



# Seas, Oceans & Public Health in Europe

Linking oceans and health research

## **A Strategic Research Agenda for Oceans and Human Health:**

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Identifying priority research areas towards establishing an oceans and human health research capacity in Europe

**2020-2030**

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Full details of these inputs can be found in Annex 1.

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# Executive summary

**Oceans and Human Health (OHH) is a meta-discipline exploring the complex and inextricable links between the health of the ocean and that of humans. It is our vision that OHH will be recognized as a core component of the Planetary Health concept, with OHH awareness spreading through all relevant fields and communities. This will help build the required OHH research capacity to understand the links between ocean health and human health, in order to optimize the outcomes for both.**

This Strategic Research Agenda (SRA) presents the necessary OHH research that will enable fundamental questions to be answered, evidence to be provided to policy, and OHH literacy to be increased in Europe and beyond.

This SRA focuses on three main target action areas (see Figure 1): Sustainable seafood and healthy people; Blue spaces, tourism and well-being; and Marine biodiversity, biotechnology and medicine. It also outlines policy, relevant research needs, public and stakeholder attitudes, and capacity and training requirements in relation to these three areas, as well

as OHH more generally. We believe that an initial focus on these three key topics will cement OHH as a meta-discipline in Europe.

## **1. Sustainable seafood and healthy people:**

Our vision for food from the oceans is for fish and seafood to be healthy, nutritious, safe and accessible to all, while ensuring sustainability of fisheries and aquaculture.

## **2. Blue spaces, tourism and well-being:**

Our vision is for improved individual and community physical and mental health and well-being through enhanced interactions with healthy blue spaces that are sustainably managed.

## **3. Marine biodiversity, medicine and biotechnology:**

Our vision is a more targeted approach to explore, identify and obtain what marine biodiversity can provide to biotechnology, medicine and disease prevention, while demonstrating the critical importance of marine biodiversity and its protection.



Figure 1 – Main target action areas of the SRA

## Overall recommendations

**In addition to providing resources to explore these three main target areas, the following main priorities and overarching recommendations emerge from this Strategic Research Agenda:**

- A formal transdisciplinary forum and/or platform should be established to encourage collaboration between researchers from all OHH-relevant fields, building on the community established within this project.
- The research community should develop best practice guidance on collaboration with stakeholders and citizens in relation to OHH research.
- Systematic reviews and longitudinal studies should be conducted to better understand the state-of-the-art in OHH research, and to identify gaps in understanding linkages.
- The benefits of designated marine protected areas (MPAs), to human as well as ocean health, should be demonstrated.
- Inter- and transdisciplinary training and education programmes should be developed at different academic levels to support the development of OHH research.
- Appropriate mechanisms for youth contribution and engagement should be established.
- Advice should be provided to policymakers regarding the additional data collection and monitoring needs for both marine and health

parameters to support the understanding of interactions and to develop a body of evidence to demonstrate these interactions. This should also consider issues of accessibility and usability of existing data and monitoring systems, and propose relevant indicators and indices.

**We will know that we have achieved our vision of recognition when we have:**

- Best practice guidelines for collaboration and engagement of stakeholders in OHH research;
- A set of OHH-specific indicators that Member States are required to monitor and report on, supported by cross-policy coordination;
- Development of a dedicated OHH community platform that can be used to initiate contacts and launch collaborations, as well as provide access to data sources and products;
- Organization of a dedicated interdisciplinary conference series and/or similar forum to present and discuss this research;
- Research calls and subsequent jointly-funded interdisciplinary and international projects which require participation from several relevant backgrounds including at least marine science, medicine and/or public health; and
- An interdisciplinary OHH-specific module(s) offered to all graduates on marine and health-related university courses, either in-house or as a massive open online course (MOOC).

# A Strategic Research Agenda for Oceans and Human Health in Europe

**Developing an OHH research agenda and implementing its findings enables Europe to promote the health of its people, the European regional seas and the wider global ocean.**

The aim of this Strategic Research Agenda (SRA) is to present an approach and framework for creating the required Oceans and Human Health (OHH) research capacity in Europe, and to outline a critical agenda for OHH research for the short and medium term in order to achieve that capacity. It is not the aim of this SRA to endorse any specific approach.

Several important cross-cutting themes arise from these target action areas, including climate- and global change, pollution, ocean literacy and citizen science, equity and equality, sustainability, innovation and employment. These topics are not discussed explicitly but are addressed as relevant within the three main areas. The SRA presents the importance of each of the

three main areas, outlines key research questions that need to be answered within an indicative structured timeline, and highlights the needs (in terms of research to inform policy, capacity and training, and for the public) that should be considered. The SRA highlights overarching recommendations for research needs that apply to all areas of OHH, and the measures of success in achieving the required capacity.

The three main target action areas and research questions were identified by a group of 20 transdisciplinary and international experts, who formed the SOPHIE Project Expert Group<sup>1</sup>, during two dedicated workshops in April 2018<sup>2</sup> and January 2019<sup>3</sup>. The action areas were then further refined using input from all other SOPHIE project activities including input from citizens and other experts. Figure 2 maps these various inputs – more information about these activities can be found in Annex 1.



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1 <https://sophie2020.eu/activities/expert-group/>; <https://sophie2020.eu/wp/wp-content/uploads/2018/05/SOPHIE-Expert-Group-Members.pdf>  
2 <https://mailchi.mp/a3130666b0c20/sophie-expert-group-workshop-1>  
3 <https://mailchi.mp/8ef76d4e104e/sophie-expert-group-workshop-2-photo-report-1159497>

