disciplines (e.g. genetic markers and otolith fingerprints for fish), taxa (e.g. fish, mollusks, microbes) and life-stages. This offers a promising avenue to improve MFC knowledge and enhance the usefulness and quality of the data collected by each discipline. Further-more, comparing standardized MFC descriptors among species will improve our ability to extrapolate spatial connectivity at broader taxonomic (e.g. family, phylum) or ecological (e.g. guild, community) scales. The area of seascape genetics has already started to move toward this approach by gathering spatial information about meta-population structures worldwide, and genetic diversity changes at population, species or community scales. We intend to continue and expand this effort, by collating and synthesizing MFC data across disciplines to generate generic descriptors of connectivity at ecological (e.g. species, guild, community) and policy-relevant (e.g. exploited stock, taxon, ecological compartment like benthos, etc.) scales. This is needed to progress from MFC patterns to processes and make use of MFC data to predict the evolution of marine wildlife and its socio-economic repercussions.

SEA-UNICORN will also innovate by providing unprecedented opportunities for bridging gaps between research fields, by fostering MFC data use in marine biogeography, functional ecology, ecological stoichiometry and socio-ecological systems science. For this, we will take advantage of recent theoretical (e.g. spatial ecology, functional biogeography) and methodological (e.g. agent-based modeling, end-to-end food web modeling) advances in these research fields to incorporate MFC data into exploratory models for marine biodiversity, oceanic productivity and material fluxes and coastal socio-economical systems. This should greatly advance our understanding of how the organisms drive ecosystem functioning, habitat characteristics and biogeochemical processes (and vice-versa). For example, matching sound MFC estimates at the species, taxonomic group, functional guild or community scales with data on seascape and species distribution will allow linking organisms' movements to their physiological and biological needs, thereby providing unprecedented insights into the evolution of marine biodiversity. Combining them with data on the organisms' ecological roles (e.g. trophic position) in their diverse lifetime habitats will allow linking organisms' movements to their ecological function within marine and adjacent ecosystems, thereby yielding precious information into how habitat use can affect species assemblages and matter fluxes at the local and global scales.

Finally, SEA-UNICORN will innovate by facilitating the incorporation of MFC data into decision-making for resource and ecosystem management at the national, regional and global scales. This will be done by forging strong operational links between MFC researchers, socio-ecological system modellers and the main actors involved in marine policy and in the management of marine and littoral areas. In particular, resource managers and policy makers with diverse expertise will be invited to actively partake in the Action (see 2.2.2), to incorporate their many and varied needs into new policy-making tools facilitating the integration of MFC data into management. With their inputs, we will:

- conduct a thorough global assessment of published and grey literature to summarize current methods to incorporate MFC into planning and policy making, providing a basis for advancing the field with a new integrated MFC approach;
- tune MFC estimates to allow their implementation into state-of-the-art projection models forecasting the consequences of environmental changes, management strategies or stakeholders behaviors.

This will significantly improve the quality of local and global strategies for the sustainable exploitation of the seas and will contribute towards a science-informed policy making in Europe (and beyond).

1.2.2 OBJECTIVES

1.2.2.1 Research Coordination Objectives

SEA-UNICORN (Fig.1) aims to improve the scientific knowledge underpinning marine management and policy strategies, by addressing five Research Coordination Objectives (RCO):

RCO 1 - Synthesizing existing MFC knowledge and overcoming disciplinary fragmentation - Due to the multidisciplinary nature of MFC research, the typical mechanisms for information exchange at the international level are not fully effective. For example, geneticists and modelers do not often attend the same conferences nor read the same literature. SEA-UNICORN will fill this gap by establishing interdisciplinary and international links among MFC scientists (e.g. through WG1 international meetings, workshops, training schools and STSMs, see 4.1.1) to promote the joint writing of reports and articles. It also aims to provide Action participants with a dedicated online communication platform to contribute with information and ideas, and synthesize existing MFC knowledge (see 3.2.2). This will help identify key knowledge gaps and the taxa and geographic areas for which substantial information is already available. It will also highlight where coordinated research efforts would produce the most significant advances.

RCO 2 - Comparing and improving MFC assessments - Multiple labs are currently attempting to address theoretical and technical limitations for effective MFC assessment. However, they lack a universal framework to integrate multi-disciplinary concepts and datasets in a statistically rigorous way. To address this, SEA-UNICORN will provide MFC researchers from different disciplines (e.g. genetics, dispersal modeling) with unique opportunities to foster collaboration and co-create common frameworks to study MFC. For example, the Action will implement a platform for coordinated discussions to identify best-practice examples within each discipline and ways to facilitate data acquisition and integration (see 3.2.2). WG1 will also hold several workshops and training schools to promote research integration and propose research projects to fill methodological or data gaps, and foster STSMs to develop new MFC approaches that build on recent advances in analytical, statistical and modeling tools (see 4.1.1).

RCO 3 - Bridging gaps between MFC and complementary research disciplines - Gathering effective knowledge to preserve biodiversity and sustain ecosystem services (e.g. fisheries, tourism) requires combining MFC data with information on the ecological roles played by different species in the various habitats/ecosystems they inhabit during their life. Unfortunately, MFC data are not yet adequately produced or referenced to allow this combination, which also precludes identifying the exact dependencies of ecosystem services and community livelihoods on marine biodiversity. To solve this problem, SEA-UNICORN will build upon recent progress in functional ecology and ecological stoichiometry by increasing the interactions between MFC scientists and modelers examining food webs ecosystem functioning and socio-ecological system dynamics. This will mainly be achieved through workshops and STSMs dedicated to transdisciplinary thinking, aiming to produce state-of-the-art methodological guidelines for advancing MFC science (see WG2 in 4.1.1).

RCO 4 - Optimizing the quality of MFC data for decision-making in policy and management - MFC knowledge can inform local management decisions and significantly improve global policy making for the sustainable exploitation of the seas. However, this requires MFC data to be generated in such a way that it can be incorporated into decision-making processes and decision-support tools for policy. To this aim, SEA-UNICORN will foster transdisciplinary STSMs and organize workshops to familiarize MFC scientists with the specific needs of management and policy-making tools, and to initiate stakeholders to the methods providing MFC data relevant to decision-making, their advances and their limitations (see WG3 in 4.1.1). Lastly, online forums on its website (see 3.2.2 and WG4 in 4.1.1) will allow to connect scientists and end-users. This will help bridge the gap between policy and science, and catalyse the implementation of research-based policies, in Europe and beyond.

