Indicator Report

Marine Research and Innovation 2023

Indicator Report

Marine Research and Innovation 2023

Colophon

The Indicator Report Marine Research and Innovation 2023 is an integral component of the Compendium for Coast and Sea initiative, serving as a one-stop-shop for coastal and marine (research) information in Flanders and Belgium. This *inter alia* includes an annual systematic mapping of the marine research landscape. The results of this mapping are featured in this publication.

The Compendium is the result of a collaboration between numerous research groups, administrations, civil society organisations and consultation platforms concerning the coast and the sea. This initiative is coordinated by the Flanders Marine Institute (VLIZ) and supervised by the Expert Group Compendium for Coast and Sea.

The Compendium for Coast and Sea can be consulted online at: www.compendiumcoastandsea.be

Contact:
compendium@vliz.be

Citation:
Pirlet, H., Dauwe, S., Verleye, T., Lescrauwaet, A., Lust, H., Bouchti, Z., Verreet, G. Janssen, C., Mertens, T., Mees, J. (Ed.) (2023). Indicator Report Marine Research and Innovation 2023. Compendium for Coast and Sea. Flanders Marine Institute (VLIZ): Ostend. 61 pp.
https://dx.doi.org/10.48470/70

Chief editor:
Jan Mees (Flanders Marine Institute, VLIZ)
Jacobsenstraat 1
8400 Ostend
Belgium

Editing:
Policy and Innovation division (VLIZ), style elements graphs based on design NV Zoeck (Oostkamp)

Credits:
Photos cover page: © Nick Decombel
Photos chapter pages: (1-2) © VLIZ, (3-4) © Nick Decombel

COMPENDIUM KUST & ZEE / COAST & SEA

VLIZ pionier in zeekennis

Vlaanderen verbeelding werkt

west-vlaanderen de gedreven provincie

Content table

1 Policy context for marine research and innovation

The policy with regard to marine research[1] and innovation is developed on different levels. In the following section, a concise overview is given of the most relevant actors on international, European, Belgian, Flemish and provincial level.

1.1 International

The global dimension of the seas and ocean requires international coordination and strategy to understand large-scale marine processes and phenomena. Therefore, the Intergovernmental Oceanographic Commission (IOC) was established in 1960 within the United Nations Educational, Scientific and Cultural Organisation (UNESCO) as the competent organisation for marine science. IOC has the mission to promote international cooperation in marine sciences to improve ocean, coastal and marine resource management. In that context, it coordinates several programmes with regard to capacity development, ocean observations and services, ocean sciences, tsunami warning and ocean knowledge (see overview). Flanders takes up a leading contribution in a number of these programmes. It *inter alia* hosts the International Oceanographic Data and Information Exchange Programme (IODE) in Ostend and supports scientific projects and programme components through the Flanders UNESCO Science Trust fund (FUST). Furthermore, IOC is also responsible for key publications such as the Global Ocean Science Report (GOSR, IOC-UNESCO 2020), that systematically maps the global marine research capacity, the Second World Ocean Assessment (2021) and the State of the Ocean Report (2022), that monitor the global health state of the ocean.

IOC-UNESCO coordinates the implementation of the United Nations Decade of Ocean Science for Sustainable Development (2021-2030) (UNDOSSD). Launched on 1 January 2021, this Decade aims to bring together scientists and stakeholders from different sectors to develop the scientific knowledge and partnerships needed to accelerate progress in ocean science. In doing so, it aims to achieve a better understanding of the ocean and develop science-based solutions in order to realise the 2030 Agenda for Sustainable Development. In this regard, the focus is not only on the 14th Sustainable Development Goal 'Life below water' (SDG 14: 'Conserve and sustainably use the oceans, seas and marine resources'). UNDOSSD also pursues other ocean-related SDGs, such as combating climate change and halting biodiversity loss. In Belgium, UNDOSSD is coordinated by a National Decade Committee (NDC), of which VLIZ takes up the secretariat and co-chairmanship (see also publication Gearing up our blue knowledge (2023) on how Flanders plans to address the challenges of UNDOSSD).

Besides IOC-UNESCO, there are several entities within the UN with ocean-related activities that directly or indirectly influence the global marine research agenda. These entities are grouped in the UN-OCEANS inter-agency network.

In addition, there are various international organisations outside the UN context which are directly or indirectly relevant for the global component of marine research. These organisations can be involved in different aspects ranging from policy, coordination, advice, funding to the actual execution of research in the marine domain (table 1, non-exhaustive list). Furthermore, the OSPAR Convention on the Protection of the Environment of the North-East Atlantic (including the North Sea) also puts a strong focus on scientific research, *inter alia* to support periodic evaluations (e.g. Quality Status Report 2023).

1.2 Europe

1.2.1 European Commission - General policy context regarding research and innovation

The Directorate General for Research and Innovation (DG RTD) of the European Commission (EC) is competent for the European research and innovation policy and is responsible for the coordination of these activities. DG RTD's strategic objectives were set out in its Research and innovation strategy (2020-2024), focusing on six themes: (1) Environment & climate, (2) Our digital future, (3) Jobs & economy, (4) Protecting our citizens and our values, (5) Europe in the world and (6) Democracy & rights. In addition, DG RTD is also responsible for the funding of research and innovation, *inter alia* by means of European framework programmes such as the current Horizon Europe programme (2021-2027).

For the implementation of its policy, DG RTD collaborates with various departments of the EC and agencies such as the European Research Council Executive Agency (ERCEA), the Research Executive Agency (REA), the European Innovation Council and Small and Medium-sized Enterprises Executive Agency (EISMEA), the European Climate, Infrastructure and Environment Executive Agency (CINEA), the European Institute of Innovation and Technology (EIT), the Joint Research Centre (JRC), etc.

[1] Unless explicitly stated otherwise, the term 'marine' is used in this report in its broadest sense, including maritime, estuarine and coastal aspects.

Table 1. Global marine research networks, organisations and programmes outside the UN context (non-exhaustive list).

Theme	Organisation	Role
Policy advice / fisheries / use of the sea	International Council for the Exploration of the Sea (ICES)	International organisation that supports marine scientific cooperation for the North-East Atlantic and formulates advice for the sustainable use of the ocean.
Policy advice	Organisation for Economic Co-operation and Development (OECD)	Within the OECD, there is a dedicated division focusing on Ocean Economy. Key publications are amongst others: The Ocean Economy in 2030 and Rethinking Innovation for a Sustainable Blue Economy.
International coordination of marine research	Scientific Committee on Ocean Research (SCOR) of the International Science Council (ISC)	This organisation attempts to answer interdisciplinary ocean-related scientific questions and is at the heart of a number of large-scale marine research projects (e.g. IMBER, SOLAS, GEOTRACES, IOQE and IIOE-2). The secretariat of the Belgian participation within SCOR is taken up by VLIZ.
Ocean observation	Partnership for Observation of the Global Ocean (POGO)	A world-wide cooperation for a sustainable, state-of-the-art global ocean observing system that serves the needs of science and society.
Coordination of marine research and education	World Association of Marine Stations (WAMS), hosted by Plymouth Marine Laboratory	A global network which clusters 800 marine stations to foster collaboration.

Initiatives in support of marine research and innovation in the EU have taken on a stronger European dimension since the introduction of a European Integrated Maritime Policy (IMP, COM (2007) 575), of which the Marine Strategy Framework Directive (MSFD, 2008/56/EC) is the environmental pillar. The EC is also strongly committed to the knowledge needs of the developing 'Blue Economy' sectors in the European sea basins.

1.2.2 Mission restore our Ocean and Waters

In the framework of Horizon Europe (2021-2027), the EC invests in a mission-driven approach to research and innovation in order to develop solutions to some of the major societal challenges. Hence, this will provide the underpinning for important policy initiatives such as the Green Deal, the Climate Adaptation Strategy, etc. The objective of the Restore our Ocean and Waters Mission (Mission Ocean) is to protect and restore the health of our ocean and waters by 2030 through research and innovation (by means of targeted project calls and tenders), citizen engagement and blue[2] investments. In this way, the Mission will contribute to achieving climate neutrality and restoring nature.

The aforementioned objective is supported by cross-cutting enabling actions, in particular broad public mobilisation and engagement and a digital ocean and water knowledge system, known as the European Digital Twin Ocean (DTO). In addition, the Mission Ocean supports regional engagement and cooperation through area-based 'lighthouses' in European sea/river basins: Atlantic-Arctic, Mediterranean Sea, Baltic-North Sea (see also BlueMissionBanos), and Danube-Black Sea. Mission lighthouses are sites to pilot, demonstrate, develop and deploy the Mission activities. On a strategic level, the implementation of the Mission Restore our Ocean and Waters is supported by projects such as PREP4Blue. A recent portfolio analysis (2023) assessed the contribution of more than 800 European projects to the Mission objectives.

1.2.3 Sustainable Blue Economy Partnership

In the context of Horizon Europe, the EC is also committed to so-called partnerships with private and/or public partners to address some of Europe's most pressing challenges through concerted research and innovation initiatives. These partnerships also help avoid duplication of investment and contribute to reducing the fragmentation of Europe's research and innovation landscape.

One of these partnerships is the Sustainable Blue Economy Partnership (SBEP), consisting of 60 partner institutes from 25 countries and the EC, to pool investments in marine research and innovation and align national programmes on a pan-European scale. SBEP is co-funded by Horizon Europe and builds on the blue R&I agendas of the sea basins

[2] Blue is used here in the sense of 'marine and maritime'.

(Mediterranean, Black Sea, Baltic Sea and North Sea) and the Atlantic Ocean. Specifically for the Baltic Sea and North Sea, the BANOS project, which is working towards a joint research and innovation programme for the North Sea and Baltic Sea, established an important foundation. Building on such initiatives, SBEP has developed a Strategic Research and Innovation Agenda (SRIA). SBEP's vision is to boost the transformation towards a climate-neutral, sustainable, productive and competitive Blue Economy by 2030 and to create and support the conditions for a healthy ocean for the people by 2050.

1.2.4 JPI Oceans

Joint Programming Initiatives (JPI) are European initiatives which aim at coordinating national (or regional) research and innovation programmes and pooling national (or regional) funding to efficiently use the available resources. One of these JPIs is the Healthy and Productive Seas and Oceans initiative (JPI Oceans), which serves as a pan-European intergovernmental platform that increases the efficiency and impact of research and innovation for sustainable, healthy and productive seas and oceans. The strategy of JPI Oceans was laid down in a Strategic Framework (2021-2025). In the meantime, the initiative can boast a whole portfolio of ongoing and past joint actions. Given the close link with the objectives of SBEP, JPI Oceans also assumes a role in this partnership.

1.2.5 European collaboration concerning research infrastructure

Marine research requires specific and often expensive infrastructure. Hence, several European initiatives facilitate collaboration with regard to marine research infrastructures in order to optimise their use. The European Strategy Forum on Research Infrastructure (ESFRI) supports a coherent and strategic approach to the European policy on this infrastructure. Within the ESFRI context, several pan-European infrastructures have already been established, of which some are of particular importance for marine research in Flanders and Belgium: the Integrated Carbon Observation System (ICOS) and more specifically the Ocean Thematic Centre (OTC), the virtual laboratory for biodiversity research (LifeWatch), the European Marine Biological Resource Centre (EMBRC), the European Plate Observing System (EPOS), eLTER (integrated long-term ecosystem research), and Distributed System of Scientific Collections (DiSSCo). In addition, there are a number of dedicated marine ESFRI initiatives without Belgian or Flemish (financed) participation: e.g. EMSO, Euro-Argo, MARINERG-i, KM3NeT and Danubius-RI. The Belgian Science Policy Office (BELSPO) covers the annual Belgian contribution for the ESFRI infrastructures, as well as the federal participation. Since 2018, the Flemish participation in large-scale international research infrastructure is facilitated by the FWO call 'International Research Infrastructure'.

In addition to the aforementioned collaboration in an ESFRI context, several European initiatives exists to stimulate cooperation with regard to marine research infrastructure. In this regard, ERVO unites the operators of European research vessels. On a project basis, a common framework was developed within Eurofleets+ (2019-2023, and its predecessor Eurofleets) to coordinate transnational access to ship time (and associated infrastructure). This transnational access will be continued in the approved Aquarius project.

In the field of marine observation and data infrastructure, the EC has launched a number of long-term key initiatives, such as the European Marine Observation and Data Network (EMODnet) and Copernicus Marine Service, which centralise marine data and knowledge from different sources and disclose it efficiently to end-users. The aforementioned initiatives form the basis for the European Digital Twin Ocean (DTO), which the EC has adopted as a transversal action in the Mission Restore our Ocean and Waters. The European marine data and observation community has also joined forces in the European Ocean Observing System (EOOS), which is taking on a coordinating role to better align the various European ocean observation initiatives. In this regard, EOOS wants to be part of the broader Global Ocean Observing System (GOOS, with EuroGOOS as the European branch).

1.2.6 European networks with regard to marine research and innovation

In addition to the organisations, entities and initiatives mentioned above, there are several consortia and networks representing (parts of) the European marine research and innovation community. The European Marine Board (EMB) is the leading think tank for marine science policy and represents an important part of the European marine research institutes and funding organisations. EMB elaborates different types of publications with recommendations for research priorities and strategies for European marine research. In this regard, the Navigating The Future-series constitutes a key publication that summarises the status of European marine research and provides recommendations to meet future scientific challenges. Furthermore, the EMB acts as a forum that brings together marine researchers and stakeholders, *inter alia* in the EurOCEAN conferences.

In addition, there are several other examples of (thematic or sectoral) partnerships between innovation and research institutes of which the European Marine Research Network (EUROMARINE), the European Fisheries and Aquaculture Research Organizations (EFARO), the European Aquaculture Technology and Innovation Platform (EATIP), the Waterborne Technology Platform, the Submariner Network, the European Cluster of Maritime Clusters (ENMC) and EurOcean are just a few.

1.3 Belgium/Flanders

1.3.1 Division of competences regarding scientific research and innovation

The division of competences with regard to the scientific research and innovation in Belgium is stipulated in the law of 8 August 1980 ('*bijzondere wet tot hervorming der instellingen*'). Article 6bis of this law defines that the communities and the regions are competent for scientific research within the scope of their respective powers, including research carried out in the context of international or supranational agreements or acts. Furthermore, this law also stipulates the competences of the federal government with regard to this matter. The primary competence for scientific research and innovation lies with the communities and regions. The communities are responsible for all personal matters, cultural matters and education and training. The regions are competent for matters related to the fields of economy, energy, public works, the environment and transport. Contrary to the other regions, Flanders has opted to combine the communal and regional competences (see **1.3.3 The Flemish policy context for research and innovation**).

The coordination of the cooperation between the different policy levels is carried out by the Interministerial Conference on Science Policy (IMCWB).

1.3.2 Federal science policy

The Belgian Science Policy Office (BELSPO) supports the science policy of the federal government. BELSPO is responsible for the management of research programmes in support of policies with regard to sustainable development, combating climate change, biodiversity, energy, health, mobility and the information society. For the funding of marine research, the Belgian Research Action through Interdisciplinary Networks (BRAIN-be 2.0), contributions to JPI-Oceans actions and the STEREO programme (currently phase IV) have been of particular importance in recent years. In addition, BELSPO manages the Belgian contribution to the European Space Agency (ESA). Furthermore, 10 federal scientific institutes are part of BELSPO. In this regard, the Institute of Natural Sciences (RBINS), the Royal Museum for Central Africa (RMCA), the Royal Meteorological Institute (RMI), the Royal Belgian Institute for Space Aeronomy and the Royal Observatory of Belgium contribute to marine research.

1.3.3 The Flemish policy context for research and innovation

In Flanders, the policy domain Economy, Science and Innovation (EWI) is the entity that is responsible for the development and implementation of the science and innovation policy. In addition, other policy domains can also (albeit to a much lesser extent) take initiatives in the field of science and innovation in order to support and underpin their policy. The policy domain EWI comprises the department and several agencies, of which the entities below are specifically relevant for the science and innovation policy (see also Speurgids Ondernemen & Innoveren 2023):

- The Department of Economy, Science and Innovation (EWI) is responsible for the preparation, monitoring, evaluation and reporting of the general economic, science and innovation policy.

The execution of this policy is carried out by various agencies, including:

- Flanders Innovation and Entrepreneurship (VLAIO) is the contact point of the Government of Flanders for all entrepreneurs in Flanders and provides stimulation and support for innovation and entrepreneurship in a favourable business climate;
- The Research Foundation - Flanders (FWO) is responsible for supporting fundamental and strategic research;
- The Flemish Advisory Council for Innovation and Entrepreneurship (VARIO) provides strategic advice to the Flemish minister responsible for science and innovation policy. In addition, VARIO also advises the Flemish Government and the Flemish Parliament on the entire innovation chain. This includes not only blue skies research at universities, but also applied research with a view to valorise and transform industry, services and entrepreneurship in Flanders.

The research is carried out primarily by the five university associations (KU Leuven Association, Ghent University Association, Antwerp University Association, Brussels University Association and University Association and Graduate Schools Limburg), the Strategic Research Centres (SRCs) (VITO, IMEC, VIB, Flanders Make) and a number of other research institutes in specific fields of expertise, such as agriculture and fisheries (ILVO), nature and forest research (INBO), marine sciences (VLIZ), tropical medicine (ITG), etc. (more information: STI in Flanders, policy and key figures 2022). In the context of the current report, it should be mentioned that the Flanders Marine Institute (VLIZ) acts as the coordination platform for marine research in Flanders. The universities and colleges in Flanders collaborate under the umbrella of the Flanders Interuniversity Council (VLIR) and the Vlaamse Hogescholenraad, respectively.

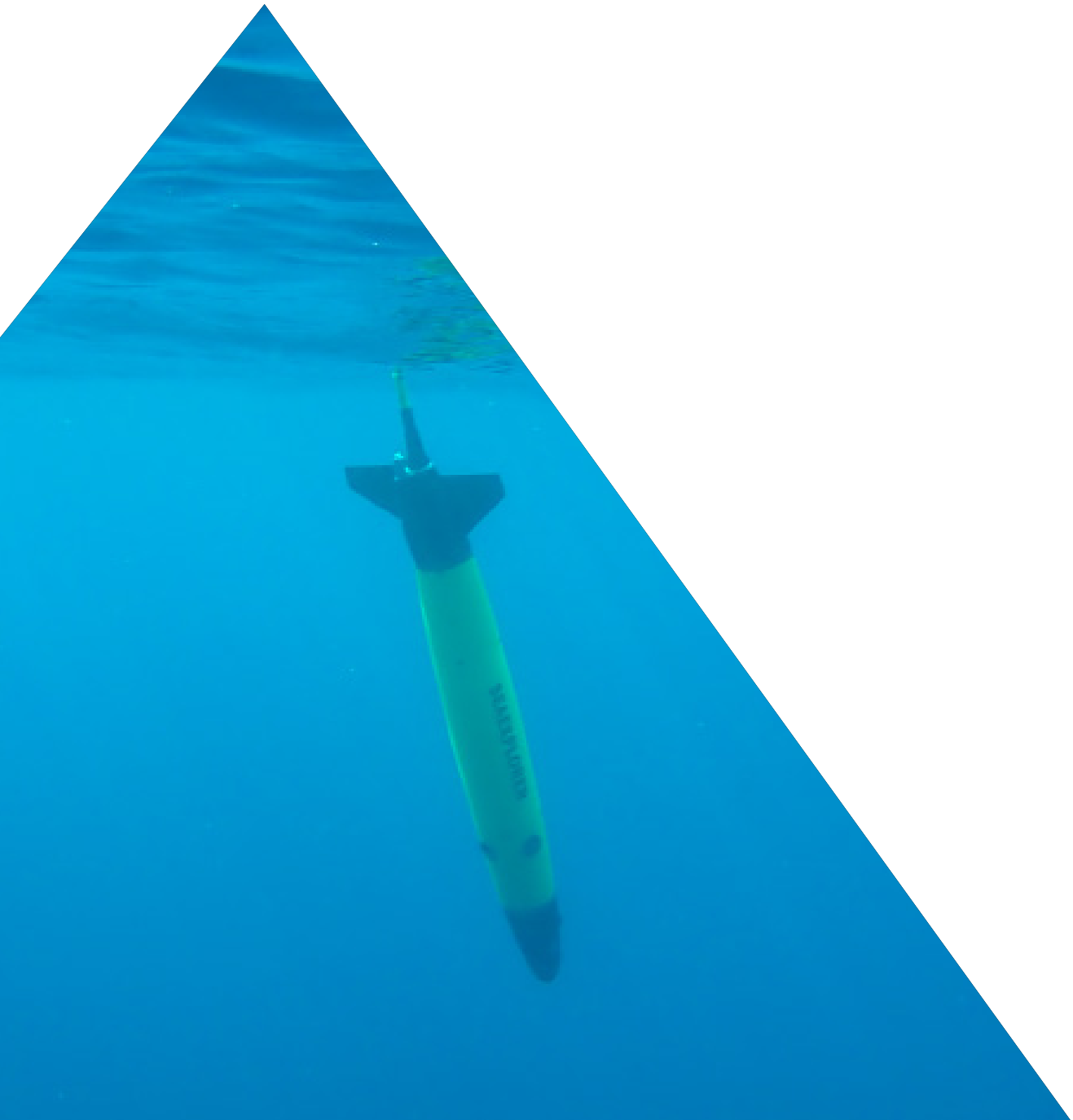
In the context of innovation, Flanders conducts a cluster policy (see also Speurgids Ondernemen & Innoveren 2023). These cluster organisations are set up to facilitate a network of companies which are active in a certain domain in order to increase their competitiveness through mutual cooperation and collaboration with knowledge institutes. Two types of clusters are distinguished: spearhead clusters and innovative business networks. The spearhead clusters are large-scale initiatives (funding for a maximum period of 10 years) that are in line with important strategic domains for Flanders. The innovative business networks are typically smaller initiatives that often arise bottom-up from companies that want to invest in a specific domain that has the opportunity to increase their competitiveness (see for example the innovative business network Offshore Energy that has now ended). At present, a total of seven spearhead clusters and 20 innovative business networks have been recognised. Specifically for the marine/maritime innovation field, The Blue Cluster ('*De Blauwe Cluster*') was established at the end of 2017, which is the network for innovative Flemish companies in the sustainable Blue Economy.

1.3.4 Province of West Flanders

At the level of the Province of West Flanders, a number of locally-anchored initiatives have been set up that have a direct relation with marine science and innovation:

- TUA West (Technical Knowledge Alliance for economic transformation in West Flanders), an external agency of the Province of West Flanders, has a liaison function and brings together companies, knowledge institutes and governments in a triple helix configuration. TUA West focuses on a number of knowledge priorities within West Flanders, namely Blue Energy, Mechatronics, Advanced Materials, Food and Care Economics;
- Within the West Flanders Development Agency (POM West Flanders), the so-called Factories for the Future (FvT) were established to foster close cooperation between companies, knowledge institutes and government. The FvT Blue Energy and (to a lesser extent) FvT Drones are of particular importance for the marine domain. Within the FvT Blue Energy, the focus is *inter alia* on testing floating energy installations, new materials and drones at the maritime test platform Blue Accelerator.

2 Marine research and innovation in Flanders/ Belgium: figures and indicators



The covenant between the Government of Flanders and the Flanders Marine Institute (VLIZ) (2022-2026) stipulates that VLIZ must guarantee "*An annual update of the inventory of the marine research landscape in Flanders (Compendium for Coast and Sea), based on an exhaustive survey of literature databases*" (Indicator to be reported in the annual report of VLIZ). Hence, every year a state of the marine research in Flanders and Belgium is drawn up, based on a replicable methodology (see e.g. Pirlet *et al.* 2022). The current publication expands this annual inventory with additional figures on the marine research and innovation landscape (e.g. funding, training, personnel, etc.).

For more information about the historical context and evolution of the marine research landscape in Flanders and Belgium, reference is made to Mees *et al.* (2015).

2.1 Methodology – Mapping of the Flemish/Belgian marine research landscape

The current inventory focuses primarily on the period 2008-2022. In order to trace evolutions on a longer term, clear definitions, preconditions and a replicable working method are used (more information: Pirlet *et al.* 2022). A central concept in this inventory is the definition of the Marine Research Group (MRG) (table 2).

Table 2. Definition Marine Research Group (MRG).

	Definition Marine Research Group (MRG)
An MRG simultaneously meets the following four criteria:	The research group is located in Flanders or in Belgium.
	The research group periodically receives government funding or subsidies embedded in policy agreements, covenants or other legal agreements
	Groups which do not belong to a university association are included in the list of institutes recognised for scientific research, as established in the Royal Decree of 22 August 2006 and the subsequent modifications of this Royal Decree.
	The research group focuses on marine research, or research which is relevant for this topic. In case of doubt, the marine research output of the group is checked over the last five years. This marine output is defined as 'more than one marine peer-reviewed or VABB-publication of which the first author is affiliated to the research group'.

The methodology of the inventory relies on the content of the Integrated Marine Information System (IMIS, VLIZ), supplemented by an annual systematic survey of literature databases. In the present inventory, these databases are Web of Science (Clarivate), the IEEE database (IEEE-Xplore) and the Flemish Academic Bibliographic Database for the Social Sciences and Humanities (VABB-SHW)[3]. The selection of publications from these databases are checked on their marine[4] focus and affiliation with a Belgian research group. Next, the publications are added to the collection of the Belgian Marine Bibliography (BMB) in IMIS, and a link is made between the publication, the institute and the author(s). Based on these links, new or additional MRGs are identified, provided they have published more than one marine peer reviewed or VABB publication as a first author in the past five years. Since 2013, the inventory and the background survey of the literature databases are conducted annually for the previous five years, on a fixed benchmark date. The benchmark date for the present inventory was 28 June 2023. The relationships that are established in IMIS between the publication, the institute and the author(s), allow quantitative measurements regarding the marine publications and the authors of the MRGs. However, the inventory of the staff of the MRGs is based on a direct survey of the research community (conducted in 2023). Every MRG, as well as the researchers, authors and publications affiliated with the MRG, are linked to one or more research domains and disciplines. To enable benchmarking at an international level, the definition of research domains and the further division into research disciplines, are based on the international available typology (Frascati Manual).

The methodology followed, the preconditions and the limitations associated with this methodology and its results are described in detail in the annual report (Pirlet *et al.* 2022). Important remarks are:

- The inventory addresses MRGs at universities, graduate schools and scientific institutes in Flanders and Belgium. Marine research performed outside of these institutes is not systematically covered in the present inventory, although the report also contains some indicators on the marine innovation landscape;
- The results of this inventory are mainly focused on peer reviewed publications and publications included in the

[3] VABB-SHW is a database containing scientific publications of researchers in the field of social and human sciences which are affiliated to a Flemish university.

[4] This theme covers marine, maritime, coastal and estuarine research activities within various research domains.

Flemish Academic Bibliographic Database for the Social Sciences and Humanities (VABB-SHW). However, a significant part of the scientific output is available in other types of publications (e.g. theses, books, scientific advices, project reports, etc.) that are disclosed and described in IMIS, but have not (yet) been included in the current inventory;

- The collection of publications included in the inventory is largely determined by the surveyed databases (Web of Science, IEEE and VABB-SHW), in which certain scientific fields are less represented. This implies a potential incompleteness or underestimation of the scientific output of the MRGs. In the future, the inventory may be expanded to new information sources, citable data sets and other scientific knowledge outputs (project deliverables, maps, models, etc.);
- In literature databases, new publications are included and described with a certain delay. Hence, in the current inventory the statistics for 2022 are incomplete with regard to publications from the Web of Science and IEEE-database. For VABB-SHW, the figures were available until 2020.

2.2 Marine research capacity in Flanders and Belgium

2.2.1 Number of marine research groups (MRGs)

A total of 135 MRGs were identified in Belgium on the benchmark date (28 June 2023). A gradual increase can be observed since the first inventory in 2013 (82 MRGs) towards 136 MRGs in 2022 (figure 1). The majority of the 'new' MRGs that were identified since 2013, are existing research groups (active in other research domains) in which a (limited) number of researchers have expanded their expertise to marine research topics and applications. Hence, the significant increase in the number of research groups does not necessarily translate into a corresponding increase in the research capacity (see below). An overview of the MRGs is available in Mees *et al.* (2023) and can also be consulted in an interactive manner on (www.compendiumcoastandsea.be).

