EUROMARINE
EUROPEAN MARINE RESEARCH NETWORK

THE EUROMARINE NETWORK

SUMMARY REPORT ON 2014–2017 ACTIVITIES

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www.euromarinenetwork.eu

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I. History and Concept

Launched in 2014, EuroMarine is *the* European marine science network. It represents the merger of the scientific communities of three former European Networks of Excellence: EUR-OCEANS, Marine Genomics Europe, and MarBEF. It was designed by the EuroMarine FP7 preparatory project (2011–13) as a bottom-up organization and meant to be a voice for the European marine scientific community, promoting the emergence of novel collaborative research topics from genes to ecosystems in changing oceans. It is intended as a durable structure with an initial duration as a consortium of 10 years. A Legal Entity has been established in 2018 as a support structure under the control of the consortium. In 2019, EuroMarine comprises 59 member organisations, 51 of which are 'full voting' members contributing to the annual budget.

The network supports a holistic and interdisciplinary approach to marine research in four priority areas:

- Understanding marine ecosystems for healthy oceans
- Biogeochemistry
- Building scenarios for marine ecosystems under changing oceans
- Marine science as a provider of new concepts for innovation and technology

EuroMarine co-operates with the European Marine Board, JPI Oceans and the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (IBPES). It intends to foster initiatives under the United Nations Decade of Ocean Science (2021–2030). It contributes to translating the objectives of the United Nations Sustainable Development Goals of the 2030 Agenda into actions, and highlights the potential to advance marine research using incentive funding, engaging with stakeholders across all levels.

The primary goals of EuroMarine are to:

- Support the identification and initial development of emerging scientific topics, issues and methodologies
- Foster new services relevant to the marine scientific community.

Accordingly, EuroMarine funds scientific, foresight, and training activities, through its annual competitive calls, bringing teams together to share, collaborate and collectively push boundaries in marine science. Support for these activities and their outcomes are expected to leverage larger projects under European, national or joint research funding programmes.

The wider goals of EuroMarine are to:

- Advocate for marine science and to contribute to the improvement of the science-governance interface, through provision of expertise and transfer of knowledge.
- Increase the visibility of the marine science community at member state, European and international levels.
- Expand recognition of the important role marine science plays in society.
- Maintain Europe's position as a global leader in marine science.

II. Overview of the Activities and EuroMarine Networking Effect

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Beyond yearly General Assembly meetings, EuroMarine networking essentially occurs through its yearly competitive calls and extends in time from the construction and submission of proposals, to funded meetings and working groups, up to subsequent publications, project proposals, other outcomes and lasting collaborations. Occasionally and outside calls, EuroMarine scientists also gather and organise workshops or sessions at the invitation of third parties or a member organisation.

1. Overview of 2014–17 activities

In line with EuroMarine's bottom-up ethos, yearly calls were widely open in terms of topics. Over the 2014–17 period, EuroMarine chose to maximize the spread of the available budget and the number of funded activities; to this end the maximum amount granted to each proposal was limited and co-funding was encouraged. However, whereas EuroMarine occasionally brought complementary funding to existing initiatives (in such cases, to widen participation to EuroMarine members), most funds were directed to new initiatives that would not have existed without EuroMarine funds (see **Figure 1**). In total EuroMarine funded 35 foresight workshops, 13 working groups or workshops, 12 courses and 3 conferences (see **Table 1**).

	Number of applications	Number funded	Success rate	Funds granted
Calls for activity proposals (2014–17)				
FWS: Foresight Workshops – Horizon Scanning	52	**35**	67%	299,984€
WG: Working Groups and Workshops	44	**13**	30%	87,055€
CBT: Capacity Building and Training	27	**12**	44%	78,644€
Conf.: Conferences or Conference Sessions	5	**3**	60%	18,400€
Total	***128***	***63***	*49%*	484,083€
Fellowship programme (2017)				
Grants to attend advanced course chosen by applicant	27	**26**	96%	12,000€
of which, eventually used		**23**	85%	10,067€
Total budget granted				***496,083€***
Total budget actually used				***494,150€***

Table 1. *EuroMarine 2014–17 calls and funded activities in numbers.*

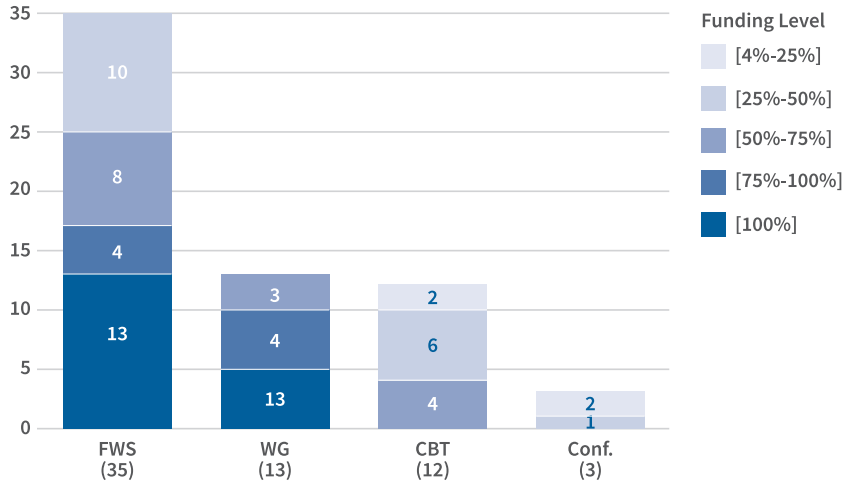


Figure 1. *Number of scientific activities funded by EuroMarine and share of EuroMarine funding in the total (final or planned) budget of these activities, by type: Foresight Workshops (FWS), Working Groups (WG), Capacity Building and Training (CBT), Conferences or Conference Sessions (Conf.). EuroMarine brought over 50% of the budget for 71% of FWS and 100% of WGs. EuroMarine was the sole funder for 37% of FWS and 46% of WGs. Overall, EuroMarine was the sole funder or the major funder bringing more than 50% of the budget in 68% of the 63 activities funded from 2014 to 2017.*

The scientific areas addressed by the 63 funded activities reflect and cover the disciplinary diversity of the network (although physical oceanography, biogeochemistry and biotechnology were under-represented in 2014–17 compared to biology and biodiversity). Most activities had strong interdisciplinary and knowledge transfer facets (see **Figure 3**).

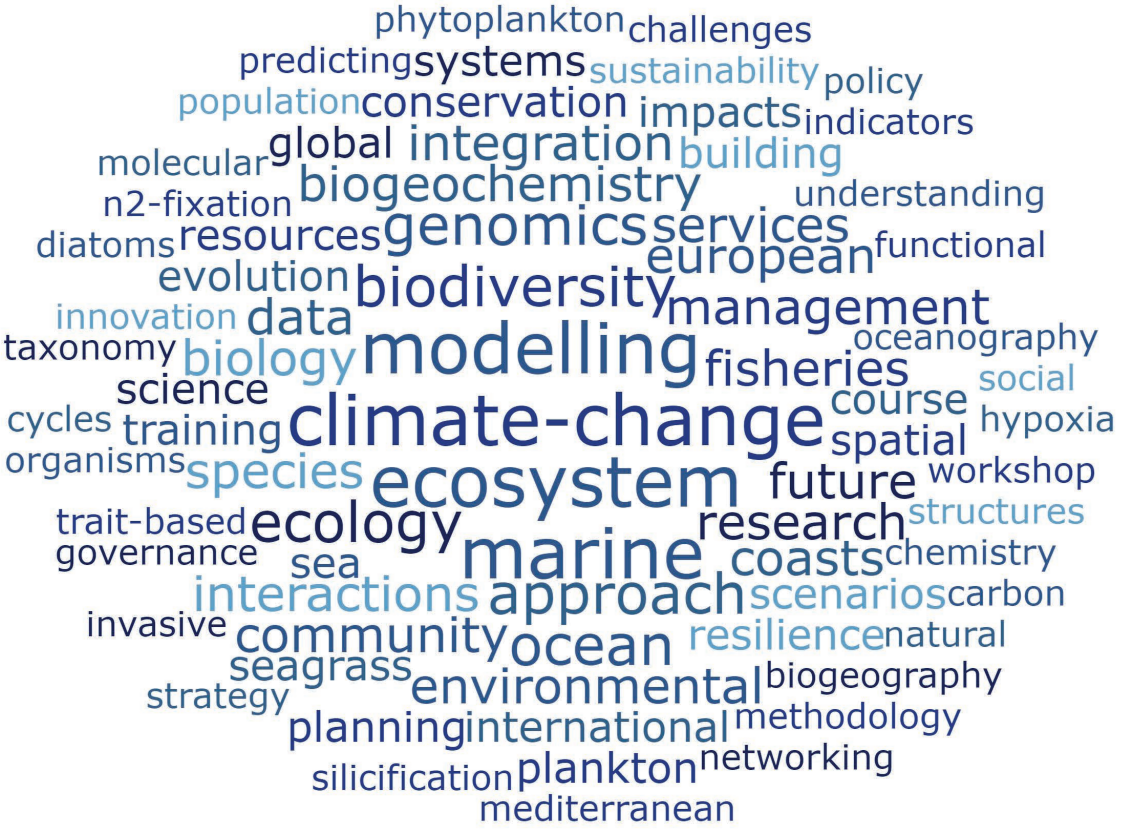
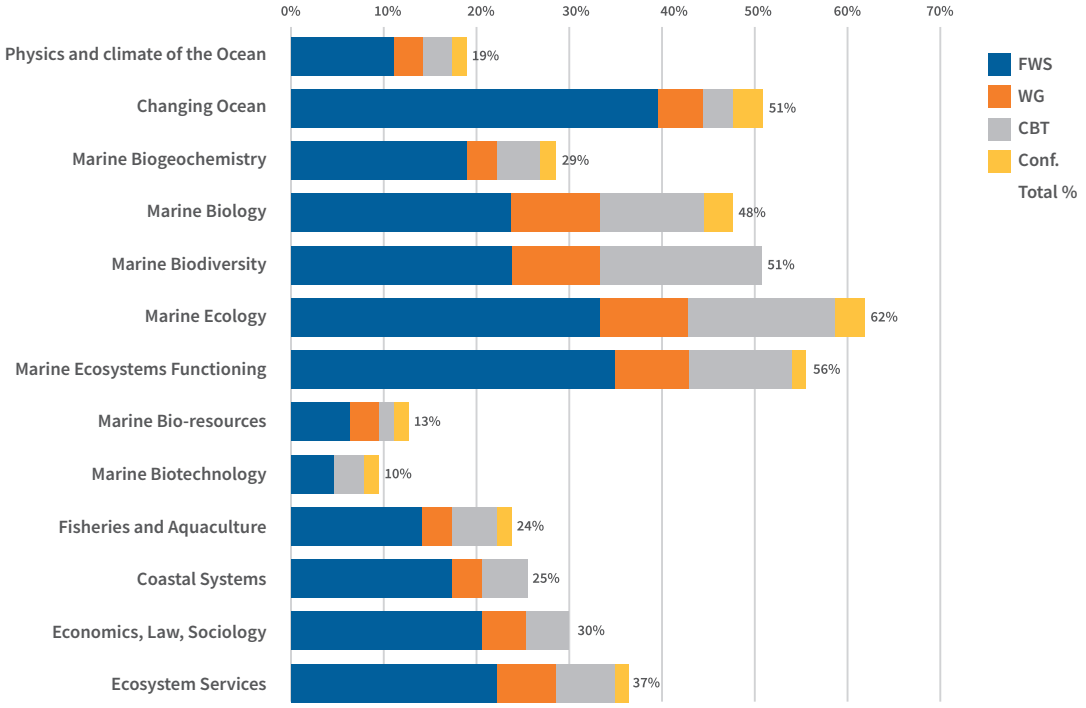