RCO 5 - Disseminating MFC knowledge - General knowledge on MFC has to be transferred to a wide audience (including scientists, stakeholders and the wider public) to promote global awareness on its ecological and economic importance (see 3.2.2). For this, the knowledge and methodological insights gained over the course of the Action will be disseminated to the research community, through the joint production of open access peer-reviewed publications (see WG4 in 4.1.1). SEA-UNICORN will also produce guidelines for scientists to help them optimize the quality and value of the MFC data they produce, and whitepapers for incorporating different types of MFC data into marine management and environmental policy-making via decision support tools. A Final Action Dissemination event (high profile international conference) will be organized (see 4.1.2 and WG4 in 4.1.1), press releases will be made and educational videos on MFC will be produced. The Action's website will also offer access to existing online databases dedicated to gathering empirical and methodological knowledge on MFC and relevant decision support tools.

1.2.2.2 Capacity-building Objectives

The following Capacity Building Objectives (CBO) should be met by the Action (see 4.1.1 and 3.2.2):

CBO 1 - Gathering and sharing multidisciplinary scientific and methodological expertise among the varied scientists currently involved in the empirical evaluation of MFC (WG1);

CBO 2 - Fostering interdisciplinary interactions among the scientists involved in the evaluation of MFC and those investigating its causes, its evolution and its ecological or economic consequences (WG2);

CBO 3 - Strengthening Europe's research and innovation capacities by creating a pan-European network of MFC experts with sufficient critical mass and complementary skills to drive international scientific and technical progress in MFC research (WG1);

CBO 4 - Promoting geographical, age and gender balance in the European scientific community by equally involving female and male participants, especially Early Career Investigators (ECIs) and participants from Inclusiveness Target Countries (ITCs), in the Action leadership positions and in the joint writing of the Action's review articles and reports (all WGs);

CBO 5 - Facilitating international cooperation and spreading scientific excellence in the field of MFC in Europe (and beyond) by providing new training and collaboration opportunities, including through the mobilty of scientists (especially ECIs and participants from ITCs and Near Neighbor Countries) and methodological developments (WGs 1-3);

CBO 6 - Contributing to the emergence of the 'next generation' of MFC scientists, with robust expertise in varied (yet complementary) disciplines to allow more comprehensive and useful assessment of interconnections among populations, communities or ecosystems (WGs 1-3);

CBO 7 - Initiating MFC scientists to the specific needs of policy makers, regulatory bodies and decision makers to provide relevant MFC knowledge for the sustainable management of the seas, in Europe and beyond (WG3);

CBO 8 - Familiarizing marine stakeholders and the public with the central role played by MFC in the resilience of marine biodiversity and with the urgent need to incorporate MFC knowledge into management strategies for the seas, thereby catalyzing environmental protection (all WGs).

2 NETWORKING EXCELLENCE

2.1 ADDED VALUE OF NETWORKING IN S&T EXCELLENCE

Advancing MFC research undeniably requires networking and trans-disciplinary cooperation at the international level. Marine resources and ecosystems often extend beyond political boundaries so local threats to biodiversity can have impacts at local, regional and international levels. Increasing the spatial scale of MFC studies is thus urgently required to define appropriate conservation measures for spatial planning and governance. Moreover, MFC research is multidisciplinary by nature, relying on techniques ranging from field surveys to complex computer modelling and genomic or biogeochemical analyses. Due to the complex technical nature of these disciplines, it is highly unusual for single scientists or research groups to be experienced in all of them. Gathering scientists from diverse research teams, disciplines and countries into a multi-disciplinary network will significantly advance MFC knowledge and generate invaluable academic and applied results (see 4.1.2). Currently, the complexity and diversity in terminology and methodology within each field has impeded cross-disciplinary collaboration and made it difficult for MFC scientists to stay informed of advances in other disciplines. This has occasionally led to erroneous interpretation of MFC data and ineffective policy implementation. Networking is also the most effective approach to ensure that future MFC research meets societal needs. Indeed, direct interaction between MFC scientists and the diverse actors involved in marine (or coastal) management and policy will help to correctly and effectively incorporate MFC knowledge into future measures for the sustainable development the seas.

2.1.1 ADDED VALUE IN RELATION TO EXISTING EFFORTS AT EUROPEAN AND/OR INTERNATIONAL LEVEL

Although still in their infancy, international coordination efforts for MFC research are being pioneered in Europe, for example via the 2015 ICES Annual Science Conference theme session "Beyond Ocean Connectivity" and the "Marine Connection" research group (iMarCo 2016-20). Both initiatives started providing opportunities for cross-disciplinary interactions among MFC researchers. Building on such thematic forums and widening their scope is essential for progressing MFC science in a timely manner. Indeed, while transnational initiatives focused on understanding human impacts on marine ecosystems or on optimizing marine biodiversity management have blossomed over the last decade (e.g. EU projects MESMA, VECTORS, PERSEUS, EMPAFISH and CoCoNET), equivalent efforts to assess regional or global MFC patterns are surprisingly rare. MFC projects have typically used a maximum of two complementary methods (e.g. the FWO project FISHCONNECT, the NSF project Multi-species connectivity or the recently BiodivERsA project RESERVEBENEFIT), or focused on a single habitat type (e.g. deep-sea biotopes in the DeepLinks NERC project) or species (e.g. eel, herring or cod in the EELIAD, HERGEN and MetaCod EU projects, respectively). Truly multidisciplinary MFC investigations are rare, and the projects conducted with this aim focused on specific groups of species (e.g. exploited fish species in EU-FP7 FishPopTrace). Identifying commonalities among these projects and developing 'best-practice' methodologies across a broader range of taxa is a critical next step in order to integrate MFC data into ecosystem-based management. In this context, a cross-disciplinary coordination framework like SEA-UNICORN is particularly timely. The Action will build on existing knowledge and recent methodological advances, and its activities (see 4.1.1) will go well beyond the level of discussion enabled by previous MFC meetings and conferences. Specifically, SEA-UNICORN will provide a structured setting for MFC scientists to learn about advances in other disciplines and for scientists and stakeholders to debate and work together. This will enhance conceptual and methodological understanding among disciplines, and enable cross-fertilization of ideas and development of robust research protocols. The Action will also complement and expand previous MFC research and coordination efforts to support knowledge transfer and integration into marine policy and water resources and ecosystem management, at sea but also on the continent. To do so, interactions could be initiated with international research groups investigating the drivers of spatial ecology and evolution (e.g. DispNet project (dispnet. github.io)) or with other COST Actions aiming to bridge the gap between science and policy in Europe (see 2.2.2).