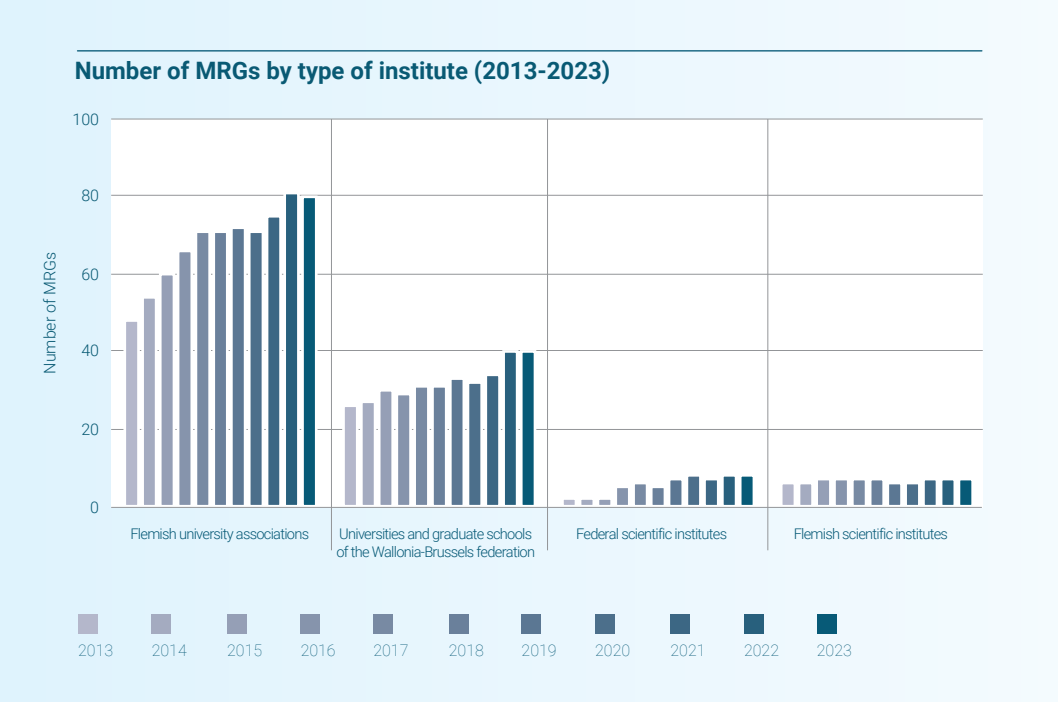


Figure 1. Number of MRGs according to the type of institute (2013-2022).

80 groups that were identified as an MRG in 2023 are affiliated with Flemish university associations, 40 with universities and graduate schools of the Wallonia-Brussels Federation (note: groups of university associations are counted at the level of laboratory, unit or research group). These MRGs can then be further classified according to the university/university association to which they belong (figure 2). The federal and Flemish scientific institutes are counted at the level of the institute and contain eight and seven MRGs respectively.

The largest share of the MRGs is situated in Ghent (30%) and Brussels (23%). A significant percentage of groups are also concentrated in Liège, Antwerp and Leuven. The MRGs affiliated with the scientific institutes are mainly situated in Brussels and Ostend (figure 3).

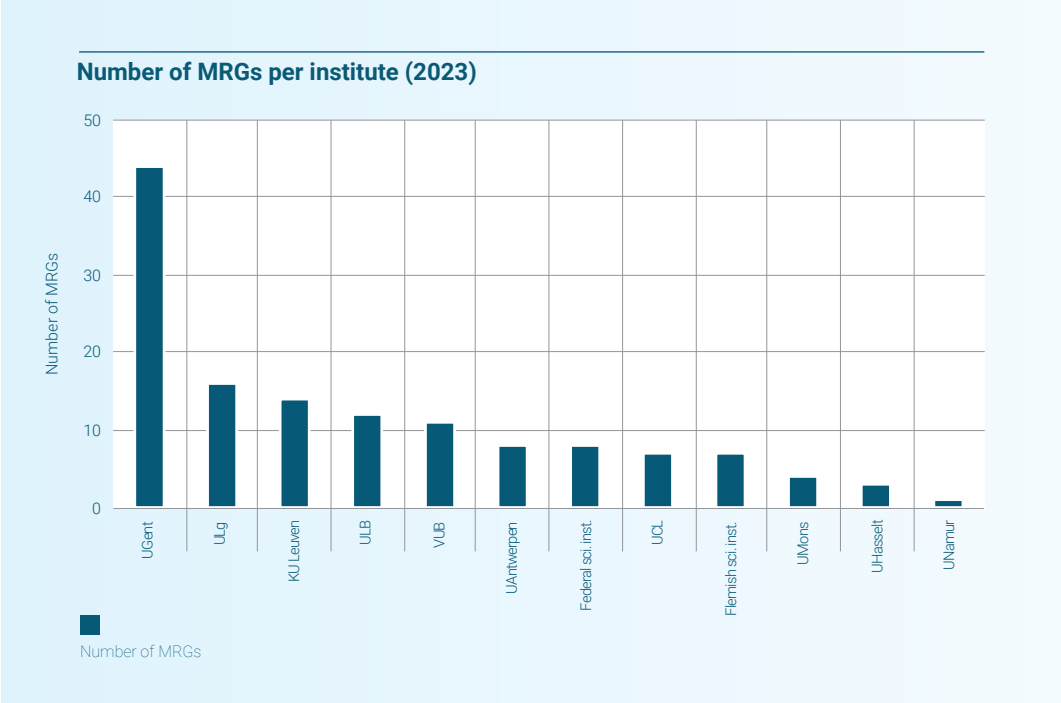


Figure 2. The number of MRGs according to the university / university association or scientific institute to which they belong (2023).

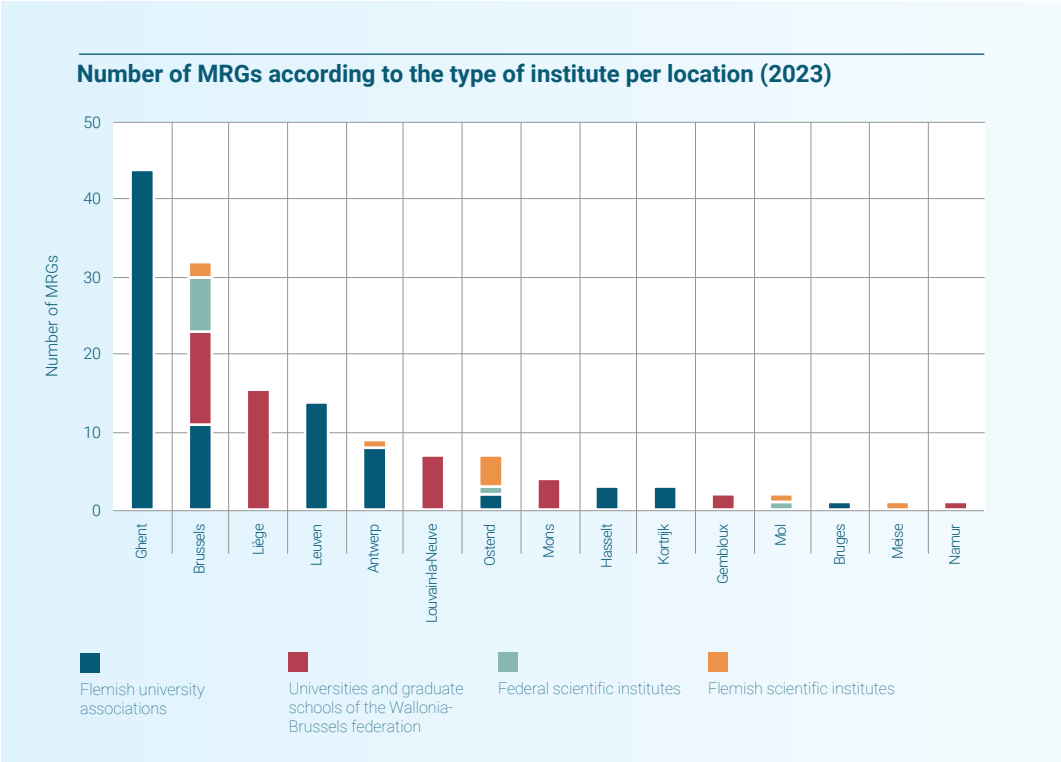


Figure 3. Number of MRGs according to type of institute per location (2023).

2.2.2 Number of marine researchers

The number of staff active in marine research provides a better insight in the actual research capacity than the number of groups. On the benchmark date of 28 June of 2023, 1,907 unique persons affiliated with an MRG were counted who are active in marine research on a full-time or part-time basis. This number is significantly higher than the benchmarks in 2013 (1,075 persons), 2015 (1,373 persons) and 2018 (1,617 persons). This increase is on the one hand the result of the increase in the number of groups that also focus on marine research themes, but can also partly be explained by the growth of certain MRGs. The Global Ocean Science Report (GOSR, IOC-UNESCO 2020) reported that Belgium is among the top five worldwide in terms of marine researchers per capita.

The 1,907 unique persons who were active in marine research in 2023 can be divided into several categories: professors and heads of department (366 staff members), researchers in PhD programmes or continued research (1,097) and specialised, research-supporting employees (441) (figure 4). It should be noted that not all persons work as full-time equivalents (FTEs) and/or are fully engaged in marine research domains.

The Flemish university associations employ 965 marine staff members which constitute about half of the marine researchers and specialised staff in Belgium. The Flemish scientific institutes (433 marine staff members) and the universities and graduate schools of the Wallonia-Brussels Federation (315 marine staff members) are followed by the federal scientific institutes (254 marine staff members). It is notable here that the number of marine staff at each of these types of institutes is increasing compared to the 2018 figures. Please note that, in contrast to the figures above, these are not always unique persons, as some persons are affiliated with several entities.

The Flemish MRGs (1,398 persons) account for 6.1% of the R&D personnel in higher education and the public sector in Flanders (2021) (Viaene 2021). This percentage is in line with the figures reported for Flemish MRGs in 2015 (6.3%) and 2018 (6.4%). It's important to note that the public sector encompasses federal institutes and foreign governments. This means that the percentage mentioned earlier might actually be higher. On the other hand, this reasoning does assume that the 1,398 people in the MRGs are all FTEs.

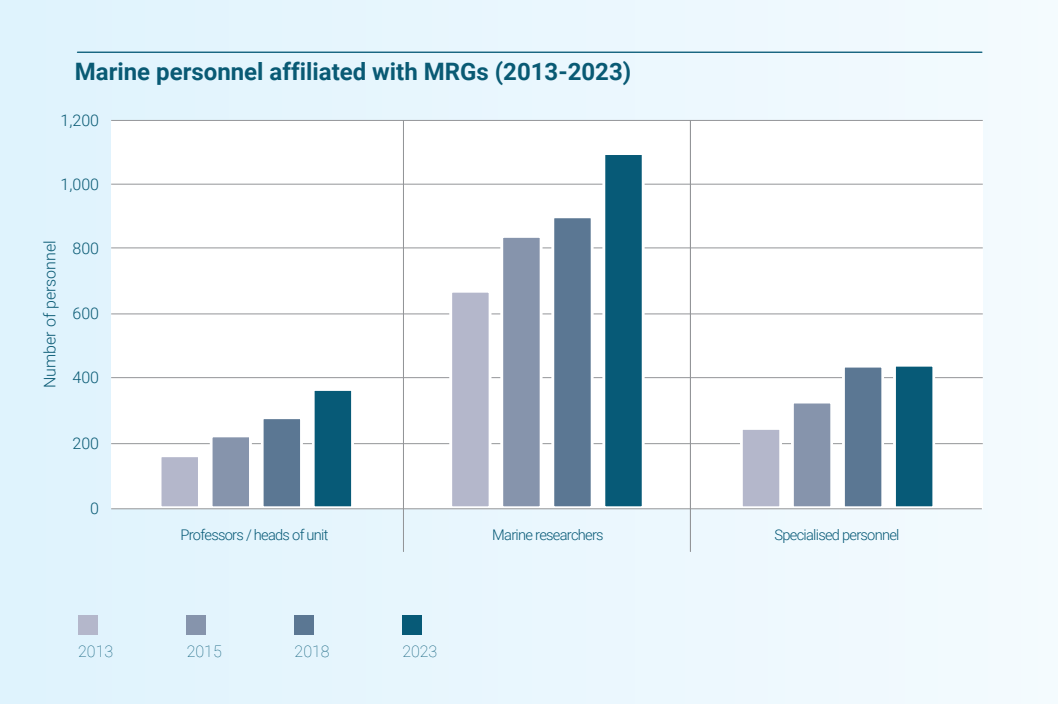


Figure 4. Evolution of different types of personnel involved in marine research.

The majority of the marine staff is male (60.4%, compared to 39.6% female), though we note an increase in the percentage of women compared to the 2015 (36.3%) and 2018 (36.2%) figures for MRGs. The percentage of women in marine research amounts to 47.4% in the category 'specialised personnel', but drops to 42.5% among marine scientists ((post)docs and PhD students) and even to 21.6% among heads of department and professors. For comparison: the share of women in marine research worldwide equalled 38.6% in 2013 (GOSR, IOC-UNESCO 2020). Also by comparison, within the Flemish higher education sector, researchers comprise 54.6% men and 45.4%

women and technical and other personnel comprise 33.8% men and 66.2% women (2021). Among public sector R&D personnel, researchers comprise 69.3% men and 30.7% women and technical and other personnel comprise 49.9% men and 50.1% women (2021) (Hoskens *et al.* 2021).

The median of the number of 'marine employees' per research group amounts to eight persons per MRG. This is a small decrease from 2018 figures when the median was nine. 11 groups have more than 30 'marine' staff members (up from 10 in 2018). These are mainly scientific institutes. Note here that staff members may belong to more than one MRG.

2.2.3 Marine research capacity by research domain and discipline

Figure 5 shows the marine research capacity according to the research domain and discipline. The bulk of the marine research at the MRGs is carried out within the research domain of natural sciences: 87 research groups out of the 135 inventoried MRGs (with more than 1,510 associated marine staff members) focus completely or partially on biological sciences, chemical sciences, earth sciences, physics or mathematics. In addition, 49 research groups are active in the domain of engineering and technology, for which a strong increase in the number of MRGs was observed in recent years. The research domains can be further divided into several research disciplines, in which the share of biological sciences (52 MRGs, 971 marine staff members) and earth sciences (29 MRGs, 711 marine staff members) stands out. In addition, research is carried out in no less than 18 other research disciplines ranging from biotechnology (18 MRGs), fisheries and aquaculture sciences (13 MRGs), civil engineering (14 MRGs), history and archaeology (4 MRGs), economics and business (5 MRGs) to law and legal studies (4 MRGs). A number of disciplines show significant growth in the number of MRGs over the years. These are primarily: biological sciences, earth sciences, chemical sciences, fisheries and aquaculture sciences, veterinary sciences, civil engineering and biotechnology. In general, the strongest growth can be noted in the research domain of engineering sciences and technology. Note that an MRG (as well as the affiliated members) can be allocated to several disciplines.

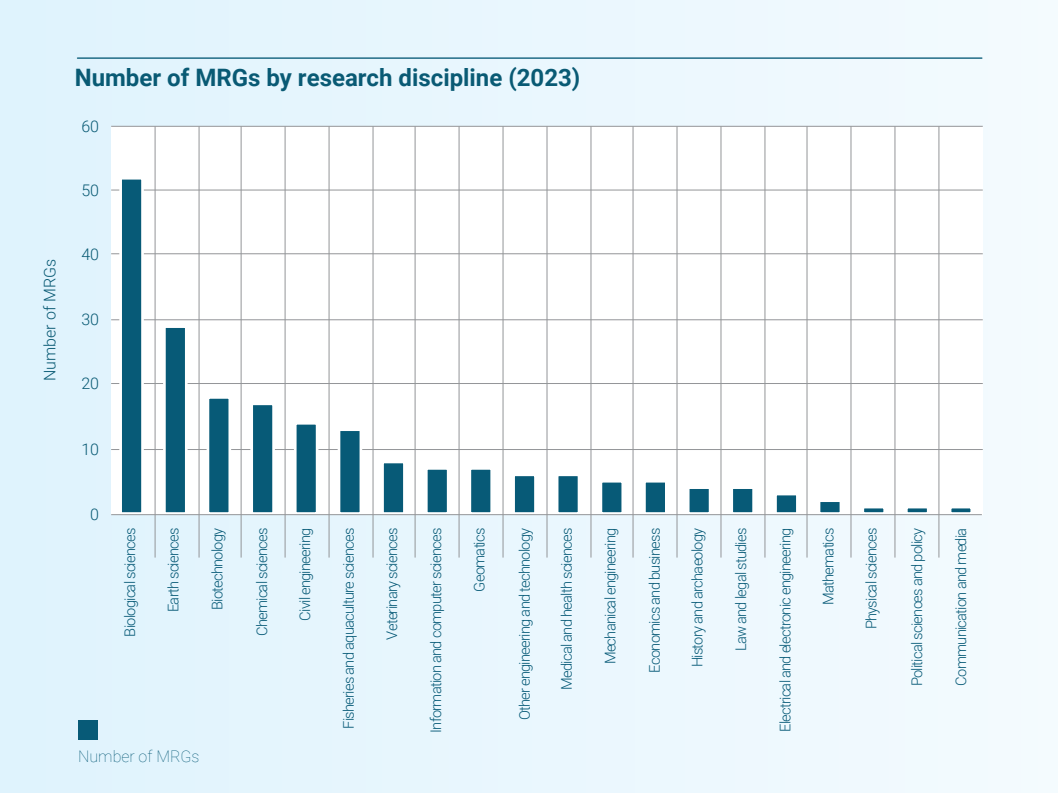


Figure 5. Number of MRGs by research discipline (2023). Note: MRGs can be allocated to several research domains and disciplines.

2.3 A bibliometric analysis of the marine research landscape

The scientific output of MRGs is diverse and includes peer reviewed publications, books, (project) reports, proceedings, scientific advices, theses, multimedia, etc. In the figures below, only the output that can be collected in an exhaustive way is taken into account: peer reviewed and VABB publications. In the Knowledge Guide Coast and Sea (Dauwe *et al.* 2022) of the Compendium for Coast and Sea, other types of publications are disclosed, linked with the respective themes. Hence, it is not the intention of the Indicator Report to express a value judgement about the different values disclosed.

2.3.1 Number of marine peer reviewed and VABB publications

Between 2008 and 2022, the Belgian MRGs published on average 645 marine peer reviewed publications per year, with an increase from 486 in 2008 to 879 in 2021[5] (figure 6). Hence, the annual scientific output of the MRGs is comparable with the output of the large marine research institutes in neighboring countries (see e.g. Pirlet *et al.* 2020). In line with the research capacity (see above), the majority of the marine peer reviewed and VABB publications is published at the universities. In this regard, it is important to bear in mind that scientific institutes mainly concentrate on various types of policy-supporting or policy-preparing knowledge outputs, such as advices, project reports, notes, etc., in addition to publishing in peer reviewed journals. In the period between 2008 and 2022, a total of 4,602 unique authors were active (an average of 873 unique authors per year). These persons are affiliated with an MRG and act as (co)authors of a marine peer reviewed or VABB publication. In this sense, this parameter is also an indirect indicator of the research capacity of the MRGs. In line with the increase in personnel of the MRGs, a gradual growth of the number of authors can be noticed during recent years from 587 authors in 2008 to 1,149 authors in 2021. The majority of these authors were affiliated with Flemish university associations (55.4%). From the perspective of the research domains, most authors are active in natural sciences (59.1%).

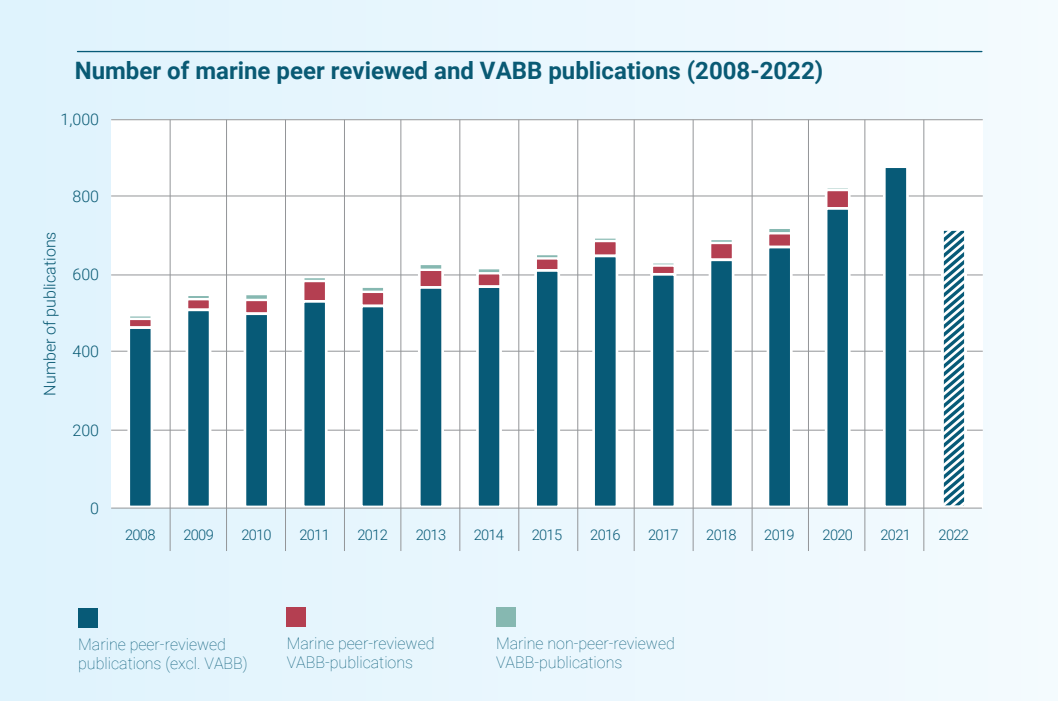


Figure 6. Number of marine peer reviewed and VABB publications affiliated with an MRG. *Note: the numbers of 2022 have a lower degree of completeness. VABB publications were available until 2020 at the time of analysis.

[5] For comparison: the publication output of Flemish and Belgian researchers (all disciplines) in 2020 amounted to respectively 29.7 and 24.2 publications/10,000 inhabitants (Debackere *et al.* 2021). For the MRGs this figure equalled 0.7 publications/10,000 inhabitants in 2020.

Between 2008 and 2022, the MRGs published in 1,605 different peer reviewed journals which is a direct result of the very diverse expertise within the marine research landscape. A striking element is the rapid increase of the share of open access journals from 41% in 2008 to 75% in 2021 (figure 7). This increase is also a retro-active phenomenon: over the last years more and more journals have switched to open access. This is also apparent from the figures in the inventories of 2015 and 2018, in which the percentages of open access publications in 2008 amounted to only 6% and 28%, respectively (Pirlet *et al.* 2015 and Pirlet *et al.* 2018). The elaboration and implementation of the Open Science policy in the Flemish knowledge institutes is monitored by the Flemish Open Science Board (FOSB).

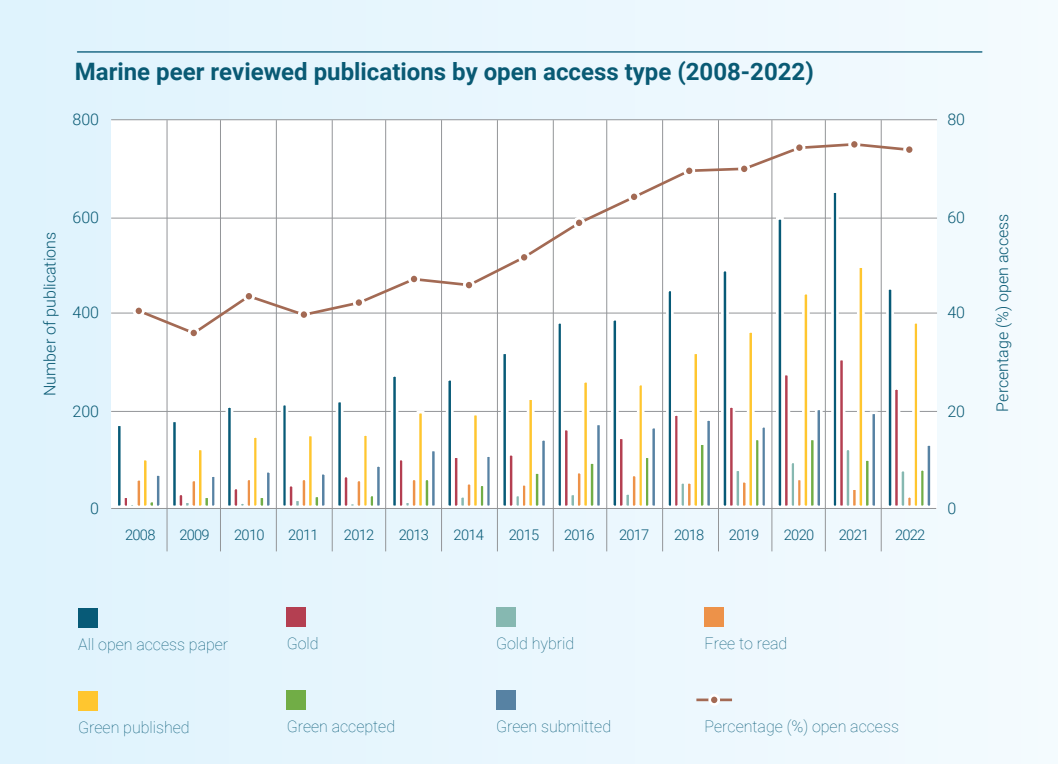


Figure 7. Number of marine peer reviewed publication in open access journals. For the definition of the different types of open access (gold, bronze or green), reference is made to Web of Science. *Note: the numbers of 2022 have a lower degree of completeness.

The largest share of marine peer reviewed and VABB publications is published by MRGs in the research domain of natural sciences (63.4%) and the domain of engineering and technology (20.3%) (2008- 2022). This is in accordance with the research capacity (MRGs and staff members), but is also the result of the nature of the surveyed database (see **2.1 Methodology - Mapping of the Flemish/Belgian marine research landscape**) and the culture within the research field of natural sciences to publish in peer reviewed journals.

2.3.2 Relative citation indicators of marine peer reviewed publications

Although relative citation indicators are no direct measure for the quality of the conducted research, they enable to benchmark according to an internationally accepted standard method. In cooperation with ECOOM (the center of expertise for mapping the Flemish R&D and innovation landscape, Bart Thijs), relative citation indicators were calculated for a list of 7,138 marine peer reviewed publications affiliated with MRGs (2008-2020) (analysis based on the Accession Number (UT-codes) in Web of Science). A time frame of three years was used for these citations. This means the year of publication and the two following years. For more information on these relative citation indicators see Debackere *et al.* (2021).

An important parameter in this context is the Relative Citation Rate (RCR), which is defined as the ratio of the Mean Observed Citation Rate (MOCR) and the Mean Expected Citation Rate (MECR) (table 3). An RCR value of more than 1 means that the set of publications is cited more than can be expected based on the journals in which they are published. For the list of marine peer reviewed publications of the MRGs, the RCR is 1.22 (2008-2020), with fluctuations observable over time: 1.12 (2008-2011), 1.28 (2012-2015) and 1.23 (2016-2020). The Normalised Mean

Citation Rate (NMCR) of the publications of the MRGs also scores above the global average with a value of 1.48 (2008-2020), which can be further broken down into 1.29 (2008-2011), 1.53 (2012-2015) and 1.52 (2016-2020). This relative indicator is defined in the same way as the RCR, but the actual impact of the citation is implicitly compared with the expectations, based on the subdomains in which these publications have appeared. The quotient of the NMCR and RCR indicators (NMCR/RCR) gives an indication of the citation impact of the journals in which the MRGs publish and is 1.21 for period 2008-2020 (which can be divided into 1.16 (2008-2011), 1.20 (2012-2015) and 1.23 (2016-2020)). These relative citation indicators show that the publications of the MRGs rate above the global average with regard to citations (figure 8).

Table 3. Clarification of relative citation indicators (see also Debackere *et al.* 2021).

Relative citation indicators	
MOCR = Mean Observed Citation Rate	The average number of citations per publication, calculated as the ratio of the number of observed citations in a three year time frame and the number of publications.
MECR = Mean Expected Citation Rate	The average number of expected citations per publication, calculated as the ratio of the number of expected citations and the number of publications.
RCR = Relative Citation Rate	The ratio of the MOCR and the MECR. An RCR value of more than 1 means that the set of publications is cited more than can be expected based on the journals in which they are published. An RCR value of 1 means that the observed value corresponds exactly with the global average.
NMCR = Normalised Mean Citation Rate	This relative indicator is defined in the same way as the RCR, but the actual impact of the citation is implicitly compared with the expectations, based on the subdomains in which these publications have appeared.
NMCR/RCR	This indicator reveals to what extent the citation impact of the journals, in which the publications appeared, is in accordance with the field standard. An indicator value of less/more than 1 therefore means that the set of publications on average appeared in journals with a lower/higher impact than can be expected based on the fields to which the publication belongs.