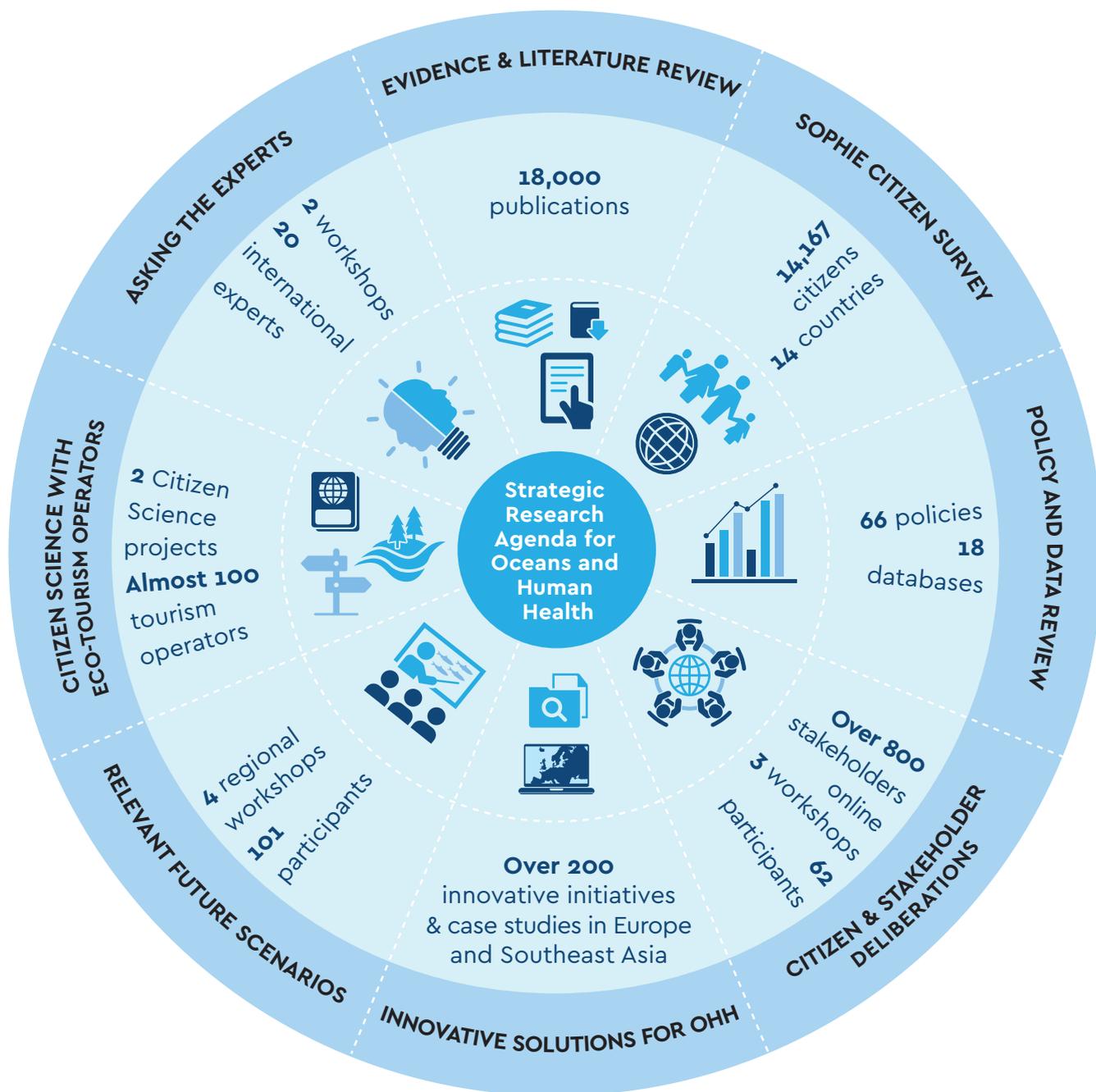


Figure 2 – SOPHIE Project inputs to the SRA from December 2017 to January 2020

# 1. Introduction



Figure 3 – The circular relationship between human health, human activities and the ocean

**Humans have always interacted with the ocean, using it for food, transportation, recreation and cultural activities, and more recently as a source of energy. We are now starting to realize that ocean health is also critical for human health and well-being (Depledge et al., 2019; Fleming et al., 2019).**

While the ocean can benefit humans via resources and services, it can also pose risks such as flooding and pollution. Climate and other environmental change is the most important risk to human health, and although the ocean has so far been instrumental in mitigating this risk, increasing pressure from further global heating will lead to an amplification of risks through increased flooding, storms etc. Some aspects, such as food from the ocean, are both a benefit and a risk.

Europe is intrinsically a maritime continent and European citizens both rely on and are affected by the ocean. We need to better understand and predict this complicated mix of threats, opportunities and their interactions. Exploring these relationships is the basis for an emerging scientific meta-discipline called 'Oceans and Human Health' (OHH). This field of research is inherently transdisciplinary, requiring collaboration between medical and public health experts; marine, environmental and social scientists; economists; lawyers; policymakers; citizens and many others.

As Figure 3 illustrates, there is not just a one-directional linear relationship between human health and the ocean: instead it is circular, multi-directional and interconnected, with both human health and ocean health being influenced by human behaviour and activity, which is increasingly affecting our oceans.

Against a background of rising healthcare costs and inequality, and growing populations, it is becoming ever more important to develop a better understanding of the links between oceans and humans, and potential co-benefits. While an increasing proportion of the healthcare community agree that 'prevention is better than cure', only around 7% of healthcare funding in Europe is currently spent on research in prevention and public health (OECD/EU, 2018). Savings could be achieved if the focus was adjusted; and the ocean can support such savings provided these interactions are sustainably managed.

Viewed within the framing of the current political agenda, the inter- and transdisciplinarity of OHH is incredibly important. The Health 2020 European Policy Framework and Strategy for 21st Century (World Health Organization, 2013) identifies "creating resilient communities and supportive environments" as one of four priority areas, and OHH sits comfortably within this remit. In 2015, the UN adopted the 2030 Agenda for Sustainable Development<sup>4</sup> together with its 17 Sustainable Development Goals<sup>5</sup> (SDGs), many of which are directly relevant to OHH including SDG 2 (zero hunger), SDG 3 (good health and well-being), SDG 10 (reduced inequality), SDG 12 (responsible consumption and production), SDG 13 (climate action), SDG 14 (life below water), and SDG 15 (life on land). It is widely acknowledged that these SDGs cannot be achieved in isolation, and that progress will require true transdisciplinary cooperation: OHH can contribute directly. In the Our Ocean, Our Future: Call to Action arising from the Ocean Conference in 2017<sup>6</sup>, the Heads of State and Government expressly recognized that

"the well-being of present and future generations is inextricably linked to the health and productivity of our ocean". The complementary UN Decades for 2021-2030 focusing on Ocean Science for Sustainable Development<sup>7</sup> and on Ecosystem Restoration<sup>8</sup> are a timely opportunity to further increase the attention on and impact of OHH, as the concept of human health is not clearly linked to the health of the ocean in either of the two Decades' aims.