Figure 2. *The most commonly used words from the titles and keywords of EuroMarine-funded proposals from 2014–2017.*

(a) Frequency of broad scientific areas addressed by EuroMarine 2014–2017 activities



(b) Frequency of broad general categories addressed by EuroMarine 2014–2017 activities

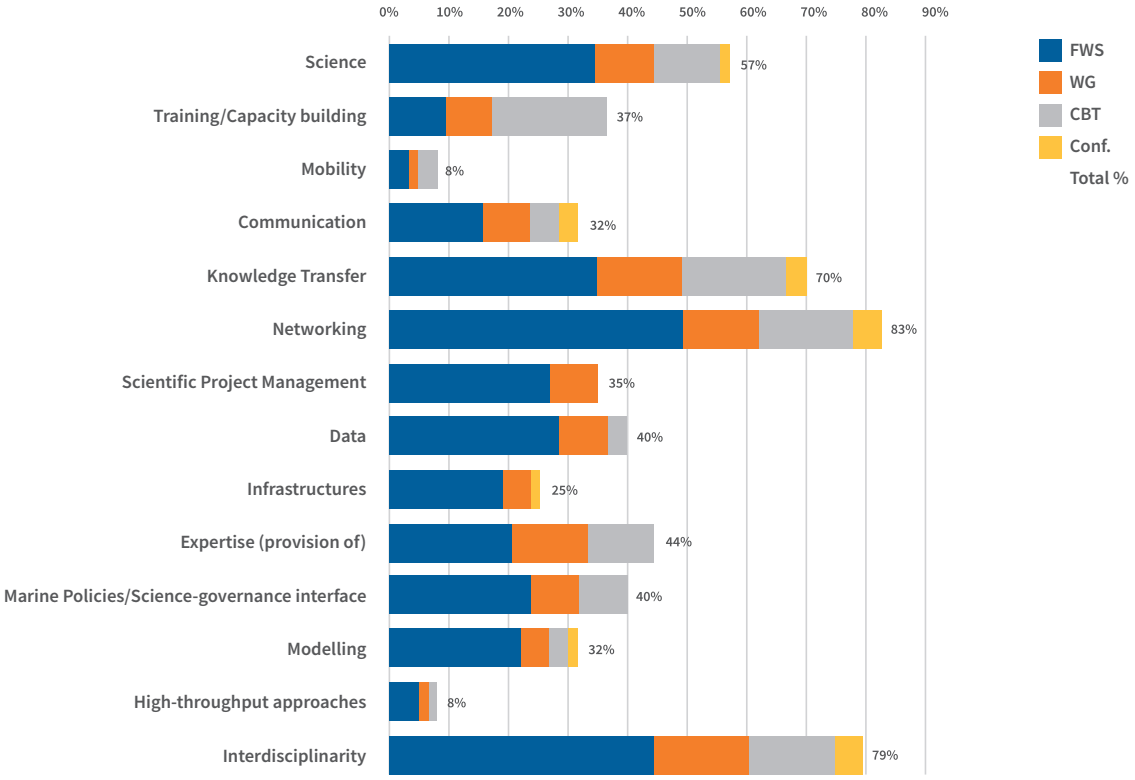
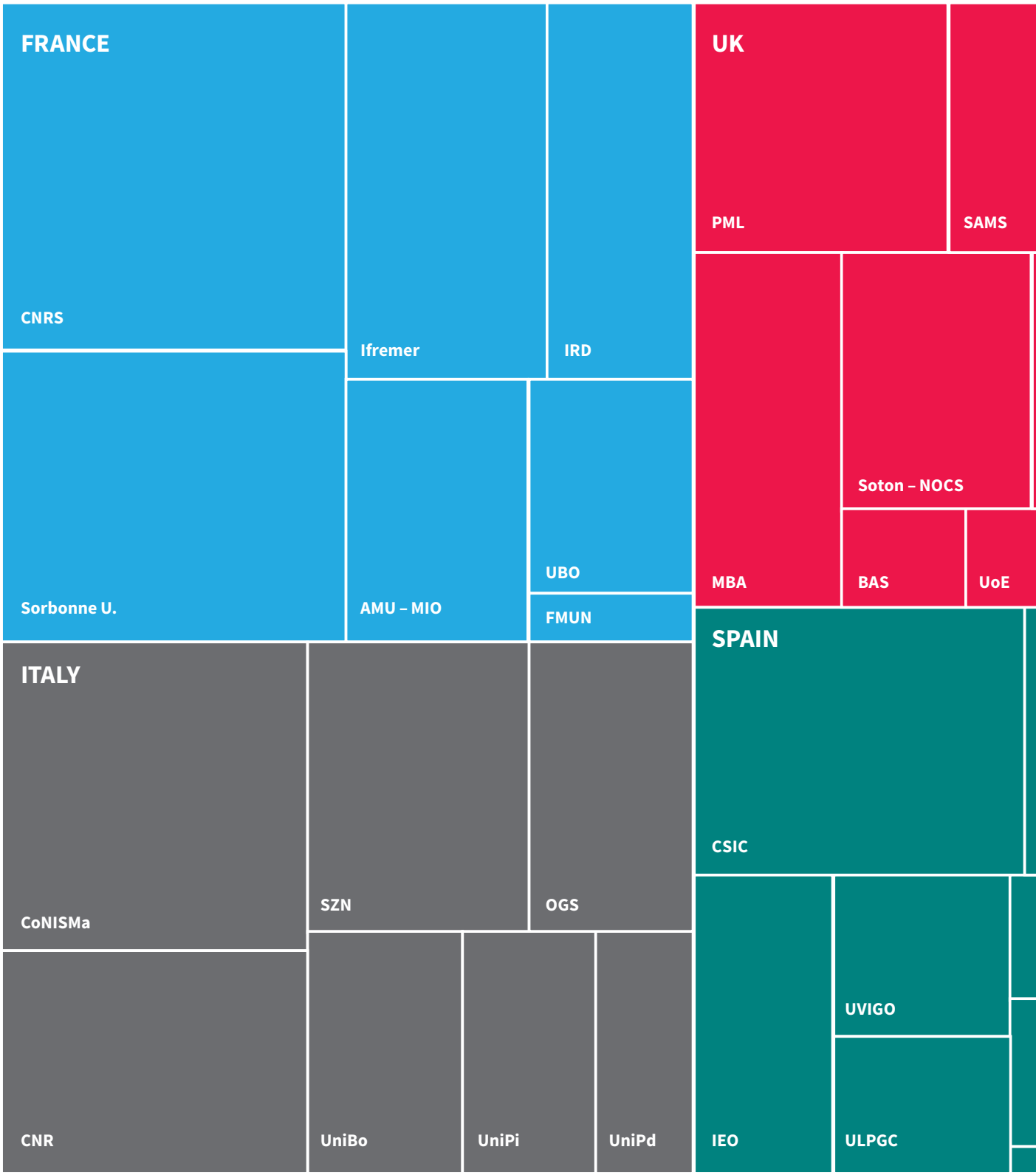


Figure 3. *Frequency with which (a) broad scientific areas or (b) broad general categories were addressed by EuroMarine activities over 2014–17, overall and by activity type: Foresight Workshops (FWS), Working Groups (WG), Capacity Building and Training (CBT), Conferences or Conference Sessions (Conf.).*

2. Internal scientific networking effect

Of 71 organisations that were full members or permanent invited members in 2014–17 (which excludes four organisation that remained transitional invited members over that period), only nine did not participate in any of the 63 proposals funded under the 2014–17 calls. Actual participation in activities however extends well beyond participation in proposals as co-organiser or key participant: considering EuroMarine members only, there were 1281 actual individual participations



in activities, and all but one of the 71 member organisations (a Turkish invited university) eventually participated in at least one activity. On average, a EuroMarine organisation counted with 18.3 individual participations in 8.6 EuroMarine activities.

Figure 4 represents the relative, actual participation of countries and organisations in EuroMarine activities. As expected, countries counting more member organisations and large organisations are preponderant.