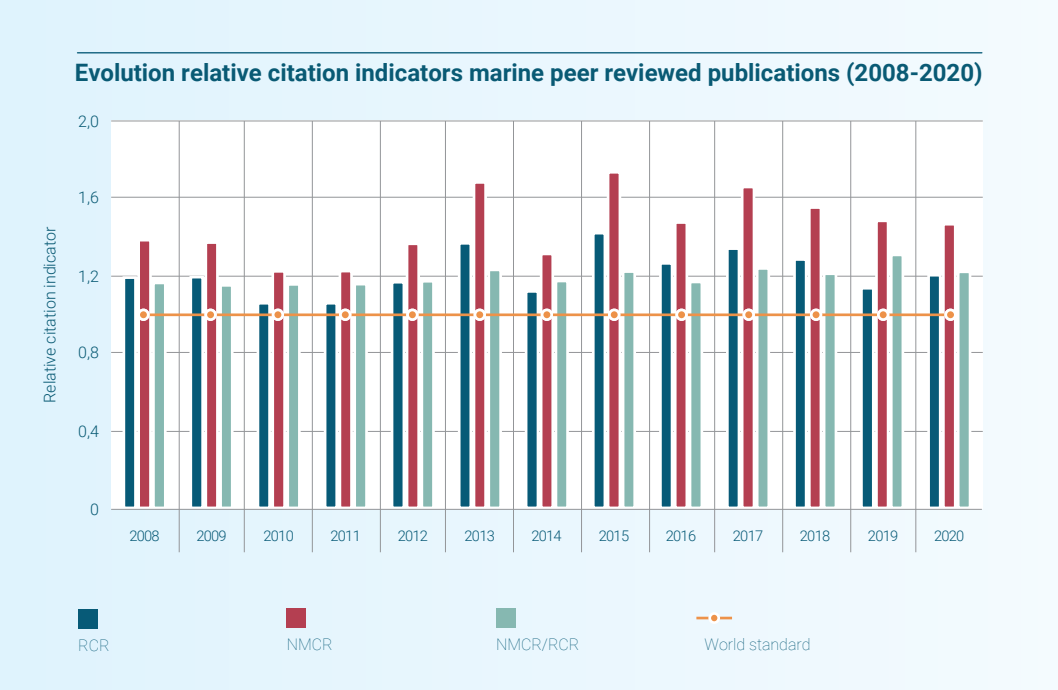


Figure 8. The relative citation indicators of the marine peer reviewed publications of the MRGs (2008-2020). RCR = Relative Citation Rate; NMCR = Normalised Mean Citation Rate.

2.3.3 Relative citation frequency MRGs according to discipline

The marine research landscape is by nature multidisciplinary and therefore consists of different disciplines. Figure 9 shows the relative citation frequency for the various disciplines in which the MRGs have published in the period 2008-2020. Some of these disciplines can be divided into subdisciplines. It should be noted that only (sub)disciplines with more than 100 publications are included in this analysis. The relative citation frequency of the publications of the MRGs is higher than or (almost) equal to the global average for all reported disciplines (RCR ≥ 1). A number of subdisciplines even rate far above the global average with RCR values up to 1.99 for the subfield of 'Meteorology/ atmospheric & aerospace science & technology' within the field of 'Geosciences & space sciences' (RCR: 1.36 based on 2,686 publications).

2.3.4 Relative citation frequency MRGs compared to other research disciplines in Flanders

In figure 10, the RCR indicator of the marine research community is benchmarked with the RCR values of the major research disciplines within Flanders (period 2008-2012 and 2015-2019) (Debackere *et al.* 2021). A clear increase can be observed in the RCR indicator of the MRGs over the two periods, with the marine research community positioning itself in the subtop of the disciplines in terms of citation impact. However, it should be explicitly noted that large differences exist between the citation practices in the different scientific (sub)disciplines (Debackere *et al.* 2021).

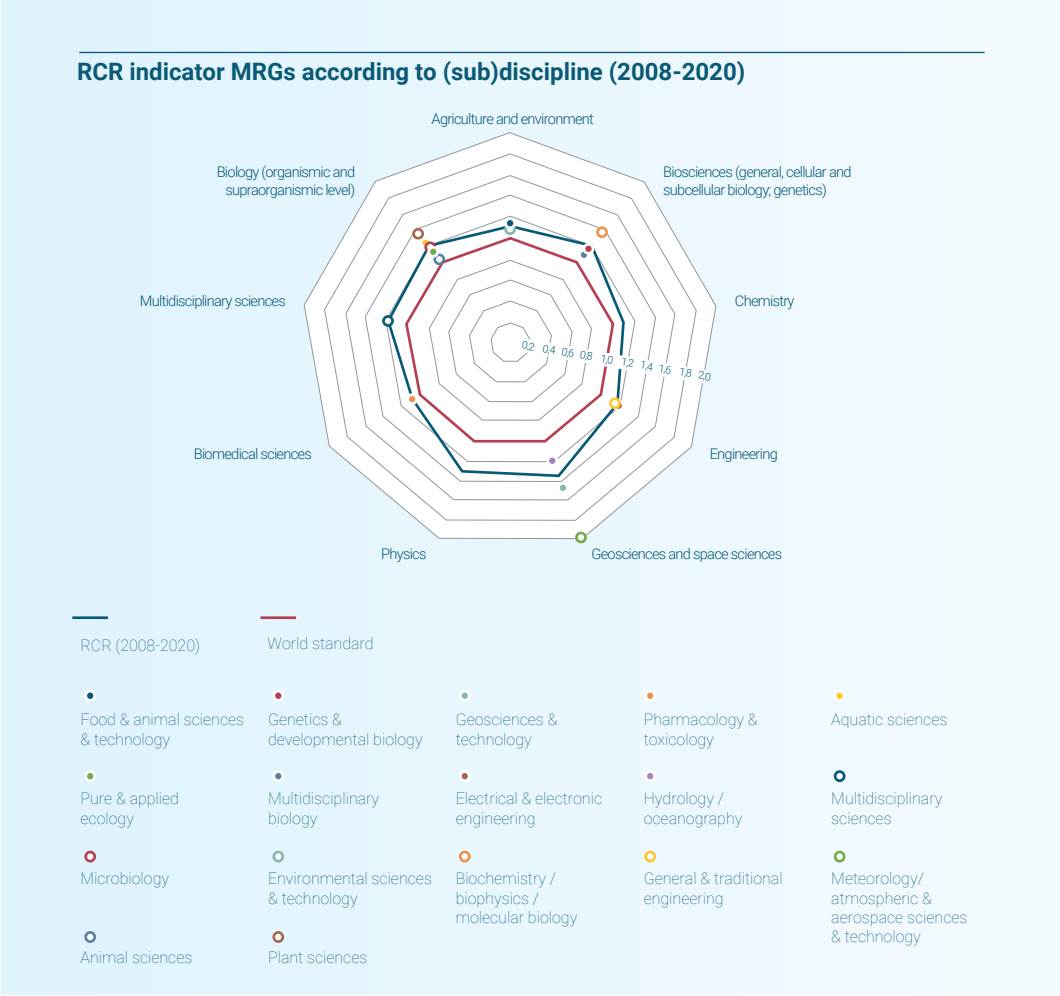


Figure 9. The relative citation frequency (RCR indicator) according to the different disciplines and subdisciplines in which MRGs have published in the period 2008-2020.

2.3.5 Relative citation map of the MRGs, Flanders and twelve reference countries

Figure 11 shows the relative citation frequency of MRGs relative to Flanders and twelve reference countries (all disciplines combined) for the periods 2008-2012 and 2015-2019 (Debackere *et al.* 2021). The RCR value of 1 represents the world standard. The results show that MRGs in the 2015-2019 period match the RCR values of the entire science community in Belgium and Flanders. This places the marine research community among the absolute top countries in terms of citation impact. It should be noted that this kind of comparison can be misleading due to large differences between citation practices in the different scientific (sub)disciplines (Debackere *et al.* 2021).

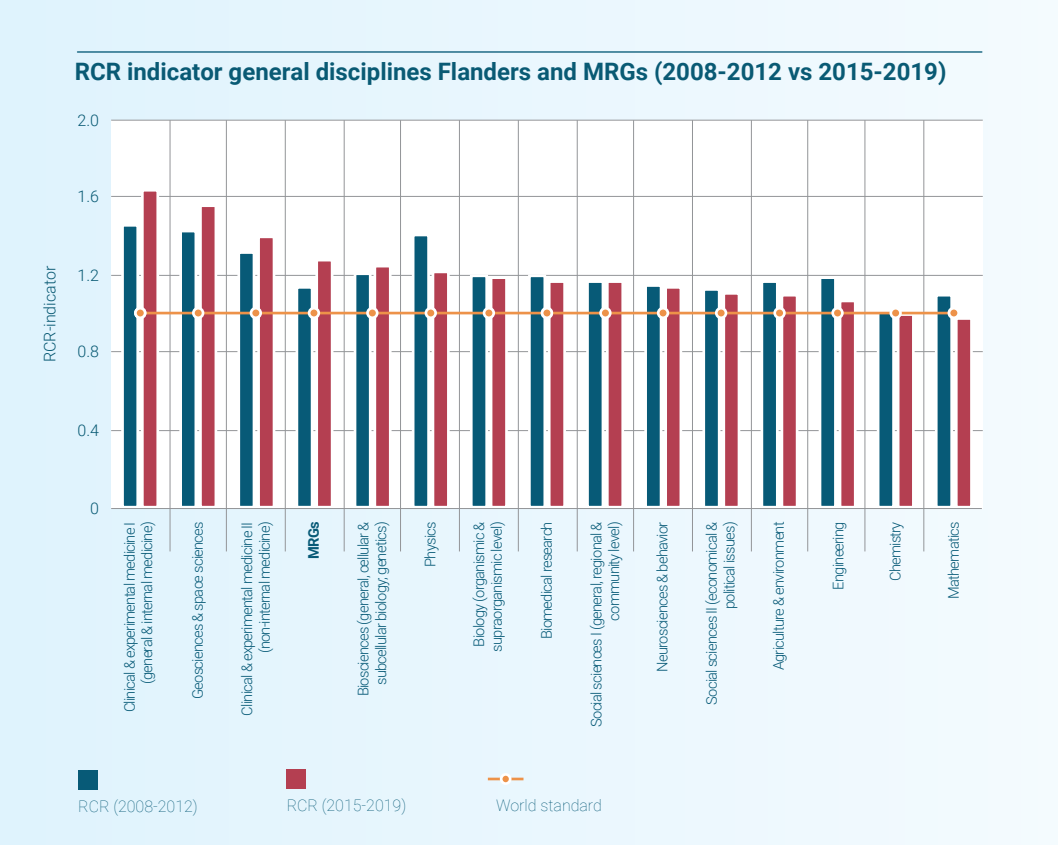


Figure 10. The relative citation frequency (RCR indicator) of the major research disciplines within Flanders, compared to the RCR indicator of the MRGs for the periods 2008-2012 and 2015-2019 (adapted from Debackere *et al.* 2021).

2.4 Detailed analysis marine peer reviewed and VABB publications

2.4.1 Geographical study areas of marine research

A detailed analysis of marine peer reviewed and VABB publications (2008-2022) in terms of study area reveals the international nature of MRGs' research. The share of publications indicating a study area[6] is 65.3%[7]. The majority (52.8%; 2008-2022) concerns international research (in terms of study areas) with the five-year averages during this period ranging between 47.3% (2010-2014) and 58.1% (2018-2022). The Atlantic region (9.0%), the polar regions (8.1%) (Antarctic and Arctic) and the Pacific region (7.7%) constitute the main international study areas of the marine research landscape (2008-2022) (figure 12).

[6] The 34.7% of marine peer reviewed and VABB publications affiliated with an MRG (2008-2022) in which no geographic study area could be identified involve studies such as lab studies, modeling, theoretical concepts, etc.

[7] This figure as well as the five-year averages from the census period (2018-2022) could potentially change marginally given the lower degree of completeness of the 2022 census.

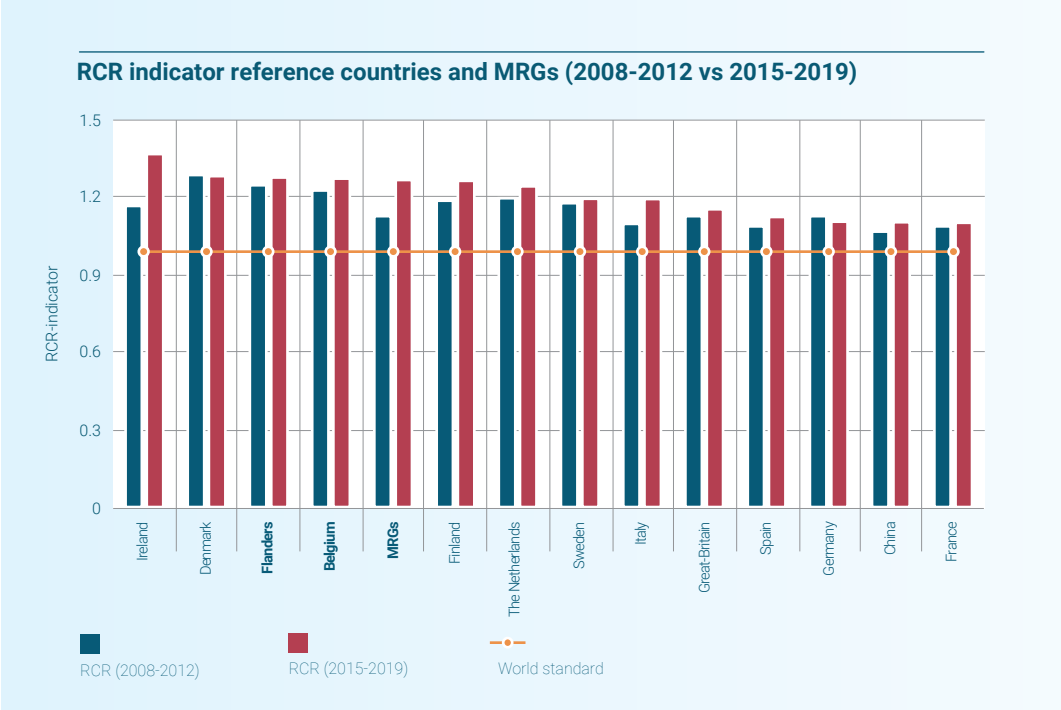


Figure 11. The relative citation frequency (RCR indicator) of the marine publications of MRGs relative to those of Flanders, 12 reference countries and the world, in all disciplines combined for the periods 2008-2012 and 2015-2019 (adapted from Debackere *et al.* 2021).

The remaining 12.5% (average 2008-2022) can be considered regional research (in terms of study areas) and includes the Southern Bight of the North Sea, the Belgian part of the North Sea, the Belgian coastal zone (beach, dunes and coastal polders), the Scheldt estuary and Flanders*. It is important to keep in mind that a significant part of the scientific knowledge on these areas is released in publication formats that are not part of this analysis. The relative importance of the different study areas has some tentative trends. Regional research is in a slightly decreasing trend (-3.5%) (average 2008-2012 vs. 2018-2022) with, on the other hand, an increasing trend in global research (+ 5.6%) (average 2008-2012 vs. 2018-2022) (figure 13).

2.4.2 Collaboration between MRGs

Between 2008 and 2022, on average 33.4% of peer reviewed and VABB publications involved collaboration by at least two different MRGs. This share varied between 30.5% in 2010 and 2011 to more than 36.4% in 2017. This collaboration is mainly situated between MRGs at universities, both within the language regions (Flanders: 13.9% and the Wallonia-Brussels Federation: 5.9% of all MRG publications) and across the language border (4.9%) (2008-2022). In addition, a significant number of publications are the result of the collaboration of MRGs at Flemish universities with federal (5.3%) and Flemish scientific institutes (7.3%).

Although the cooperation to produce these joint publications occurs mainly between different MRGs within the research domain of natural sciences (26.3% of the total number of MRG publications), respectively 11.5% of these publications resulted from cooperation between natural sciences and engineering and technological sciences and 5.1% with agricultural and veterinary sciences. These figures obviously also reflect the research capacity present in the respective types of institutes and research domains (see **2.2 Marine research capacity in Flanders and Belgium).**

These figures only reflect marine research collaboration at the level of peer reviewed and VABB publications. In addition, there is also a diversity of collaborations in terms of projects, study assignments, monitoring, teaching, etc. that do not necessarily result in joint peer reviewed publications.

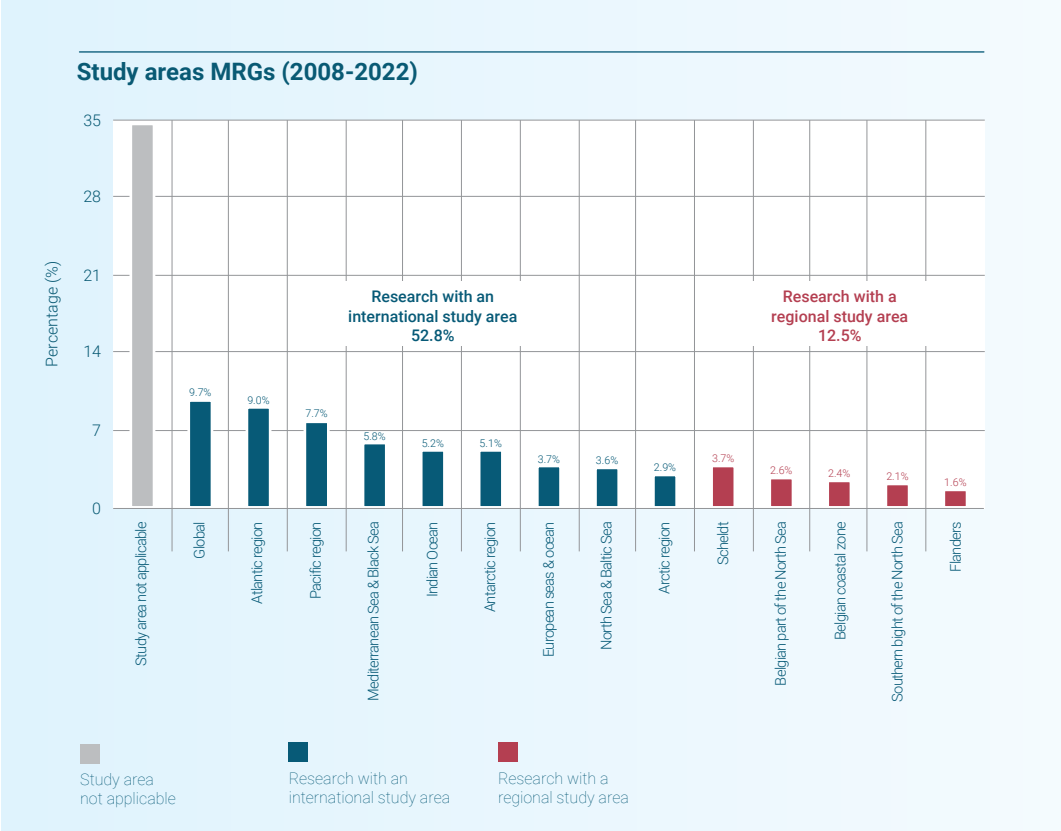


Figure 12. Share of marine peer reviewed and VABB publications affiliated with an MRG by geographic study area (period 2008-2022). Each publication is assigned to one geographic area. *Research assigned to the region 'Flanders' also includes the 'Belgian coastal zone' but is not limited to the latter region. Not applicable = no geographic study area could be assigned to the publication.

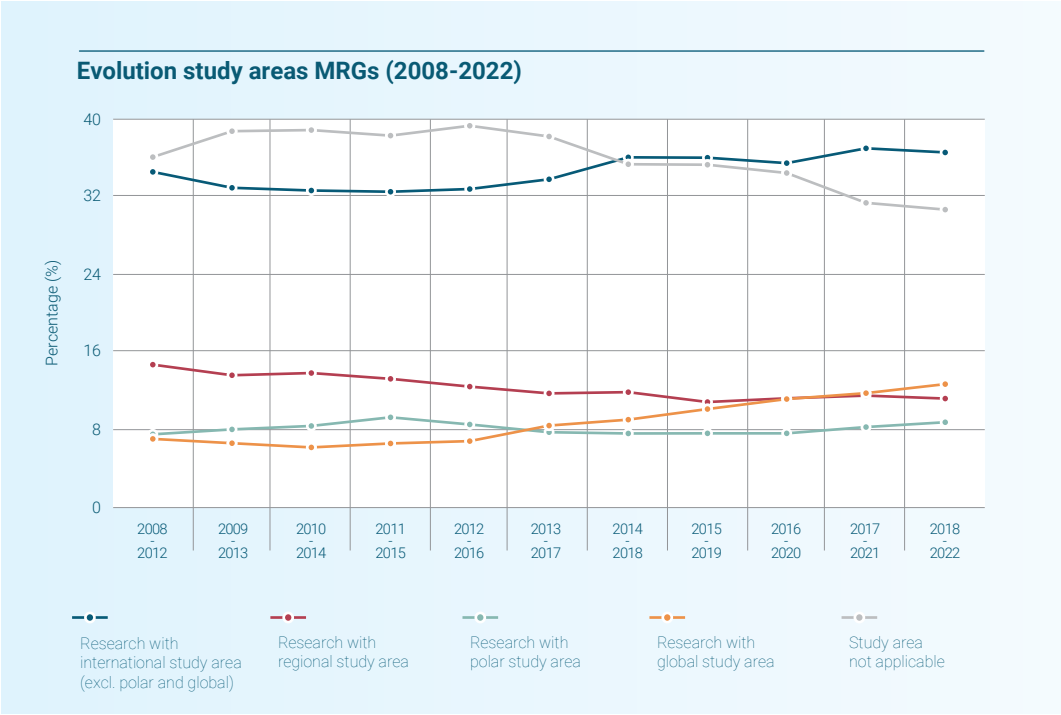


Figure 13. Evolution in five-yearly averages of the geographic study areas of marine research groups (2008-2022). A publication is assigned to one geographic study area each time. Not applicable = no geographic study area could be assigned to the publication.

2.4.3 International copublications

International copublications are publications in which at least one coauthor with a working address outside Belgium has collaborated. Consequently, the number of international copublications is an indicator of the degree of international cooperation within the marine research field. Furthermore, it is a bibliometric truism that international copublications receive on average more citations than 'domestic' publications (Debackere *et al.* 2021).

In 74.9% of the marine peer reviewed and VABB publications of the MRGs (period 2008-2022) there is collaboration with at least one foreign author[8]. This figure even reached 82.1%[9] in 2022 (figure 14). With this, the MRGs score higher than the Belgian and Flemish average share in terms of international peer reviewed copublications, which were 74.7% and 77.7%, respectively in 2020 (Debackere *et al.* 2021). Between 2008 and 2022, the MRGs published with authors from 163 different countries. They mainly worked with researchers from neighboring countries (France, UK, Germany and the Netherlands), as well as with researchers from the US (figures 15 and 16). This is also reflected in the institutes/organisations they most frequently collaborate (Centre National de la Recherche Scientifique (CNRS), Udice French Research Universities, Sorbonne Université, Utrecht University, Helmhotz Association, Institut de Récherche pour le Développement (IRD), Muséum national d'histoire naturelle, Ifremer, Royal Netherlands Institute for Sea Research (NIOZ), etc.). In 55.7% of MRGs' marine peer reviewed and VABB publications (2008-2022), the first author is associated with a Belgian marine research group, followed by France (5.5%), Germany (4.1%) and the Netherlands (3.8%) (figure 17). The proportion of foreign first authors is on the rise and the representation of foreign first authors is also becoming increasingly international (figure 17).

Figure 14. Evolution of the share of international collaboration in marine peer reviewed and VABB publications of the MRGs (2008-2022). The share of 2022 has a lower degree of completeness.

[8] In the analysis of the international copublications a country is counted once per publication.

[9] It should be noted that this share may change marginally when more figures become available.

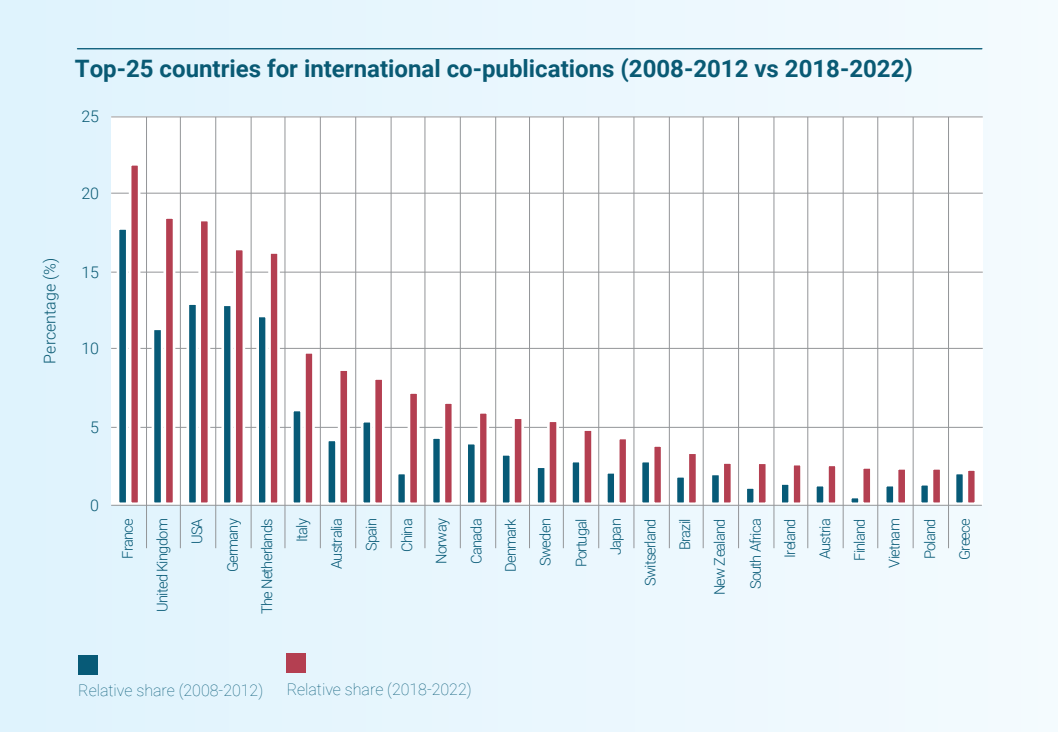


Figure 15. Comparison (2008-2012 vs. 2018-2022) of the share of marine peer reviewed and VABB publications affiliated to an MRG between 2008 and 2022 according to countries that most frequently act as coauthors. A country is counted once per publication.

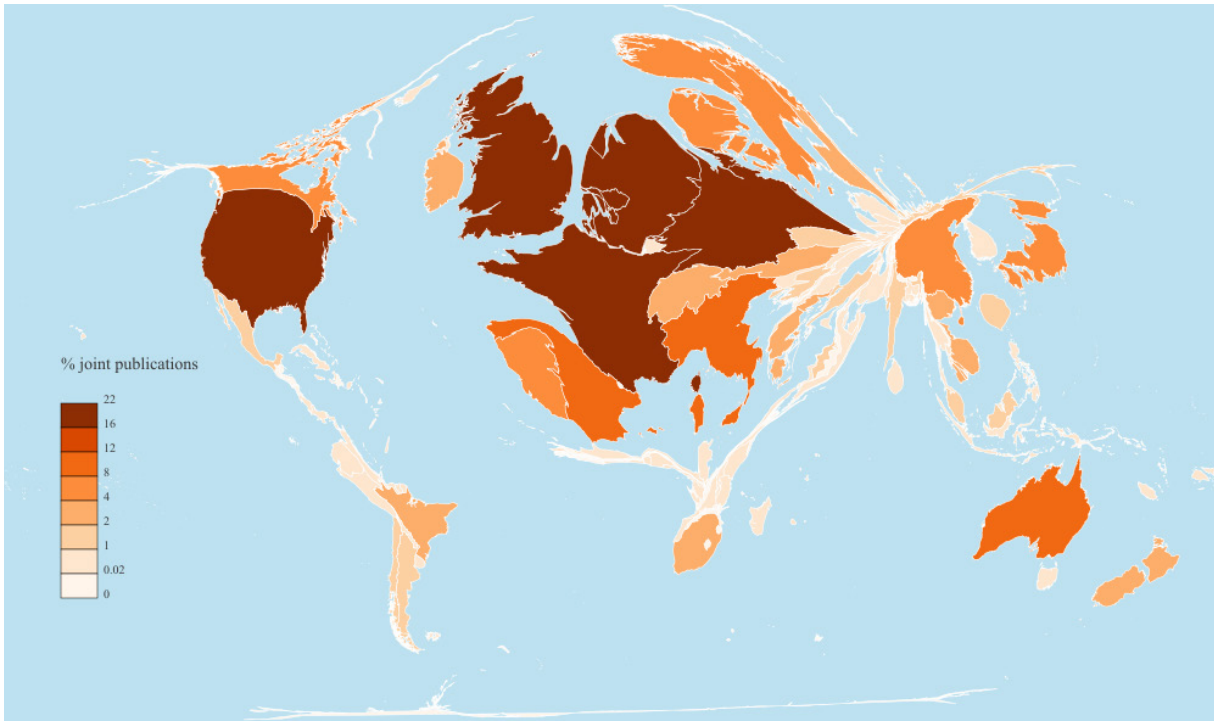


Figure 16. Geographic visualisation of the number of marine peer reviewed and VABB publications between 2018 and 2022 of MRGs according to country of affiliation of the coauthors.