2.2 ADDED VALUE OF NETWORKING IN IMPACT

2.2.1 SECURING THE CRITICAL MASS AND EXPERTISE

The SEA-UNICORN network of proposers already gathers the necessary critical mass and possesses the essential skills and technical infrastructures to successfully address the objectives listed above (see 1.2.2). Indeed, it comprises >50 scientists from >40 research institutions spread in 27 countries in Europe and beyond, and includes internationally recognized experts in all the diverse yet complementary disciplines that investigate MFC (e.g. marine genetics, marine ecology, animal behavior science, ocean modelling) and its consequences (e.g. biogeography, functional ecology, ecosystem modelling, social-ecological systems science). SEA-UNICORN scientists complement one another through their varied areas of scientific or technical expertise, their diverse perspectives on MFC and their experience with different marine species, ecoregions and/or habitats. Indeed, the Action not only has a pan-European focus but also extends outside the limits of Europe. Among the 38 existing COST Member Countries, 22 are in the Action network of proposers and we strive to include more of them after the start of the Action. The additional participation of three COST Near Neighbour Countries and two COST International Partners brings in valuable complementary knowledge on other species, habitat types and ecoregions. Importantly, the network as it stands, already features expertise covering the full array of marine ecosystems and resources found in European and adjacent seas. The additional participation of three Near Neighbor Countries and two COST International Partners adds valuable complementary knowledge on other species, habitat types and ecoregions. The network is also diverse in terms of gender and career stage, featuring a similar proportion of male and female participants and 15 Early Career Investigators so far. Moreover, many of the scientists in the network have already collaborated in the past and co-supervised students. SEA-UNICORN will thus provide unprecedented opportunities to foster future interdisciplinary research collaborations, share and transfer skills, ideas, and expertise at local, regional and international levels, and promote gender balance in the field of MFC. Finally, the network also includes stakeholders with varied expertise (e.g. in marine policy, fisheries or MPA management) and more will be invited to participate in the future (see 2.2.2). The interactions between scientists and stakeholders in the network will ensure that MFC research addresses the data gaps currently impeding decision making for marine management and policy in Europe, and hopefully promote innovation in the fields of marine conservation and spatial planning. In conclusion, SEA-UNICORN will offer valuable opportunities to advance and disseminate MFC knowledge, identify and communicate its importance in policy and management, and ensure that future efforts meet societal needs in Europe and beyond.

2.2.2 INVOLVEMENT OF STAKEHOLDERS

The most relevant stakeholders for this Action (e.g. national, supranational and non-governmental organizations, coastal communities and national or local agencies involved in marine governance, fishery or coastal management) were consulted during the building of this proposal. Some already agreed to participate in its activities and we aim to increase their numbers at the launch of SEA-UNICORN. During the four years of the Action, these varied stakeholders will be invited to inform MFC scientists about their missions and specific needs (see 4.1.1 and Fig. 1). In return, they will be taught a basic understanding of the main scientific methods to study MFC, so they know their advantages and disadvantages and can make a better use of the associated data. This will promote appropriate data use by stakeholders and help MFC scientists plan their studies to generate datasets that can be more easily and effectively applied to decision making (at the local and global scale). To further foster knowledge exchange between MFC scientists and stakeholders and to expand the range of end-users involved in the improvement of MFC data and its use, the SEA-UNICORN website will include online forums dedicated to specific management issues for scientists and stakeholders to share ideas, information, and new reports/publications (see 3.2.2). Finally, dissemination of the knowledge gained during the Action will be designed to target several audiences. For example, given that MFC includes transboundary connections with freshwater, estuarine and coastal lagoon habitats, some of the data gathered will be of interest for stakeholders involved in river basin or littoral management. The outcomes of SEA-UNICORN should thus be relevant for the implementation of the EU Integrated Maritime Policy (IMP), the Marine Strategy Framework Directive (MSFD), as well as the Water Framework Directive (WFD) and the Habitats Directive (HD). To promote effective knowledge transfer across a wide range of stakeholders, contacts with the Management Committees of the concluding COST Actions OceanGov and MarCons (both aimed at bridging the gap between science and policy makers in Europe) will be initiated during the first year of the Action. We will build on their experience to ensure that the white papers produced by SEA-UNICORN (see 3.2.2) are relevant for the target audiences and disseminated through the appropriate channels. Given the international scale of this COST Action and the relevance of its outcomes for mitigating climate change effects and optimizing global environmental governance, the UN Environment Agency (UN Environment, in particular the Mediterranean Action Plan), the Food and Agriculture Organization (FAO), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and several international non-governmental organizations (e.g. IUCN, WWF, Oceana) will also be privileged targets in the frame of SEA-UNICORN dissemination activities (see WG4 in 4.1.1).

2.2.3 MUTUAL BENEFITS OF THE INVOLVEMENT OF SECONDARY PROPOSERS FROM NEAR NEIGHBOUR OR INTERNATIONAL PARTNER COUNTRIES OR INTERNATIONAL ORGANISATIONS

As stated above (see 2.2.1) experienced researchers from three COST Near-Neighbour Countries (Algeria, Morocco and Tunisia) and two COST International Partner Countries (Australia and the USA) have already joined the SEA-UNICORN network on the principle of mutual benefit. Their addition will greatly strengthen the expertise of the network, as several of these scientists are leading experts in their disciplines. They have agreed to share their valuable methodological and conceptual expertise on MFC and its drivers within the frame of the COST Action and will, in return, benefit from a wide range of complementary skills, experiences and knowledge through their interactions with the other members of the network. These non-european scientists also bring valuable knowledge on other taxa and habitat types, especially in the southern part of the Mediterranean, the Western part of the Atlantic and in the Indian, Pacific and Antarctic oceans. Because many marine resources and ecosystems extend beyond political boundaries, and the interdependency of socio-ecological systems is increasing, only a global approach to marine connectivity will truly allow us to define appropriate conservation measures for our oceans. Advancing MFC understanding therefore undeniably requires trans-disciplinary cooperation at the global scale. The intercontinental and multidisciplinary SEA-UNICORN network is particularly valuable with this regards, as it encompasses an unprecedentedly broad range of experience and skills in MFC research, covering all phylum and eco-regions, as well as expertise in national and international ecological management covering all continents and oceans. This will place Europe in a leading position for driving international research and innovation in the field of MFC and providing sound advice for marine management and policy setting worldwide.