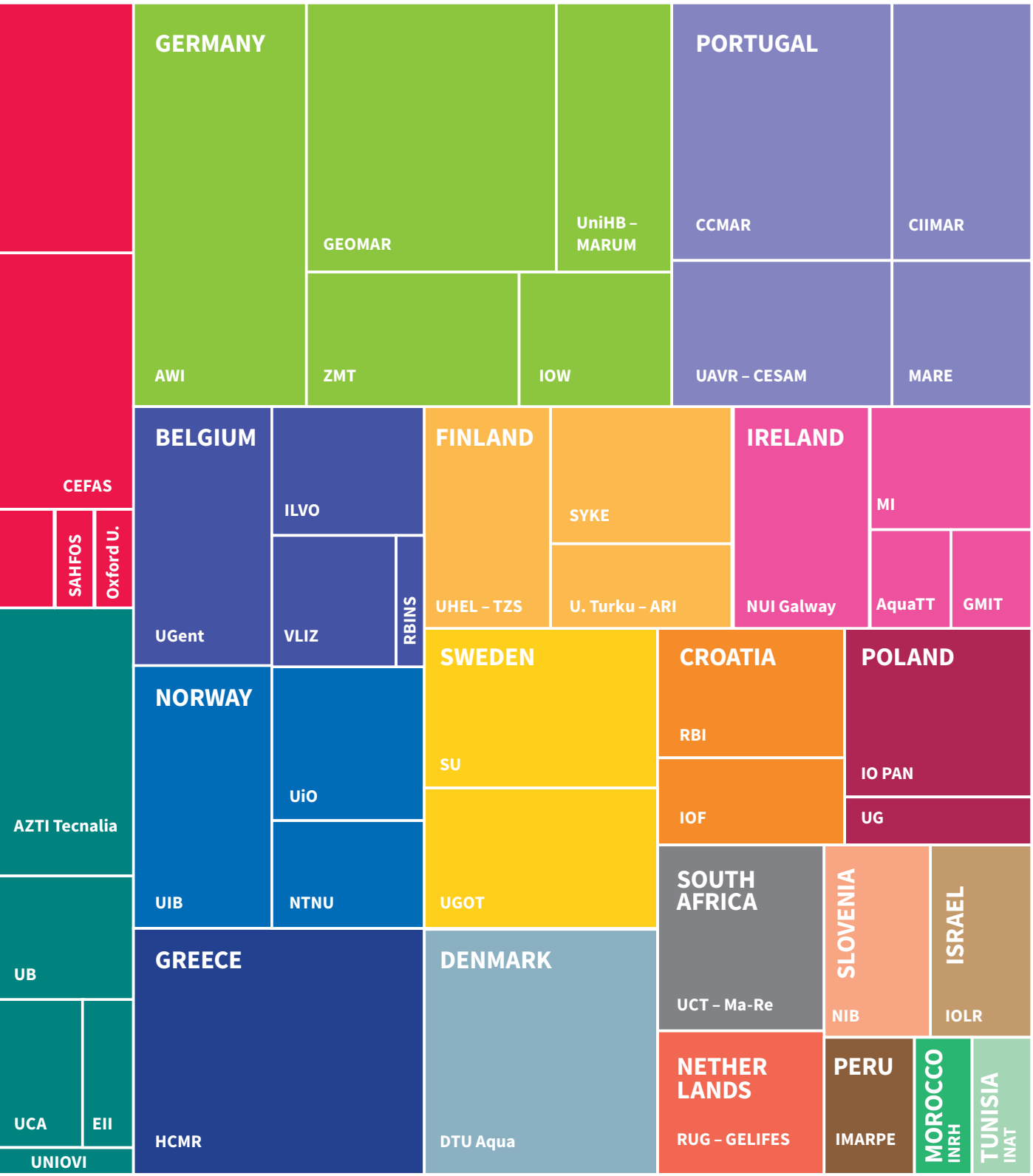


Figure 4. *Relative participation of EuroMarine countries and member organisations in the 63 activities funded under EuroMarine 2014–17 calls. The area of countries and member organisations is proportional to the number of individual, actual participations in EuroMarine activities, as compiled after participant lists and activity reports. Individual participations from member organisations sum up to 1281, with an average of 18.3 participations and 8.6 activities per organisation, and encompass 70 of EuroMarine 71 member organisations in 22 of the 23 EuroMarine countries.*

Figure 5 however provides a different perspective: Firstly, participation is this time measured by the number of activities a given organisation was involved in; secondly, involvements at proposal stage and in actual activities are compared (again showing that participation of EuroMarine organisations in actual activities is wider than in proposals); thirdly, the number of participations of any country was standardized by the number of organisations in that country, thus highlighting relative over- or under-presence of a country as a whole in activities. (Note that as a consequence of this standardization, the areas of organisations are comparable within any given country but not across countries.)

Relative presence of countries in activities (standardized by the number of organisations in each country)

Figure 5. *Relative participation of EuroMarine countries in the 63 activities funded under EuroMarine 2014–17 calls. The number of EuroMarine organisations in each country is shown in parentheses below each country. Each country's participation is here measured by the number of activities its member organisations were involved in, on average. Participation is shown both at proposal stage taking into account co-proposers (left), and as reported by the organisers after the activities were actually carried out (right). The relative contribution of organisations to their country average is shown (but the areas occupied by organisations are not comparable across countries given the chosen representation). This type of representation clearly shows that some countries counting a single member organisation (notably Denmark and Greece) were particularly active and present both in successful proposals and in subsequent funded activities.*

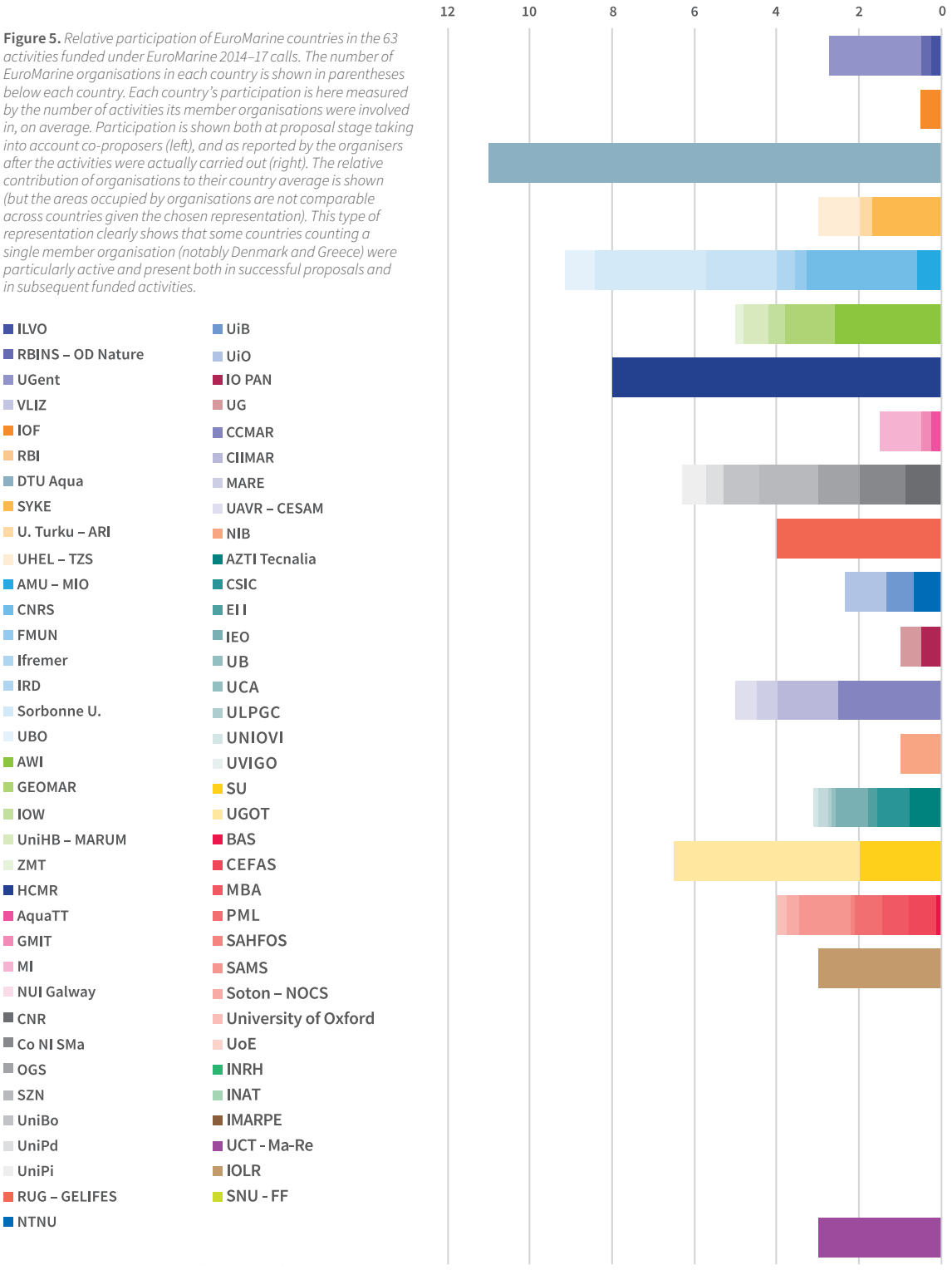
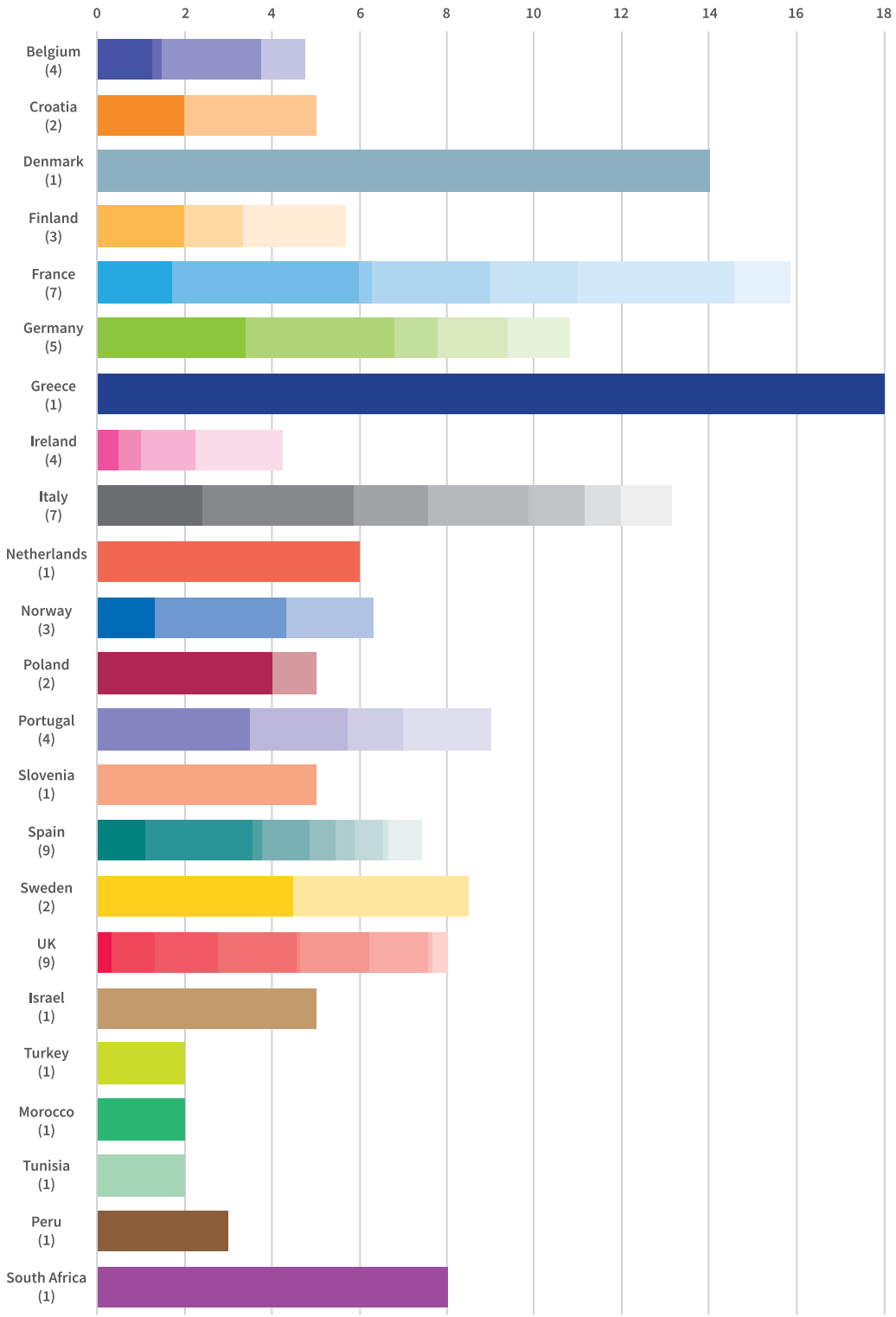


Figure 6 sheds light on the interactions between scientists belonging to different member organisations, through their joint participation in EuroMarine scientific activities. As visually obvious, the overall connectivity of the interaction graph is high; each organisation is on average connected to 40 other EuroMarine organisations (with a median of 42, a minimum of 6 and a maximum of 63). Supplemental graphs that show pairwise interactions separately for each of the 70 member organisations can be consulted at **www.euromarinenetwork.eu/2014_2017_membership_interactions**.