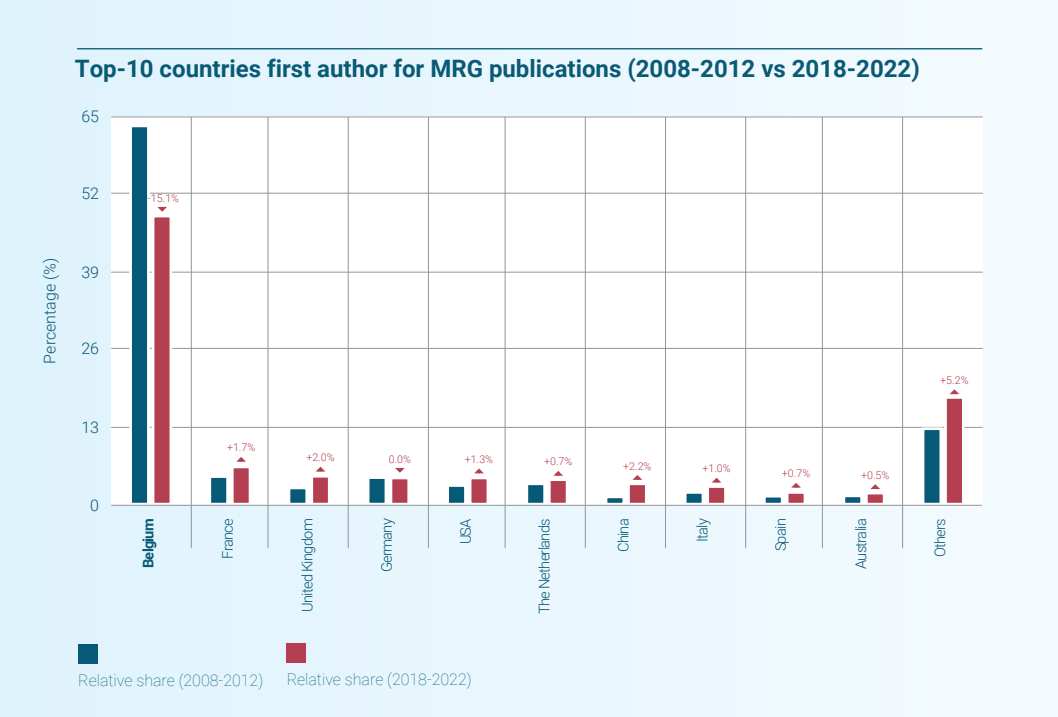


Figure 17. Evolution of the share (2008-2012 vs. 2018-2022) of the marine peer reviewed and VABB publications affiliated to an MRG according to countries that most frequently act as a first author.

2.4.4 Use of research vessels

Between 2008 and 2022, an average of 24.9%[10,11] of marine peer reviewed and VABB publications from the MRGs involved a research vessel for sampling or data collection. This proportion fluctuates between 18.9% (2016 and 2022) and 34.7% (2009) with no apparent trend (figure 18). These publications constitute the 'sea-going' research of the MRGs. The remaining publications concern mainly coastal and estuarine research, modeling studies, laboratory experimental studies, social and economic studies, historical studies, etc. However, an unknown share of these relies indirectly on marine research (e.g., for the validation of models or experiments).

1,036 publications (10.7%) mentioned the ship by name (2008-2022). This concerns 328 different research vessels from 49 different countries where RV Belgica (Belgian, mentioned in 205 publications), RV Polarstern (German, 131 publications), RV Simon Stevin (Belgian, 131 publications), RV Zeeleeuw (Belgian, 61 publications) and RV Marion Dufresne (French, 60 publications) were the most reported. Thus, in addition to Belgian research vessels, foreign vessels are used to a significant extent, with Germany (reported in 252 publications) and France (183 publications) being particularly important.

2.5 Marine research infrastructure

Marine research (Ocean Science) is considered 'Big Science', requiring expensive and sophisticated infrastructure that necessitates coordinated (observational) programmes with long-term funding (see a.o. the Global Ocean Science Report (GOSR, IOC-UNESCO 2020) and Dañobeitia *et al.* 2023). Due to the challenging nature of our seas, ocean, and coastal areas and the interdisciplinary nature of research in these environments, a wide range of specialised marine research infrastructure exists, including mobile platforms (research ships, ships of opportunity), underwater platforms (submarines, Remotely Operated Vehicles (ROVs), etc.), autonomous platforms (Autonomous Underwater Vehicles (AUVs), gliders, etc.), fixed platforms and systems, (*in situ*) sensors (chemical, biological, geophysical, etc.), remote sensing (satellites, drones, aircraft, radar, etc.), specialised laboratories and analysis capacity, e-infrastructure

[10] It should be noted that this share may change marginally when more figures become available.

[11] This figure includes publications which specifically mention a research vessel by name, as well as publications which have used a research vessel without including a reference.

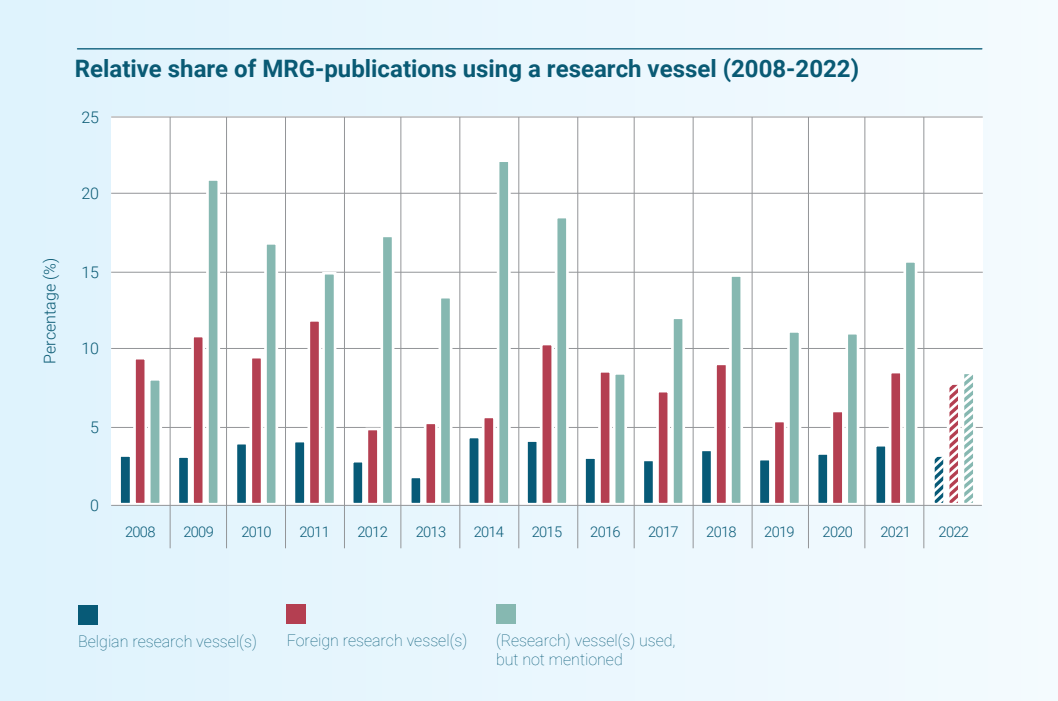


Figure 18. Evolution of the share of marine peer reviewed and VABB publications of MRGs in which a research vessel was used divided by publications using a Belgian research vessel(s) or a foreign research vessel(s) or publications in which the name of the vessel(s) was not mentioned.

(databases, models, digital twins, etc.), collections, etc. (see a.o. EC Expert group on marine research infrastructures 2013, European Marine Board 2019 - Next Generation European Research Vessels - Current Status and Foreseeable Evolution, European Marine Board 2020 - Next Generation European Research Vessels, European Marine Board 2021 - Sustaining in situ Ocean Observations in the Age of the Digital Ocean, Dañobeitia *et al.* 2023). The availability of marine research infrastructure significantly determines the scope of marine research that can be conducted. Additionally, the infrastructure must be connected to the necessary technical and scientific expertise.

Flanders and Belgium possess several major marine research infrastructures that serve the research community (see below). It should be noted that the following list is a selection of the available large-scale marine research infrastructure and is by no means exhaustive. The 'marine research infrastructure' module of the Compendium for Coast and Sea provides more detailed information on the infrastructure available at each of the Flemish/Belgian MRGs.

2.5.1 Sea-based/marine research infrastructure

- Belgian marine researchers have access to two complementary research vessels:
  - The Federal Science Policy Office (BELSPO) owns the oceanographic research vessel RV Belgica, which entered service in 2022 (investment: 54.5 million euros). This 71 meter long ship is used for marine research in the Belgian part of the North Sea, as well as in the broader North Sea, Northeast Atlantic Ocean, Mediterranean Sea and Black Sea. During the summer, the ship can also operate in Arctic waters. The ship is managed by the Operational Directorate for the Natural Environment (OD-Nature, RBINS) (scientific and budgetary management). A private operator is responsible for the ship's crew and operational aspects and maintenance, in close cooperation with the Belgian Navy, which provides personnel on the bridge. BELSPO provides approximately 6 million euros annually for the operational costs of the Belgica (including the ship's crew, part of the support services/personnel of RBINS, costs related to warranty claims, etc.).
  - The RV Simon Stevin is used for coastal oceanographic research in the Southern Bight of the North Sea and the eastern part of the Channel. The ship was built on behalf of the Government of Flanders and entered service in 2012 (investment of 11.5 million euros + 1 million euros for scientific equipment). The operation is carried out by VLOOT (the shipping company of the Government of Flanders responsible for the operational aspects of the vessel) and VLIZ (responsible for the scientific programme and the management of the research equipment), with the Government of Flanders providing an average of 1.2-1.3 million euros annually for ship operational costs. Additional budget is also allocated (approximately 100,000 euros per year) for scientific operational aspects.

- To optimise the use of the two research vessels, the managing authorities (VLIZ and RBINS) have signed a cooperation agreement;
- VLIZ also has a Rigid Inflatable Boat (RIB) Zeekat (built in 2017, 120,000 euros) and a work boat (built in 2023, +/- 600,000 euros) that can be used by the marine research community in the Belgian part of the North Sea and adjacent estuaries, with a specific focus on nearshore work;
- In 2017, the Government of Flanders decided to invest 3 million euros in the development of a Marine Robotics Centre (MRC) at VLIZ for the benefit of the marine research community. The MRC now has a specialised robotics laboratory in the Marine Station Ostend (MSO) and various robotic platforms (AUV, USV, glider, autonomous moorings, etc.). In 2024, a long-distance USV for the North Sea will be added (investment of +/- 2 million euros via the Brexit Adjustment Reserve and VLIZ);
- The Blue Accelerator platform of the West Flanders Development Agency (POM West Flanders) provides test infrastructure for marine knowledge institutes and companies to test innovative applications in a marine environment. This includes an offshore test platform near Port Oostende. This test facility was realised in part through an ERDF ITI project (European Regional Development Fund - Integrated Territorial Investment, budget of +/- 3.7 million euros with co-financing from the Government of Flanders, the Province of West Flanders and the involved partners).

2.5.2 Specialised, large-scale marine research laboratories

- The Flanders Maritime Laboratory, an initiative of UGent, KU Leuven and Flanders Hydraulics in the Ostend Science Park, has been fully operational since 2023. The Government of Flanders, along with the two universities, invested over 28 million euros in this laboratory, which consists of two main parts:
  - A wave tank (Coastal and Ocean Basin, COB) measuring 30 x 30 meters where scale models can be exposed to waves, including multi-directional wave climates, currents and wind. This specialised infrastructure is particularly suitable for research related to coastal defense measures, offshore/floating structures, and technologies for renewable energy;
  - A towing tank with a total length of 174 meters (of which 136 meters are usable for testing), a width of 20 meters, and a maximum water depth of 1 meter. Waves with amplitudes of up to 0.2 m can be generated. This new towing tank offers significant advantages over the existing towing tank in Antwerp. Tests with ship models in the new towing tank are a.o. crucial for ensuring maritime access to Flemish ports;
- UGent, POM West Flanders and Port Oostende have jointly established Ostend Science Park (OSP). This high-tech knowledge hub is aimed at marine and maritime companies and research institutes and includes specialised test facilities such as a multispecies hatchery, a saltwater wave flume, marine biotechnology/ecology labs, etc;
- In 2022, the InnovOcean Campus was opened in Ostend, housing ILVO, VLIZ and their partners (an investment of over 20 million euros by the Government of Flanders). The building includes specialised labs for ILVO, particularly for aquaculture research;
- With the Marine Station Ostend (MSO, VLIZ), the marine research community in Flanders and Belgium has a satellite laboratory near the sea. The station houses various facilities: a storage room for sediment cores, wet, dry and molecular laboratories, a cold room with three water tanks for marine organisms, a technical workshop, etc. Several of these facilities are utilised as part of European infrastructure networks (see below for **2.5.3 Marine (digital) research infrastructure in a European/international context**). In 2023, the capacity of the MSO was significantly expanded with the Ocean Innovation Space (investment of +/- 4 million euros by the Government of Flanders) featuring new lab facilities and technological labs (including the Marine Robotics Centre, as mentioned above in **2.5.1 Sea-based/marine research infrastructure)**. Direct access to the adjacent fishing dock is also provided through an installation of a pontoon for scientific research (investment of +/- 500,000 euros via the Brexit Adjustment Reserve and VLIZ);
- OWI-Lab manages specialised research and testing infrastructure related to (offshore) wind turbines. This includes a large climate chamber for testing under extreme climate conditions (investment in 2011-2012 of approximately 1.2 million euros) and instruments for corrosion testing;
- MariFish Inc. was launched in 2021 as an ERDF project involving the European Food Centre, UGent, ILVO and Ostend Science Park (an associated partner). The project aims to partially transform the fishery site in Ostend into an incubator space for companies active in aquaculture and related areas of the Blue Economy. Additionally, the site will serve as a test environment with access to sufficient volumes of high-quality seawater. The project budget amounts to 6,940,000 euros, with 50% (3,470,000 euros) financed by ERDF and 50% by project partners;
- Through the University of Liège (ULg), the marine research community has access to a marine station in the Mediterranean Sea (Calvi, Corsica): *Station Sous-Marines et Océanographiques* (STARESO).

2.5.3 Marine (digital) research infrastructure in a European/international context

Belgium and Flanders participate in various so-called ESFRI research infrastructures (European Strategy Forum on Research Infrastructures). Several of these pan-European research infrastructures are specifically relevant to the marine research community: ICOS (Integrated Carbon Observation System), LifeWatch (a virtual laboratory for biodiversity research) and EMBRC (European Marine Biological Resource Centre). The Government of Flanders allocates approximately 3.1 million euros annually to support these 'marine' infrastructures through the FWO. Since 2018, Flemish participation in such international research infrastructures has been facilitated through an FWO call for 'International Research Infrastructure'. The Federal Science Policy Office (BELSPO) covers the Belgian participation in EPOS (European Plate Observing System) and foresees in the budget for the annual Belgian contributions to the ESFRI research infrastructures that support the operations of these infrastructures on a European level.

Flanders plays a leading role in the field of marine data infrastructure within a European and international context (see also **4. Discussion 'Indicator Report Marine Research and Innovation'**). The pioneering role that VLIZ has undertaken since its establishment in 1999 in terms of marine data management has particularly led to the anchoring of several internationally recognised data systems in Flanders. These include the World Register of Marine Species (WoRMS), the Ocean Biodiversity Information System (OBIS) and the European component EurOBIS, Marine Regions, Sea Level Station Monitoring Facility, etc. Within the European Marine Observation and Data Network (EMODnet), Flemish and Belgian actors, such as VLIZ, play a pivotal role, including the coordination of the Biological component of EMODnet and the development of the central portal. This prominent position also places Flanders in an excellent position to seize the opportunities that arise within the framework of the new digital knowledge system for the ocean and water established by the EC, known as the European Digital Twin Ocean (DTO).

2.6 The funding of marine research and innovation

The marine research and innovation landscape in Flanders is funded by a multitude of funding channels. The present report provides an overview of the funding streams in the most relevant competitive funding channels for this landscape. This is by no means an exhaustive overview as a number of important funding sources are not included (direct government funding of universities and scientific institutes, investments in research infrastructure (see above), etc.).

2.6.1 European funding channels for marine research and innovation

In the text below, the funding of marine projects between 2008 and 2022 with Belgian participation in different European channels is discussed. The selection of European marine research and innovation projects with a Belgian partner occurred until the census year 2017 mainly based on the Marine Knowledge Gate, in collaboration with Eurocean (Cristina Costa, figures provided in April 2018). The data collection from 2018 was done for the Horizon 2020 (H2020) and Horizon Europe (HEurope) programmes based on a query of the CORDIS database based on marine keywords, in cooperation with the Department of Economy, Science and Innovation (EWI) (Pascale Dengis and Dries Maes, figures delivered July 2023). Interreg programmes were surveyed through the ERDF-Flanders database with support from VLAIO (Jorre Vandamme, figures delivered September 2023). Finally, marine projects funded by the European Fund for Maritime Affairs, Fisheries and Aquaculture (EMFAF) were also included in this report (figures collected and screened from 'list of beneficiaries' by VLIZ in April 2023). Other European channels through which marine research and innovation can be funded were not included in this analysis. The screening of a project as being marine was done by VLIZ using the following criteria:

- The project deals with marine and/or maritime research, either entirely or in certain components of the project. For the definition of marine and maritime research reference is made to the EU Strategy for Marine and Maritime Research;
- The component of marine/maritime research entails a significant part (of the funding) of the project;
- Projects strictly focused on freshwater, predominantly terrestrial applications or projects that have a pure theoretical marine application (e.g., technical research of wind turbines (non-specifically marine)) were not included.

The figures below, unless explicitly stated otherwise, are based on the partner budgets[12] of the Belgian organisations, with these budgets allocated to the project's[13] starting year.

[12] The partner budget refers to the exact budget a certain project partner receives within a project.

[13] Unless mentioned otherwise, in the EU-funding analysis the following institute types are not considered: NATO, international and European interest groups and clusters, the European Commission (EC), and institute types not falling within the aforementioned categories.

FP7 and Horizon 2020

In the European 7th framework programme (FP7, 2007-2013), a total of 204 marine projects with a Belgian partner were funded, representing a total partner budget of 68.4 million euros. When excluding the European and international interest groups and clusters, it concerns 140 marine projects with a total partner budget of 46.2 million euros[14] (figure 19). In 16 of these projects, a Belgian partner acted as the project coordinator.

Horizon 2020 (2014-2020) united the (successors of) European research and innovation programmes, such as the 7th Framework programme (FP7, see above), the Competitiveness and Innovation Framework Programme (CIP) and the European Institute of Innovation & Technology (EIT), into one programme. In the course of the programmes duration[15], a total of 217 H2020 marine projects were identified with a Belgian partner, representing a total partner budget of 156.9 million euros. When support for NATO, the European Commission (EC), international and European interest groups and clusters are excluded, it concerns 177 projects with a total Belgian partner budget of 138.2 million euros (figure 19). The H2020 funding towards Belgian university associations and scientific institutes – which includes the MRGs, averaged 2.1 million euros annually (2014-2022)[16]. In 29 (16%) of these marine H2020 projects a Belgian organisation acted as the project coordinator.

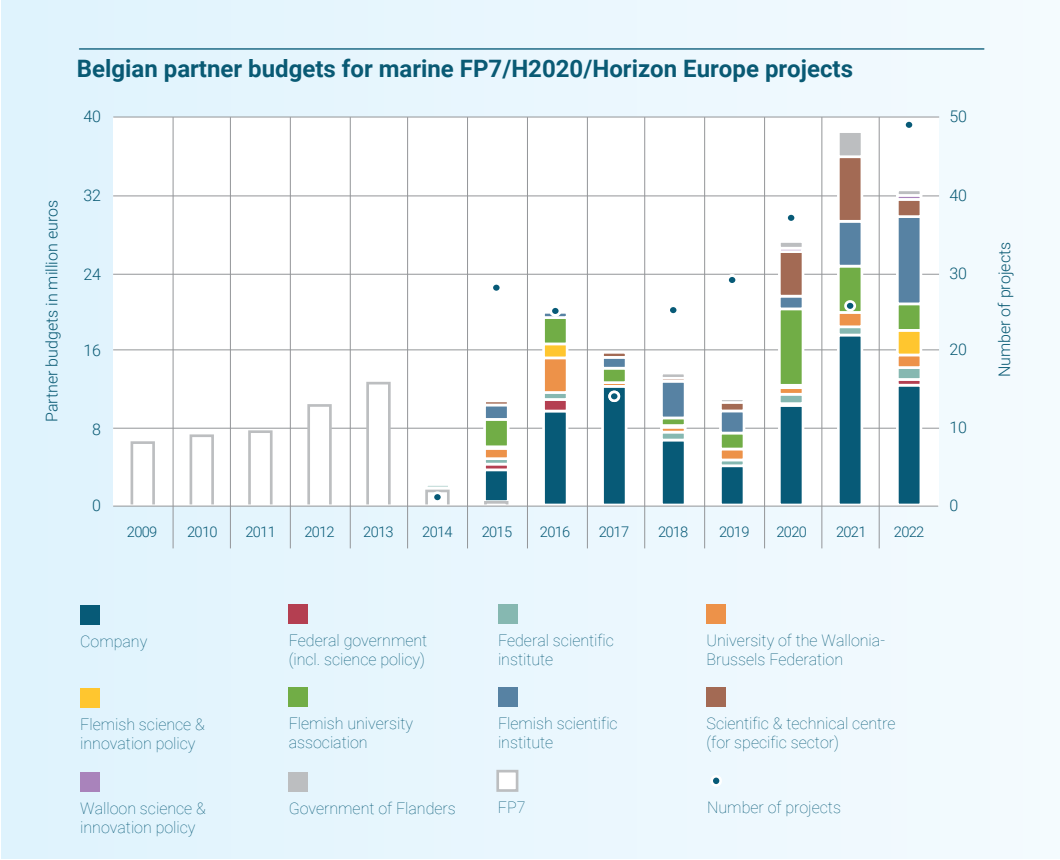


Figure 19. Evolution of the partner budgets (in million euros) and the number of starting projects for Belgian organisations in marine Horizon 2020 and Horizon Europe projects according to organisation type. For completeness this also included the evolution of the FP7-funding programme.

[14] For comparison: The Belgian participation in FP7 equaled 3,652 projects and a budget of 1,814.9 million euros (including European and international (stakeholder) organisations based in Belgium) (Van Langenhove & Dengis 2014).

[15] In 2021 and 2022 27 marine projects with a Belgian partner funded by Horizon 2020 started, accounting for a total budget of 39.5 million euros.

[16] In 2014, no marine projects with Belgian partners within Flemish university associations (FUA) and Flemish scientific institutes (FSI) were funded from Horizon 2020. If the average of project funding to FUA and FSI is considered over the period 2015-2022, the amount involved is 2.3 million euros.

Figure 20 provides an overview of the Belgian partner budgets of marine projects, according to three different Horizon 2020 pillars and two 'specific objectives' that represent the key priorities of the H2020 programme. The 'Societal Challenges' pillar is the clear leader with a total Belgian partner budget of 112.3 million euros (81.8%). Within this pillar, research is mainly carried out in the categories 'Secure, Clean and Efficient Energy' (37.4 million euros; 27.0%) and 'Smart, Green and Integrated Transport' (36.7 million euros; 26.5%). In second place is the 'Excellent Science' pillar with 19.3 million euros (13.9%), mainly involving research supported by 'Marie-Sklodowska Curie Actions' (6.8 million euros; 35.1%) and 'European Research Council' (ERC) grants (6.3 million euros; 32.6%). A detailed overview of the H2020 programme structure, goals and overall budget distribution can be viewed on the European Commission website (EC Funding and tender opportunities).

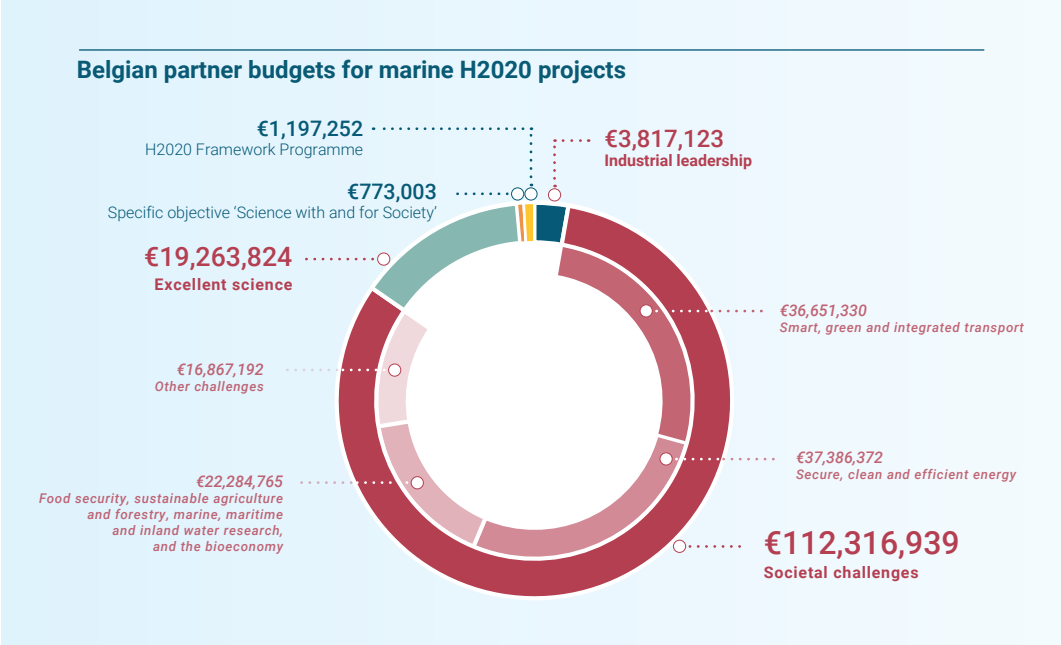


Figure 20. Partner budgets (in euros) for Belgian organisations in marine projects according to the three overarching pillars and specific objectives within Horizon 2020 (2014-2020).

Horizon Europe

The H2020 programme was succeeded in 2021 by Horizon Europe (2021-2027) (HEurope). With a total budget of 95.5 billion euros, HEurope is Europe's main funding programme for research and innovation. It is specifically aimed at helping Europe achieve its climate and sustainability goals and boosting Europe's economic competitiveness and growth. In 2022, the HEurope programme funded 61 marine projects with a Belgian partner, totaling 40.3 million euros. Excluding support from NATO, the European Commission, international and European interest groups and clusters, this amounts to a total of 31.5 million euros spread over 45 projects (figure 19).

Figure 19 shows the evolution of the partner budgets of Belgian organisations in marine H2020 and HEurope projects by institute type between 2014 and 2022. During this period, the budget for Belgian partners averaged 18.5 million euros annually[17], with the largest share taken by companies with an average of 8.5 million euros annually, followed by Flemish university associations (2.8 million euros annually) and Flemish scientific institutes (2.7 million euros annually). The overall trend in budgets for Belgian partners is upward, with a clear jump in H2020 and HEurope funding starting in 2020.

Figure 21 provides an overview of the thematic distribution of total Belgian partner budgets within the HEurope programme (2022). The main themes in budgetary terms are 'Food, Bioeconomy Natural Resources, Agriculture and Environment' (12.2 million euros; 38.7%), 'Climate, Energy and Mobility' (11.1 million euros; 35.1%) and 'Digital, Industry and Space' (5.5 million euros; 17.3%). The remaining themes follow at a considerable distance.

[17] In comparison, the total Belgian Horizon 2020 funding was 3.39 billion euros (4.97% of the total) with an average of ca. 484 million euros/year (2014-2020) (Belgium Horizon2020 country profile).