3 IMPACT

3.1 IMPACT TO SCIENCE, SOCIETY AND COMPETITIVENESS, AND POTENTIAL FOR INNOVATION/BREAK-THROUGHS

3.1.1 SCIENTIFIC, TECHNOLOGICAL, AND/OR SOCIOECONOMIC IMPACTS (INCLUDING POTENTIAL INNOVATIONS AND/OR BREAKTHROUGHS)

SEA-UNICORN should significantly impact science, technology and socio-economy, in Europe and beyond (Fig.1). In terms of science, it will create unprecedented multi-, inter- and trans-disciplinarity to MFC research, and thereby lead to important conceptual and knowledge advances, not only in MFC science but also in diverse complementary research fields that investigate ecosystem functioning and evolution (e.g. biogeography, functional ecology, ecological stoichiometry). In particular, the Action will provide new insights into the role of MFC in the evolution of communities, ecosystems and bio-geochemical fluxes at sea and at the sea-continent interface, as well as into its importance for spatio-temporal dynamics of socio-ecological systems. From a technological point of view, SEA-UNICORN will substantially improve methods to assess MFC. It should produce new estimates of lifetime movement (i.e. new functional 'traits' based on connectivity) at individual, population, species, guild, taxon and community levels. Combining these estimates with descriptors of ecological function (e.g. trophic position) will help refine the ecological roles that organisms play in meta-ecosystems, both at sea and at the sea-continent interface. The absence of such estimates currently impedes our understanding of the levels of interdependencies among species and ecosystems, which is essential if we are to predict the consequence of habitat and species loss at sea. Finally, from a socio-economic point of view, the Action will promote capacity building among European scientists and stakeholders, strengthen knowledge transfer and public awareness of marine issues, and promote better policy through science. The many interactions scheduled between the scientists and stakeholders involved in the Action network (see 4.1.1) will ensure that future MFC knowledge is practical enough to be integrated into decision-making tools for management and policy. The activities of the Action's WG4 (see 3.2.2 and 4.1.1) and WG3 (see 4.1.1) will also ensure that the importance of MFC knowledge is widely understood and accepted, not only by marine stakeholders and end-users (e.g. fishing communities), but also by society at large. This will help national and international entities implement strategies that address urgent challenges to marine governance and management, thereby contributing to long-term human well-being.

3.2 MEASURES TO MAXIMISE IMPACT

3.2.1 KNOWLEDGE CREATION, TRANSFER OF KNOWLEDGE AND CAREER DEVELOPMENT

SEA-UNICORN will generate valuable new knowledge, both fundamental and applied, and facilitate knowledge transfer among research disciplines, end-users and countries (see 4.1.1), resulting in important impacts on science, technology and socio-economy, in Europe and beyond (see 3.1.1). In terms of knowledge creation, the Action will greatly advance MFC research through the development of (1) a new conceptual and methodological framework to study connectivity at sea, and (2) a suite of comprehensive, universal MFC descriptors (WG1). Moreover, because the tools developed within the course of the Action will specifically aim at facilitating the uptake of MFC data by other scientific communities, SEA-UNICORN will contribute to the emergence of pioneering transdisciplinary research fields (WG2), placing Europe at the forefront of marine ecology research. The knowledge generated by the Action will contribute to improving our understanding of population, species and ecosystem interdependencies, both in the ocean but also at the ocean-continent interface. The Action will also contribute to knowledge transfer within and across disciplines by stimulating discussion, exchange of ideas and methods between MFC scientists, and by funding capacity building STSMs for early carrier scientists and stakeholders (see 4.1.1). This will provide SEA-UNICORN participants with unprecedented career development opportunities via international and interdisciplinary collaborations. As these interactions will also foster the co-supervision of PhD students and post-doctoral fellows, the Action will also allow young MFC scientists to reach true multidisciplinarity in this field. This will contribute to the emergence of a new, more efficient, generation of MFC scientists, accomplished enough in various research fields to tackle tomorrow's challenges regarding Blue Growth and the international governance of the seas. Besides, one of the main ambitions of SEA-UNICORN is to ensure that MFC research is needs oriented and policy-relevant (WG3), and that the importance of MFC knowledge is widely acknowledged, not only by marine stakeholders, but also by the public at large (WG4). The Action therefore aims to significantly contribute to the transfer of knowledge from Academia to Society. Thanks to its comprehensive dissemination plan (see 3.2.2), SEA-UNICORN will increase global awareness of MFC and its importance for preserving ocean biodiversity and ecosystem services (WG4). The Action will also facilitate MFC data uptake by a wide range of stakeholders (see 4.1.1 & 2.2.2) and provide a much-needed forum for dialogue between MFC scientists, policy-makers and stakeholders implementing new marine management strategies (see 3.2.2). This will generate new collaboration opportunities between Academia, Policy and stakeholders that have hitherto worked in isolation on closely-related problems, and catalyse the implementation of research-based policies at all levels of marine management and governance.

3.2.2 PLAN FOR DISSEMINATION AND/OR EXPLOITATION AND DIALOGUE WITH THE GENERAL PUBLIC OR POLICY

SEA-UNICORN places a strong emphasis on disseminating outcomes in order to maximize the impact of the Action (Fig. 1). As detailed below, we will catalyze knowledge transfer from Academia to Society by popularizing MFC concepts and methods and increasing public awareness about the ecological and economic importance of MFC knowledge. During the first three months of the Action, a strategic plan for the dissemination and exploitation of the Action's outcomes will be established and a Science Communication Manager will be elected to help leading the Working Group (WG4) that will oversee its application. The plan will include the following science communication tools:

- Website/social media networks: the Action website will provide open access non-confidential information on the project (objectives, structure, participants and news) along with links to MFC-relevant publications and educational materials (e.g. explanatory cartoons) produced during the Action. It will also provide the indispensable online platform for exchanges among Action participants, using password-protected forums to allow sharing of ideas, bibliography or MFC data, as well as forums dedicated to specific management or MFC issues to connect scientists and end-users. Social media networks (e.g. Twitter, Facebook, Instagram) will also be used for wider and more active dissemination and discussion. Finally, to promote global learning on MFC, a Massive Open Online Course (MOOC) will be produced to be hosted by a non-profit open-source educational platform (e.g. fun-mooc.fr).

- Peer-reviewed publications: SEA-UNICORN's participants will publish the results obtained from the Action activities, particularly those gathered through the Action STSMs. All the collaborative review/opinion papers written jointly as WG deliverables will be open access (a budget will be secured to that end).

- International conferences/seminars: a Final Action Dissemination event will be organized to publicize the Action outcomes to relevant international communities of scientists and stakeholders. Early Career Investigators will be encouraged to present MFC results at large conferences in Europe and beyond. Additionally, Action scientists frequently participate in large international meetings where they are committed to promoting the results and products of the Action.

- Dissemination to the end-users: SEA-UNICORN's outcomes will be shared with the stakeholders via the publication of white papers. The MFC data compiled or generated by the Action participants will also likely be published on the World Data Center PANGAEA (pangaea.de) and added to databases of recent initiatives aimed at describing global patterns in species connectivity, which until now have been largely restricted to terrestrial species, e.g. the MiCO project (mgel.env.duke.edu/mico), the ICARUS initiative (icarusinitiative.org) or the Migratory Connectivity Project (migratoryconnectivityproject.org). Lastly, the workshops planned in WG3 (see 4.1.1) will ensure that SEA-UNICORN's stakeholders and end-users can start implementing new tools and findings in a timely manner.

- Articles in newspapers or dedicated magazines: At the start and end of the Action (as well as following significant breakthroughs), press releases will be used to publicize the Action and its outcomes across multiple media outlets (e.g. Nature, New Scientist, CNRS journal).