Recent reports highlight with increasing clarity the links between climate and other environmental changes, the ocean and its 'health', and the health of humans (IPCC, 2019). It is clear that the existential threats we face are a product of our own behaviours and choices (e.g. in food consumption, energy use, waste management, and transport). As such we need a far greater understanding of why these behaviours are so resistant to change in the face of overwhelming evidence of their harm both to the natural world and to our own long-term health and well-being – and how they need to be changed as we move towards a low-carbon economy. In this regard, OHH is also highly relevant to the European Green Deal<sup>9</sup> outlined in 2019, which aims to achieve climate neutrality in Europe by 2050. The issues are not merely academic, they are social, political, economic and cultural, and will affect all of humanity. The concept of Planetary Health<sup>10</sup> which frames the health of humans and the planet together, is also growing within the medical and public health communities. OHH is part of this wider environment and health research field, but awareness of this link should be strengthened as it has received relatively little attention to date.

4 <https://www.un.org/sustainabledevelopment/development-agenda/>

5 <https://www.un.org/sustainabledevelopment/sustainable-development-goals/>

6 <https://oceanconference.un.org/callforaction>

7 <https://oceandecade.org/>

8 <https://www.decadeonrestoration.org/>

9 [https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal\\_en](https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en)

10 <https://www.thelancet.com/infographics/planetary-health>

Another issue featuring highly on global agendas is plastics. Growing awareness across the whole of society of plastic pollution has resulted in encouraging measures, including the EU ban on single-use plastics<sup>11</sup>. It is noted that empirical links between marine plastic pollution and human health outcomes are still lacking in the literature, and concerns remain risk- rather than evidence-based (Science Advice for Policy by European Academies (SAPEA), 2019). It is however also crucial to look beyond plastics, to all pollutants (both

natural and man-made) in the marine environment, in order to raise awareness and inspire similar decisive political and innovative action.

The interconnections and interrelationships between healthy oceans, human activities and healthy humans, some of which are highlighted in Figure 4, are not well documented or researched. Given the complexity demonstrated in this figure, this is a top research priority. This SRA will delve into these connections in more detail, and highlight some key areas for research.



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*Plastic straws collected during the Viladecans beach clean, Spain*

<sup>11</sup> <https://www.europarl.europa.eu/news/en/press-room/20181018IPR16524/plastic-oceans-meps-back-eu-ban-on-throwaway-plastics-by-2021>

## A Tangled Net

Selected interconnections between human health and activities in and around seas and oceans.

A positive impact on a harm has a mitigating force.

A negative impact on a benefit represents a limiting force.

- ⊕ — Positive Impact
- ⊖ — Negative Impact
- Benefit to Humans
- Harm to Humans

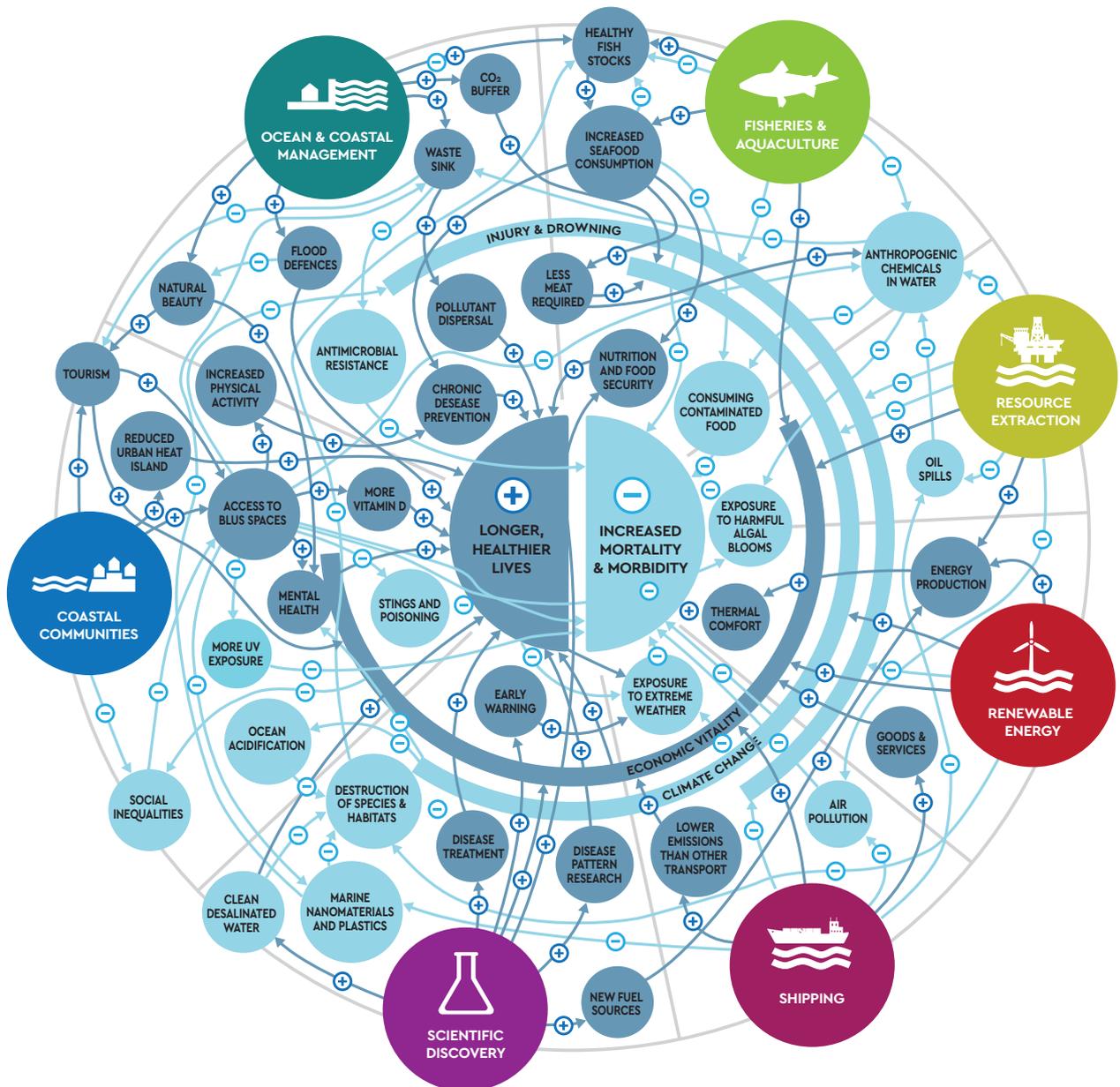


Figure 4 – A tangled net – selected interconnections between human health and activities in and around the seas and oceans (designed by Will Stahl-Timmins, in Fleming et al., (2019))

# 1.1 The Oceans and Human Health landscape



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View of Dún Laoghaire, Ireland

**The concept of a meta-discipline known as Oceans and Human Health began to emerge at the turn of the millennium, with publications appearing in the US (Knap et al., 2002; National Research Council, 1999).**

In the US, where significant funding for OHH research was first awarded, the research has typically focused on addressing key threats to human health from harmful algal blooms (HABs), chemical and microbial pollution, as well as the potential for tackling human health issues through the use of marine natural products (e.g. using marine sponges to develop cancer drugs). In 2018, the USA's National Science Foundation (NSF) and National Institute of Environmental Health Sciences (NIEHS) announced a new round of OHH funding with the addition of climate change, demonstrating the continued recognition of the importance of OHH<sup>22</sup>.