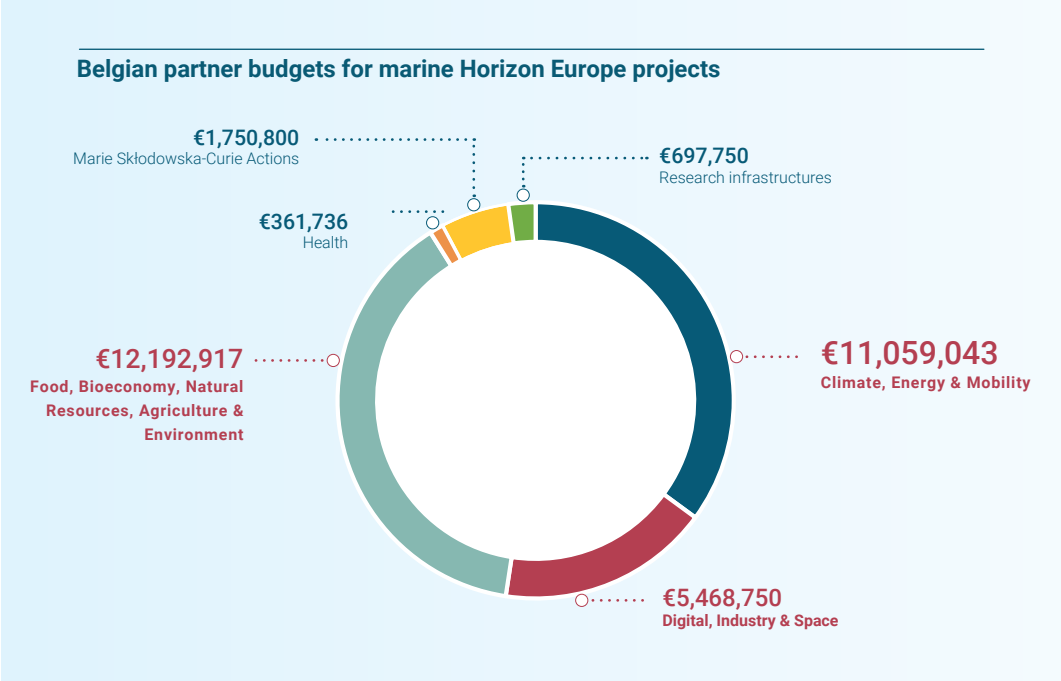


Figure 21. Thematic distribution of the Belgian partner budgets in euros within the Horizon Europe programme (2022).

The European Maritime, Fisheries and Aquaculture Fund (EMF(A)F)

The European Maritime and Fisheries Fund (EMFF, 2014-2020) supports the fisheries and aquaculture sector in Member States to achieve the objectives of the European Common Fisheries Policy (CFP). EMFF's successor, the European Maritime, Fisheries and Aquaculture Fund (EMFAF) (2021-2027), launched in 2021. However, figures for the EMFAF are currently unavailable as subsidy applications for this channel were only made possible from July 2023.

In addition to 'direct' management (distribution of funds directly from the European Commission), the vast majority of funds are allocated through 'shared' management (through national governments) cf. the strategic priorities in the national operational programmes (Department of Agriculture and Fisheries website). The current analysis focuses on the funds allocated by Flanders (i.e., shared management) for research and innovation projects and data collection programmes. Subsidies for the purpose of compensation for the temporary cessation of the fishing fleet, technical assistance, vessel-specific or company-specific investments, preparation of marketing plans, creation of promo videos and concrete actions related to control and enforcement by the Government of Flanders are not considered here.

Between 2014 and 2022, over 12.9 million euros in support was disbursed through the EMFF for research and innovation projects and data collection programmes, representing an average of 1.4 million euros annually (figure 22). The bulk of the funds were framed within the implementation of the Belgian National Data Collection Programme (NDCP), accounting for 10.3 million euros. The NDCP provides for data collection on Belgian commercial marine fisheries in support of the European CFP.

European Fund for Regional Development (EFRD) – Interreg programme

The Interreg programme is funded by Europe to promote cooperation between regional areas in different countries. To identify the marine Interreg projects, all approved projects of Interreg V (2014-2020) and Interreg VI (2021-2027) were screened by VLIZ for their marine themes. Subsequently, the partner budgets of the marine Interreg projects were supplemented by VLAIO and by VLIZ based on a screening of the Keep.eu database. For Interreg IV (2007-2013), the starting point was marine projects with a Belgian partner included in Eurocean's Marine Knowledge Gate, which is no longer up to date. As a result of this different approach, the marine Interreg IV projects with Belgian participation have a lower degree of completeness than Interreg V and Interreg VI. In what follows, only the marine Interreg V and Interreg VI projects will therefore be discussed in more detail.

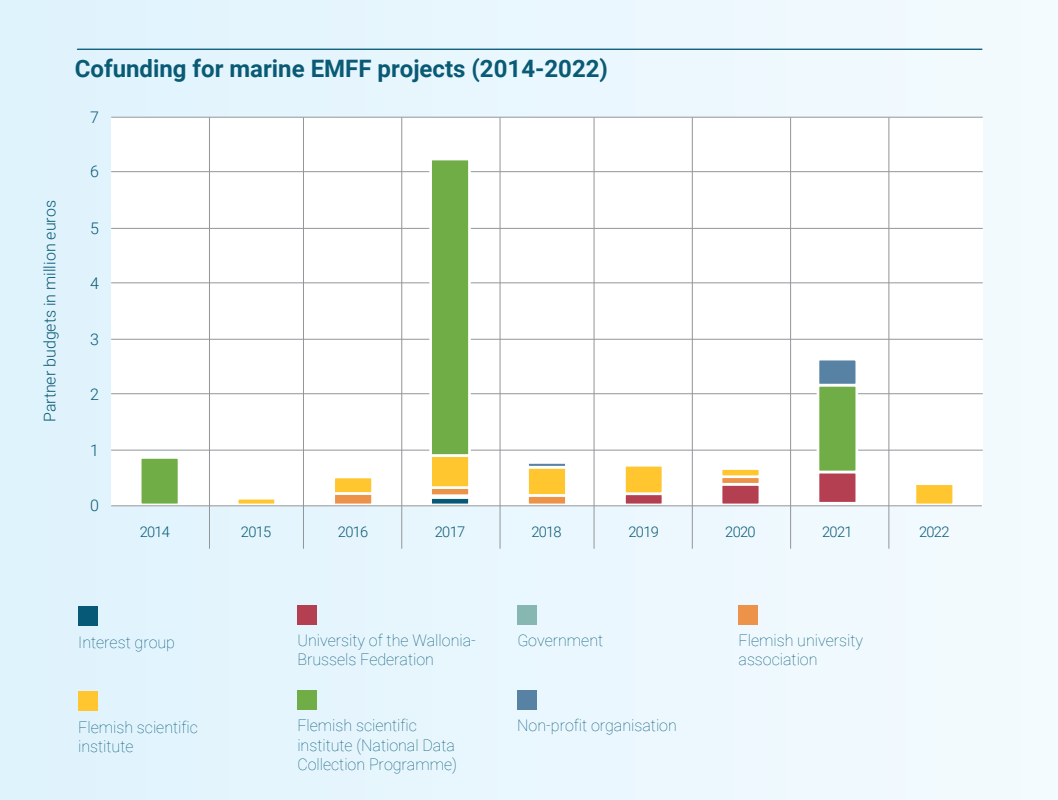


Figure 22. Evolution of the cofounding (in million euros) of EMFF projects between 2014-2022 according to organisation type.

The Interreg V programme ran from 2014 to 2020. During this period, a total of 58 marine projects with a Belgian partner started for a total ERDF funding of 31.6 million euros. Most of this funding went to administrations and public companies (Flemish seaports), together accounting for 14.2 million euros, and to Flemish university associations (7.2 million euros) (figure 23). The Interreg VI programme (2021-2027) represents a total of 1.5 million euros in ERDF funding, spread over three marine projects that all started in 2022. In the analysis of the evolution of the funding of marine projects by the Interreg programmes, each time a rather large gap is noticed during the transition years between the different programmes (IV, V and VI). As a result, Interreg funding shows a rather erratic pattern, although a decreasing trend is noticeable since 2016.

Figure 24 shows that most marine projects in Interreg V (2014-2020) were funded within the Interreg 2 Seas programme (9.5 million euros funding), followed by the Flanders - Netherlands programme (8.8 million euros funding) and the Interreg North Sea Region programme (5.7 million euros funding). The marine projects with Belgian partner within the Interreg VI programme all belong to the Interreg North Sea Region programme (1.5 million euros funding).

2.6.2 Federal funding of marine research and innovation

BELSPO

For the funding of marine research by BELSPO, a selection of projects with a marine finality was made by BELSPO based on the Fedra database and various BELSPO websites. After validation by VLIZ, a list of 86 marine BELSPO projects starting between 2008 and 2022 was obtained (different phases of a project are not counted separately). Except for one project, each of the selected projects involved at least one marine research group (MRG).

Figure 25 shows the evolution of budgets for BELSPO marine projects (2008-2022) by type of organisation. This figure also visualises the budget allocated to marine research groups (MRGs). In the trend analysis, two low values stand out. A first marked decline occurred in 2011 (265,000 euros) and was caused by the former federal government crisis. A second sharp decline occurred in 2018 (300,000 euros). In general, a clear downward trend in funding for marine projects has been observed since 2012 (from 6.6 million euros in 2012 to 300,000 euros in 2018 (-95.4%)). After 2018, a slight increase is recorded, although the average annual project budget (1.0 million euros for the period

2019-2022), remains well below the values recorded in previous years (average 3.9 million euros between 2012 and 2017). Over the period 2008-2022, an average annual project budget of 2.3 million euros is recorded. For the MRGs, the annual average for the same period was 2.1 million euros.

The evolution of BELSPO funding of marine projects according to funding programmes, is shown in figure 26. It shows that the period 2012-2017 is dominated by the BRAIN programme (Belgian Research Action through Interdisciplinary Networks) with an annual average of 2.7 million euros. As of 2018, marine projects are mainly supported within the JPI-Oceans programme with an average annual budget of 0.6 million euros.

Figure 23. Evolution of the funding (in million euros) for marine Interreg projects according to organisation. It's worth mentioning that Interreg IV has a lower degree of completeness than Interreg V and that the transition year (2022) between Interreg V and VI may not be presented entirely accurately.

Energy Transition Fund

The federal Energy Transition Fund (ETF) which was initiated in 2016 aims to encourage and support research, development and innovation by energy related companies and organisations. In the offshore context, this often revolves around renewable energy developments in Belgium's exclusive economic zone in the North Sea. Based on the list of approved projects within the ETF (situation September 2023), a selection of marine projects was made by VLIZ. Project budgets were then added to this selection by the FPS Economy.

From 2018 to 2022, 24 marine projects with a Belgian partner were supported by the ETF for a total of 37.8 million euros (figure 27). Between 2018 and 2022, most ETF related research is conducted within knowledge institutes (20.4 million euros; 54.1%), followed by research through a partnership between knowledge institutes and companies (16.7 million euros; 44.2%). A small fraction of research occurs purely within a business context (0.6 million euros; 1.6%). Projects where knowledge institutes and companies collaborate are experiencing a solid rise after 2020, with a clear peak in 2022.

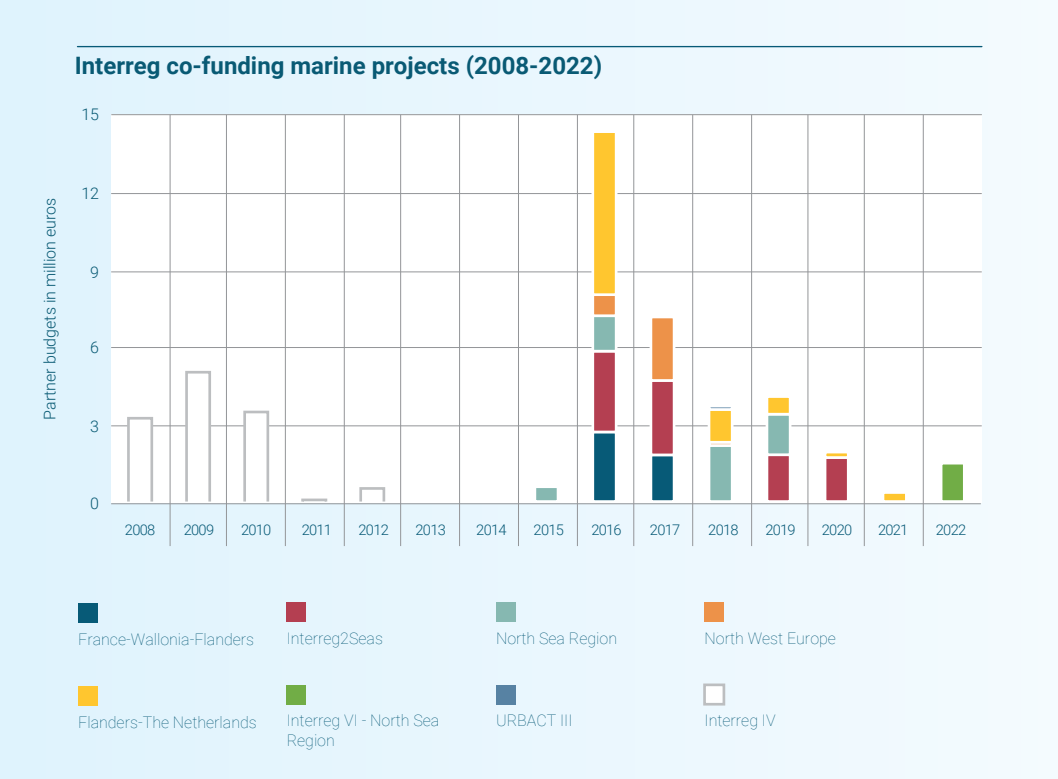


Figure 24. Evolution of funding (million euros) for marine Interreg projects according to the different programmes. It's worth mentioning that Interreg IV has a lower degree of completeness than Interreg V and that the transition year (2022) between Interreg V and VI may not be presented entirely accurately.

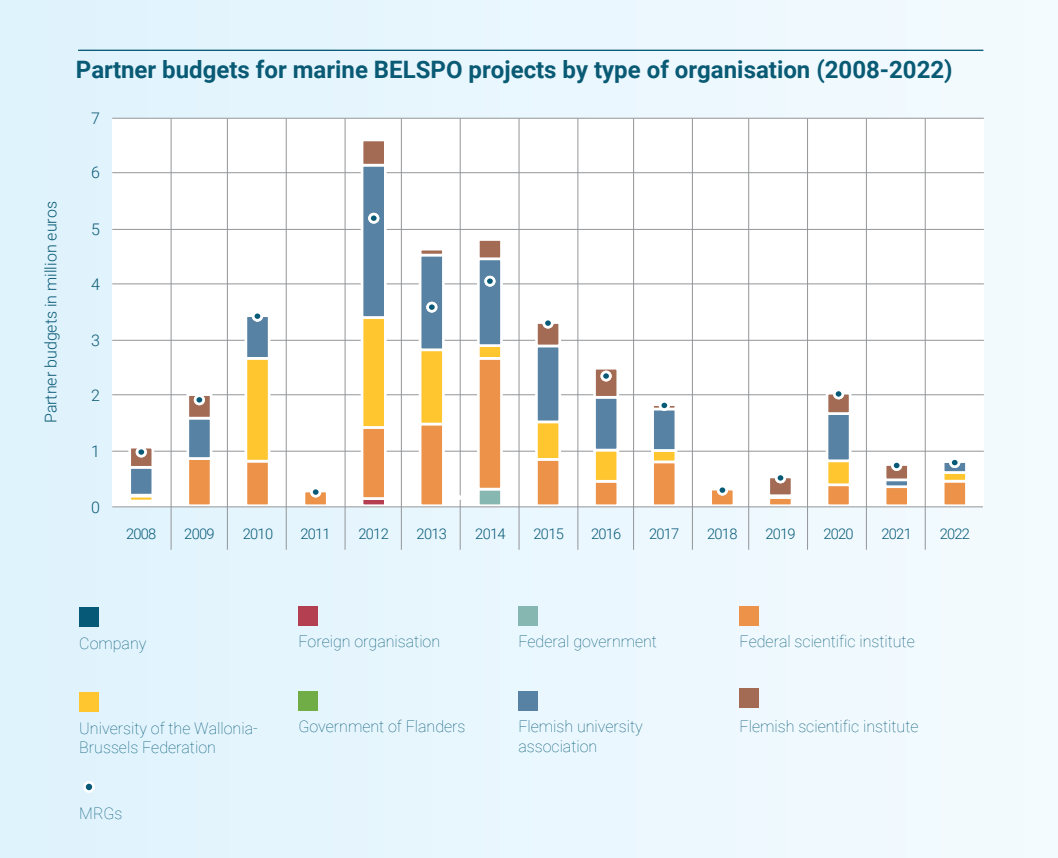


Figure 25. Evolution of the annual BELSPO budget (in million euros) for marine project according to organisation type. Budgets allocated to the project's starting year.

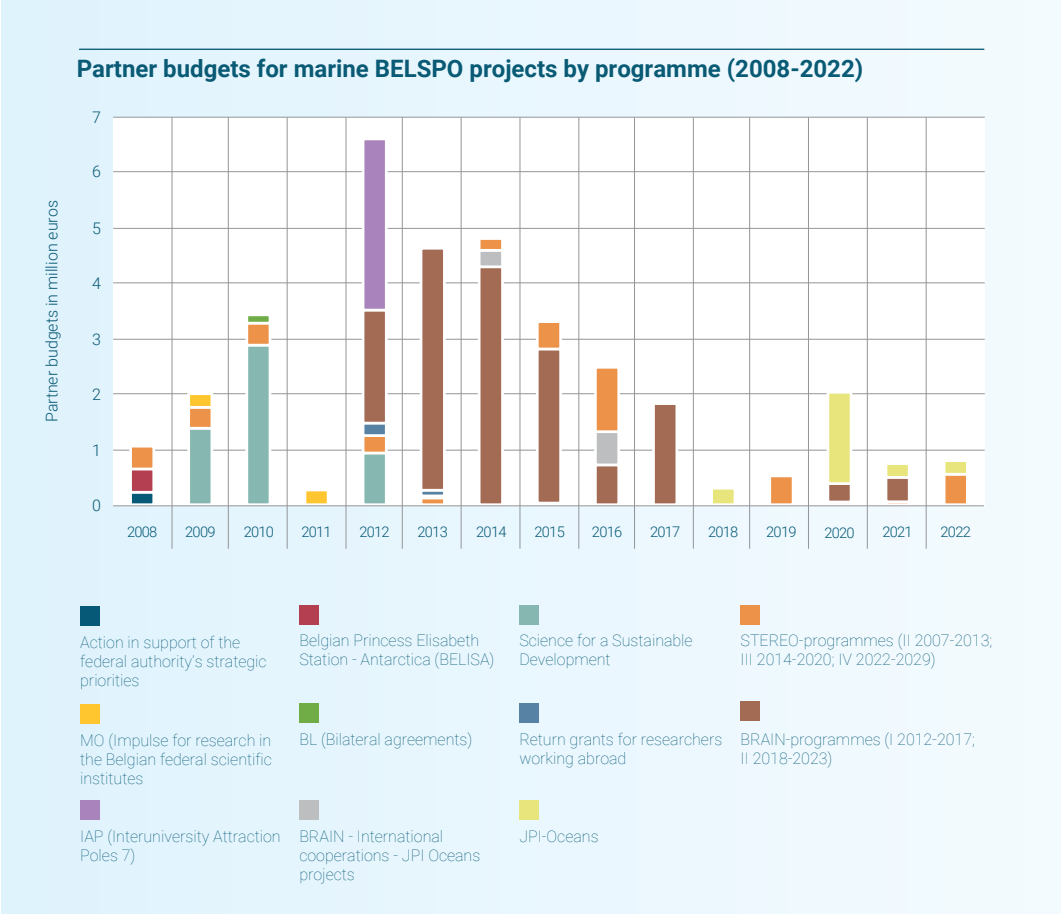


Figure 26. Evolution of the annual BELSPO budget (in million euros) for marine projects according to the funding programme. Budgets allocated to the project's starting year.

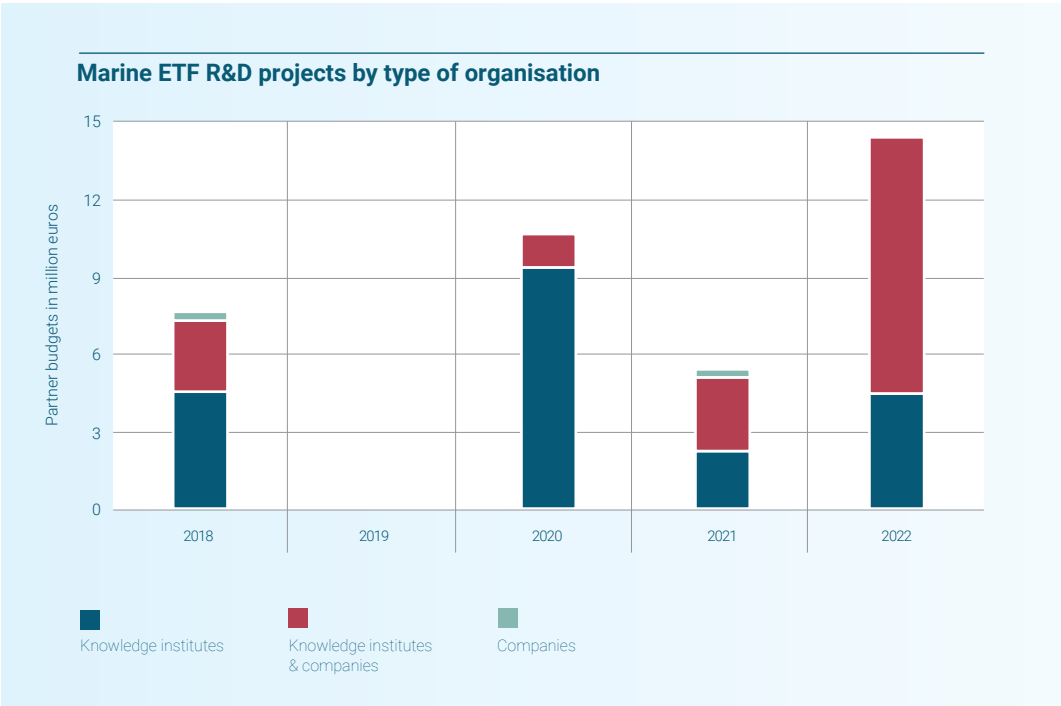


Figure 27. Analysis of budget of marine projects within the ETF according to organisation type. Budgets allocated to the project's starting year.

2.6.3 Flemish funding chanels for marine research and innovation

The text below provides an overview of the funding of marine research and innovation projects through the following Flemish channels: the Research Foundation - Flanders (FWO), the Special Research Fund (*Bijzonder Onderzoeksfonds*) (BOF), the Industrial Research Fund (*Industrieel Onderzoeksfonds*) (IOF), the Flanders Innovation & Entrepreneurship (VLAIO, and former IWT), the Flemish Interuniversity Council for University Development Cooperation (VLIR-UOS) and the Flanders UNESCO Science Trustfund (FUST).

Research Foundation – Flanders (FWO)

To identify marine FWO projects and mandates, a list of (potential) project promoters of the marine research groups (MRGs, 2008-2022) and a list of marine keywords (not applicable to marine FWO projects and mandates for 2018) was delivered to EWI (Pascale Dengis) in spring 2023, on the basis of which a wide selection of projects was obtained from the FRIS research portal. Consequently, these projects were screened by VLIZ for a possible marine theme. The reduced project list was subsequently returned to EWI and the project information was completed with the budget info by the data providers (FWO).

In the period 2008-2022, a total of 173 marine FWO projects were identified (with a promoter associated to an MRG), accounting for a total amount of 48.4 million euros or an average of 3.2 million euros[18] annually. Until 2017, a decreasing trend is noticeable with a peak from 6.1 million euros (27 projects) in 2009 to less than 1 million euros (three projects) in 2017 (figure 28). This decline shows some degree of correlation with the general decline in the success rates of FWO research projects (FWO Bestedingsanalyse 2014-2018). Since 2017, annual funding for FWO projects has increased again, albeit without an unambiguous trend. Whereas the average budget for marine FWO projects remained relatively stable in the past, a trend towards more expensive projects seems to have emerged in recent years. For example, the average budget for a marine FWO project doubled from 0.2 million euros pre-2018 to almost 0.5 million euros post-2018.

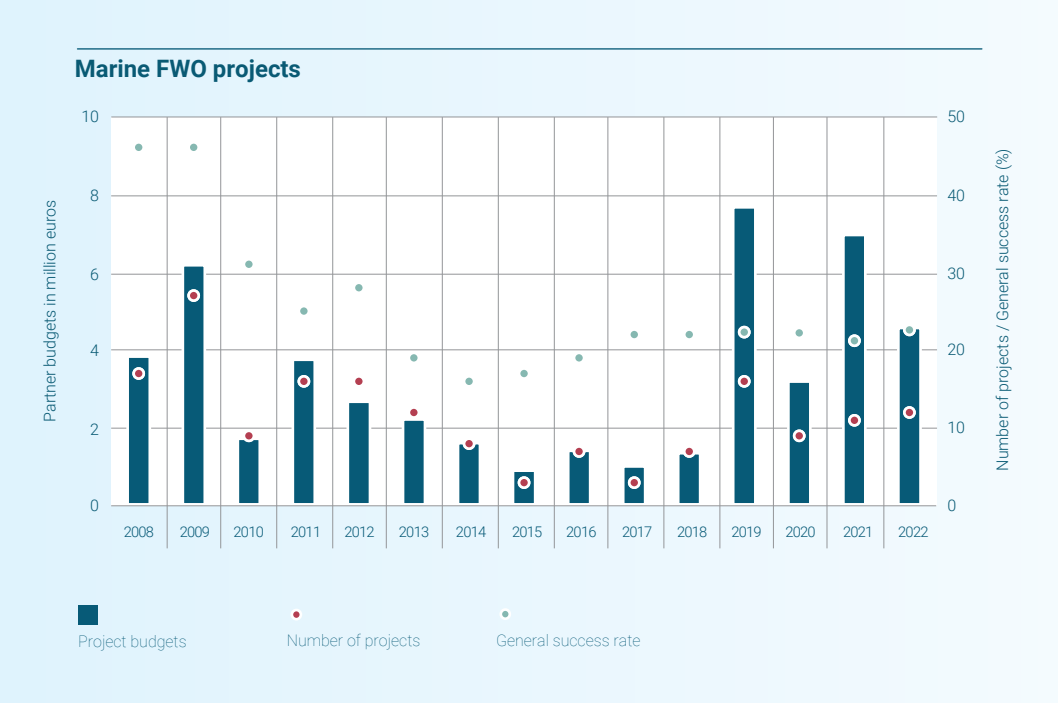


Figure 28. Evolution of the annual budget (in million euros) for marine FWO projects with a promotor affiliated to an MRG. The figure also demonstrates the number of annually financed FWO projects next to the overall success rate of FWO research projects (Source: FWO bestedingsanalyse 2014-2018 and FWO annual reports (2019, 2020, 2021 and 2022)). Budgets allocated to the project's starting year.

[18] For comparison: within the 'fundamental research' pillar of the FWO, a total of 246.2 million euros was reserved for research projects (Speurgids Ondernemen & Innoveren 2022).

As for FWO mandates (with a promoter associated to an MRG), 235 marine mandates were counted between 2008 and 2022, accounting for a total budget of 36.2 million euros. The mandates can be further divided into aspirant mandates (16.4 million euros) and post-doc mandates (19.8 million euros). It should be mentioned here that the renewal of a mandate is counted separately. After a peak in 2009 with 4.2 million euros of funding for marine FWO mandates, a gradual decline is observed until 1.2 million euros in 2016 (figure 29). After 2017, a new increase in funding for marine FWO mandates occurs. This increase is mainly observed for the aspirant mandates (from 0.5 million euros in 2017 to 2.3 million euros in 2018). The post-doc mandates fall to 0 euros in 2018 after which a recovery emerges in the following years (1.2 million euros in 2020). Over the entire period (2008-2022), and for aspirants and post-docs combined, the annual average funding for FWO mandates is ca. 2.4 million euros. Unlike for FWO projects, there is no correlation with the overall success rates[19] of FWO mandates (Source: FWO bestedingsanalyse 2014-2018 and FWO-annual reports (2019, 2020, 2021 and 2022)).