4 IMPLEMENTATION

4.1 COHERENCE AND EFFECTIVENESS OF THE WORK PLAN

4.1.1 DESCRIPTION OF WORKING GROUPS, TASKS AND ACTIVITIES

The coordination, implementation, management, and dissemination of SEA-UNICORN activities will be under the responsibility of the Action Management Committee (MC). To facilitate achievement of the SEA-UNICORN objectives (5 RCO and 8 CBO, see 1.2.2), the tasks will be allocated to three complementary Working Groups (WG), each with specific activities and deliverables. Communication and dissemination activities (see 3.2.2) will be under the responsibility of a cross-cutting WG(WG4) composed of both scientists and stakeholders and at least 1 representative of WG1, WG2 and WG3.

WG1: Improving knowledge on MFC and its drivers

The goal of this WG (RCO 1 & 2, CBO 1 to 6) is to compile and compare MFC information from a wide range of taxa, eco-regions and methods and to provide a general conceptual and methodological framework to integrate data across disciplines. To this aim, WG1 will critically evaluate the current state of knowledge on MFC (including at the sea-continent interface) and its evolution in the face of global environmental change. It will unify concepts and approaches to harmonize MFC research across disciplines and allow a more efficient use of resources at all levels (from sampling to results exploitation). Finally, it will seek to build comprehensive standardized MFC descriptors, applicable to diverse taxa, regions and habitats and encompassing the lifetime movements of marine organisms.

WG1 specific tasks (T) include:

T1.1: Reviewing empirical knowledge from all disciplines involved in MFC assessment.

T1.2: Identifying critical gaps and bottlenecks in MFC knowledge, establishing priorities for future investigations and proposing international strategies to address them.

T1.3: Evaluating and compiling present knowledge on the impacts of environmental stressors linked to climate change (e.g. temperature rise) and anthropogenic activities (e.g. fishing) on MFC.

T1.4: Investigating the role of inter-specific interactions in controlling MFC, in particular the importance of trophic interactions and the influence of macro-organism connectivity on micro-organisms dynamics (e.g. the spread of pathogens by invasive species).

T1.5: Improving the theoretical framework for evaluating MFC by unifying concepts and approaches across disciplines.

T1.6: Improving the technical framework for assessing MFC, in light of recent methodological break-throughs in fundamental connectivity and ecology research, to integrate data across disciplines and produce more comprehensive and universal MFC descriptors.

Expected activities (A) include:

A1.1: 4 annual meetings (duration: 1-2 days) gathering people with expertise spanning all relevant MFC research disciplines, taxonomic groups, habitats and eco-regions, to discuss new developments in MFC research, allow comparative analysis of results, assemble empirical MFC knowledge to expand international databases on connectivity (see 3.2.2) and propose strategies for addressing critical knowledge gaps and methodological bottlenecks.

A1.2: 3 methodological workshops (duration: 1 day) to familiarize MFC scientists with pioneering techniques or modeling tools for studying MFC, contribute to the development of new statistical tools and investigate their respective value by applying them on a set of case studies.

A1.3: 2 conceptual thinking workshops (duration: 1-2 days) to educate MFC scientists about pioneering concepts to study connectivity (from network science, socio-ecology, spatial ecology and/or continental connectivity) and build on them to unify concepts and approaches between the varied disciplines investigating MFC.

A1.4: 4-6 training schools (duration: 2-3 days) in varied research fields to promote understanding among MFC scientists, facilitate methodological exchange between disciplines and disseminate MFC knowledge to stakeholders. Organized by experts in each field (e.g. geneticists), they will aim to teach 10-30 participants from other fields the basic information required to collect, understand

and critically exploit the MFC-relevant results produced by their discipline. They will be open to stakeholders (1-10) and designed to promote geographical and gender balance in MFC research.

A1.5: 5-10 Short Term Scientific Missions (STSMs), targeting early career scientists, to start addressing gaps in MFC knowledge and foster the development of integrative statistical methods that allow simultaneous analysis of large MFC datasets from various fields.

Expected deliverables (D) include:

D1.1: Scientific review papers (at least 2, open access) on the current knowledge on MFC, its drivers and its sensitivity to Global Change.

D1.2: Scientific opinion/perspective papers (at least 2, open access) identifying critical knowledge gaps and bottlenecks in MFC Science and providing recommendations on how to address them.

D1.3: Scientific methodological papers (at least 1, open access) on new MFC descriptors, and the methods used to produce them.

D1.4: Publication of MFC data from all research disciplines in appropriate online databases.

WG2: Incorporating MFC knowledge into forecasting

The goal for this WG (RCO 2 & 3, CBO 1 to 6) is to contribute to the development of projection models that integrate MFC data (at sea but also at the sea-continent interface) to predict the vulnerability of marine populations, communities, and ecosystem services to environmental change, in order to better anticipate the evolution of MFC, marine biodiversity, and related socio-ecological systems. To allow this, WG2 will foster the integration of concepts and methods between MFC scientists and complementary research fields (e.g. theoretical ecology, functional ecology, biogeography, socio-ecological system science) to help produce operational MFC data to use in innovative demographic, food-web, ecosystem and stoichiometric models currently developed in the emerging disciplines of seascape genetics, spatial ecology, and ecological stoichiometry.

WG2 specific tasks (T) include:

T2.1: Fostering integration of methods/ ideas across the complementary research fields listed above.

T2.2: Evaluating the diverse data types currently produced to describe MFC (e.g. in terms of taxonomic, spatial or temporal precision), assessing their respective value for understanding/predicting resource and/or ecosystem dynamics and proposing international strategies to improve and integrate them.

T2.3: Integrating the new MFC descriptors developed in WG1 (e.g. lifetime dispersive areas) to produce standardized MFC functional traits applicable at population, species, guild and community levels.

T2.4: Relating these MFC traits to other relevant traits (e.g. trophic position, body size) to better reflect species' functional niche and their roles in material flows, at sea and at the sea-continent interface.

Expected activities (A) include:

A2.1: 4 annual meetings (duration: 1-2 days) gathering scientists from all MFC disciplines and modelers to discuss new developments, propose strategies for incorporating the new MFC descriptors developed by WG1 into forecasting, and identify case studies to evaluate their respective value.

A2.2: 2 conceptual thinking workshops (duration: 1-2 days) to initiate MFC scientists to the pioneering theoretical frameworks emerging in other research fields (e.g. spatial ecology, ecological stoichiometry) and discuss their application to MFC science.

A2.3: 2-3 methodological workshops (duration: 1-2 days) to teach 10-30 MFC scientists the basic data requirements and methodologies of each complementary research field (e.g. functional ecology, socio-ecological system science) and familiarize them with new modeling tools and techniques (e.g. those developed in network science and spatial ecology).

A2.4: 1-5 STSMs, targeting early career scientists, to develop new projection models integrating MFC data to better anticipate the response of marine resources and ecosystems to global change.