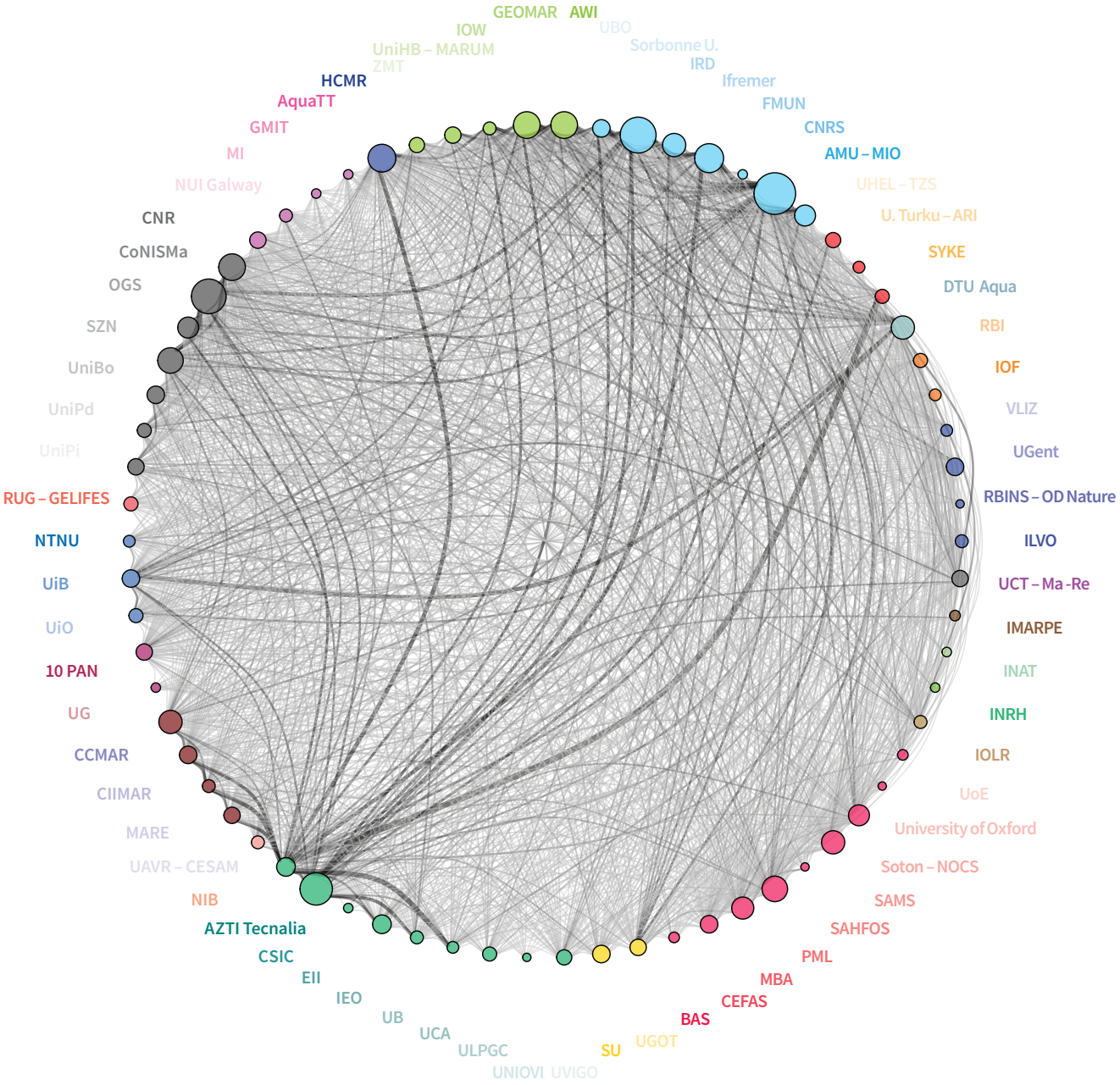


Figure 6. *Interactions between 2014–2017 member organisations through their joint participation in EuroMarine 2014–17 scientific activities. The area of circles representing organisations grows with the number of activities an organisation was involved in. The thickness and darkness of edges connecting two organisations grows with the number of mutual individual interactions made possible by their scientists' joint participation in EuroMarine activities. Similar graphs showing pairwise interactions separately for each of the 70 organisations are available at* ***www.euromarinenetwork.eu/2014_2017_membership_interactions.***

3. External scientific networking effect

While EuroMarine funds return in priority to EuroMarine members, most EuroMarine-funded activities reach well beyond member organisations and countries. Of 63 activities funded from 2014–2017, there were in total 2211 individual participations from 565 organisations in 65 countries. Of these, 1281 (58%) corresponded to full or permanent invited EuroMarine members, 30 (1%) corresponded to transitional invited members or to organisations that joined EuroMarine after 2017, and 900 (41%) to organisations outside EuroMarine. In total 495 external organisations from 64 countries participated in EuroMarine activities (194 organisations from 42 non-EuroMarine countries; and 301 from 22 EuroMarine countries).

Figure 7 represents interactions between EuroMarine organisations (seen as a whole, regardless of their regional location) and non-EuroMarine organisations grouped by world regions. Remarkably, the graph is fully connected (each group node is connected to every other node), meaning that scientists from any two given groups participated in at least one common activity. It is to be noted that such interactions add up to the inter-regional interactions (not represented here) that already occur within the EuroMarine membership: obviously, between European sub-regions; but beyond this and through EuroMarine invited members, with Northern and Sub-Saharan Africa, Latin America and Western Asia.

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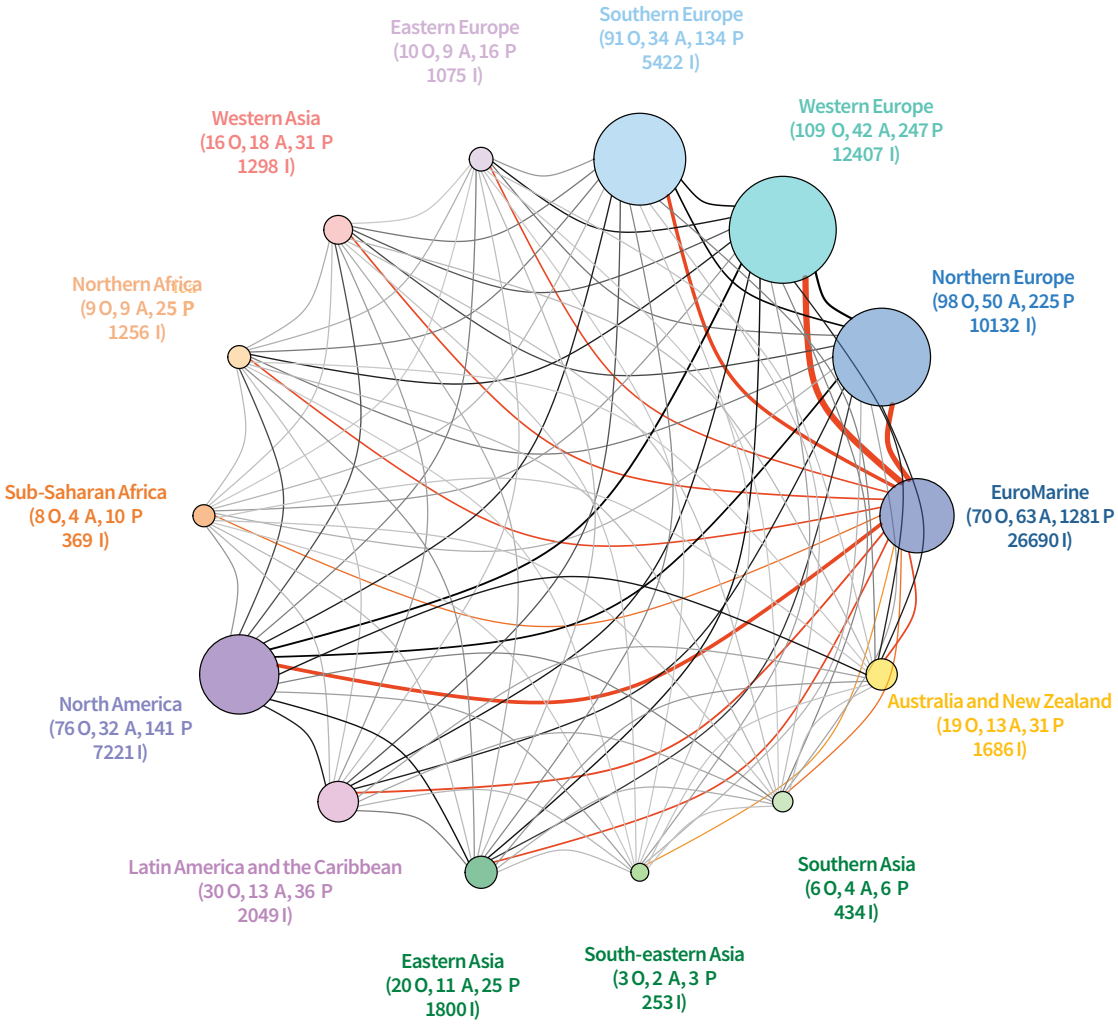

Figure 7. *Interactions between EuroMarine organisations and non-EuroMarine organisations grouped by world regions. The EuroMarine group includes 2014–2017 member organisations, regardless of their regional location. The area of circles representing groups grows with the number of organisations in the group. The thickness and darkness of edges connecting two groups grows with the number of mutual individual interactions made possible by their scientists' joint participation in EuroMarine activities. Group labels provide some indicators for the group: O: number of organisations; A: number of activities organisations from the group participated in; P: number of individual participations in EuroMarine activities (summed over organisations in the group and over activities they were involved in); and I: number of individual interactions between scientists from the group and scientists from all the other groups, as made possible by their joint participation in EuroMarine activities. Similar graphs showing pairwise interactions separately for each of the 14 groups are available at* ***www.euromarinenetwork.eu/2014_2017_regional_interactions.***

4. Network communication

The goal of the EuroMarine communication effort is primarily to raise awareness of the network's objectives, members and activities, and to promote participation and interest in EuroMarine initiatives and research. Recognising that messaging must be tailored to the target audience, EuroMarine communicates across a variety of formats, including through the website, a regular newsletter, social media and press releases.

The primary communication tools are the EuroMarine content-heavy website (**www.euromarinenetwork.eu**) and the bi-weekly newsletter. Through these media, from the website launch on 22 September 2016 to April 2019, EuroMarine has posted 525 announcements of marine science activities, 204 calls for proposals, applications for fellowships, expertise, participation in surveys or other initiatives, and 682 miscellaneous news items including job, training and publication announcements. This dissemination activity is consumed by an engaged audience, with 2,303 newsletter subscribers and nearly a quarter of a million website visits (as of April 2019).

Public outreach is also a critical aspect of EuroMarine's work, and as part of the effort to raise awareness of ongoing marine challenges and research the network maintains an active social media presence through Twitter and Facebook. There are over 1,300 followers of EuroMarine on each of these social media platforms. EuroMarine also developed a promotional video, which has received over a thousand views.

The breadth of the network's engagement can be seen below in **Figure 8**.