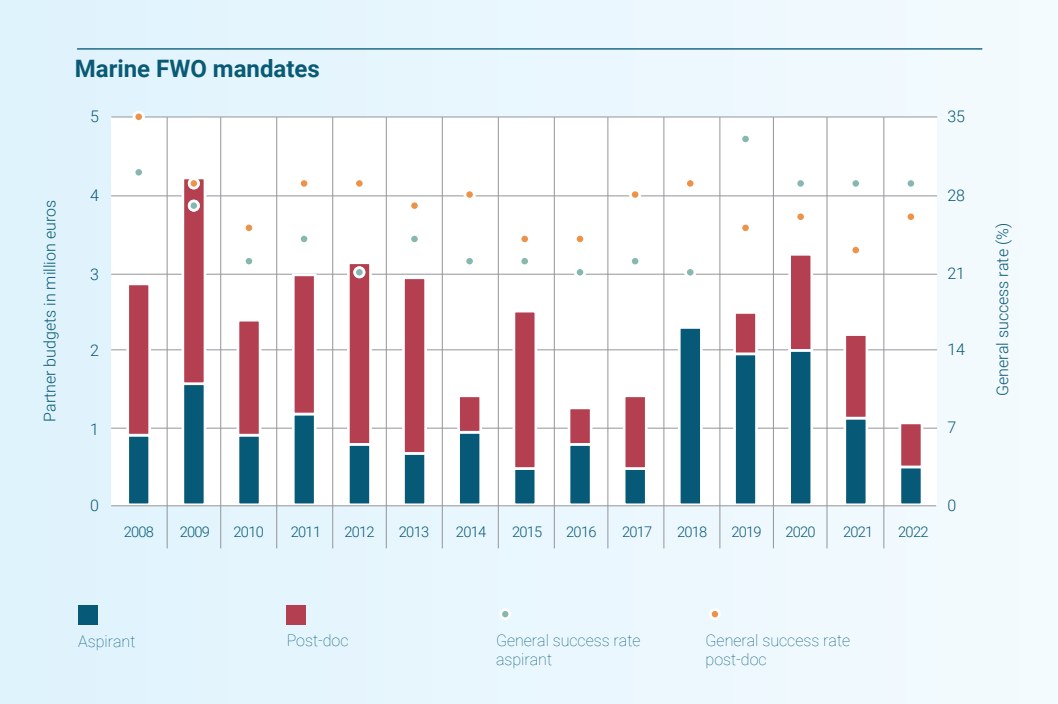


Figure 29. Evolution of the annual budget (million euros) for marine FWO mandates (with a promotor affiliated to an MRG). The figure also demonstrates the overall success rate of FWO mandates (aspirant and post-doc) (Source: FWO bestedingsanalyse 2014-2018 and FWO annual reports (2019, 2020, 2021 en 2022)). Budgets allocated to the project's starting year.

Special Research Fund (BOF) and Industrial Research Fund (IOF)

Like the FWO, the Special Research Fund (BOF) focuses on basic scientific research, but unlike the FWO, these are subsidies that are allocated to universities based on fixed criteria after which they are further distributed within the university based on intra-university competition. For the mapping of marine BOF projects and mandates, a list of (potential) project promoters from the marine research groups (MRGs, 2008-2022) and a list of marine keywords (not applicable to marine BOF projects and mandates for 2018) were delivered to EWI (Pascale Dengis) in spring 2023, after which a wide selection of projects was obtained from the FRIS research portal. These projects were screened by VLIZ for a possible marine theme, whereafter a reduced list was returned to EWI and completed by the data providers with the budget info.

A total of 242 marine BOF projects and mandates were identified (with a promoter associated to an MRG) during the period 2008-2022. This corresponds to a total amount of 54.3 million euros or an annual average of 3.6 million euros[20]. The figures fluctuate considerably due to the launch of concerted research actions, although a rather decreasing trend can be observed. Compared to the total BOF funding for research projects, marine projects with a Flemish university partner account for ca. 1% (Speurgids Ondernemen & Innoveren 2022) The number of BOF supported projects shows no clear trend (figure 30).

[19] The presented success rates are the average success rates of fundamental and strategic basic research and not specifically marine.

[20] For comparison: in 2022 the Flemish universities received a total of 222.2 million euros in BOF-funding (Speurgids Ondernemen & Innoveren 2022).

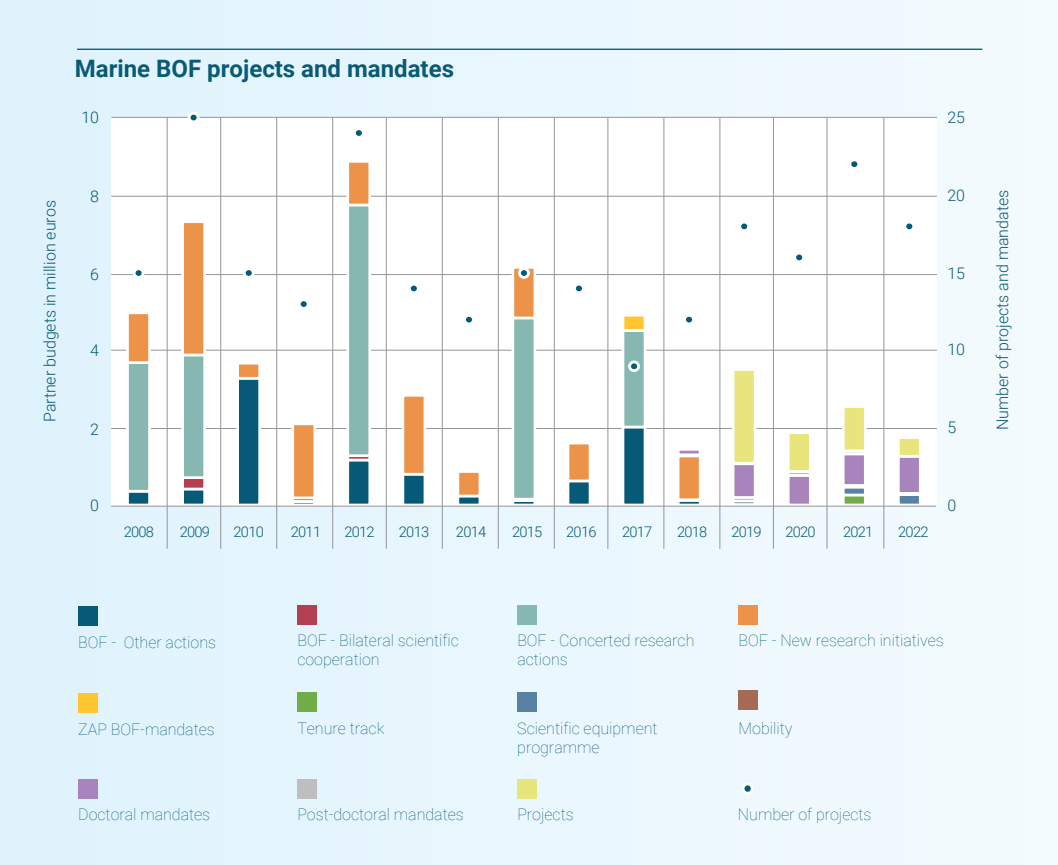


Figure 30. Evolution of the annual BOF budget (million euros) for marine projects and mandates (with a promotor associated to an MRG) according to funding programme. The figure also demonstrates the number of annually funded marine BOF projects and mandates. Budgets allocated to the project's starting year.

Unlike the FWO, the Industrial Research Fund (IOF) is an internal earmarked fund of a university association whose resources are used for strategic basic research and applied scientific research with an economic or mixed economic-social finality. The collection of project budget data for marine research with Belgian partners was done analogously to the method described above for FWO funding.

Between 2018 and 2022, a total of 16 marine projects were funded with a total budget of 2.6 million euros or an average of 0.5 million euros annually. For now, the figures do not show a clear trend (figure 31). 2021 was the most successful year in the considered period with five projects approved for a total of just under 1 million euros of IOF funding.

Flanders Innovation & Entrepreneurship (VLAIO (and IWT))

For the identification of marine VLAIO (and IWT) projects and mandates, a broad selection of possible marine projects and mandates funded by IWT (until 2015), and subsequently by Flanders Innovation and Entrepreneurship (VLAIO)[21], was provided based on a list of marine keywords (Donald Carchon, August 2023). This broad list was carefully screened by VLIZ for initiatives with a marine finality.

A total of 241 marine projects and mandates were identified that were funded by IWT or VLAIO between 2008 and 2022 (figures 32 and 33). This represents a total budget of 130.6 million euros or an annual average of 8.7 million euros. This annual average can be further divided into 2.2 million euros for projects with companies only, 4.7 million euros for projects with companies and knowledge institutes and 1.8 million euros for projects with knowledge institutes only. Within the latter two categories, projects with the participation of an MRG represent an average of 5.7 million euros per year.

[21] VLAIO was established in 2016 as a merging between Enterprise Flanders and IWT. This new agency has taken over all former IWT funding channels where a company is the applicant.

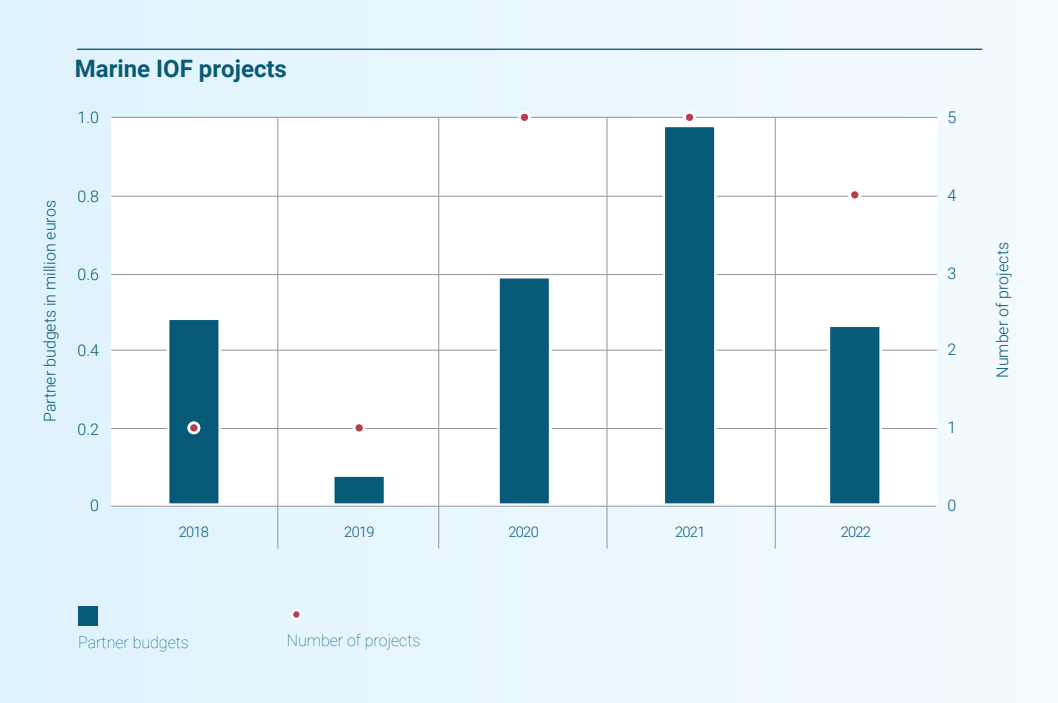


Figure 31. Overview of the Industrial Research Fund (IOF) funding of marine projects (in euros) between 2018-2022 as well as the evolution of the number of IOF-funded marine projects. Budgets allocated to the project's starting year.

The transition from IWT to VLAIO is marked by a clear increase in the number of projects involving only companies (figure 32). In addition, there's a significant increase in funding after 2018 that can be directly attributed to the creation of The Blue Cluster ('*De Blauwe Cluster*', DBC). This spearhead cluster aims to boost the marine innovation landscape in Flanders with the mission of a forward-thinking, sustainable development of the Belgian Blue Economy. As the leading marine network organisation, DBC is strongly committed to building partnerships between companies, knowledge hubs and government agencies. This is clearly reflected in the figures, as since the establishment of DBC, marine projects and mandates supported by VLAIO funding have been primarily executed within partnerships between companies and knowledge institutes (figure 32). Since the establishment of DBC in 2018, approximately 55.7% (37.0 million euros) of all VLAIO-supported marine projects and mandates go to projects of DBC. When projects in which DBC acts as a partner are included, this share rises to 67.3%, or 48.2 million euros (figure 32).

With the transition from IWT to VLAIO (2016), an increase in company funding focusing on research and development is observed. This trend continued after the establishment of DBC, as company funding is since then also applied within the context of academic strategic basic research, ICON projects and innovation projects of spearhead clusters (figure 33). Overall, between 2018 and 2022, ca. 42.3 million euros was attributed to company funding focusing on R&D (59.1%), followed by strategic basic research (SBO) with ca. 22.6 million euros (31.6%). The decline in R&D budgets after the strong peak in 2019 can possibly be explained by a limited capacity of R&D activities that companies and knowledge institutes can engage in within a given period.

Marine IWT and VLAIO funding goes for 23% to projects related to Blue Energy (offshore wind, wave energy, offshore energy storage, etc.) (period: 2008-2022) (figure 34). The other Blue Economy themes represent between 11% and 5% of the marine IWT and VLAIO budget: maritime transport and ports (11%), offshore materials (11%), marine biotechnology (11%), hydraulic engineering (8%), aquaculture (7%), etc.

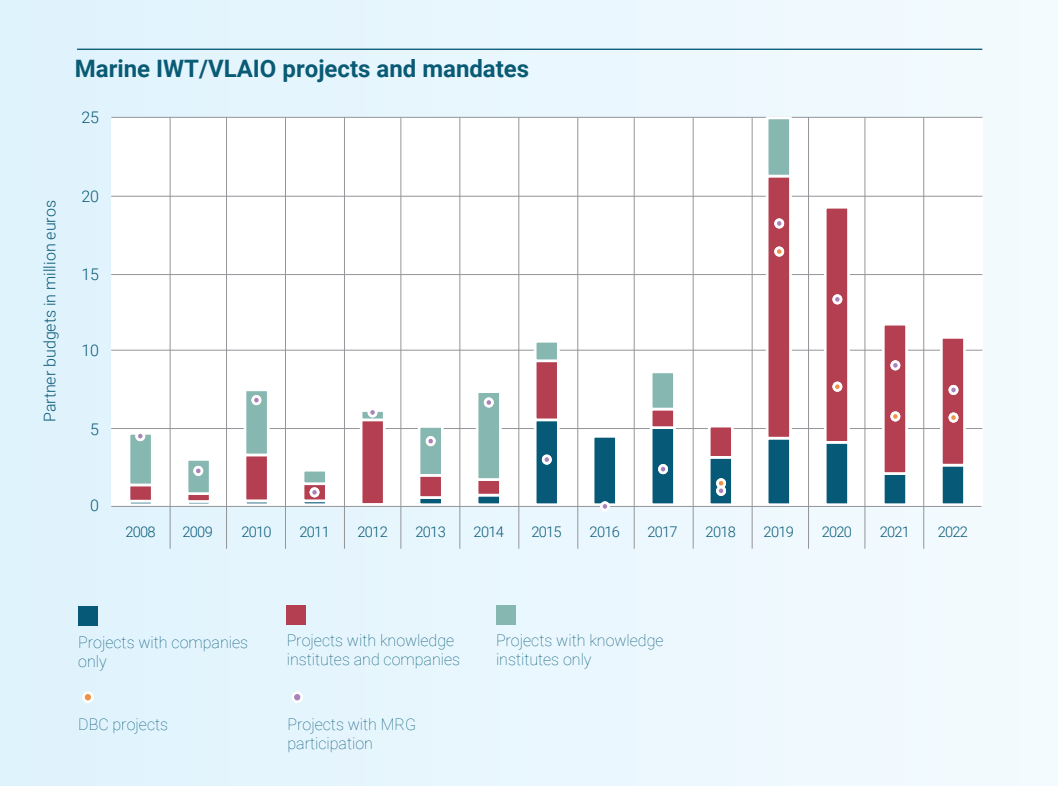


Figure 32. Evolution of the annual IWT/VLAIO-budget (in million euros) for marine projects and mandates according to participation of companies, knowledge institutes and MRGs. The figure also presents VLAIO project budgets in which DBC acts as a project coordinator and as a project partner (coordinator + partner budgets). Budgets allocated to the project's starting year.

VLIR-UOS – Flemish Interuniversity Council for University Development Cooperation

Subsidies from the Flemish Interuniversity Council for University Development Cooperation (VLIR-UOS) support partnerships between Flemish university associations and universities in the South. The subsidies specifically target projects that seek to respond to local and global challenges. For the identification of marine VLIR-UOS projects, a list of (potential) project promoters from the marine research groups (MRGs, 2008-2022) and a list of marine keywords (not applicable for marine VLIR-UOS projects prior to 2018) was delivered to EWI (Pascale Dengis) in spring 2023, after which a wide selection of projects was obtained from the FRIS research portal. These projects were screened for a possible marine focus by VLIZ, after which a reduced list was delivered back to EWI and completed with the budget info by the data providers.

A total of 79 marine VLIR-UOS projects, mandates or programmes were identified between 2008 and 2022 (with a promoter linked to an MRG), accounting for a total budget of 12.3 million euros (annual average of 0.8 million euros). Funding shows an erratic pattern, although since the middle of the last decade there seems to have been a decline in both the number of projects and the associated budgets (figure 35).

Slightly less than half (48.3%) of the total VLIR-UOS budget for marine VLIR-UOS projects, mandates or programmes, goes to the so-called International Course Programme (ICP) to support capacity building activities within marine training programmes in Flanders (see section **3. Marine and maritime training**) (figure 36).

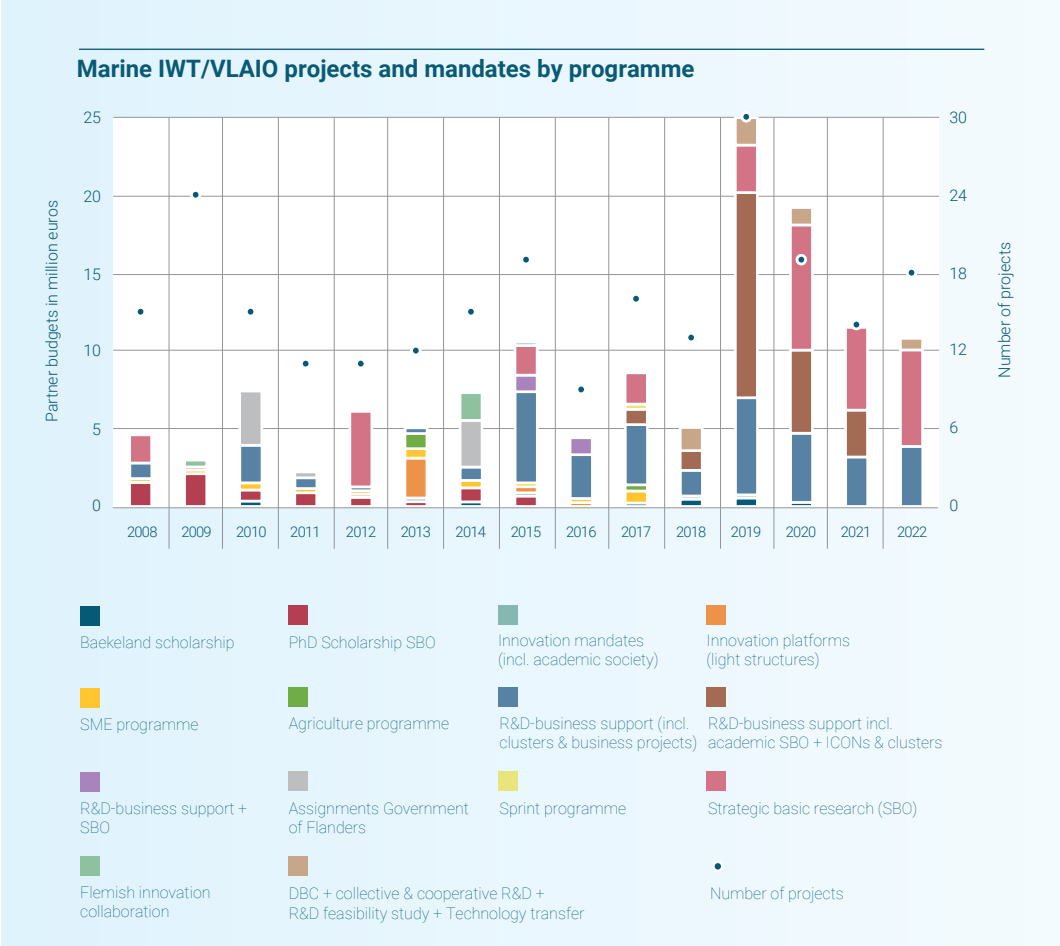


Figure 33. Evolution of the annual IWT/VLAIO budget (in million euros) for marine projects and mandates according to funding programme. Budgets allocated to the project's starting year.

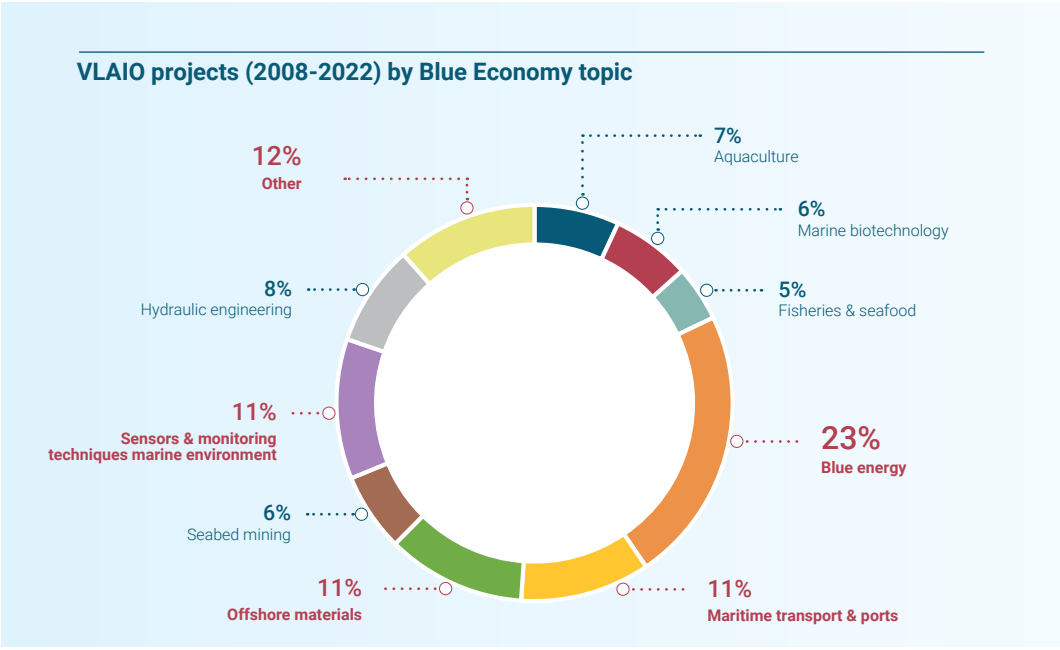


Figure 34. Distribution of the IWT/VLAIO funding between 2008-2022 according to the Blue Economy topic. Remark: A project can be attributed to multiple topics.

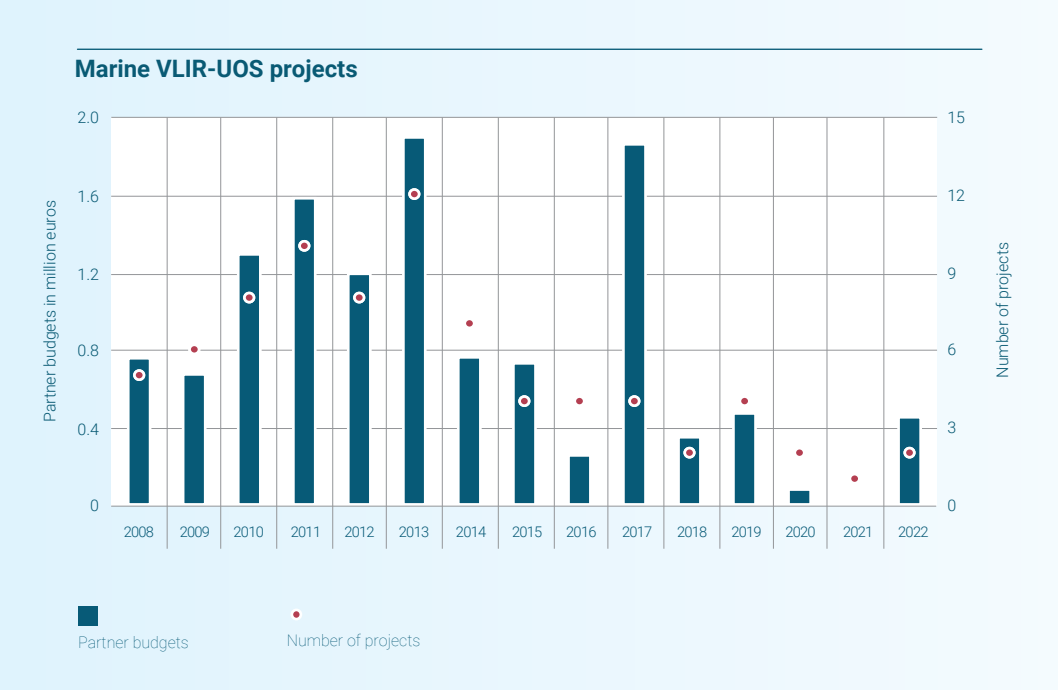


Figure 35. Evolution of the annual VLIR-UOS budget (million euros) for marine projects, mandates and programmes (with a promotor affiliated to an MRG). The figure also presents the annual number of funded marine VLIR-UOS project, mandates and programmes. Budgets allocated to the project's starting year.

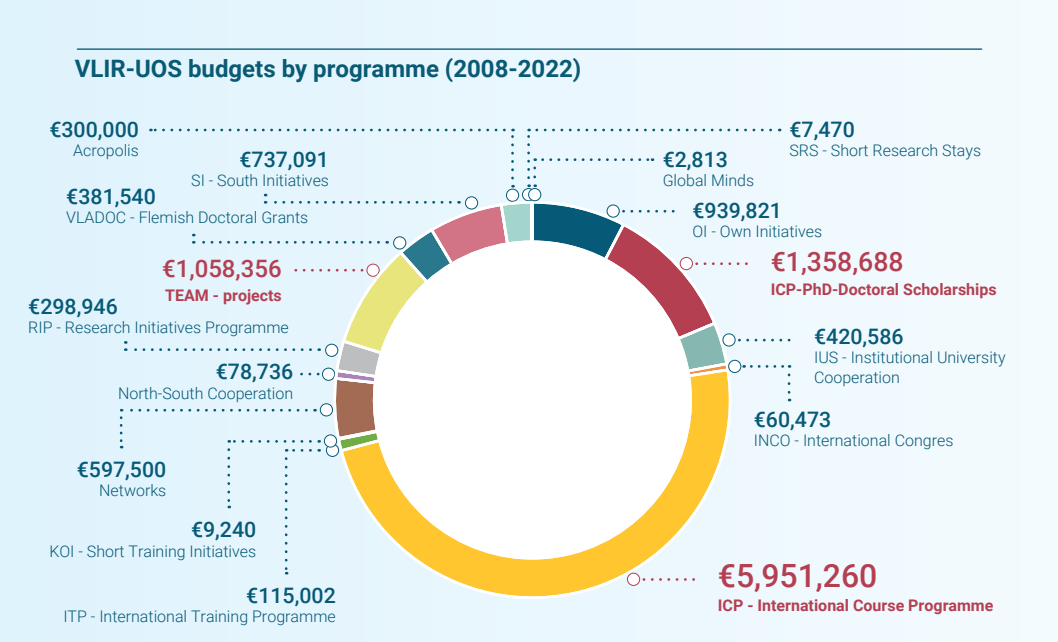


Figure 36. Distribution of the VLIR-UOS budget (in euros) for marine projects, mandates or programmes (with a promotor affiliated to an MRG) according to the programme (2008-2022).

Flanders UNESCO Science Trustfund (FUST) and Flanders UNESCO Trustfund (FUT)

The Flemish Department of Economy, Science and Innovation (EWI) has been funding UNESCO science projects for more than 20 years through the Flanders UNESCO Science Trustfund (FUST), with a focus on UNESCO's natural science programmes for oceanography, hydrology, ecology and earth sciences (see also https://fust.iode.org/en). In addition, the Flanders UNESCO Trustfund (FUT) was also established in 2001 and has focused on heritage projects (mainly in Africa, through FDFA) since 2010. To map the marine FUST projects, a general list of approved FUST projects was obtained through EWI (Gert Verreet). These projects were then screened by VLIZ in terms of marine focus. A total of 81 marine projects were identified totaling 28.0 million USD over the period 1998-2023, accounting for 48% of all FUST funds. The vast majority of these marine funds go to research coordinated by the Intergovernmental Oceanographic Commission (IOC), although some funds go to marine projects funded through other programmes, such as World Heritage (see also Brochure Flemish UNESCO Commission 2021).