Expected deliverables (D) include:

D2.1: Scientific reports (at least 2) presenting methods to improve the evaluation of marine populations/species inter-dependencies and functional roles, including the definition of functional guilds based on species movements across marine meta-ecosystems, and the integration of multi-disciplinary MFC descriptors into meta-population, meta-community and meta-ecosystem models.

D2.2: Scientific opinion/perspective papers (at least 2, in open access) on how to better integrate MFC science into predictive models of species distributions, ecosystem dynamics and ecosystem services (e.g. fisheries, organic matter fluxes) to evaluate changing socio-ecological systems.

D2.3: Scientific methodological papers (at least 1, in open access) proposing improvements of MFC descriptors to allow including MFC knowledge into forecasting models.

WG3: Producing relevant MFC data for management and policy-making

The goal of this WG (RCO 2, 4 & 5, CBO 7 & 8) is to ensure that future developments in the field of MFC are policy-relevant and needs-oriented, and that the scientific information produced is operative and communicated effectively to a wide audience of stakeholders and end-users. For this, WG3 will encourage stakeholders to translate the improved knowledge gained in WG1 and WG2 into fit-for-purpose science, and provide practical advice for ecosystem or resource managers and national and international policy-makers. By defining the policy and management context in which MFC science needs to operate, WG3 will also play a fundamental role in determining the direction and scope of work performed by the other two WGs.

WG3-specific tasks (T) include:

T3.1: Developping strong interactions between the scientists (e.g. geneticists, ecologists, modelers) and the multiple-level stakeholders involved in the production and the use of MFC information.

T3.2: Identifying the specific knowledge needs of the varied stakeholders (e.g. ecosystem managers, national and international policy makers) in each domain of marine management and governance (e.g. fishery management) and the specific ways in which MFC knowledge can inform them.

T3.3: Evaluating the strengths and uncertainties of available MFC data and prediction models, and developing approaches to integrate them with specific management or policy needs.

T3.4: Producing operational MFC knowledge, in a suitable format for supporting decision taking for the management and conservation of the seas, at the local or international scale.

T3.5: Ensuring that marine stakeholders and end-users in Europe (and beyond) are aware of the central role played by connectivity in the functioning of marine ecosystems and of the importance of using robust MFC knowledge for backing management decisions and policies for the seas.

Expected activities (A) include:

A3.1: 4 Annual Meetings (duration: 1-2 days) to evaluate the strengths and uncertainties of the MFC data and forecast models available to answer each specific management or policy needs, discuss new methodological developments and propose strategies for using the information from WG1 and 2 to inform management and conservation planning processes.

A3.2: 3 Transfer of knowledge Workshops (duration: 1-2 days, open to all participants) on marine policy/management objectives and on knowledge requirements for effective decision making in these areas. Involving varied experts in marine management and governance in Europe, these workshops will help MFC scientists to gain a better understanding of the current legal and policy frameworks and familiarize them with the specific MFC knowledge needs of marine managers and policy makers.

A3.3: 4-6 Practical Workshops (duration: 1-3 days). Co-organized by a relevant subset of scientists and stakeholders, each will focus on a key management issue related to the soundness of MFC estimates (e.g. fisheries management, marine spatial planning, control of invasive species). Their aim will be to familiarize 10-30 multi-disciplinary MFC scientists about this particular issue and organize brainstorming sessions on how to produce accurate and effective MFC estimates to address it.

A3.4: 1-5 STSMs, targeting early career stakeholders or scientists, to develop new decision-making tools allowing to incorporate MFC knowledge in marine resource and ecosystem management.

Foreseen deliverables (D) include:

D3.1: Scientific reports (1-3) identifying gaps in MFC knowledge that are currently impeding decision making in different areas of marine management or policy (e.g. marine spatial planning, fisheries management, control of invasive species) and proposing guidelines for improving MFC assessments to address the specific needs of each domain.

D3.2: White papers (at least 2) to inform marine managers and policy makers about existing MFC descriptors, and their respective value for varied planning and governance needs (e.g. fishery man-agement, MPA design, coastal ecosystem management, sustainable aquaculture).

D3.3: Scientific opinion papers (at least 2, in open access) on how to better integrate MFC science into marine governance and marine resource management in Europe and beyond.

WG4: Promoting awareness on MFC and its ecological and economic importance

Under the supervision of the Science Communication Manager, this cross-cutting WG will comprise both scientists and stakeholders, and include, among others, the Action's Chair and Vice-Chair plus at least one representative of WG1, WG2 and WG3. It will have the responsibility of supervising the implementation of all communication and dissemination activities planned in the frame of the action (see 3.2.2). By promoting the transfer of the knowledge gained over the course of the Action to a wide audience (including scientists, stakeholders, end-users and the wider public), WG4 will play a key role in promoting global awareness on MFC's ecological and economic importance and its implementation in decision-making processes for management and policy.

WG4-specific tasks (T) include:

T4.1: Launching the Action’s website and supervising its implementation to make sure that it offers access to relevant and up-to-date MFC knowledge and associated decision support tools (either produced by the three other WGs or through access to existing online databases).

T4.2: Helping the Action Chair to organize the Action general kick-off meeting in the form of an international workshop (see 4.1.2). This official launching event will gather up to 50 participants from varied countries, including all Core Group members. It will be hold to communicate and discuss the action plan validated during the MCM1 and organize its implementation by engaging the right people in each working group and spreading the workload among them.

T4.3: Regularly issuing press releases about the Action's activities/outcomes and communicating about it on social networks.

T4.4: Overseeing and assisting all communication and dissemination activities planned in the other WGs, including the production of educational videos on MFC and its role in shaping the biodiversity and productivity of the seas.

T4.5: Supervising the organization of the Final Action Dissemination event in the form of a high profile international conference (see 4.1.2).

Expected activities (A) include:

A4.1: 7 Semestrial Meetings (duration: ½ to 1 day) to evaluate the progress made by the three other WGs regarding the Action Dissemination Plan (see 3.2.2), exchange about possible new communication tools, organize the production of press releases, coordinate activities linked to international conferences/seminars and propose strategies for optimizing knowledge and expertise dissemination by WG1, 2 and 3.

A4.2: 1 training school (duration: 1-2 days, open to 10-20 participants, with priority to WG leaders) on MFC science communication and engagement. Involving external experts in science communication, this workshop will help empowering the Action's researchers, managers and policy makers (especially WG leaders) to build the communication skills, networks, and relationships they need to successfully communicate SEA-UNICORN outcomes to any audience.

Foreseen deliverables (D) include:

D4.1: Launch and regular update of the SEA-UNICORN's website.

D4.2: Report on the strategy adopted under task 4.2 (during the Action general Kick-off meeting) communicated to all SEA-UNICORN participants.