Figure 8. *Snapshot of EuroMarine communication and dissemination statistics. The numbers in this graphic are all current as of April, 2019. The Facebook page was restructured in September 2016 to be in line with the EuroMarine website and to accommodate new Facebook tools. Facebook, YouTube, MailChimp and Twitter statistics were sourced from tools hosted by each of those services. The EuroMarine website page view statistics were gathered via Google Analytics. All other publication and participation data were compiled by the authors.*

5. Outcome of EuroMarine activities

At the core of EuroMarine's support for marine science in Europe are the activities the network funds after its annual calls for proposals. These present researchers, from across Europe and beyond, with the opportunity to forge collaborations and to identify and shape some of the leading emerging ideas in a variety of marine scientific fields. Activities usually result in publications or declarations, some lead to the development of follow-on conferences or workshops, and some even went on to be developed into successfully funded European projects. Figures about reported and measurable outputs are listed in **Figure 8.**

Beyond the published outputs and as previously mentioned, EuroMarine has facilitated thousands of crucial interactions among scientists, fostering the connection of ideas, people, institutions, facilities, tools and research, the full impact of which is difficult to capture.

Less tangible but nonetheless important are the outcomes of EuroMarine's efforts in the realm of Capacity Building and Training and the impact that the establishment of a Young Scientists Network will have (see the corresponding subsequent Sections).

EuroMarine activities cover a wide breadth of topics and include conferences, working groups, workshops and training events. From top left, clockwise: EuroMarine Representatives in Brussels for the 2017 General Assembly; a meeting of the ICES COMEDA working group; attendees of a Marine Phytoplankton Identification and Taxonomy Workshop; an intensive 3-day CoDReG workshop in Oslo; students attending a training course on established and emerging model organisms for marine science; workshop attendees learning new cutting edge molecular techniques.

III. A Think Tank for Marine Sciences in Europe

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There is no doubt that inter- and cross-disciplinary collaborations are absolutely necessary to address the complexities of ocean ecosystem function—whether in the context of basic knowledge, conservation, restoration or sustainable management.

Rising to this challenge, EuroMarine members organized **35 foresight workshops** (FWS) (see **Figure 1**) focused on the science needed to effect integrative approaches. For example: the effects and importance of spatial scaling (metres to thousands of kilometres); how to best utilize new types of "big data" from ocean observation systems (physical-chemical data, biodiversity, functional proxies, biogeochemical fluxes, 'omics); how to integrate new discoveries (the role of diverse microbiomes); how to combine data and determine which combinations of data are most predictive (meta-analyses, integrated models) of regime shifts and tipping points; how to better assess and reduce cumulative impacts (pathogens, blooms, invasive species, chronic stress, pollution); and how to utilize "what if" scenarios and modelling to full effect.

Following the EuroMarine Network's holistic and interdisciplinary approach to marine research, FWS focused on its four priority areas: The basic science of ocean health in terms of functional biodiversity (Priority Area 1) and its intimate linkage to biogeochemistry (Priority Area 2), followed by scenarios and modelling to understand and ensure ecosystem sustainability against socio-economic exploitation (Priority Area 3) and how all three areas propel innovation (Priority Area 4). Section VI—*Ocean Frontiers for Sustainable Development*, will extend the priority areas further.

1. Understanding marine ecosystems for healthy oceans under global/climate change

A healthy ocean is one whose ecosystems function naturally, while still providing sustainable ecosystem services for humankind. As a core principle, the role of biodiversity in ecosystem-function—BEF theory—is well-advanced with a wealth of experimental support and continually sophisticated simulation models able to explore cumulative impacts, resistance/resilience, regime shifts and tipping points in both pelagic and benthic domains.

Understanding the complex biotic and abiotic interactions in these dynamic systems is arguably the most challenging endeavor in marine ecosystem science because of the natural high dimensionality of the systems coupled with anthropogenic pressures/drivers—overharvesting, habitat fragmentation/loss, pollution, invasive species, and climate warming. This high dimensionality requires increasingly intensive inter- and cross-disciplinary collaboration among empiricists, modellers and experimentalists in order to move—beyond descriptions, factors and processes that drive the system—to predictive outcomes essential for proper sustainability.

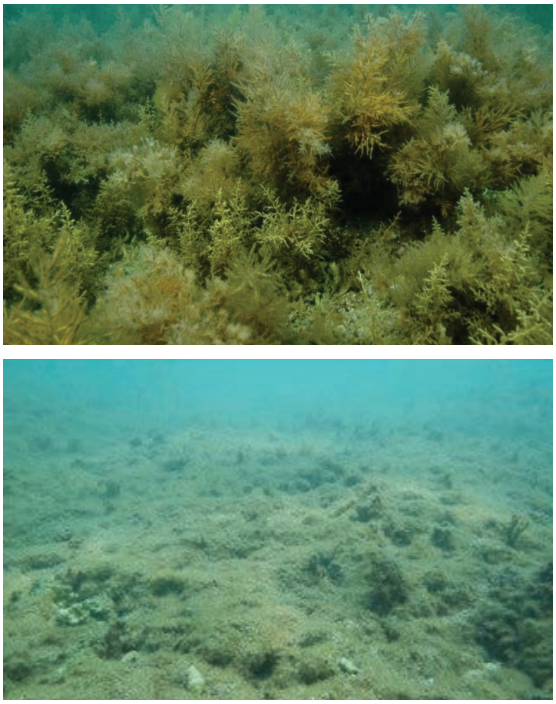

Figure 9. *Example of benthic ecosystem regime shifts: macrophytic algal canopies of kelps and fucoids (Cystoseira) such as those in the top image are turning to algal turfs (bottom image). (Top image from Bulleri et al., 2018, bottom image ©L. Airoldi.)*

With respect to benthic coastal ecosystems, the FWS **STRANGE** (Status, Trends and Conservation options for marine coastal biodiversity under global change scenarios) brought together EuroMarine researchers to discuss approaches to forecasting trends along Mediterranean coasts that have led (or are likely to lead) to regime shifts and tipping points. Identification of "critical slowing down" of recovery and triggers, as well

as identification of feedback mechanisms that may allow the system to re-cross the threshold to restore altered communities were central points of attention. Triggers and impacts, for example, include the role of emerging pathogens (*Vibrio*), invasive species disruption (*Caulerpa cylindracea*) and altered sediment microbiomes in warming seas. The focus was on macrophytic algal canopies of kelps and fucoids (*Cystoseira*) that have shifted to algal turfs (see **Figure 9**), or *Posidonia oceanica* seagrass meadows that have been reduced to turfs and sand. Products of the workshop include a review and perspectives paper which has been accepted as a book chapter (Benedetti-Cecchi *et al.*, 2018, In Press), which makes the plea for distributed macro-ecological experiments in specific habitats and localities in order to better inform model parameterization.

Marine forests are ecosystem-structuring species of large brown algae (kelps) and are key components in coastal ecosystems. **MARFORSTAKE** (Marine Forests for Stakeholders) held a series of four workshops to identify research priorities to fill knowledge gaps. The focus was on understanding geographical variation in biodiversity components that affect fitness and consequently the fate and future trajectories of these keystone ecosystems. The initiative was instrumental in developing three white papers and a booklet to raise awareness about European coastal ecosystem vulnerability and in launching a global web-based citizen science initiative on marine forest, MARFOR (www.marineforests.com). **COMPSEAGRASS** (Linking biodiversity, ecosystem function and ecosystem services: A comparison between temperate and tropical seagrass meadows) emphasized the need for distributed experiments comparing BEF between tropical and temperate seagrass ecosystems. Outputs from the workshop included establishment of a network and a developing proposal for an MSCA-ITN in 2018/19. **MESB** (*Marine Eco-Systems Biology*) met to bridge the gap between environmental and ecological data with integrated "omics" to understand and predict future seagrass ecosystems. A position paper is in preparation. **POSTCLIMA** focused on development of a blue tool in which positive ecological interactions (ecological facilitation) can be used to restore biodiversity of temperate coasts. Distributed experiments were again stressed (see Bulleri *et al.*, 2018).

TraitBa (Trait Base Approaches to Ocean Life) has the mission to understand ecosystem function based on a limited number of organismal traits—not species. This was the third workshop with 120 participants. Utilizing perspectives from general ecology, break-out groups focused on grazing responses, environmental heterogeneity, elemental composition of unicellular organisms, and the role of ecosystem "dark matter"—the

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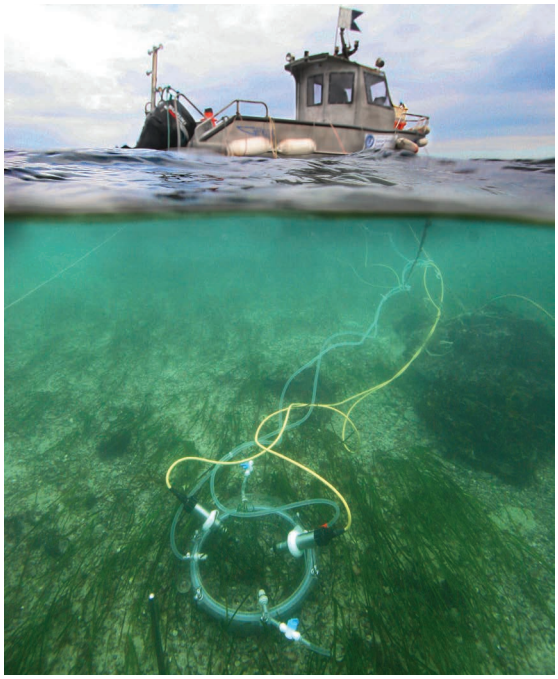