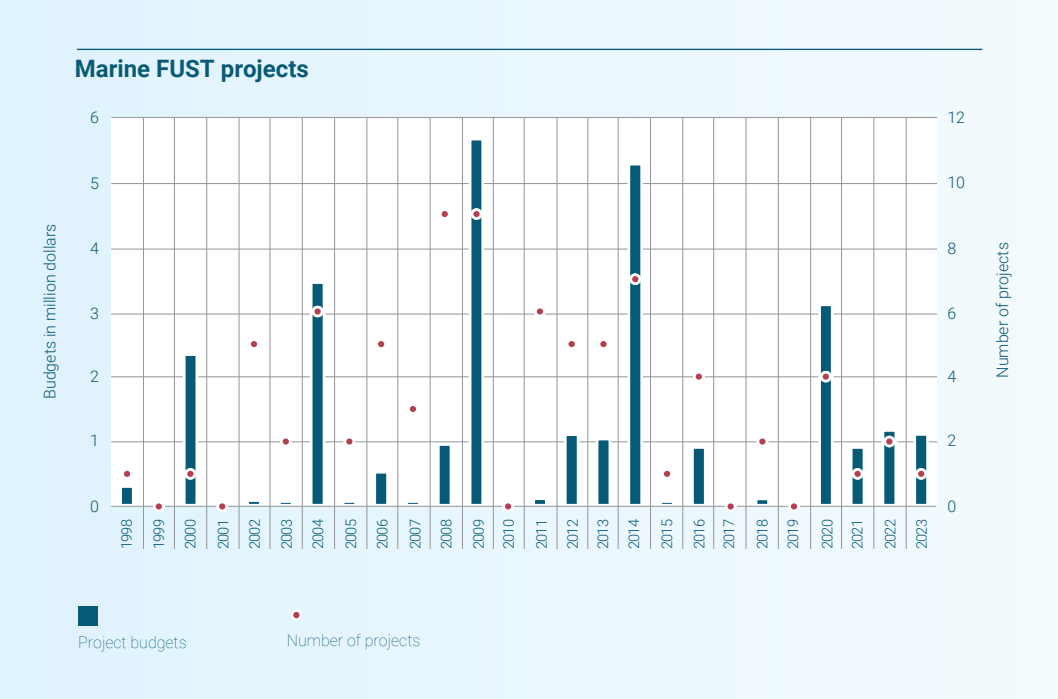


Figure 37. Evolution of the annual FUST budget (in million US dollars) for marine projects. Budgets allocated to the project's starting year.

For the focus period of the present report (2008-2022), 55 marine projects were funded totaling 20.2 million USD, or an average of 1.3 million USD annually (figure 37). No clear trend can be observed in this funding. Although these FUST and FUT funds do not fund the MRGs, Flemish research groups with relevant expertise are proactively involved in the projects. In this way, these FUST and FUT projects act as a lever for international cooperation for the Flemish marine research landscape. Moreover, due to this sustained – mostly marine – funding, Flanders is considered one of the most reliable donors within UNESCO.

2.6.4 Overview of 15 years funding of marine research and innovation (2008-2022)

The present Indicator Report lists the funding streams to marine research and innovation in Flanders/Belgium (knowledge institutes and industry) for the most prevalent competitive funding channels. It is hence worthwhile to aggregate the reported figures of the past 15 years to detect trends in the funding of marine research and innovation landscape. However, this exercise should also consider some important restrictions and considerations:

- It is not an exhaustive overview of the funding involved in the marine research and innovation landscape. A number of important funding streams are not included in the listed figures: e.g., direct public funding of universities and scientific institutes, investment in research infrastructure, private funding, non-European resources, additional funding channels such as CIP, COSME, COST, FIVA, etc.;
- Figures are not always coherent over the entire 2008-2022 period:

    - The different European framework programmes are not exact copies of each other. For example, channels such as Competitiveness and Innovation Framework Programme (CIP) and European Institute of Innovation & Technology (EIT) were integrated into Horizon 2020. In addition, neither is Horizon Europe an exact copy of Horizon 2020. For example, Horzion Europe is more open to international partnerships regardless of their proximity or affinity to Europe;
    - Unlike Pirlet *et al.* (2018), the current version includes budget data of marine research and innovation projects supported by the federal Energy Transition Fund and the Flemish Industrial Research Fund (IOF). In each case, these are budget data for the period 2018-2022. In the case of IOF, which also ran prior to 2018, this creates a (small) bias in the evolution of aggregate research and innovation funding by institute type and policy level (figures 38 and 39). For the Energy Transition Fund, it was only possible to report based on total project budgets (see **Energy Transition Fund**). This means that this funding instrument is not included in the aggregate analysis of institute types, resulting in a more pronounced bias between the aggregate analysis of institute types versus policy levels as of 2018;
    - VLAIO was created in 2016 from the merger of IWT and Enterprise Flanders (AO) whereby certain parts of IWT were also merged into FWO. Thus, in the period before 2016, only the projects and mandates of IWT are included;
    - Although EFF budget data are not part of the analysis of funding of marine projects within the EMF(A)F (see **The European Maritime, Fisheries and Aquaculture Fund (EMF(A)F)**) these figures are included in the aggregated European funding pre-2014. These figures are also the only figures reported according to the year of disbursement rather than the project's starting year. This creates a very slight distortion in the trend;
    - The Interreg programme budget was not included in this overview as the difference in completeness between Interreg IV and V could lead to a distorted trend.
- VLIR-UOS is distributed at the Flemish level, but the underlying funding comes from a federal budget line. Consequently, the VLIR-UOS budgets are counted with the federal funding in figure 38;
- The reported FUST figures aren't included in the overview.

Considering the above limitations and observations, the following findings regarding marine research and innovation funding can be observed (figure 38 and 39):

- Between 2008-2018, the overall trend of reported funding for marine research and innovation projects is slightly positive. When comparing the average annual budget of marine research and innovation projects between 2008 and 2012 with the period between 2013 and 2017, it concerns an increase of 12.8%. What stands out during this period is the occurrence of several short-term declines in marine research and innovation budgets. These declines can be related primarily to major changes at funding agencies. Notable examples are the federal start-up of the BRAIN programme (2011), the transition from FP7 to Horizon 2020 (2014) and the transition from IWT (and Enterprise Agency) to VLAIO (2015-2016) (including tilting of certain parts into FWO). It should be mentioned that these short-term decreases are punctuated by the fact that total project funding is allocated to the project's start year (with the exception of the European Fisheries Fund (EFF));
- After 2018, a rather abrupt increase in funding for marine research and innovation projects and mandates occurs. An increase mainly due to increased budgets from European funding channels for the Belgian/Flemish marine research and innovation landscape (average annual budget 2018-2022 +57.9% compared to 2013-2017) and a general step up in Flemish resources (average annual budget 2018-2022 +71.6% compared to 2013-2017). During the same period (2018-2022), there's an increase in federal funding (average annual budget +64.5% vs. 2013-2017). This is entirely due to the Energy Transition Fund (first projects started in 2018) which is a new funding channel for marine research and innovation compared to the previous version of the Indicator Report (Pirlet *et al.* 2018). In case of excluding this fund between 2018 and 2022, the trend of federal funding for marine research and innovation is negative (-67.4% vs. 2013-2017).
- When plotting the evolution in marine research and innovation funding by type of organisation, a decrease in marine research funding to university associations is observed until 2018 (-29.7% in average annual budget between 2013-2017 compared to 2008-2012). After 2018, funding for Flemish university associations within the considered competitive channels returns to a higher level (+19.1% 2018-2022 compared to 2013-2017). Flemish scientific institutes show strong growth in project funding over the past 15 years. For example, the average annual budget increased by +176.9% over the last five years (2018-2022) compared to the 2013-2017 period. Looking back even further, a strong increase in the average annual budget of 155.1% can already be observed in the period 2013-2017 compared to the period 2008-2012. In addition, funding for marine R&I with and by companies within the considered competitive channels also has an upward trend with two clear steps in funding between 2008 and 2022. A first step-up occurs at the time of the formation of VLAIO (2016) and a second in 2019 following the formation of The Blue Cluster ('*De Blauwe Cluster*') (2018). Furthermore, European funding for companies also contributes significantly to the observed increase in resources for companies. This increase is clearly reflected in the five-year average annual budgets: +148.2% (2013-2017 vs. 2008-2012) and +60.6% (2018-2022 vs. 2013-2017).
- However, in the above analysis of the evolutions in marine research and innovation funding according to organisation type, it should be noted that due to the absence of partner budgets for marine research and innovation projects supported by the federal Energy Transition Fund, this fund is not included in this analysis.

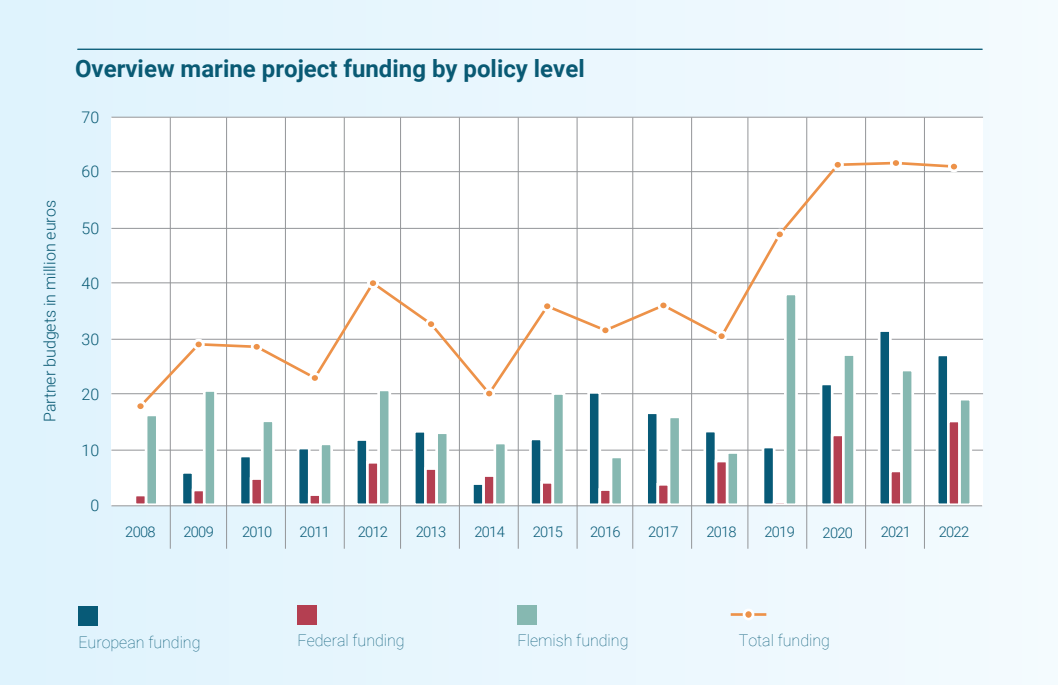


Figure 38. Evolution of the sum (in million euros) of the reported marine research and innovation funding at European (FP7, Horizon 2020, Horizon Europe and EMF(A)F and EFF cofounding), federal (BELSPO, Energy Transition Fund and VLIR-UOS) and Flemish level (FWO, BOF, IOF, IWT and VLAIO) between 2008 and 2022. Except for EFF, total project budgets are allocated to the project's starting year.

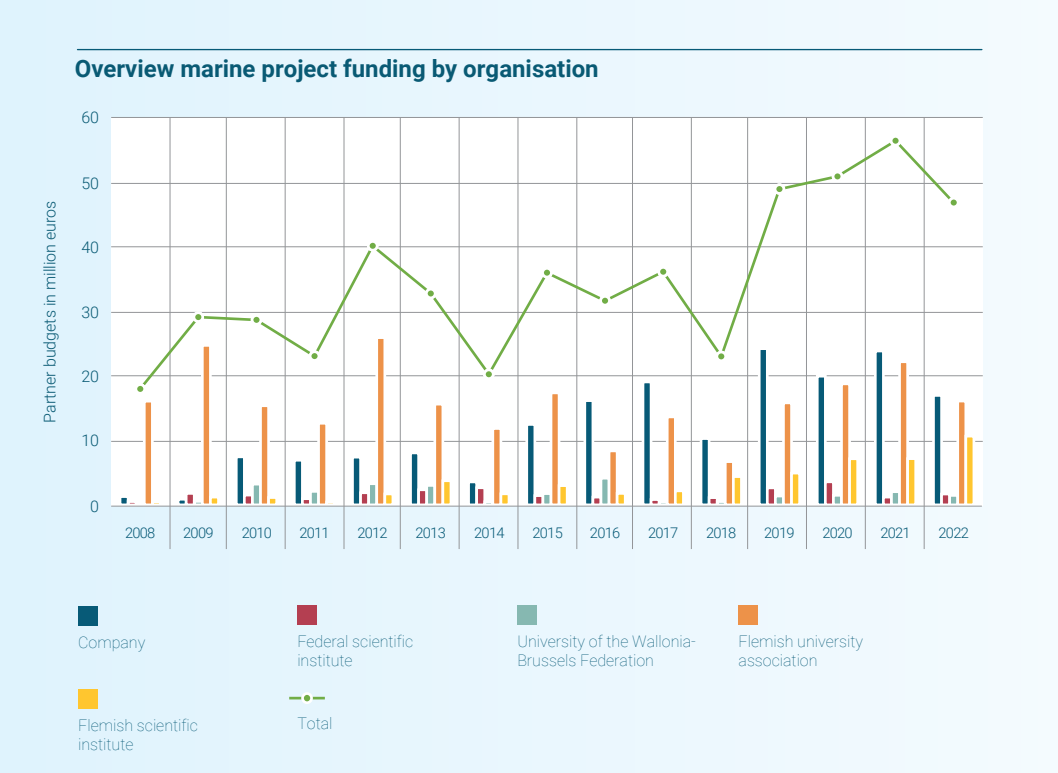


Figure 39. Evolution of the sum (in million euros) of reported marine research and innovation funding by type of organisation in the period 2008-2022. In this overview figure, both channels at European (FP7, Horizon 2020, Horizon Europe and co-funding EMF(A)F and EFF), federal (BELSPO and VLIR-UOS) and Flemish level (FWO, BOF, IOF, IWT and VLAIO) were included. The federal Energy Transition Fund is not included (see above). Except for EFF, total project budgets are shown according to project's starting year.

3 Marine and maritime trainings

3.1 Context

In today's global knowledge economy, knowledge (development) is key. Effective alignment between training programmes, student intake and outflow, and the demands of the business world (and society) is crucial in this regard (Debackere *et al.* 2021). The rapid developments in various, often knowledge-intensive, sectors of the Blue Economy also contribute to an increasing demand for high-quality and specialised marine education programmes to address the needs of industry, science and policy. This section provides an overview of the available educational opportunities within a marine and maritime context in Belgium.

On the international level, education and scientific/technological knowledge are highlighted as one of the ten challenges for collective impact by the United Nations Decade of Ocean Science for Sustainable Development (2021-2030) (UNDOSSD) ('Challenge 9: Skills, knowledge and technology for all'). The UNDOSSD aims for comprehensive capacity development and equitable access to data, information, knowledge and technology for all aspects of ocean science and for all stakeholders. Promoting education and training in professions related to ocean science is also one of the nine key actions set forth in the Global Ocean Science Report (GOSR, IOC-UNESCO 2020) to achieve the vision of UNDOSSD and the 2030 Agenda for Sustainable Development (including SDG 14 goals). The rapid evolutions in science and technology require, in addition to obtaining a higher education degree, continuous professional development, making short-term training programmes of only a few days important. From this perspective, the OceanTeacher Global Academy was established, supported by Flanders (FUST) and under the auspices of the International Oceanographic Data and Information Exchange (IODE) programme of IOC-UNESCO. Its aim is to develop short-term training programmes focused on science, monitoring, and data and information management, tailored to the needs of the IOC and other partners. A comprehensive overview of the current state and trends in global marine scientific research and the need for associated capacity development is presented in GOSR (2020).

Investing in so-called blue skills is also considered crucial by Europe with a view to achieving sustainable growth and employment in the coming years and meeting the goals of the European Green Deal (COM (2019) 640). The importance of marine and maritime training and education, and the necessity for a solid alignment with industrial and policy needs, have been emphasised at the European level over the past decade (e.g., COM (2014) 254, Rome Declaration 2014, Vincx *et al.* 2018, COM (2021) 240, MATES 2022). The European marine education landscape was initially analysed through the FP7 EuroMarine project, which later evolved into the European Marine Research Network (EuroMarine). This effort was further deepened through the Belgian contribution to EMBRC (European Marine Biological Resource Centre, an ESFRI-ERIC), with Ghent University establishing the European Marine Training Portal as a one-stop-shop for European marine training.

In Flanders, with a focus on West Flanders, there is a deliberate effort to align marine and maritime training programmes with the needs of the Blue job market. The West Flanders Development Agency (POM West Flanders), for instance, has established a region-specific initiative centered around Lifelong Learning (Levenslang Leren), with particular attention to the Blue Energy sector. Within this framework, initiatives like the UPSKILL project aim to bridge the skills gap between the labor market demand and supply by investing in state-of-the-art training facilities specialising in digitalisation and digital applications. As part of this initiative, the Training Lab for Blue Energy was inaugurated on September 14, 2023.

For this report, the objective is to catalog marine and maritime training programmes in Flanders and Belgium from 2013 to 2022. In addition to programmes at universities and higher education institutes, data was gathered from accredited vocational and corporate training, secondary and adult education, VDAB, Syntra West, etc. The European Marine Training Portal served as the initial starting point. Subsequently, additional training opportunities and courses were identified through various supplementary sources, such as the OceanTeacher Global Academy (OTGA), the Education Agency (*Agentschap Onderwijs*), VDAB, university websites, companies providing training, etc. This comprehensive approach enabled us to identify 59 long-term training programmes with a duration of at least one semester (e.g., secondary education, Bachelor, Master, etc.), as well as 418 short-term courses, held annually or as single events, spanning from several hours to several days. Subsequently, the organisers of the respective courses were contacted to obtain the annual enrollment data. Data was obtained for 97% of the long-term training programmes and 83% of the short-term courses.

While our endeavor aims to provide a comprehensive overview of the Belgian marine/maritime training landscape and student enrollment, it's crucial to acknowledge several significant conditions and limitations:

- Programmes are included only if they have a clear marine/maritime focus. In the case of university programmes where the marine component constitutes only a fraction of the total credits (e.g., Master's in Biology with <5 credits of marine subjects), only students were considered who have chosen optional courses with a marine focus;

- Beyond the identified marine/maritime programmes, there are numerous other programmes that are not specifically marine/maritime but are relevant within the context of the Blue Economy. For example, the 'Master of Engineering: Energy' at KU Leuven is obviously pertinent to the offshore energy sector. However, the programme was not included in the analysis because none of its (optional) courses focus explicitly on offshore energy;
- Due to the varying nature of the programmes, total enrollment figures for short-term and long-term programmes cannot be directly compared. For long-term programmes, each enrollment is counted as a 'unique head,' assuming that the same individual generally does not pursue two parallel programmes within the same academic year. For short-term programmes, the same individual may register for multiple courses in the same year, resulting in a (considerable) overestimation of total enrollments, not accurately reflecting the unique individuals involved. Hence, we analyse both separately.

3.2 Long-term educational programmes

Long-term educational programmes are one semester or longer in duration and can be categorised into various types. In alphabetical order, these are the following types:

- Adult education
- Bachelor
- Bridging program
- Master
- Master after Master (Ma-na-MA)
- Postgraduate
- Secondary
- Short-cycle tertiary education

3.2.1 Number of organised long-term educational programmes

The total number of organised programmes per year varies between 33 (2013, 2018) and 48 (2021, 2022) and is characterised by an increase observed between 2018 and 2021 (figure 40). University Master's programmes make up approximately 45% of the total number of programmes over the years, with an increase from 14 (in 2018) to 21 (in 2021 and 2022) Master programmes in the past five years. This growth does not focus on a specific sector or topic but includes Master's programmes related to various Blue Economy sectors (maritime transport and ports, aquaculture), hydrology, engineering, as well as pollution and ecotoxicology. The number of Master after Master (Ma-na-Ma) programmes has remained relatively constant over the past decade (five to six annually), primarily focusing on various aspects of maritime transport (transport management, maritime sciences, maritime law, shipbuilding), followed by water management and aquaculture.

In terms of the number of programmes, secondary education ranks second, with nine to ten programmes annually (figure 40). These programmes are organised by three different schools and primarily focus on the maritime (and inland navigation) sector (maritime engineering deck/engines, helmsman, maritime sciences), with the exception of one programme focusing on fisheries.

For professional and academic Bachelor programmes, an increase in the number of programmes is observed over the period 2013-2022 (from two to six), all of which can be attributed to the Antwerp Maritime Academy, and, consequently, entirely focus on the maritime sector (marine engineering and nautical sciences) (figure 40). However, except for the introduction of a new academic Bachelor programme ('Marine Engineering') in 2021, the increase results from the division of the Bachelor programmes into Dutch and French branches from 2019 onwards. Hence, in terms of content, it can be noted that only three marine Bachelor programmes exist.

After 2019, two short-cycle tertiary education programmes were launched (Portilog – Port Professional; Syntra West – Wind Turbine Technician on & offshore), and the University of Antwerp also initiated two bridging/preparatory programmes focused on maritime and logistics management. In adult education (CVO Scala), one programme was considered relevant: '*Opleiding Maritiem Dek*', which was renamed to '*Aspirant Officier STCW II/3*' with a focus on coastal navigation in 2023 (figure 40).

Taking all the above-mentioned programmes into consideration, it becomes evident that the topic 'maritime transport and ports' is by far the best represented in the courses, with 24 programmes (figure 41). In 2022, with the exception of short-cycle tertiary education and postgraduates, all types of programmes are available for this topic. Natural and engineering sciences follow with eight and six programmes, respectively, and include only Master programmes. The topic 'fishery and aquaculture' comprises a total of five programmes, with the sole fishery programme found in secondary education, while aquaculture is exclusively featured in Master and Ma-na-ma programmes (figure 41).

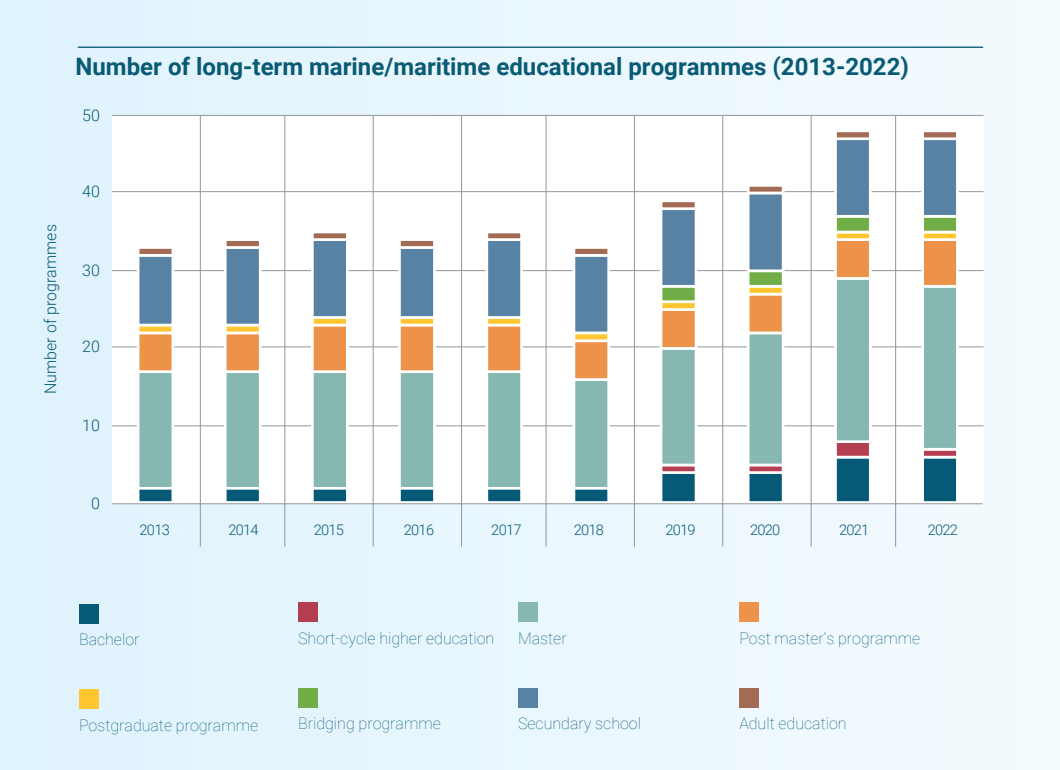


Figure 40. Overview of the number of long-term educational programmes organised on an annual basis, divided by type of programme. The years refer to the start of each academic year.

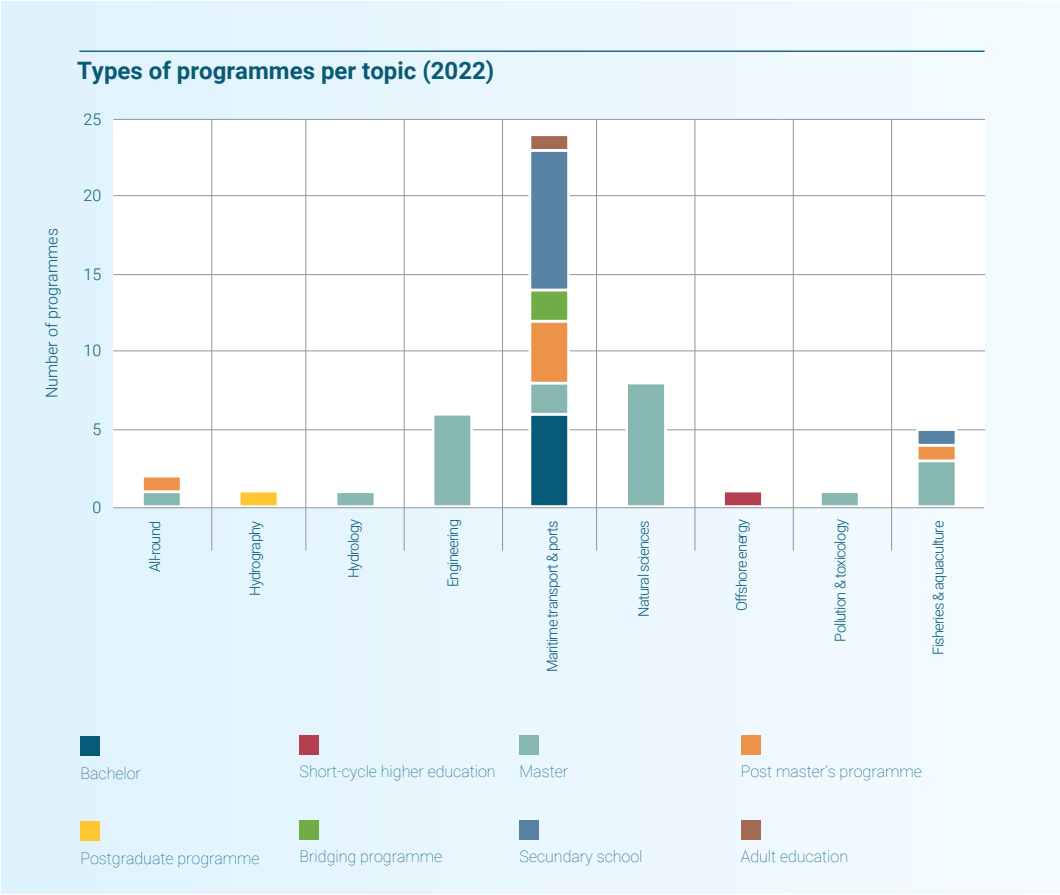


Figure 41. Overview of the types of programmes by theme.

3.2.2 Number of enrollments for long-term programmes

In general, the increase in the number of long-term programmes over the past decade (+40%) does not translate into a similar increase in the number of enrollments (-1%). In 2013, 1,800 students enrolled for a long-term educational programme, while in 2022, 1,782 individuals registered. That being said, there has been a continuous and steady increase since the low point in 2018 (+15%). The largest declines since 2013 can be observed in adult education (-60%) and maritime Bachelor programmes (-30%) (figure 42). The biggest increases are seen in the Masters (+27%) and Ma-na-Ma's (+19%). Postgraduates also show an almost doubling, but this involves only one programme with fewer than 20 students.