D4.3: Press releases (at least one per Grant Period) on the Action's activities and outcomes.

D4.4: Educational videos (including a MOOC) to popularize MFC Science and inform the wider public of the importance of gathering sound MFC knowledge for the sustainable management of the seas.

D4.5: 1 high profile international conference on MFC (Final Action Dissemination event, see 4.1.2).

4.1.2 DESCRIPTION OF DELIVERABLES AND TIMEFRAME

The Action Management Committee (MC) will be established at the start of the Action and meet at least once per year, to monitor the Action's progress towards its objectives (RCO & CBO, see 1.2.2) and supervise the allocation and use of COST funds. All WGs will operate in parallel during the four years of the Action, but regular interactions are planned among them. Indeed, each WG will have its own meetings (see 4.1.1 & 4.1.4) to organize its activities (A), address its tasks (T) and meet its deliverables (D), but work coordination across WGs will be provided via semi-annual meetings of WG leaders and by annual cross-group meetings open to all participants. For the efficient use of the budget, cross-group meetings and key workshops will be combined with MC annual meetings and videoconference will be used for semi-annual meetings. In terms of timeframe (see 4.1.4), the network management, the gathering and online storage of MFC data (D1.1 & D1.4) and the dissemination/sharing of knowledge through the SEA-UNICORN website (CBO-2, 7 & 8, D4.1) will take place over the four years of the Action. The other activities will be structured as follows.

Year 1 will be dedicated to the launch of the Action, WG consolidation and initiation of multi-, inter- and trans-disciplinary collaboration. During its first meeting, the MC will elect WG leaders (2 per WG), with at least two key positions reserved for ITC representatives (CBO-4). The MC will also establish a Science Communication Manager, responsible for creating and launching the SEA-UNICORN website (D4.1) and overseeing the Action communication strategy with the support of WG4 (CBO-8, see 3.2.2 and 4.1.1). The first press releases will also be made (D4.3). The Action general kick-off meeting (T4.2) will take place during the first 6 months of the Action and bring together up to 50 participants from varied countries (including all Core Group members). On this occasion, the first meetings of all WG (A1.1, 2.1, 3.1 & 4.1) will be hold to identify the groups of experts in charge of (i) leading the review on the current state of MFC knowledge and its drivers (T1.1, 1.2 & 1.3), (ii) leading reflections on the incorporation of MFC data into the evaluation of species inter-dependencies and functional roles (T2.1 and 2.2) and (iii) identifying current gaps in the MFC knowledge needed for decision making in marine management or policy (T3.2 & 3.3). To further spread the workload for each WG among key scientists and stakeholders, the conclusions of this meeting will be communicated to all SEA-UNICORN participants (D4.2), who will be invited to join the varied groups of experts, on a voluntary basis. This first year will also involve multidisciplinary training and sharing of information, expertise and knowledge. WG1, WG2 and WG3 will each organize at least two workshops (A1.2, 1.3, 2.2, 2.3, 3.2 & 3.3), in order to stimulate the exchange of ideas and methods among MFC scientists (T1.2 & 1.3), familiarize them with the needs of resource managers and policy makers (T3.1), inform them about pioneering approaches for studying connectivity (T1.6) and initiate them to emerging theoretical frameworks and methods in complementary research fields (T2.1). WG4 will propose its training school on MFC science communication and WG1 will hold at least two training schools (A1.4) to spread knowledge and understanding among the varied scientists and stakeholders that investigate MFC (T1.5 & 1.6). Lastly, the first STSMs (A1.5, 2.4 & 3.4) will be scheduled, to start addressing gaps in MFC knowledge (T1.2 & 1.4) and facilitating its consideration in marine resource or ecosystem management (T2.2). By the end of the first year, the SEA-UNICORN network should be able to produce its first set of educational materials on MFC (D4.4, see 3.2.2) and start contributing to online databases on worldwide connectivity (D1.4). The Action's first scientific reports will be released: one reviewing the knowledge gaps in MFC Science and how to address them (D1.2), one on promising methods to incorporate MFC data in evaluations of ecosystem inter-dependencies and species functional roles (D2.1), and one on specific MFC knowledge needs for decision making in varied areas of marine management or policy (D3.1).

The 2nd and 3rd years of the Action will be devoted to conceptual and methodological advances, in MFC science and complementary research disciplines. Building on the training and exchanges initiated during Year 1, WG1, WG2 and WG3 will each hold two to five workshops (A1.2, 1.3, 2.2, 2.3, 3.2 & 3.3), aiming to further spread state-of-the-art concepts and methods among MFC scientists (T1.2 & 1.3), fulfilling the needs of resource managers and policy makers in terms of MFC knowledge (T3.1) and facilitating MFC data incorporation into complementary research fields (T1.5 & 1.6). Meanwhile, WG1 will organize two to four training schools (A1.4) to continue promoting mutual understanding and knowledge transfer among MFC scientists and stakeholders (T1.5 & 1.6). Finally, WG and cross-group meetings (A1.1, 2.1, 3.1 & 4.1) will allow Action participants to advance on ways to unify concepts and approaches across disciplines under a general framework for evaluating MFC (T1.5 & 1.6), produce operational MFC data to parameterize forecasting models (T2.3 & 2.4) and provide decision support tools for marine management and policy (T1.5 & 1.6). This will facilitate the development of standardized MFC descriptors for better forecasting changes in marine biodiversity and associated socio-ecological systems (D2.2). STSMs for all WGs (A1.5, 2.4 & 3.4) will also be scheduled to contribute to this aim. These two years will also be largely dedicated to knowledge dissemination (T4.1, 4.3 & 4.4), in particular through publication of scientific papers: on the current state of MFC knowledge and its drivers (D1.1), new MFC descriptors and the methods to produce them (D1.3), and how to improve MFC descriptors to incorporate these data into forecasting models (D2.2 & 2.3). WG3 will also produce scientific reports proposing guidelines for improving MFC assessments address current issues in marine management and policy (D3.1). Finally, WG1 leaders and WG4 will oversee the production of a Massive Open Online Course (MOOC) to increase public awareness about the importance of MFC in ecosystem and resource conservation (CBO-6 & 8, D4.4).

The 4th and final year will be mainly dedicated to the synthesis and dissemination of the Action out-comes (T4.1, 4.2 & 4.3), with a particular focus on the needs of marine stakeholders, end-users and society. During the first part of the year, the last STSMs (A1.5, 2.4 & 3.4) will be scheduled and WG1 and 2 will submit their last scientific papers (D1.2, 1.3, 2.2 & 2.3). WG3 will produce white papers to inform marine managers and policy makers about new MFC descriptors and their value for planning or governance needs (D3.2). WG3 will also generate scientific opinion papers on how to better integrate MFC knowledge into marine governance and marine resource management, in Europe and beyond (D3.3). In addition, the Action MC and WG4 will seek complementary funds to support the Final Action Dissemination event (D4.5), probably in the form of a special session on MFC in an international marine conference open to worldwide scientists and stakeholders. The Action will also organize press releases (D4.3) publicizing the main outcomes across different media outlets (RCO-5 & CBO-8).