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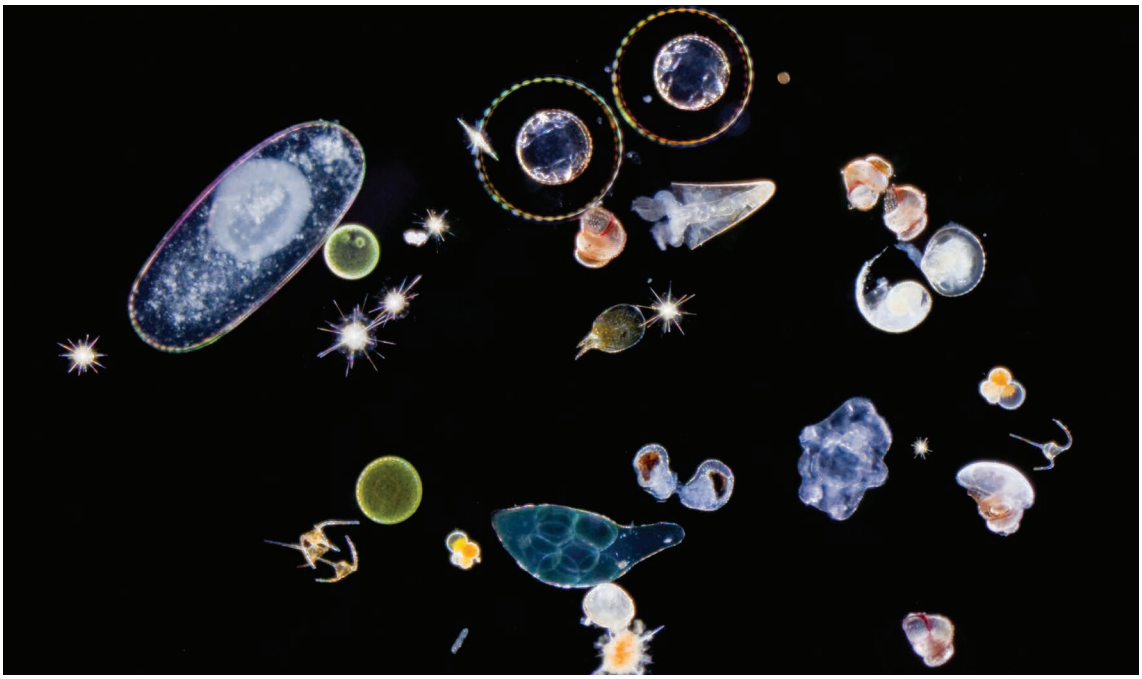
microbiomes of viruses and bacteria and interactions that are still in the discovery stage. Information and updates can be found at **traitbased.b.uib.no**. Non-indigenous species (NIS) continue to increase with varying but mostly negative effects on marine ecosystem function. **SEAGRASS** (Developing an integrated framework for studying *Halophila stipulacea*) focused on the seagrass's microbiome-mediated invasive properties with exchanges of microbial diversity data between the Red Sea and Caribbean. A number of workshop participants were also involved in COST Action 15121 MarCons (Advancing Marine Conservation in the European and Contiguous Seas). See Katsanevakis *et al.*, 2017. **MedBioInvas** participants wrote the *Ischia Declaration* (Galil and Gambi, 2016; see **www.euromarinenetwork.eu/Ischia-declaration**) designed to address Mediterranean-wide management of NIS under a "one-authority" approach. A general framework and an action plan have been developed.

Moving to pelagic and open ocean ecosystem health, the nature and stability of the food web is central to a healthy ocean and sustainable fishery. Forecasting changes in plankton distribution, phenology and biomass are essential because they create trophic mismatches and amplifications that directly impact fisheries and global biogeochemical cycles. Likewise, forecasting changes in apex predators/fisheries at the top of the foodweb is essential for maintenance of a balanced and healthy ocean fishery. The FWS **PlankDiv** (Impact of climate change on functional and phylogenetic diversity of plankton: a modelling approach) brought together 24 participants to discuss ecological niche modelling approaches against the background of highly variable and changing environments. Incorporation of single and time-series data from 'omics, along with distribution and physical/chemical oceanographic measurements were discussed. Results of the workshop were synthesized in a review paper (Chust *et al.*, 2017) in which they identified the need for concomitant team developments in the field of bioinformatics and biostatistics, ecological niche modelling, and genetic reference database assembly. In 2017 a follow-up Working Group (WG) was established (**PlankBioS** –Present and future plankton biogeography and links between community structure, marine ecosystem functioning and ecosystem service provision. See **plankbios.wordpress.com**). **PlankBioS** has ambitious plans to: 1) establish an MC-ITN on plankton biodiversity modelling, metrics and validation methods (2019); 2) a symposium at the ASLO Aquatic Sciences meeting in 2019 (Puerto Rico) on plankton biogeography and 'omics; 3) interaction with several ICES groups (2018); and 4) further reports, reviews and best practice guidelines. The WG is well poised for H2020 and the upcoming Horizon Europe (from 2021).

2. Biogeochemistry

As EuroMarine encourages a holistic and interdisciplinary approach to marine research, marine biogeochemistry continues to be well-linked to marine biodiversity in many actions. The concept is to build scenarios for marine ecosystems under changing oceans in which both biotic and abiotic interactions are integrated. The 2017 **Ramon Margalef Summer School** with 25 students focused on this integration. The object was to consider the reciprocal contributions of living and non-living processes in spatial-temporal patterns, and how these interactions give rise to complexity (Priority Area 1).



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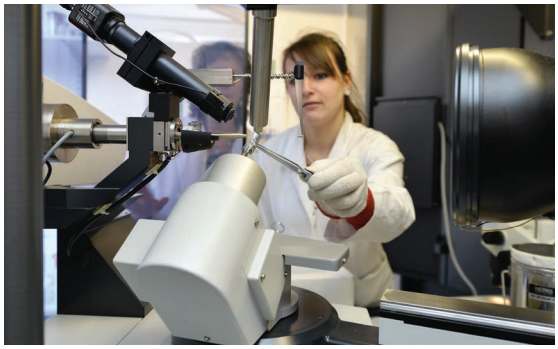
The FWS **N2Fix** (Environmental controls of marine N2 fixation: Present knowledge and future challenges) examined ocean eutrophication as guided by cyanobacteria—some of which are very harmful to humans. A special issue of Frontiers in Marine Science focused on N-fixation with 12 articles including challenges and needs for future actions and new methodologies (**www.frontiersin.org/research-topics/4947/marine-n2-fixation-recent-discoveries-and-future-challenges#overview**). Silicifiers (glass producing organisms) are among the most important organisms on Earth. They are able to take advantage of the abundance of silicon. The main marine silicifiers are diatoms, siliceous sponges and radiolarians. Following their evolution ~100 Million years ago, these

silica-utilizing organisms have remained the primary contributors to the "biological pump"—the physical mechanism that transports CO2 from the atmosphere to the deep ocean and thus counteracts greenhouse gas emissions. These organisms also contribute to the cycling of other key chemical elements, thus modulating the C, N, P, and Si biogeochemical cycles on Earth. **SILICAMICS** (Biogeochemistry and genomics of silicification and silicifiers) attracted 65 participants and produced a special issue of *Frontiers in Marine Science* with 13 contributions. (**www.frontiersin.org/research-topics/5364/biogeochemistry-and-genomics-of-silicification-and-silicifiers**). The third



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SILICAMICS conference took place in June 2018 at the U. of Victoria (Canada). **EMOSE** (Intercomparison of marine microbiome analysis methods) brought together 24 participants to discuss alternative approaches to microbiome analyses using GADGET and MICE on a series of comparative data sets. A recommendation for Global Ocean Genomics Observatories is in preparation. **BENTHIC** (A consortium approach for advancement of conceptual frameworks, modelling, and experimental approaches to benthic-pelagic coupling) identified five priority areas to advance benthic-pelagic models: lability of organic matter, variability of extreme events and recovery, scales and complexity, benthic primary production, and the continuum of the benthic-pelagic interface. A transdisciplinary working group was formed to develop next-generation models and a perspectives paper was produced (Lessin *et. al*, 2018). Additional activities focused on the future of European coastal areas, research needs and interlinkages to coastal spatial planning and marine protected areas (Priority Area 3).

3. Building scenarios for marine socio-ecological systems under changing oceans

Humans are dependent on ecosystem services and ecosystem services are shaped by people. This interdependence of nature and man comprises a social-ecological system (SES). Translating complex aspects of biodiversity-ecosystem-function (BEF) theory to language useful for marine spatial planners (MSP) and managers remains challenging though progress is being made. SES are complex adaptive systems (link to Priority Area 1).

SCENARIOS for future marine ecosystems brought together marine and social scientists to learn about "how" social-ecological scenarios are actually built. A critical discussion of the strengths and weaknesses of particular modelling approaches took place with ideas on how to advance a new generation of models and "serious games" in marine spatial planning. Two new "serious games" were scheduled for release in 2018–2019 (North Sea and Celtic Sea), as was a perspective paper. How to develop more "nature-based" and more resilient waterfronts was the focus of **ECORES**. Understanding status, threats and conflicting uses helps to guide mitigation and reduce escalating impacts. Products include an opinion paper (in preparation). The submission of ITN and ERASMUS+ proposals is planned. **CoastComVul** met to develop community level indices to assess ecosystem and social vulnerabilities of European coasts and harbours. Indices will be developed using the US-NOAA template on publicly available demographic and fisheries data. Goals are to utilize basic scientific data to inform a new CFP, MSFD and MSPD within the Blue Growth framework. Exploration of the data and a perspectives paper are in preparation for 2019.

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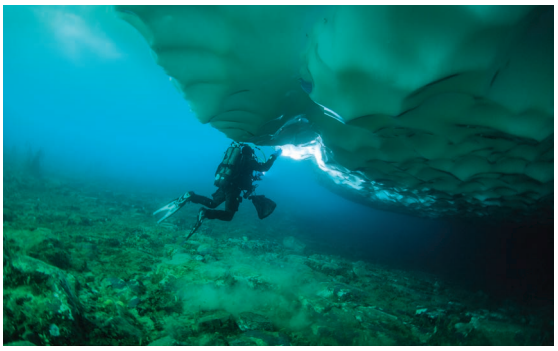
Several foresight workshops focused on fisheries, as it is here that the greatest single threat to ecosystem function continues. **EBFM** (Indicators for ecosystem-based fisheries management 2020) brought together experts in fisheries, ocean foodwebs and modelling to select a set of ecosystem indicators. These were judged on their performance sensitivity, specificity and responsiveness based on simulations in different ecosystems and statistical evaluation. The network has produced four research papers with more on the way (Bundy *et al*., 2016; Fu *et al*., 2018; Reed *et al*., 2016; Shin *et al*., 2018). **GlobOcEc** dissected differences between SSPs (shared socio-economic pathways) and ecosystem-based OSPs (ocean system pathways) for oceanic fisheries. Five OSPs were identified and used in scenario modelling. Future OSPs are under development for coastal and reef fisheries. The group was subsequently

acknowledged as a CLIOTOP task team to produce the milestone article (Maury *et al*., 2017) that is expected to be the global fisheries scenario reference for all future FishMIP (model intercomparison project) simulations. **COMEDA** is an ICES working group that met to set out to deconstruct fish community composition between Atlantic and Mediterranean fisheries by disentangling



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processes at the population, community and ecosystem levels. The first of five planned publications focused on life-history traits (Pecuchet *et al*., 2017). Reports are available at **www.ices.dk/community/groups/Pages/WGCOMEDA.aspx**. The FWS **PopGenFishMan** brought together 56 fisheries experts and genomic scientists from 14 countries to discuss applications for better fisheries management within the foodweb, such as stock monitoring, demographic modelling and forecasting of sustainable catch levels. Baseline genomic data is paramount as is time series sampling. There is also the need to break the barrier of "technical language" and to harmonize the mismatch of necessary detail between scientists and managers. A paper is in preparation. **Barents** analysed ecosystem scenarios for maintaining a healthy Barents Sea. The 16 participants represented a wide range of institutions, universities, ministries, NGOs and Fishing Associations thus ensuring appropriate expertise from fisheries modelling to petroleum-fish interactions and socio-economics. Various numerical models were critically assessed. The researchers published one paper (Planque *et al*., 2019) and one poster (Benjamin *et al*., 2017) in the wake of the activity, with another paper in preparation. Additionally, a "Serious Game"—Barents Sea—is being developed by ICESoft 2018. **SocialSMF** (Social transformations on small-scale fisheries) met for three days to develop a conceptual network less skewed towards the natural systems at the expense of the social system. Seven steps for the analysis of social transformation were formulated: a) provide key information about local dynamics of the marine SES that are currently unavailable on official databases, b) recognize the spatial and temporal dimension of social transformations, c) indicate what the adaptive strategies are so far, d) identify barriers that fishers, enterprises and institutions are facing in relation to current social transformations, and f) identify the best plausible management strategies and scenarios to test. Results of the workshop were presented at the 2016 ICES MSEAS conference in Brest. **CODREG** (Connecting the Dots to Reveal the Gaps: Ecosystem challenges beyond climate change for Nordic Seas) reviewed available knowledge on climate change effects on the Greenland, Norwegian and Icelandic Seas ecosystems with the goal of developing a research roadmap for the next decade. This includes coastal and blue-water ecosystems including fisheries and outlining avenues for addressing emerging threats to marine ecosystems. **FutureCoast** participants focused on spatial scaling, drivers and ecosystem interactions. A key finding from the workshop is the ongoing, unbalanced representation of ecologists, sociologists, economists and experts in governance; and the lack of fluency in communication between disciplines. Further discourse with JPI-Oceans is planned, as this is a serious obstacle to further progress.