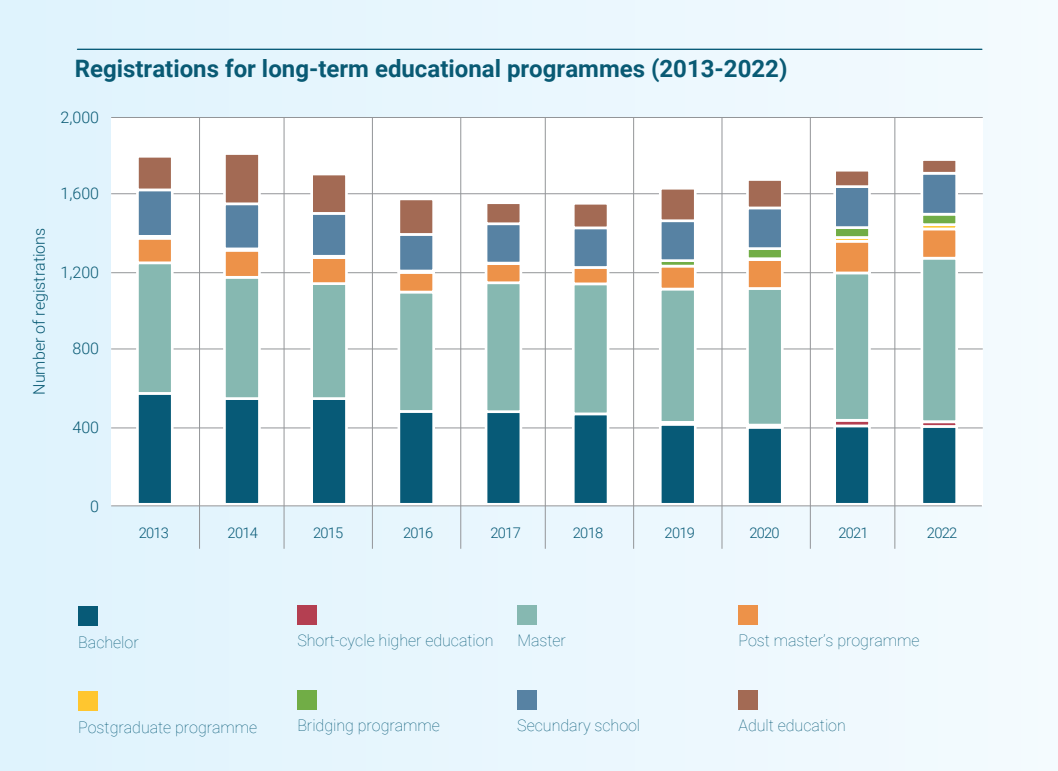


Figure 42. Overview of the number of enrollments in long-term educational programmes on an annual basis, divided by type of programme. The years refer to the start of each academic year.

The average number of enrollments for a single programme over the studied period (2013-2022) was highest for adult education (153 individuals), followed by Bachelor programmes (147), Masters (42), Ma-na-Ma's (24), bridging programmes (24), secondary education (22), short-cycle tertiary education (10) and postgraduate programmes (7).

Nearly half of the registered students are enrolled in programmes in Antwerp, accounting for approximately 855 students in 2022 (including programmes organised by multiple institutes). Ghent follows in second place with 525 students, followed by Ostend (217), Brussels (205), Liège (146), Leuven (84) and Kortrijk (11). In Antwerp, the range of programme types is quite diverse (Bachelor, Master, Ma-na-Ma's, bridging programmes, secondary education), while Ghent, Liège, Brussels and Leuven primarily offer Masters (including Ma-na-Ma's), and Ostend focuses on secondary and adult education.

In line with the distribution of the number of programmes across various themes, the programmes related to 'maritime transport and ports' also lead in terms of enrollments. In 2022, they accounted for 952 students, representing 53% of the total student registrations for long-term marine and maritime programmes. However, it should be noted that the number of enrollments within this theme has decreased by 22% over the past decade. Natural sciences make up about 25% of the total enrollments in 2022 (445 students) and have more than doubled (+128%) over the past 10 years. This trend is observed in each of the individual programmes across different universities, with growth ranging from doubling (95%) to quadrupling (313%) between 2013 and 2022. Engineering sciences, with 217 students in 2022, represents the third-largest theme in terms of enrollments (12%). While the number of students has decreased by 7% compared to 2013, enrollments have remained stable in the past six years (figure 43).

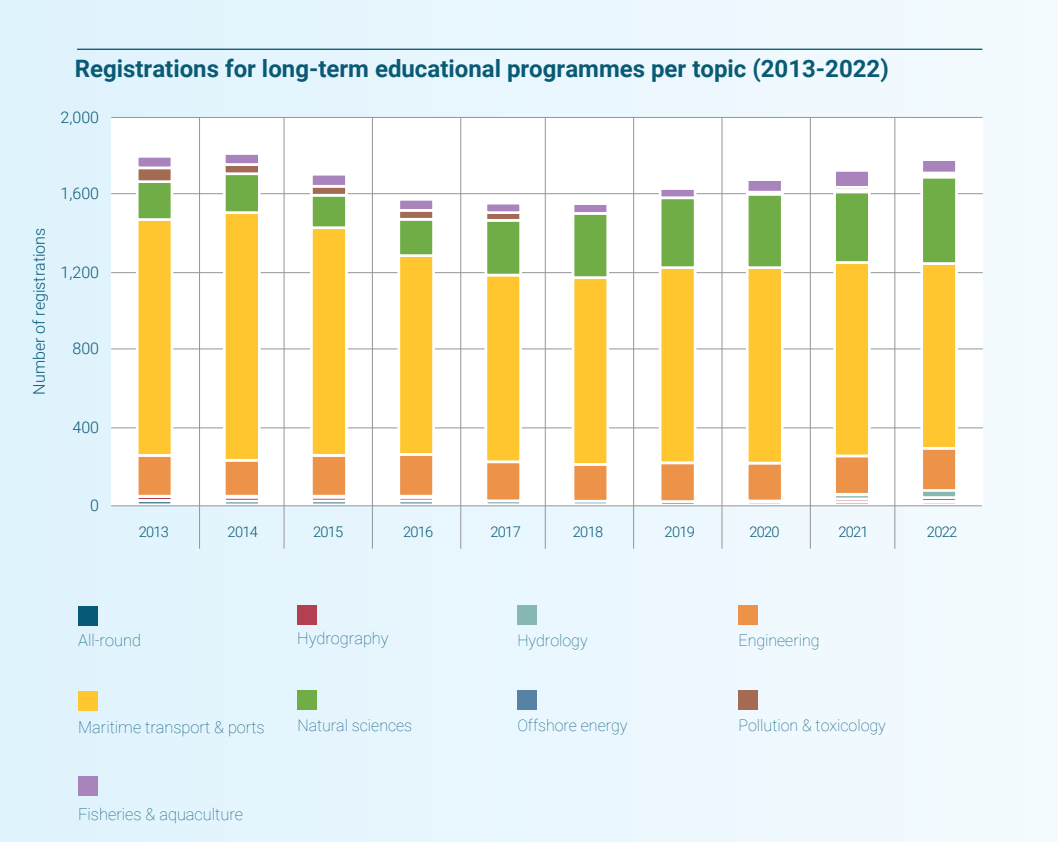


Figure 43. Overview of the number of enrollments in long-term educational programmes by theme on an annual basis. The years refer to the start of each academic year.

3.3 Short-term educational programmes

3.3.1 Number of organised short-term educational programmes

The total number of identified short-term programmes (with an average duration of 4.4 days) gradually increased from 253 in 2013 to 328 in 2022 during the study period (figure 44). Of all the courses surveyed, on average, 62% were organised by VDAB over the period of 2013-2022. Higher education institutes were responsible for 19% of the courses, companies for 17%, and international organisations with a Belgian base for 2%. In the case of the latter, only the courses organised in Belgium are taken into account.

In terms of topics, 81% of the courses were related to maritime transport and ports (figure 44). These primarily included STCW (Standards of Training, Certification and Watchkeeping) training, but they could also encompass specific specialisations (e.g. meteorology, polar waters navigation, international maritime law, maritime economics, etc.), or courses for dockworker. Additionally, courses related to the dredging industry accounted for 10%. Other courses were aimed at the offshore industry in general (e.g., fire safety, applicable to all offshore activities) (4%), marine data management and technology (2%), fisheries (1%), aquaculture (1%), offshore energy (1%), and general topics and natural sciences (<1%) (figure 44).

Over the past 10 years, an average of 62% of the short-term courses were organised in Zeebrugge, followed by Antwerp (23%) and Oostende (11%). The number of online and hybrid courses has increased since 2020 from 3% (pre-2020) to 6%, a trend undoubtedly influenced by the Covid-19 pandemic.

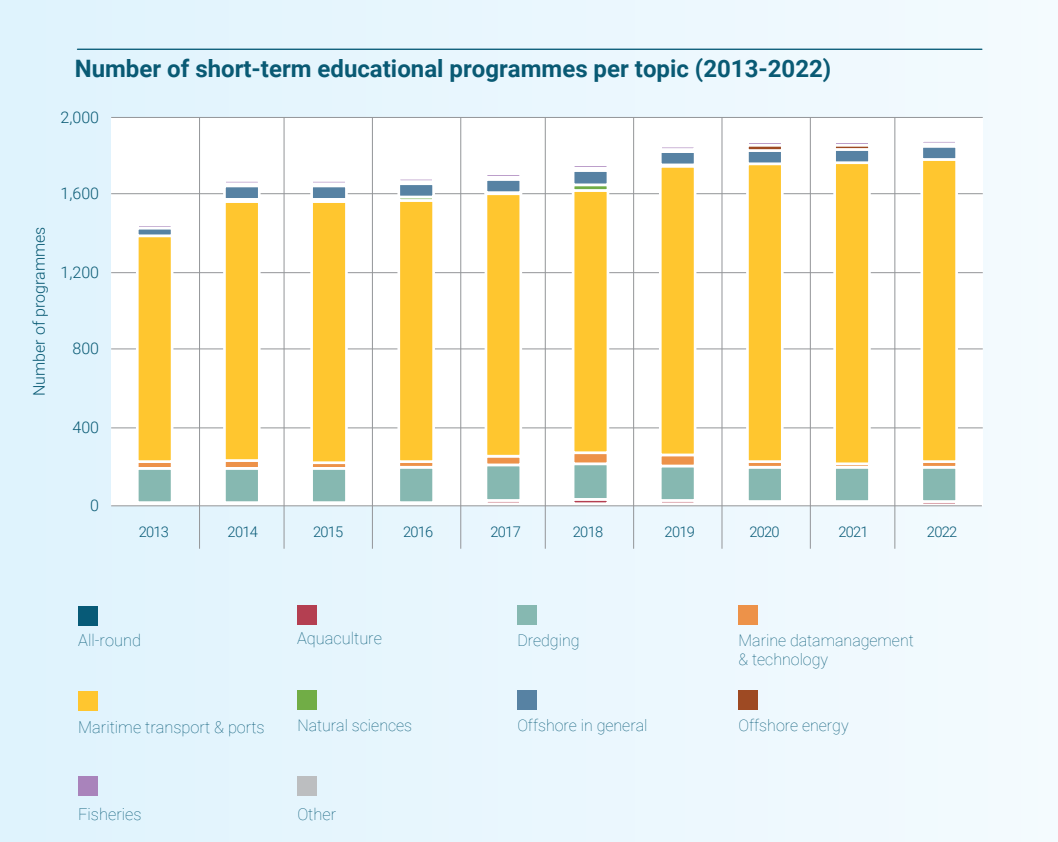


Figure 44. Overview of the number of short-term courses by topic on an annual basis.

3.3.2 Number of enrollments for short-term programmes

As mentioned earlier, it's important to note that the sum of enrollments for individual short-term courses cannot be considered as 'unique individuals' since individuals often go through several short courses in the same year (unlike long-term programmes). Therefore, these figures should be interpreted purely as the sum of individual short-term trajectories. While the number of short-term courses shows a gradual increase, the number of enrollments is characterised by strong interannual variations without a clear trend over the studied period. The number of enrollments fluctuates between slightly less than 3,000 enrollments in 2013 and nearly 5,000 registrations in 2021 (figure 45). The annual figures for many 'safety' courses (STCW) are significantly affected by the presence or absence of a so-called 'refresher year'. These courses must be renewed by the participants every five years. The request for renewal varies over time, with certain years experiencing a significantly higher demand than others (VDAB, personal communication).

In analogy with the number of organised short-term programmes, the topic ‘maritime transport and ports’ accounted for an average of 80% of enrolments over the past 10 years, followed by marine data management and technology programmes (7% of enrolments), the offshore industry in general (7% of enrolments), and dredging-related courses (4% of enrolments). Behind these averages, some notable trends emerge, such as a significant decline in enrolments for dredging-related courses from 2013 to 2022, dropping from 24% to 1% (from 713 to 34 registrations). Additionally, a clear increase has been recorded in the number of participants in marine data management and technology programmes since 2021 (2013 = 5%; 2022 = 16%, or from 143 to 726 registrations).

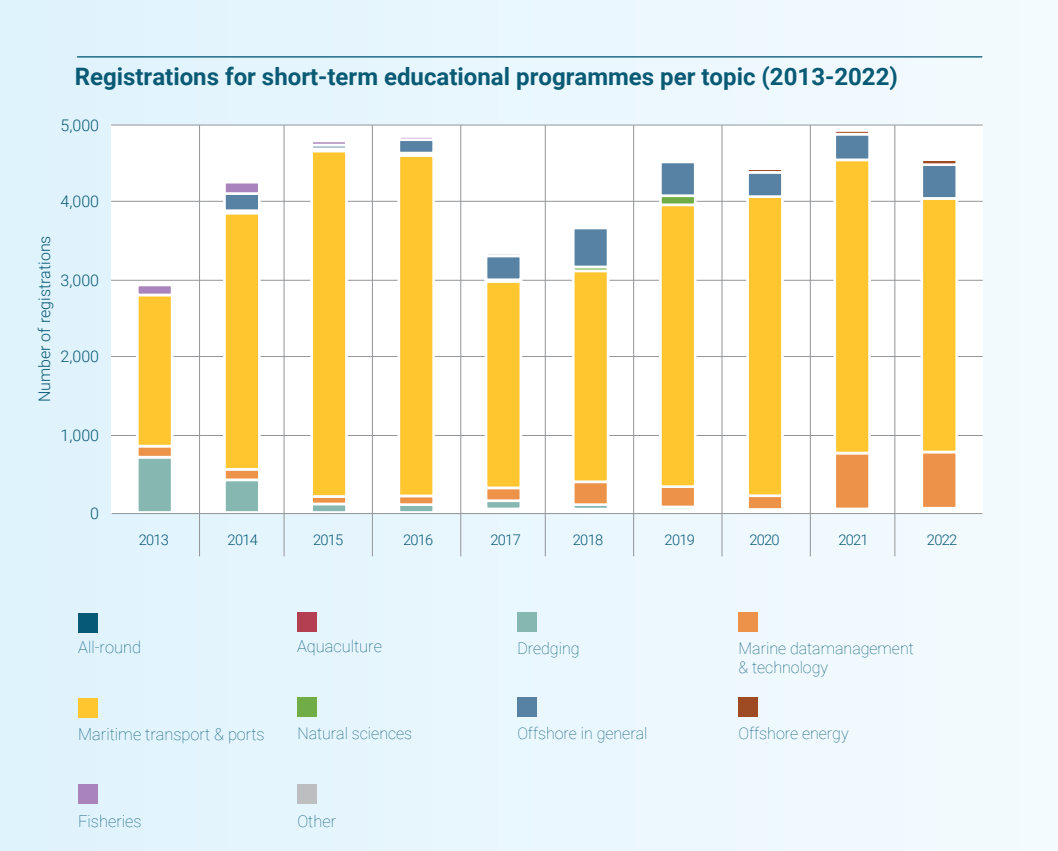


Figure 45. Overview of the number of short-terl educational programmes per topic on an annual basis.

4 Discussion 'Indicator Report Marine Research & Innovation'

4.1 Drivers for marine research and innovation

Marine research and innovation are higher than ever on the agenda. This trend is noticeable at virtually every policy level and should be no surprise. The seas and ocean are undeniably vital to sustainably meet several major societal challenges, such as food and energy supply. In addition, the ocean is considered the main regulator of the global climate system, making climate change increasingly seen as a marine issue with challenges such as sea level rise, ocean acidification, marine heat waves, etc. It is undeniable that the seas and ocean will continue to play a central role in climate adaptation and our pursuit of climate neutrality. A ramp-up in our marine knowledge and innovation capacity is therefore necessary to arrive at evidence-based solutions to meet our climate ambitions.

A key driver at the international level concerns the United Nations Decade of Ocean Science for Sustainable Development (2021-2030) (UNDOSSD). This initiative represents a milestone in accelerating the global marine research capacity needed to address the major societal challenges of our time. At the European level, a Mission Ocean was set up to develop the necessary scientific knowledge base to provide the marine implementation for major policy initiatives, such as the Green Deal, the Digital Strategy and the Climate Adaptation Strategy. Also at the Flemish level, marine research and innovation capacity is being upgraded with the establishment of The Blue Cluster ('*De Blauwe Cluster*'), as a spearhead cluster within the Flemish innovation policy, and a gradual strengthening of marine knowledge institutes, such as the Flanders Marine Institute (VLIZ).

4.2 A growing marine research landscape

The growing political attention to marine research and innovation also translates into a steady increase of marine research capacity in Flanders and Belgium over the last decade. There are now 135 marine research groups (MRGs), representing more than 1,900 people actively contributing to marine research. The increase in research capacity occurs both at the Flemish and French-speaking universities and colleges and at the Flemish and federal knowledge institutes. At the thematic level, the growth of natural sciences and engineering and technological sciences stands out. We observe not only a growing number of large MRGs (over 30 marine staff members) but also an increase in research groups with a smaller number of marine personnel. For the latter, in many cases these are existing research groups starting up a new marine research line (either temporary or permanent). The continuous inflow and outflow of MRGs typifies the dynamics within the marine research landscape with it's constant evolution of research topics across a wide range of research disciplines.

Within a broader Flemish research context, Flemish MRGs account for more than 6% of R&D personnel (Viaene 2021). This share has remained relatively constant since 2015, showing that marine research capacity is growing at the same rate as the full Flemish research community. Also at a global level, our marine research capacity does not stay under the radar. According to the Global Ocean Science Report (GOSR, IOC-UNESCO 2020), Belgium ranks fifth worldwide in terms of the number of marine personnel per capita.

Finally, we record a cautiously positive evolution in the number of women employed in marine research (39.6% of marine personnel). For the first time, we score higher in this respect than the global average (38.6%) (GOSR, IOC-UNESCO 2020). It should be noted, however, that the representation of women in the category of research heads and professors remains lower (21.6%).

4.3 A growing volume of high quality marine peer reviewed and VABB publications

In tandem with the growing marine research capacity, the publication output of MRGs is also steadily increasing. Since 2008, the number of marine peer reviewed and VABB publications published annually has increased by ca. 80%. In the years 2020 and 2021, an acceleration of publication output was recorded, which was particularly noticeable at universities and Flemish scientific institutes. The question is whether this is a temporary effect that can (in part) be attributed to the Covid-19 pandemic in which (presumably) there was less time for fieldwork and the research results that were on the shelf were published in full, or whether there is a structural growth in publication output. At a thematic level, we mainly observe an increase in the number of publications in the natural sciences and engineering and technological sciences.

In addition to the growing volume of marine peer reviewed and VABB publications from the MRGs, we equally notice an increase in citation impact (analysis conducted in collaboration with ECOOM). Based on the relative citation indicators, the MRGs for each (sub)discipline in marine research all score above the world standard, with outliers doing twice as well. Especially in recent years (period 2015-2019) we notice a clear increase in citation impact, with the marine research field establishing itself in the subtop if we compare it with the scientific fields in Flanders. If we

plot the relative citation indicators of the MRGs against ECOOM's 12 reference countries (and Flanders), they rank with Flanders and Belgium among the absolute top countries. Although these relative citation indicators are not a direct measure of the quality of the research conducted, they do constitute an internationally accepted standard method of assessing the impact of research.

Finally, a strong increase can be noted in the number of publications of MRGs published in open access, with a share of 75% in the most recent years. It is to be expected that this increase will continue due to the growing number of open access journals, but equally due to the objectives imposed by the Government of Flanders within the Flemish Open Science Board (FOSB).

4.4 An internationally focused marine research landscape

All the parameters indicate that the MRGs have a strong international focus. As such, the proportion of international copublications increases year on year, with the marine research community scoring well above the Flemish and Belgian averages. It is a commonality within bibliometric studies that such international copublications receive on average more citations than 'domestic' publications (Debackere *et al.* 2021). Furthermore, the analysis of the study areas of the MRGs shows that most of the conducted research in which a study area applies has an international study area and only to a lesser extent (+/- 20%) a local/regional study area.

This international focus is facilitated by investments in state-of-the-art and often unique research infrastructure that put Flanders' and Belgium's marine research on the global map and stimulate international cooperation. This includes not only seagoing infrastructure (such as the research vessels Belgica and Simon Stevin and marine robotics platforms) but equally unique land-based research facilities (e.g., Flanders Maritime Laboratory) and internationally anchored data systems housed in Flanders (**see box**).

In addition, the international outlook of the MRGs is strengthened by targeted policy choices of the Government of Flanders. For example, Flanders' loyal contribution to the marine UNESCO science programmes through FUST generates leverage for the international cooperation of the MRGs. In addition, the Government of Flanders provides funding for the Secretariat of the National Decade Committee (NDC) for the United Nations Decade of Ocean Science for Sustainable Development (2021-2030). Flanders also actively invests in attracting and supporting international marine organisations. As such, several international organisations are accommodated at the InnovOcean Campus in Ostend (e.g., IODE project office, European Marine Board, EMODnet Secretariat, etc.), which in turn has a pull effect for international events, projects and collaborations. It is thus fair to say that marine research and innovation are increasingly a part of Flanders' bilateral and multilateral foreign policy and contribute to the international appeal of the region.

Finally, as an expression of the international focus of the marine research community in Flanders and Belgium, Ghent University decided in 2023 to further develop its South Korean hub with a branch of the interfaculty consortium on marine research 'Marine@UGent'.

Flanders - a strong international brand for marine data systems

For over 20 years, the Government of Flanders has been actively engaged in the development of marine data systems. Partly through the Flanders Marine Institute (VLIZ), which was founded in 1999, Flanders has developed several marine databases that have since become world standards. These include the World Register of Marine Species (WoRMS), which is considered the taxonomic standard for international marine biological research, and Marine Regions, which is an internationally acclaimed database for marine place names. The map layer of global exclusive economic zones provided in Marine Regions is now internationally regarded as the reference and used by policy makers, researchers, professionals and media around the world.

Flanders has also invested in anchoring several international organisations involved in marine data management. Among others, the IODE project office of IOC UNESCO (International Oceanographic Data and Information Exchange) and the secretariat of EMODnet (European Marine Observation and Data Network) of the European Commission are housed in Ostend. This in turn ensures that Flemish/Belgian scientific institutes, universities and administrations can take a leading role within these marine data initiatives. Flanders' above-average capacity in marine data systems does not go unnoticed. Currently, within an international study by the OECD, Flanders is being used as a prime case study to map the value chain of marine data for the Blue Economy.

4.5 Increased funding for marine research and innovation

Between 2008 and 2022, there is a clear increase in marine research and innovation projects in the competitive funding channels. Moreover, this increase has a clear step up from 2019, with mainly companies and Flemish scientific institutes contributing to this leap. The increase in funding for marine research and innovation projects is observed at both the European, federal and Flemish level. The main driver behind this increasing funding can be traced back to the increased focus on marine research and innovation in the context of several major societal themes:

- For example, European policymakers are increasingly looking at the potential of the ocean and its ecosystem services to address major challenges such as climate change, the biodiversity crisis and ensuring sustainable economic growth and societal development. Within this context, some important policy initiatives have been adopted in recent years such as the European Green Deal (climate, COM (2019) 640), the European Sustainable Blue Growth Strategy (Blue Economy, COM (2021) 240) and the launch of the European Mission Ocean as part of the European 'Mission' strategy (sustainability/environmental quality, COM (2021) 609). The mission aims to stimulate cutting-edge research and testing for mapping, monitoring, forecasting, managing and restoring the ocean and waters subject to climate change and anthropogenic pressures;
- At the federal level, we see that the decline in traditional marine research funding through BELSPO is completely offset by the launch of the Energy Transition Fund in 2016. This fund focuses on research, development and innovation specifically in the field of energy, including renewable energy sources in the Belgian exclusive economic zone of the North Sea;
- In Flanders, marine research and innovation has also moved sharply up the political agenda. Since the establishment of The Blue Cluster ('*De Blauwe Cluster*') in 2018, marine and maritime innovation has been one of the spearheads of Flemish innovation policy. The cluster's innovation agenda focuses on the sustainable Blue Economy in which different sectoral domains are represented, ranging from blue renewable energy to sustainable coastal protection. The Government of Flanders has also made additional investments in marine research, including a step-up in support for the Flanders Marine Institute (VLIZ) and additional investments in large-scale marine research infrastructure, ranging from funding for marine ESFRIs to the construction of the Flanders Maritime Laboratory.

It is evident that the financing for marine research and innovation has increased significantly in recent years and this also resulted into a growing marine research capacity in Flanders and Belgium (see above). The increase in marine R&I resources occurs mainly in applied research and innovation rather than additional funds for fundamental research. There is also a trend towards more cooperation between companies and knowledge institutes, in line with the Government of Flanders' vision of a knowledge-driven economy (see also below).

4.6 Spillovers from marine R&I and training to the Blue Economy

In recent years, we have seen a growing nexus between MRGs and the Blue Economy field. The establishment of The Blue Cluster ('*De Blauwe Cluster*') has played a key role in aligning the research agenda of the MRGs with the innovation needs of maritime companies. Consequently, since 2019, we note a strong increase in projects where partners from the research and business worlds collaborate and this mainly through VLAIO subsidies and Horizon 2020/Horizon Europe. This evolution is now providing its first success stories. For example, a direct line can be drawn between R&I projects, such as Symapa, which conducted research and testing on mariculture and passive fishing in the '*Westdiep*', and the commercial '*Zeeboerderij*', which was launched in the same area. Also, within emerging fields, such as floating solar panels, ongoing R&I projects are leading to the first tests with prototypes at sea, positioning Flanders among the absolute pioneers in this industry. If we look at a slightly longer time scale, however, it is mainly the case of offshore wind energy that stands out (**see box**).

Likewise in the field of marine training, we see a certain degree of alignment between the training offer (including the MRGs) and the needs of the Blue Economy. For both long-term and short-term marine courses, we record an increase in the number of courses offered. Specific chairs are even being set up together with industry players, such as the chairs in Coastal Hydrology (KU Leuven) and Marine Bioeconomy (UGent). However, enrollment figures for these programmes show that student enrolment tends not to show the same upward trend, although there are quite large differences between them. For example, enrollments in professional bachelors decrease by 30% over the period 2013-2022, while enrollments in master's programs increase by 27% over the same period.

R&I-projects as a driver for the offshore wind sector

The first projects in the offshore wind sector were funded some 15 years ago at the Flemish level by the former IWT (predecessor of VLAIO). In 2017, Flanders decided to structurally support innovation activities within this sector through the Innovative Business Network (IBN) Offshore Energy. Initially, efforts at the regional level did not result in a comparable increase in partner budgets within the former European Framework Program (FP7). However, in the subsequent Horizon 2020 programme, a multiplier effect arose and approximately 37 million euros of Belgian partner budgets were secured within Blue Energy projects. At the same time, offshore wind developed into an established sector within the Blue Economy in Flanders and Belgium. There are now eight wind farms operating in the Belgian part of the North Sea (BNS) with a total installed capacity of 2,262 MW, which places us fifth worldwide. The Belgian Offshore Platform (BOP) estimates that approximately 14,000 people are now working in the offshore wind sector in Belgium (directly + indirectly) (BOP 2021). In addition, work is underway on a new zone for offshore wind farms, the Princess Elisabeth Zone, which will raise the production capacity of offshore wind in the BNS to at least 4,000 MW (see also Goethals *et al.* 2022).

Whereas the initial R&I projects at the Flemish and European level helped to facilitate the start-up of this sector, we are currently noticing a new wave of R&I projects linked to topics such as turbine scale-up, innovative R&M strategies, new monitoring techniques, merging offshore wind with other blue energy forms and storage systems, multi-use of space, nature inclusive design, decommissioning, etc. These projects are mainly supported within The Blue Cluster ('*De Blauwe Cluster*') (48 million euros, 2019-2022), which took over the operation of the IBN Offshore Energy, as well as through the Energy Transition Fund (38 million euros, 2018-2022) and Horizon Europe (11 million euros, 2022). Such R&I projects are essential to perpetuate and strengthen the leading position of Flemish and Belgian actors within this sector and help to further reduce the LCOE (levelized cost of energy) of offshore wind.


COMPENDIUM
KUST & ZEE / COAST & SEA
VLIZ
pionier in zeekennis
Vlaanderen
verbeelding werkt
west-vlaanderen
de gedreven provincie