In Europe, OHH was initially profiled in Marine Pollution Bulletin (Bowen et al., 2006), later by the European Marine Board (Moore et al., 2013); and interest and investment has grown since then, covering a far wider scope of interactions. The research was initially into negative interactions between oceans and humans, but it has more recently expanded to consider positive

interactions and the ways in which both could benefit (Depledge et al., 2013). This is evidenced by the recent Horizon 2020 Framework programme funding by the European Commission of projects such as SOPHIE<sup>23</sup>, BlueHealth<sup>24</sup>, SeaChange<sup>25</sup> and BONUS ROSEMARIE<sup>26</sup>, as well as a number of other initiatives, publications and activities. In its Strategic Research and Innovation Agenda for 2015-2020<sup>27</sup>, JPI Oceans<sup>28</sup> included "Linking Oceans, Human Health and well-being" as one of 10 strategic areas in which it plans to initiate research funding, and its support for this topic is expected to continue.

The BANOS CSA<sup>29</sup> is currently developing its own Strategic Research and Innovation Agenda, of which one of the main pillars is human health, and its key objectives agree with the SOPHIE SRA. The topic of OHH has been fostered through the EuroOCEAN conference series<sup>20</sup>, with dedicated sessions during the 2014 and 2019 editions as well as an explicit mention in the Rome Declaration (European Marine Board, 2014).

The OHH concept is beginning to gain traction at national level, with projects such as UK Global Challenge Research Fund (GCRF) Blue Communities<sup>21</sup> raising awareness of this topic in East and Southeast Asia. In

November 2019, the Asia-Pacific Academic Consortium for Public Health<sup>22</sup> (APACPH) passed a resolution to make Planetary Health, and in particular OHH, a priority programme. These projects enable OHH professionals

across the globe to collaborate, and share ideas and experiences, helping to further develop the field.

The timeline in Figure 5 shows the emergence and development of OHH in Europe and globally.

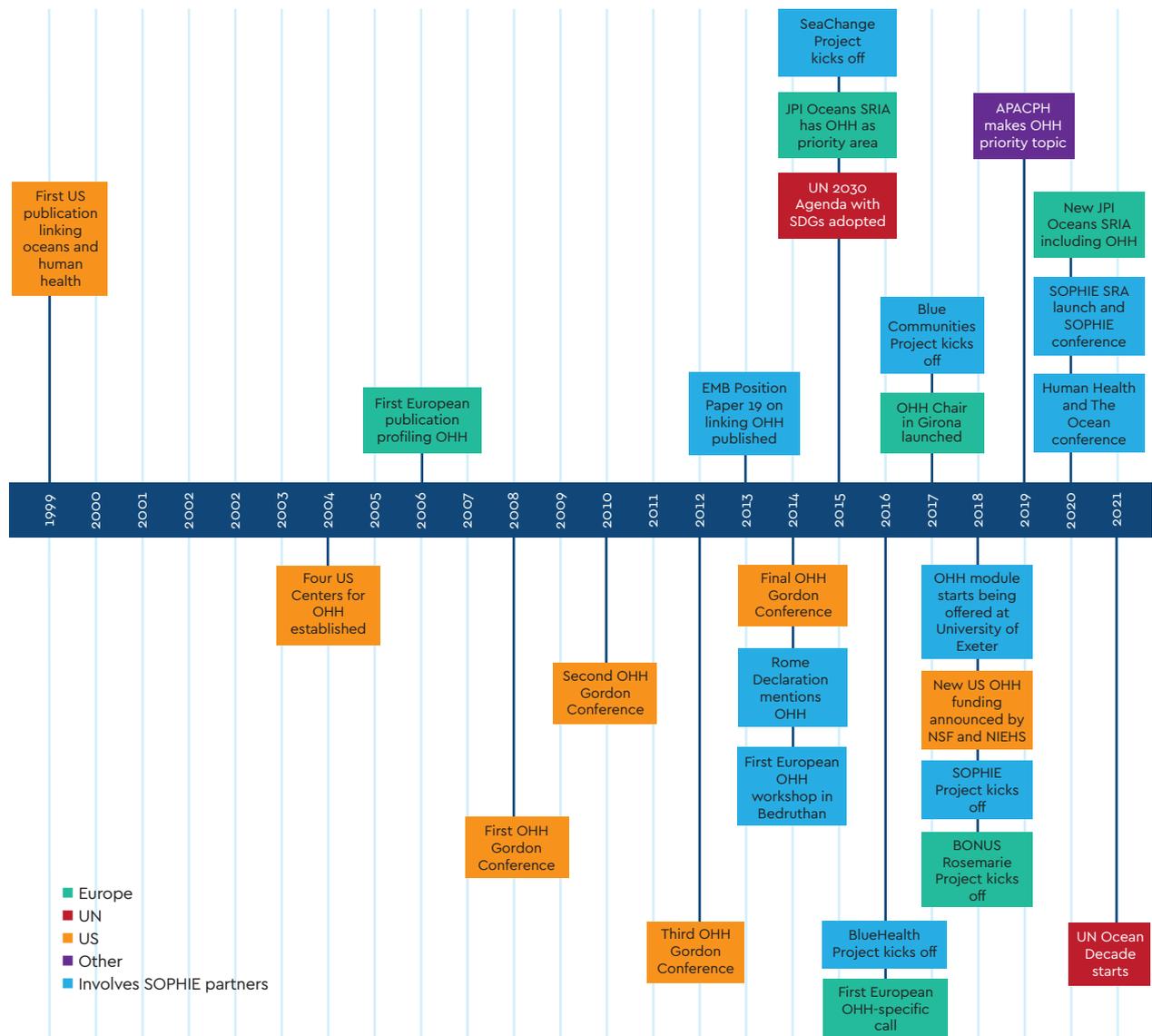


Figure 5 - An OHH timeline showing key milestones in the development of this meta-discipline