4.1.3 RISK ANALYSIS AND CONTINGENCY PLANS

Potential risks for this COST Action, are listed below, together with planned mitigation measures.

- Insufficient participation of scientists from enough countries, limiting the attraction of the Action and its outcomes.

Likelihood: extremely low, given the composition of the Network of proposers for this Action: >50 young (~30%) and senior researchers from 27 countries (22 COST Member countries) encompassing diverse skills and expertise.

Mitigation plan: The Action MC will be able to solve this problem, by encouraging the Network of proposers to invite their most relevant collaborators to join the Action Network.

- Failure of the scientific network to function as a whole or crucial participants leaving the Action (thereby limiting its success).

Likelihood: low, given the critical mass of the Action Network of proposers and because many of the proposers have previously worked together. This has already built trust and reciprocity among them, on which successful networks are based.

Mitigation plan: The Action MC will be able to solve this problem, by building upon previously successful ventures to help formalize relationships between scientists and institutions, as well as forge new ones.

- Insufficient engagement of the stakeholders preventing the use of the outcomes of the Action by policy-makers and end-users.

Likelihood: low, as some stakeholders have already joined the Network of proposers, and several of the proposers have already forged strong links with local industries (e.g. fishery, aquaculture, oil) or already successfully participated in networks encompassing scientists and stakeholders.

Mitigation plan: we will use the professional networks of some proposers to invite more stakeholders to participate in the Action, and propose workshops on specific management issues / resource types to attract them.

- Poor contribution or defaulting of crucial secondary proposer (e.g. WG leader) or conflicts emerging among participants.

Likelihood: low, as several of the proposers have already successfully coordinated multi-disciplinary research projects and organized international events. Many of them have already worked in partnership in the past and all are enthusiastic about collaborating in the SEA-UNICORN framework.

Mitigation plan: two co-leaders will be designed for each WG and the Action MC will be able to address personality clashes, e.g. by deciding on changes in WG leaders or inviting alternative scientists / stakeholders to join the Action.

- Failure to unify all methods under the same framework.

Likelihood: moderate, as conceptual frameworks and statistical methods for this are already being developed.

Mitigation plan: we plan to build on previous successful initiatives in other disciplines. We will also invite scientists that have already developed and used complex statistical tools to share their experience with Action participants.

- Failure to produce relevant and needs-oriented MFC data.

Likelihood: moderate, as varied stakeholders have expressed their interest to participate to the workshops planned in WG3 (see 4.1.1) and several of the scientific Action proposers have already been involved in successful initiatives involving stakeholders.

Mitigation plan: We will build on existing experience in the network to ensure that interactions and discussions between MFC scientists and stakeholders are fruitful and productive. The Action website will also host forums to facilitate communication between scientists and end-users.

- Failure to disseminate the Action outcomes to the targeted audiences or to communicate about the Action.

Likelihood: low, as many of the proposers have extensive experience in science dissemination using varied communication tools.

Mitigation plan: a Science Communication Manager will be elected to coordinate dissemination activities. With the help of the Action MC, he/she will manage the Action DG / WG4 (see 4.1.1) and ensure that the knowledge gathered is appropriately communicated, in accordance with intellectual property rights.

4.1.4 GANTT DIAGRAM

	YEAR 1				YEAR 2				YEAR 3				YEAR 4			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MC activities																
Network coordination	RM		RM		RM		RM		RM		RM		RM		RM	
Meetings		A, CG				A, CG				A, CG				A, CG		
International event organisation		*K*														*F*
Grant Period Reports		*GPR1*				*GPR2*				*GPR3*				*GPR4*		*FR*
WG1 - Improving knowledge on MFC and its driver																
Coordination of activities	RM		RM		RM		RM		RM		RM		RM		RM	
Meetings		A				A				A				A		
Training Schools (4-6)																
Workshops (4-5)		CT, M				CT, M				M?						
STSMs (5-10)																
Redaction of WG Reports		*GPR1*				*GPR2*				*GPR3*				*GPR4*		*FR*
Review/opinion papers writing								*SP*								
Methodological papers writing												*SP*			*SP*	
MFC data gathering				*DB*				*DB*				*DB*				*DB*
WG2 - Incorporating MFC knowledge into forecasting																
Coordination of activities	RM		RM		RM		RM		RM		RM		RM		RM	
Meetings		A				A				A				A		
Workshops (4-5)		CT, M				CT, M				M?						
STSMs (1-5)																
Redaction of WG Reports		*GPR1*				*GPR2*				*GPR3*				*GPR4*		*FR*
Scientific reports writing				*SR*				*SR*				*SR*				
Review/opinion papers writing								*SP*							*SP*	
WG3 - Producing relevant MFC data for management and policy-making																
Coordination of activities	RM		RM		RM		RM		RM		RM		RM		RM	
Meetings		A				A				A				A		
Workshops (7-9)		T, P		P		T, P		P		T, P						
STSMs (1-5)																
Redaction of WG Reports		*GPR1*				*GPR2*				*GPR3*				*GPR4*		*FR*
Scientific reports writing				*SR*				*SR*				*SR*				
Review/opinion papers writing															*SP*	
White papers writing															*WP*	
WG4 - Dissemination and communication																
Coordination of activities	RM		RM		RM		RM		RM		RM		RM		RM	
Meetings		A				A				A				A		
Training School (1)																
Redaction of WG Reports		*GPR1*				*GPR2*				*GPR3*				*GPR4*		*FR*
Online communication	*W*		*W*	*DB*	*W*		*W*	*DB*	*W*		*W*	*DB*	*W*		*W*	*DB*
Article and paper writing	*PR*		*PR*				*PR*	*SP*			*PR*	*SP*			*SP, WP*	*PR*
Educational videos preparation				*V*								*V*				
International event organisation		*K*														*F*

LEGEND:

Activities

- A — Annual meeting with all participants
- CG — Cross-Group meeting with all participants
- RM — Regular meetings (including video conference)
- CT — Conceptual thinking workshop
- M — Methodological workshop
- T — Transfer of knowledge Workshop
- P — Practical Workshop

Milestones & deliverables

- *K* — *General kick-off meeting (international workshop)*
- *F* — *Final Action Dissemination event (international conference)*
- *GPR* — *Grant Period report (4)*
- *FR* — *Final report*
- *W* — *Website update (including feedback forums)*
- *PR* — *Press releases*
- *V* — *Release of educational videos*
- *DB* — *Contribution to online databases*
- *SP* — *Scientific publications*
- *SR* — *Scientific reports*
- *WP* — *White papers*

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