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4. Marine model organisms for innovation and technology

The ocean is a reservoir of the most phylogenetically diverse organisms on Earth with a broad range of potential applications. Model organisms have been developed from nearly all domains and phyla (e.g., bacteria, algae, sponges, jelly fish, worms, sea stars and urchins, tunicates, sharks, zebra fish and many more). A few have provided the basis for Nobel prizes (e.g., green fluorescent protein from the jelly fish *Aequorea victoria).* Over the past decade especially, ocean sciences and blue biotech have been profoundly transformed with the advent of 'omics technologies and the still-nascent systems biology. New marine model systems are under development. Among the most exciting is the field of metagenomics of interacting microbiomes.
The current scientific challenges are to further deepen our understanding of marine model systems, through

fundamental research (Priority Areas 1 and 2). In parallel, the discovery, development and sustainable use of marine bio-resources must also be considered a priority. Further, protection and ethical use must comply with regulations set out in the Nagoya Protocol, relating to the benefits arising from the utilization of biodiversity. EuroMarine activities have been at the heart of these important issues, organizing five events to federate new scientific communities—fostering interdisciplinary collaborations, bringing out new concepts, promoting the diffusion and appropriation of new technologies, developing knowledge transfer in the biotechnology sector, and addressing societal challenges. **VIBRIO** brought together basic and applied researchers to discuss virulence mechanisms of emerging Vibrio bacteria in marine systems and resulted in a perspectives paper (Le Roux *et al.*, 2015). **ChemEco** (Chemical ecology and interactions) met twice in 2015 and 2016 to discuss chemical signalling and how terrestrial knowledge might be transferred to marine systems. A 10-year roadmap is currently in draft form, aiming to understand the mechanistic basis of chemical signalling in various marine ecosystems, as well as to develop applications relevant to food security and climate change. Another outcome is an article (Saha *et al.*, In Press). Marine biological resources are often promoted as sources of novel compounds, however recent legal constraints have introduced additional procedures for exploiting marine genetic resources. **LegGenChem** focused on the exploitation of marine genetic and chemical resources, sustainable production of bioactive compounds from the sea, legal issues on marine resources exploitation and the preclinical testing of bioactive compounds for therapeutic applications. The meeting brought together scientists from a range of backgrounds, from ecology to chemistry in order to explore and attempt to predict new trends in marine biotechnology, create new collaborations, and commence discussions with EMBRC-ERIC regarding problem-solving of legal issues derived from the Nagoya protocols and access and benefit sharing (ABS). Products of this workshop included a review article on deep-sea antibiotics (Tortorella *et al.*, 2018), a paper on the marine biodiscovery pipeline (Jaspars *et al.*, 2016), and the preparation of a project proposal in the framework of the call Bio-Based Industries in 2017. In addition, part of the consortium went on to develop two successful H2020-MSCA-ITN-ETN: MarPipe (Marine drug discovery) & Ocean Medicines. The **MARISTEM WG** aimed to better coordinate and promote research in the emerging field of marine and aquatic stem cells, a dynamic area in biology and biomedicine, by sharing ideas and discussing common aims. The efforts of the working group resulted in the funding in October 2017 of a COST Action entitled "Stem Cells of Marine/Aquatic Invertebrates: From Basic Research to Innovative Applications".

The conference JELLY on novel foods displayed the ability of the EuroMarine community to innovate and turn perceived biological nuisances into opportunities. Organized in the framework of the Universal Exposition of Milan in 2015, the conference highlighted opportunities for exploiting increased jellyfish biomass as food or feed resource, or as ingredients in pharmaceutical, cosmetic and biomedical products, exploiting their high levels of bioactive molecules. The conference was highly successful in focusing the attention of the general public on topics of interest in marine research and policy. It raised awareness of transdisciplinary approaches to developing sustainable food resources at a time when climate change is impacting the abundance of marine bioresources, leading to issues of food security and nutrition related problems. Products of the conference include a book chapter entitled, "Jellyfish and Humans: not just Negative Interactions" (D'Amico *et al.*, 2016) in *Jellyfish - Ecology, Distribution Patterns and Human Interactions*. The JELLY conference ultimately generated the H2020 BG project, GoJelly, that started in January 2018 and which focuses on the use of jellyfish as a source of innovative solutions to combat marine litter and deliver new food products, foods/feed, as well as cosmeceutics, fertilizers, biofuels, and cement fabrication - eventually creating new jobs in the blue economy.

IV. EuroMarine: Training the Next Generation of Marine Scientists/Capacity Building

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1.Twelve training courses supported by EuroMarine calls

Twelve diverse training courses have been supported under EuroMarine calls from 2014 to 2016 (see **Table 2**). Some 616 individuals (including 444 PhD students and post-docs - 53% of which were from EuroMarine organisations - and 177 established researchers and other stakeholders - 58% of which were from EuroMarine organisations - took part in these courses, whose aims ranged from training in specific skills to providing a broad overview of topics. Three further follow-on courses were planned, as were seven papers (one published to date), a book, and a proposal for an ERASMUS grant.

For more information on the training courses which received funding from Euromarine, please visit ***www.tinyurl.com/yxsa9hyg*** *(or please visit* ***www.euromarinenetwork.eu/activities*** *and use the filters "Relation to EuroMarine" and "Category" respectively selecting "Internal" and "Capacity and training" filter values).*

Capacity Building and Training Courses per funding year	2014	2015	2016	*Total*
11th Advanced Phytoplankton Course: Taxonomy and Systematics	•			
Summer Course on Marine Ecological and Evolutionary Genomics	•	•	•	
Integrative Assessment of Marine systems: The Ecosystem Approach in Practice	•			
Established and Emerging Model Organisms for Marine Science	•			
Marine Ecosystem Services, Management and Governance: Linking Social and Ecological Research/DEVOTES-EuroMarine Summer School		•	•	
GODAE International School: New Frontiers of Operational Oceanography			•	
Ramon Margalef Summer School: Spatial and Temporal Patterns in Physical-Biological Oceanic Processes: from Scale Interactions to the Rise of the Living Ocean			•	
Introduction to Marine Phytoplankton Identification and Taxonomy			•	
Advanced School on Multispecies Modelling Approaches for Ecosystem Based Marine Resource Management in the Mediterranean Sea			•	
EuroMarine Open Science Exploration—2017 Intercomparison of Marine Microbiome Analysis Methods			•	
Number of courses	4	2	6	*12*
Number of students	152	87	205	*444*
Number of participants	213	101	302	*616*
Intended follow-up papers	2	1	4 + 1 book	
Intended follow-up proposals	1			
Intended follow-up courses	1		2	

Table 2. *Capacity Building and Training Courses funded by EuroMarine from 2014 to 2016 and their outcomes.*

2. Training the 21st Century Marine Scientists and Technologists working group

In early 2016, 17 participants gathered to identify cross-disciplinary training needs, discuss ideal curricular models of PhD-level education and to propose solutions or instruments to train the new generation of marine scientists. Particular focus was given to the role of EuroMarine to potentially foster the development of multiple educational partnerships and consortia, combining different skills to proactively coordinate and prepare an ambitious Horizon 2020 proposal that can deliver both virtual and hands-on education.

The working group considered a scheme specifically designed to promote advanced transdisciplinary competencies. Short-term conventional approaches and medium-term bold approaches to meet the goal of Training the 21st Century Marine Scientists and Technologists were identified. The group concluded that EuroMarine should take advantage of the growing political and funding landscapes that will support marine graduate education and move it forward.

The European Marine Board commissioned a future science brief entitled "Training the 21st Century Marine Professional" that was published in April 2018 (**www.marineboard.eu/publications-full-list**), in which the EuroMarine working group contributed along with members from JPI Oceans. The Future Science Brief presents key recommendations for the future development of marine graduate training in Europe and calls for collaboration between key actors from the marine education community, the marine and maritime industries, and research funding to come together to jointly develop an education and training system which will benefit all.

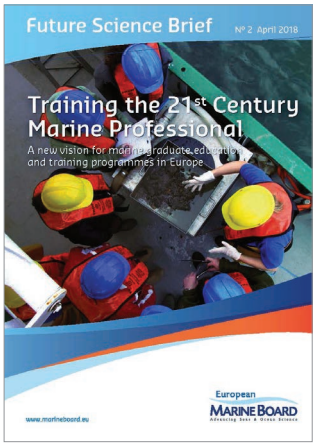

Figure 10. *Future Science Brief, Training the 21st Century Marine Professional (European Marine Board, 2018).*

3. Individual Fellowship Programme (2017, 2018)

In 2017, instead of funding Capacity Building and Training courses, EuroMarine chose to directly support young researchers willing to attend a course of their choice through an individual fellowship programme. Grants of up to €500 were made available to 23 early-career marine scientists (16 PhD students and 7 researchers in their first post-doctoral position) from 13 member organisations in 9 countries.

The success of the programme led to its renewal in 2018 and 2019. The training events attended in 2017 and 2018 addressed various topics and skills such as DNA phylogenies, genomics, ocean processes, modelling, and data analysis, covering the following broad categories: Marine Ecology (54%); Marine Biodiversity (45%); Marine Biology (45%); Marine Ecosystems Functioning (27%); Changing Oceans (22%); Fisheries and Aquaculture (22%); and Marine Biogeochemistry (13%). Further information on the Individual Fellowship Programme can be found at **www.euromarinenetwork.eu/call2017_fellowships** and **www.euromarinenetwork.eu/call2018_fellowships**.

4. Young Scientists working group and network

The Young Scientists working group was funded under the EuroMarine 2016 call for proposals. The aim of this initiative, which was achieved in 2018, was to establish a Young Scientists network within EuroMarine and to organise mutual interactions between this group and the EuroMarine Steering Committee, and the EuroMarine network at large. The purpose of opening an international, interdisciplinary and intergenerational dialogue was twofold: to give a voice to young scientists, and to let them provide perspectives to define the goals and shape the development and progression of the EuroMarine network as a whole; and to provide opportunities for young scientists to "learn the ropes" of how the greater marine sciences community is organized and functions.