12 [https://www.nsf.gov/news/news\\_summ.jsp?cntn\\_id=296579](https://www.nsf.gov/news/news_summ.jsp?cntn_id=296579)

13 <https://sophie2020.eu/>

14 <https://bluehealth2020.eu/>

15 <http://www.seachangeproject.eu/>

16 [https://www.syke.fi/en-US/Research\\_Development/Research\\_and\\_development\\_projects/Projects/BONUS\\_ROSEMARIE](https://www.syke.fi/en-US/Research_Development/Research_and_development_projects/Projects/BONUS_ROSEMARIE)

17 <http://www.jpi-oceans.eu/library?refid=246303>

18 <http://www.jpi-oceans.eu/>

19 [https://www.banoscsa.org/banos\\_csa](https://www.banoscsa.org/banos_csa)

20 <http://www.marineboard.eu/eurocean>

21 <https://www.blue-communities.org/Home>

22 <http://www.apacph.org/wp/>



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## 1.2 What does the literature tell us?

A review of current research provides baseline information that is crucial for underpinning the direction of future research as well as identifying where synthesis of existing evidence is required for policy.

As part of the SOPHIE Project an evidence and literature review<sup>23</sup> was undertaken to understand what links have been researched to date between marine environments and positive and negative impacts on human health and well-being. This review included grey and peer-reviewed literature identified by a systematic search process, and mapped empirical evidence with a defined coastal or marine exposure and a measurable human health outcome. It is however noted that this review should not be considered to be exhaustive, as the number and exact search synonyms selected as well as the requirement for a measurable human health outcome will inevitably have excluded some literature. This had to be done in order to keep the numbers of appears to be screened within manageable limits and highlights the difficulty of conducting evidence mapping for topics with a wide

scope. It should be noted that this approach does not give any information about the quality of research or infer any overarching direction of relationships, but presents the research landscape as a whole, helping to identify knowledge gaps and prioritize further syntheses.

Half of the studies examined came from the US. Research was mostly from coastal countries, with particular focus on health impacts linked to activities such as fisheries, oil and gas extraction, shipping, and emergency services. Other notable topics included agricultural and microbial pollution, chemical pollution, coastal habitation, consumption of marine products, coastal recreation, and marine microbes, toxins and parasites. As this review was restricted to measurable health outcomes, it is worth noting that a considerable amount of emerging research was identified where potential risks and opportunities for human health have been identified but where the research has yet to make explicit links, e.g. the impacts of plastic pollution. Figure 6 presents an overview of the numbers of studies for different marine exposure and human health interactions.

Marine resource use exposures											Occupational marine exposures						Health outcomes
Agricultural, microbial & air pollution	Carbon sink and climate change	Chemical pollution	Coastal populations	Consumption of marine products	Marine microbes, toxins & parasites	Plastic pollution	Recreation and physical activity	Marine biotechnology	Fisheries	Oil industry	Other coastal and maritime industries	Other marine occupations	Shellfish	Shipping / ship building	Tourism		
2	0	10	11	3	0	0	0	0	3	0	0	2	0	2	0	Cancer & cancer risk	
1	1	13	0	139	4	0	12	408	0	4	0	0	0	1	0	Cardiovascular condition	
40	1	5	6	0	10	0	1	3	4	2	0	2	0	2	0	Dermatological condition	
0	0	7	0	50	1	0	0	189	1	2	1	0	0	0	0	Endocrine / immune system	
111	2	0	1	12	17	0	0	0	5	2	1	3	3	1	0	Gastrointestinal condition	
9	4	20	11	85	3	0	3	68	4	12	0	4	0	3	2	General health	
0	0	37	0	0	0	0	0	0	2	0	2	0	0	0	0	Heavy metal poisoning	
41	1	1	3	5	35	0	4	0	2	1	2	3	1	0	0	Infection	
1	24	30	20	1	0	0	2	0	3	53	1	6	0	2	0	Mental health condition	
5	10	8	4	58	16	0	13	1	13	0	1	2	0	7	2	Mortality	
0	0	1	0	4	0	0	3	57	3	1	0	2	0	0	0	Musculoskeletal condition	
35	1	157	2	11	8	0	15	51	5	4	1	4	1	1	0	Neurological condition	
0	2	13	0	2	0	0	0	0	4	16	3	7	1	3	0	Reproductive / developmental	
71	2	5	2	5	5	0	0	0	0	3	0	0	0	0	0	Respiratory condition	
0	0	0	6	0	0	0	3	0	3	0	1	1	0	1	0	Well-being	
1	4	1	0	0	2	1	8	0	11	3	1	2	0	2	1	Wounds and injuries	

Figure 6 – Systematic mapping matrix showing the number of articles presenting evidence on each identified interaction between marine exposures and human health outcomes. Papers include synthesized (included in a systematic review) and non-synthesized primary research and grey literature. Dark colours indicate more articles and light colours fewer.

23 <https://sophie2020.eu/activities/systematic-map/>

Figure 7 shows the cumulative representation of research over time for six research areas, with Biotechnology identified as the dominant topic. At present, research on positive health outcomes totals roughly half that of negative ones.

Evidence synthesis efforts have been heavily dominated by systematic reviews in marine biotechnology research, particularly related to cardiovascular health. There is some synthesis of evidence on fish-based

diets and health, heavy metal pollution and microbial pollution, but many *in situ* marine health issues are yet to be explored. The mapping exercise has identified a need for formal evidence syntheses in areas such as pollutants and respiratory conditions, mental health outcomes from marine disasters, naturally-occurring marine microbes and changing infection burdens. The exploration of trade-offs is another priority area, e.g. the balance of damaging heavy metal intake vs. the benefits of high-seafood diets.

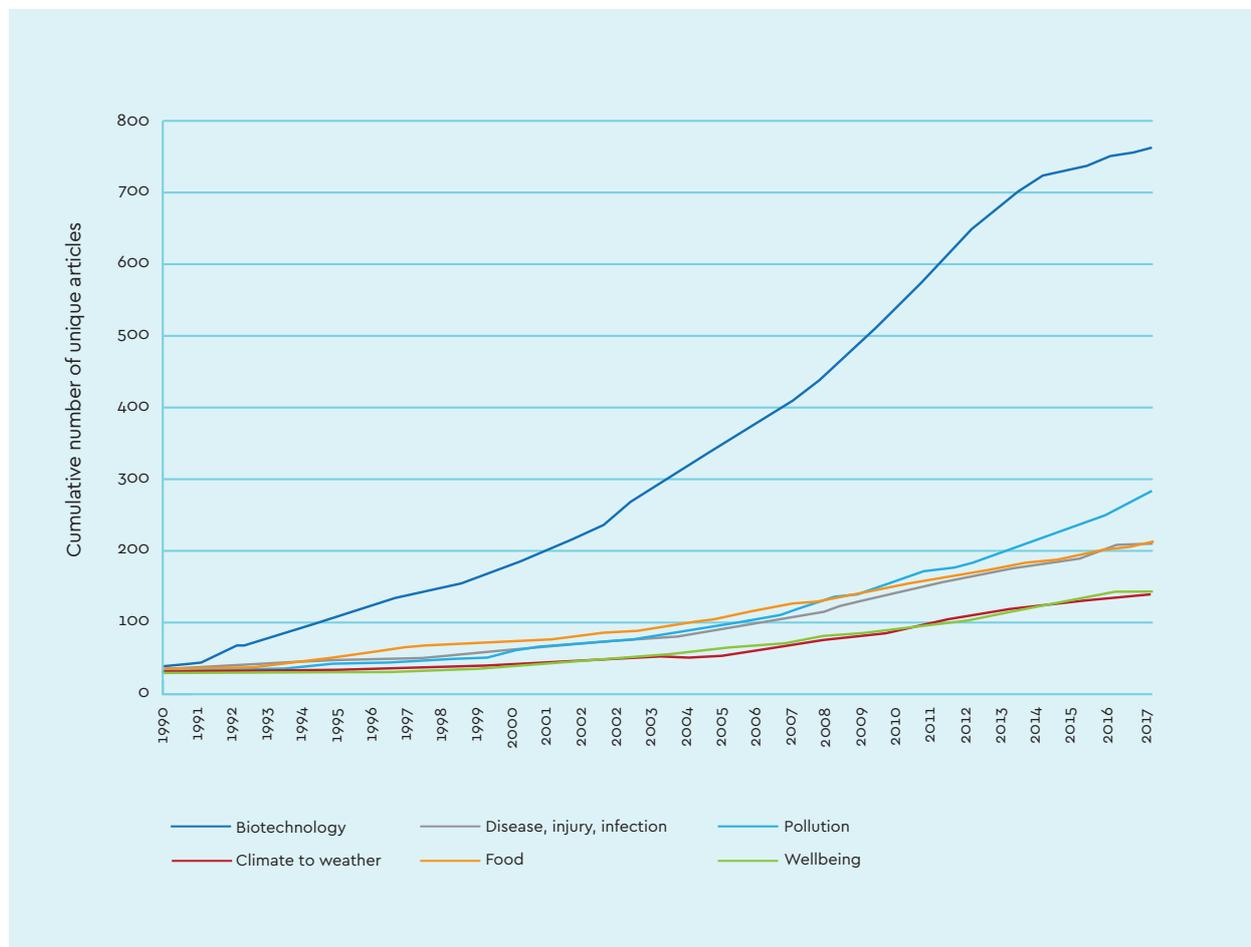


Figure 7 - Timeline of OHH research beginning and growth

# 1.3 Understanding links between research and policy in Oceans and Human Health

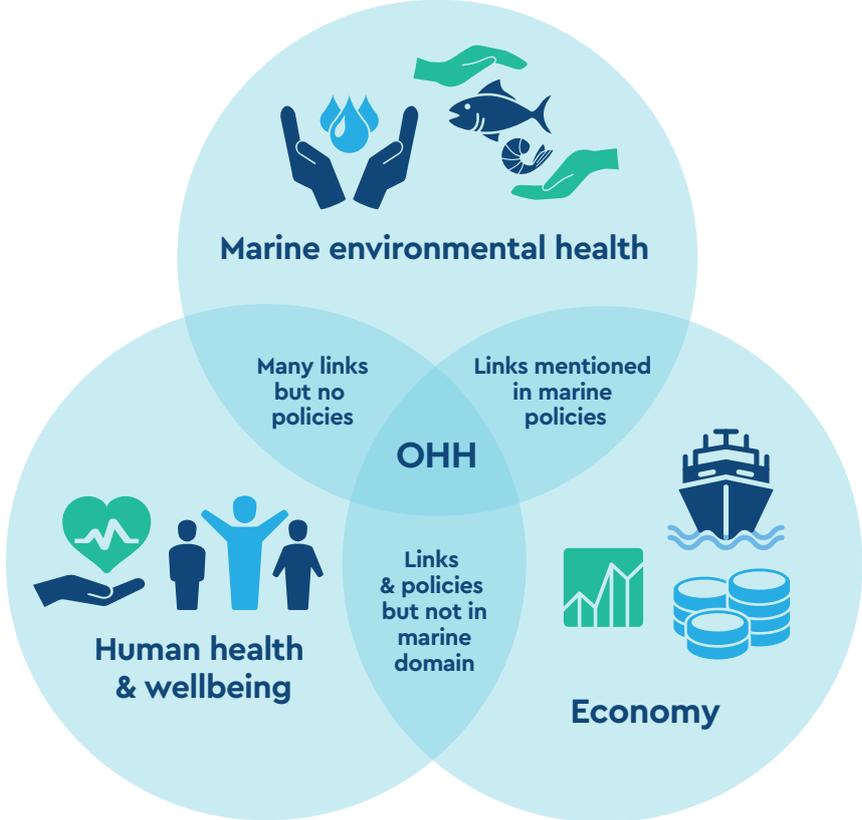


Figure 8 – Overview of current policies relating to OHH, and their interaction

**Current policy approaches can act as barriers to the development of OHH research, therefore we first identify these challenges, and then propose research to address them.**

The marine policy landscape works largely at a European level, as it is designed to regulate human activities in and underpin protection of the marine environment, with Directives and other instruments specified for Europe as a whole (Borja et al., 2020; McMeel et al., 2019). Member States implement these nationally and are mandated to report on their approach and progress.