The Young Scientists group obtained new EuroMarine funding under the 2018 call for proposals and further structured itself as an autonomous network. It was formed and renewed after calls for applications and it comprises 18 early career researchers from 13 countries. One of the activities it already conducted is a survey highlighting the many concerns of young scientists in relevant fields of marine research. A link to the survey outcomes can be found in the appendix on page 38.

Attendees of the Young Scientist working group in Cádiz, 2019 (from left to right): Front row: Lucy Gwen Gillis, Alina Wieczorek, Stefania Piarulli, Costanza Scopetani, Javier Moreno-Andrés. Standing: Marco Freire Custódio, Marek Lubośny, Ivana Bušelić Garber, Timotej Turk Dermastia, Rui Pedro Vieira, Himansu Pradhan, Ismael Jerez Cepa, Maria Protopapa.

The cumulative outputs of the YSWG were presented and discussed at a workshop held in the University of Cádiz in January 2019, ahead of the EuroMarine General Assembly. The workshop was highly productive, and the results were presented to the EuroMarine General Assembly, where they were well-received by both Member Organisation representatives and the guest speaker Vladimir Ryabinin, Executive Secretary of the Intergovernmental Oceanographic Commission and Assistant Director General of UNESCO. This workshop also collaborated with Stéphane Pesant and OpenAIRE (bottom right), and provided the OpenAIRE team with valuable feedback from highly engaged early-career researchers.

V. EuroMarine and Stakeholders

V. EuroMarine and Stakeholders

1. Blue Science for Blue Growth event

Over 120 stakeholders, including marine scientists, industry members, policymakers, and students, convened at the European Parliament on 8 February 2017 to contribute to the EuroMarine event "Blue Science for Blue Growth—EuroMarine: connecting ideas and people". MEP Ricardo Serrão Santos opened the session with a rousing call to action with the statement: "The balance between encouraging economic growth in the ocean and nurturing the health of ocean ecosystems will be a complex mission. Without good science, blue growth can turn on wrong pathways." A short introductory film followed (**vimeo.com/203426012**) on the significance of the ocean in our lives and how EuroMarine works to enhance our knowledge on the marine world, both to increase our capacity to use the oceans wisely, and to contribute to its protection. Four EuroMarine activities were presented, highlighting the potential of the bottom-up network to achieve major results in a short time frame with incentive funding. The talks covered a wide spectrum - pathogens and chemical ecology of marine interactions, marine trophodynamic models, and ecosystem-based solutions for resilient urban harbours. These showcased the EuroMarine vision, its achievements and perspectives, while simultaneously presenting an engaging narrative on marine issues.
As co-moderator of the discussion on the added value of EuroMarine to the European marine landscape, MEP José Inácio Faria noted the need for concerted collective action to secure the valuable resources of the ocean. The Executive Secretary of the European Marine Board, Niall McDonough,

José Inácio Faria, MEP addresses the Blue Science for Blue Growth Event in the European Parliament, 8 February 2017.

as well as Kathrine Angell-Hansen, JPI Oceans Director, and Iliaria Nardello, EMBRC Executive Director, each presented their visions of how these different initiatives can work together to complement each other in the European Marine landscape, stressing the need for the different approaches but also unified action. Sigi Gruber, Head of the DG research marine unit, provided some positive insights into how EuroMarine, as a group of core researchers, can provide responsive science to topical issues and meet the needs for capacity building in marine sciences.

MEP Ricardo Serrão Santos (centre left) opens the Blue Science for Blue Growth Event alongside senior EuroMarine members Patrizio Mariani, Philippe Cury, Catherine Boyen and Laura Airoldi.

2. A New Era of Blue Enlightenment

The wider Atlantic Ocean community gathered in Lisbon, Portugal, marking the beginning of the "A New Era of Blue Enlightenment" event and the potential of collaborations for years to come with a firm commitment for greater cooperation between the European Union, Brazil and South Africa. Key stakeholders—including high-level government representatives, industry experts, funding agencies, research organisations, marine networks, foundations and academia—gathered from 12–14 July 2017 to highlight their work so far and identify opportunities to collaborate on ocean research. The South Atlantic Flagship Initiative between these regions was launched, aiming to better understand and protect marine ecosystems, taking advantage of closely linking research activities.
EuroMarine held a session on 12 July, to introduce the network and how it assists scientists from its member institutes and beyond to collaborate and innovate for marine science, highlighting the potential to achieve big results with incentive funding. Four activity leaders presented their work with EuroMarine. The EuroMarine workshop was conceived to:

- Highlight the contribution that EuroMarine has made to the research community
- Identify the potential breadth of collaborations and opportunities for cooperation on ocean research available within the network
- Provide an example of a network model that can be extended to other regions
- Invite relevant parties to explore funding opportunities and collaborations with the network.

The workshop attendees applauded the success of EuroMarine's model, which clearly demonstrates that the sustained support of basic research is key to applied research, both of which inform policy.

3. EuroMarine and IPBES

As the European network of marine research institutes, EuroMarine was keen to engage with UN IPBES—the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services—in order to increase the under-represented expertise in the "Marine" portion of IPBES.

A Marine-IPBES working group was formed in 2014 and formally approved by EuroMarine in 2015. EuroMarine's first involvement focused on where it could serve within the various IPBES working groups, task forces and assessment arms.

Utilizing the annual EuroMarine General Assembly, the Newsletter and dedicated email messages, the network repeatedly encouraged European marine scientists to seek their nomination by their government or a recognised stakeholder (such as EuroMarine) in order to engage themselves in IPBES biodiversity assessments as authors or reviewers. Several EuroMarine scientists—whether nominated by EuroMarine, another stakeholder or their government—have been able to significantly contribute to activities of the IPBES mission. A non-exhaustive list of these scientists is shown in **Table 3.**

Isabel Sousa Pinto-Portugal (member of EuroMarine's Steering Committee) was elected in 2018 to the Multidisciplinary Expert Panel (MEP), which oversees the scientific work of IPBES. Her appointment ensures the continued engagement of EuroMarine and the European Marine expert community in this policy platform.

Expert	Member Institution	Country	Expert group and function
Philipe Cury	IRD	France	LA Scenarios and Modelling
Isabel Sousa Pinto	CIIMAR	Portugal	ECA CLA, Scoping Regional Assessments
			Scoping Global Assessment
Martin Solan	U Southampton	UK	ECA LA
Paolo Magni	CNR	Italy	AP LA
Marta Coll	IRD	France	ECA LA
Cosimo Solidoro	OGS	Italy	ECA LA

Table 3. *Some of the experts from EuroMarine member institutions who have contributed to the first IPBES assessments. This non-exhaustive list only includes scientists who are involved in EuroMarine's Steering Committee or were nominated by EuroMarine, and were approved by IPBES. LA – Leading Author, CLA – Coordinating Lead Author, ECA – Regional Assessment on Biodiversity and Ecosystem Services in Europe and Central Asia, AP - Regional Assessment on Biodiversity and Ecosystem Services in Asia-Pacific.*

VI. Perspectives—Ocean Frontiers for Sustainable Development

VI. Perspectives—Ocean Frontiers for Sustainable Development

In its first four years of existence, EuroMarine has demonstrated its value as a bottom-up network, most notably through its horizon-scanning exercises: Within a limited budget and a two- to three-year time frame, new initiatives addressing emerging topics are fostered, multi-disciplinary teams of experts are gathered and significant results are obtained, moving things forward up to a point where valuable topics and approaches can be brought to the attention of EU bodies and funding agencies. While foresight workshops do not aim at the preparation of project proposals, several of them however incidentally and directly led to the submission of successful proposals.

As regards its scientific strategy, EuroMarine organised in April 2018 the *Ocean Frontiers for Sustainable Development* open workshop to contribute to the ongoing discussions on the future European research agenda and to identify priorities in the marine research area. This led to the publication in November 2018 of an *Ocean Frontiers for Sustainable Development Manifesto* (**doi.org/10.5281/zenodo.1494917**), which complements and prolongs EuroMarine's initial scientific strategy. The manifesto reminds us that the Earth's ocean is the cradle of life and a central component making our planet habitable. It notes that as Earth's largest domain, it is of paramount importance for mankind to maintain its health in a worldwide context. It argues that the ocean should consequently be present on all sustainable development agendas. It identifies four research frontiers in ocean science that will facilitate understanding and guidance for protection and management of the ocean, in support of the health and wellbeing of present and future generations, namely:

- Manage Ocean complexity
- Secure Coastal Areas
- Target Ocean and Human Health
- Protect Ocean Commons

It is in this direction that EuroMarine intends to keep contributing to pushing the frontiers of marine science in the coming years.

However, although now recognised at EU level as a major European marine scientific network, EuroMarine clearly needs to find other funding sources than its membership fees in order to increase its budget, reach the breadth envisioned by its business plan and deploy its full potential. Rising to this challenge, EuroMarine managed in 2018 to create the EuroMarine Association. This association implements, within a mixed legal framework, the support structure to the EuroMarine Consortium prescribed by EuroMarine's preparatory FP7 project. Its existence makes it possible for EuroMarine to seek public and private external funding, an objective that could be attained in 2020. This would not only let EuroMarine increase funds granted to each activity; it would enable the development of new services for the European marine science community, for which suggestions made during past General Assembly meetings do not lack, ranging from online collaborative platforms (e.g. for the mentorship of young scientists, to facilitate the organisation of co-funded post-docs among members, or for participative science initiatives) to the possible maintenance of a dashboard offering scholarly services to the marine sciences community in the context of OpenAIRE projects.

Appendices

Appendices

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2. Supplemental online information on EuroMarine and its activities

General presentation materials

- EuroMarine website

- EuroMarine promotional film
  - on Vimeo: **vimeo.com/203426012**
  - on YouTube: **youtube.com/watch?v=ryZhfl7bpwY**

- EuroMarine flyer: **www.euromarinenetwork.eu/flyer**
- EuroMarine poster: **www.euromarinenetwork.eu/poster**

Governance

- Organisational chart and Steering Committee composition:
  - Online presentation:

www.euromarinenetwork.eu/about-us/organisation-and-governance

  - Printable document:

www.euromarinenetwork.eu/organigramme

- General Assembly representatives:
  - Online list (past and present representatives):

bit.ly/2vSZvhu

  - Printable document (current representatives and their substitutes):

www.euromarinenetwork.eu/GArepresentatives

Outcomes of EuroMarine-funded activities

Please visit **www.euromarinenetwork.eu/activity_outcomes** to consult the latest online update.

Activities

- Online list of all EuroMarine scientific activities

www.euromarinenetwork.eu/all-own-scientific-activities

- Printable yearly lists of all EuroMarine scientific activities

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To be kept informed of EuroMarine activities, please subscribe to our mailing list and newsletter at: **goo.gl/CjSu9v** or **bit.ly/2G7ZES5**

EuroMarine Young Scientists

To view the the diagram of young scientists' concerns which emerged from the Young Scientists working group, please visit **bit.ly/2HGu4ww**

To follow the development of the EuroMarine Young Scientists network, please visit **www.euromarinenetwork.eu/YSWG** and **www.euromarinenetwork.eu/OYSTER**

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- Online list of EuroMarine membership: please use the "MEMBERSHIP" menu entries at **www.euromarinenetwork.eu.**
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