Clearly, marine issues themselves (e.g. pollution and marine life) are not constrained by national boundaries but instead travel freely through Europe and beyond. In

contrast, Member States are primarily responsible for health services and medical care, therefore at European level health policy aims to protect and improve the health of EU citizens and complements national policies. The Europe-wide health policies that do exist do not generally have the same regulatory weight as those of marine policies. Coupled with the relatively recent increase in awareness around OHH, this means that at present there are no policies in Europe that explicitly cover both oceans and human health. Examples that do overlap, such as the Bathing Water Directive<sup>24</sup>, are limited in scope and in the risks addressed. This poses challenges to both the research and policy communities. Figure 8 presents an overview of the status of policies relating to OHH.

<sup>24</sup> [https://ec.europa.eu/environment/water/water-bathing/index\\_en.html](https://ec.europa.eu/environment/water/water-bathing/index_en.html)

The **first challenge** for the research community is that OHH does not clearly sit within a single policy remit, at either European or national level. This can make the funding of research more difficult, and communication pathways for needs and results unclear. The OHH research community could help to address this challenge by further raising awareness of OHH and research policy gaps at all relevant policy levels.

The **second challenge** is a resulting lack of data (and a lack of availability of existing data) linking both oceans and human health, especially in emerging areas such as new pollutants. This is a challenge for policymakers attempting to devise integrated policies because the evidence of cause and effect relationships is lacking. In the near future, the OHH research community should further explore what relevant data are already available and being collected under which frameworks, identify data which could easily be collected under existing monitoring and observation programmes, propose new indicators of both human and ocean health, and create a body of evidence to better link cause and effect in support of policymaking.

A **third challenge** lies in what different stakeholders expect from these policies and other governance approaches. In the various stakeholder interactions that took place within the SOPHIE Project (see Annex 1), citizens tended to prioritize measures based on accountability within industry, whereas other stakeholders tended more towards regulatory and governance systems. Traditional top-down policy measures play an important role and will always be required, but they are not the only solution. Increasingly, science, policymakers and citizens themselves are also recognizing the importance of bottom-up and local initiatives. This is especially relevant given the diversity of people and marine environments in Europe. Some issues will have greater importance in some sea-basins and/or countries than others; and the appropriate solutions will vary depending on where, at what scale, and by whom they are being implemented. In this regard, the OHH research community can support policy by further exploring ways in which this dual approach of top-down and bottom-up measures could be achieved, identifying key stakeholder groups for different areas of interest and developing specific best practice approaches for ensuring stakeholder and citizen input for informing policy.



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# 1.4 Citizen and stakeholder priorities for Oceans and Human Health

During the course of the SOPHIE project, stakeholders and citizens acknowledged and appreciated the links between the ocean and human health, but indicated that they need to know more about these links to provide meaningful input to policy and decision-making.

In the societal stakeholder and citizen workshops to build consensus around priorities and solutions for OHH<sup>25</sup>, they recognize the gaps between the descriptions of OHH and understanding the causal processes that drive OHH dynamics (McHugh et al., 2020). In the priorities that stakeholders and citizens identified for OHH, the nine themes presented in Figure 9 were perceived to be the most influential for Europe.

In this map, the Stage 1 themes are perceived to have the greatest influence on the subsequent themes

and on OHH generally, while the Stage 6 themes are perceived to be the most impacted by processes and outcomes of the preceding themes and to have a lower level of influence on OHH.

In terms of research and successful mobilisation action, the themes to the left of the map are more likely to have a stronger impact on "the overall system of priorities" (Domegan et al., 2014) while at the same time relieving pressure on the priorities belonging to the themes on the right. It is important to be aware that this influence map is not to be considered an action plan, since other factors may also come into play when deciding on actions to be taken. It is not necessary to address OHH knowledge first if there is an immediate opportunity e.g. to address pollution (Stage 2) or protect the public from health risks (Stage 3).

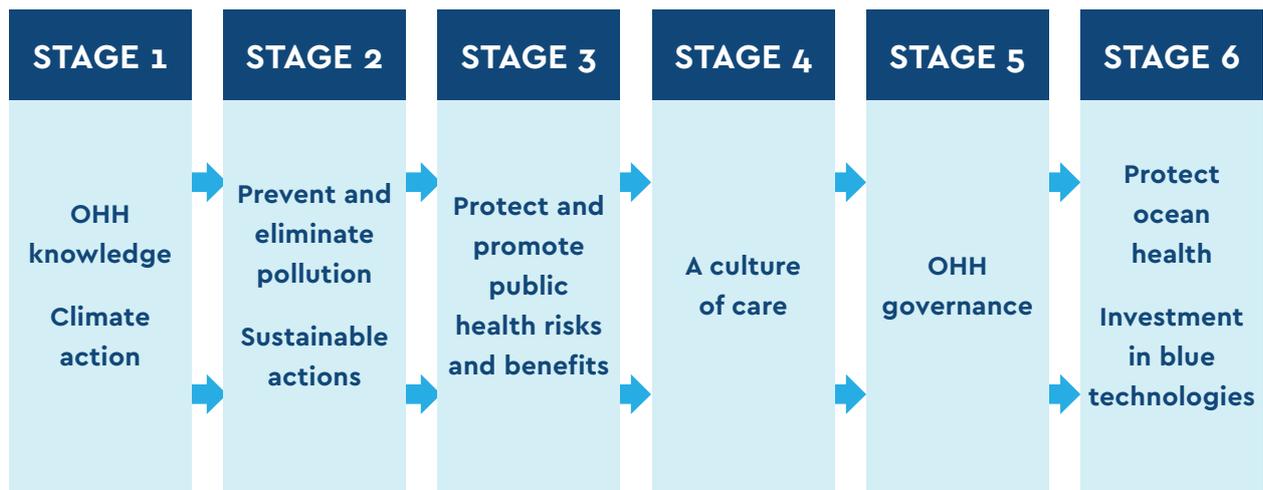


Figure 9 – Meta-analysis map showing responses to the question, "What, in your opinion, are the top priorities for protecting public health and the health of the marine environment for a sustainable future?"

25 <https://sophie2020.eu/activities/stakeholder-discussions/>

	Concern	Views	Policy	Research
Fishing	<b>Collapse of fish stocks</b>	<b>Commercial fishing</b>	<b>Commercial fishing</b>	<b>Research</b>
	<p><i>Higher concern</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- Lower 25% income</li> <li>- Living &lt;1km from the coast</li> <li>- Eating Seafood/sea fishing</li> </ul> <p><i>Less concern</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> <li>- University degree</li> <li>- Right orientated Political view</li> </ul>	<p><i>More positive view</i></p> <ul style="list-style-type: none"> <li>- Retired individuals</li> <li>- Living 5-20km from the coast</li> <li>- Working in the marine sector</li> <li>- Eating seafood/sea fishing</li> </ul> <p><i>More negative view</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- Left orientated political view</li> </ul>	<p><i>More policy</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- University degree</li> <li>- Eating seafood/sea fishing</li> </ul> <p><i>Less policy</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> <li>- Right orientated political view</li> </ul>	
Fishing	<b>Contamination of Seafood</b>	<b>Aquaculture</b>	<b>Aquaculture</b>	<b>Sustainable aquaculture</b>
	<p><i>Higher concern</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- Lower 25% income</li> <li>- Living &lt;1km from the coast</li> <li>- Water based recreation activities</li> <li>- Eating Seafood/sea fishing</li> </ul> <p><i>Less concern</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> <li>- University degree</li> <li>- Right orientated Political view</li> </ul>	<p><i>More positive view</i></p> <ul style="list-style-type: none"> <li>- Right orientated political view</li> <li>- Working in the marine sector</li> <li>- Eating seafood/sea fishing</li> </ul> <p><i>More negative view</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- University degree</li> <li>- Non-reported income</li> </ul>	<p><i>More policy</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- Living 5-20km from the cost</li> <li>- Eating seafood/sea fishing</li> </ul> <p><i>Less policy</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> <li>- Retired and unemployed individuals</li> <li>- Right orientated political view</li> </ul>	<p><i>More research support</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- Eating seafood/sea fishing</li> </ul> <p><i>Less research support</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> <li>- Non-reported income</li> <li>- Right orientated political view</li> </ul>
Medicine	<b>Emergence of drug resistant microbes</b>	<b>Producing medicines from marine organisms</b>	<b>Producing medicines from marine organisms</b>	<b>Producing medicine from marine organisms</b>
	<p><i>Higher concern</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- Lower 25% income</li> <li>- Water based recreation activities</li> <li>- Eating Seafood/sea fishing</li> </ul> <p><i>Less concern</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> <li>- University degree</li> <li>- Upper 25% income</li> <li>- Right orientated political view</li> </ul>	<p><i>More positive view</i></p> <ul style="list-style-type: none"> <li>- Retired &amp; unemployed individuals</li> <li>- Upper 25% income</li> <li>- Living &lt;1km from the coast</li> <li>- Eating seafood/sea fishing</li> </ul> <p><i>More negative view</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> <li>- Females</li> <li>- Left orientated political view</li> </ul>	<p><i>More policy</i></p> <ul style="list-style-type: none"> <li>- Females</li> </ul> <p><i>Less policy</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> <li>- Right orientated political view</li> </ul>	<p><i>More research support</i></p> <ul style="list-style-type: none"> <li>- University degree</li> <li>- Working in the marine sector</li> <li>- Eating seafood/sea fishing</li> </ul> <p><i>Less research support</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> </ul>
Recreation	<b>Drowning from Recreational activities</b>	<b>Recreational visits</b>	<b>Recreational visits</b>	<b>Health and Wellbeing effects of spending leisure time by the sea</b>
	<p><i>Higher concern</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- Lower 25% income</li> <li>- Living 5-20km from the coast</li> <li>- Working in the marine sector</li> </ul> <p><i>Less concern</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> <li>- University degree</li> <li>- Non-reported income</li> <li>- Eating seafood/sea fishing</li> </ul>	<p><i>More positive view</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- Living &lt;1km from the coast</li> <li>- Water based recreation activities</li> <li>- Eating seafood/sea fishing</li> </ul> <p><i>More negative view</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> <li>- University degree</li> <li>- Working in the marine sector</li> </ul>	<p><i>More positive view</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- Living 1-5km from the cost</li> <li>- Working in the marine sector</li> </ul> <p><i>Less policy</i></p> <ul style="list-style-type: none"> <li>- University degree</li> <li>- Retired and unemployed individuals</li> <li>- Non-reported income</li> <li>- Water based recreation activities</li> <li>- Eating seafood/sea fishing</li> </ul>	<p><i>More research support</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- Lower 25% income quartile</li> <li>- Living &lt;1,1-5 and 5-10km from the coast</li> <li>- Working in the marine sector</li> <li>- water based recreation activities</li> <li>- Eating seafood/sea fishing</li> </ul> <p><i>Less research support</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> </ul>
Wildlife	<b>Loss of marine species</b>	<b>Conservation activities</b>	<b>Conservation activities</b>	<b>Marine Species protection</b>
	<p><i>Higher concern</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- Lower 25% income</li> <li>- Living &lt;1km from the coast</li> <li>- Water based recreation activities</li> <li>- Eating seafood/sea fishing</li> </ul> <p><i>Less concern</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> <li>- Right orientated political view</li> <li>- Working in the marine sector</li> </ul>	<p><i>More positive view</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- lower 25% income quartile</li> <li>- Living &lt;1km from the coast</li> <li>- Eating seafood/sea fishing</li> </ul> <p><i>More negative view</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> <li>- Retired individuals</li> <li>- Right orientated political views</li> <li>- Working in the marine sector</li> </ul>	<p><i>More policy</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- Eating seafood/sea fishing</li> </ul> <p><i>Less policy</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> <li>- Right orientated political view</li> </ul>	<p><i>More research support</i></p> <ul style="list-style-type: none"> <li>- Females</li> <li>- Lower 25% income quartile</li> <li>- Living &lt;1km from the cost</li> <li>- Water based recreation activities</li> <li>- Eating seafood/sea fishing</li> </ul> <p><i>Less research support</i></p> <ul style="list-style-type: none"> <li>- Younger individuals</li> <li>- University Degree</li> <li>- Right orientated political view</li> </ul>

Figure 10 – Summary of the main results of the SOPHIE Survey

The map suggests, however, that the chance of a successful outcome might be greater if the priorities for OHH knowledge were implemented at the same time. No matter where research is conducted and/or the initial action is taken, the map can advise us on the possible impact of research and mobilization actions, as well as priorities that will have an effect on their success, and hence can serve as an invaluable planning tool. This map highlights a need to link knowledge with practice in a way that can support and promote sustainable actions and greater citizen engagement. This presents opportunities for transdisciplinary research and partnership building between research scientists in OHH and marine science, social sciences and public health.

The SOPHIE Survey<sup>26</sup> delved into the opinions of over 14,000 European citizens, to find out more about

their feelings regarding marine activities relating to topics including those linked to the three target action areas of this SRA. Figure 10 opposite outlines the main results. It was found that citizens believe that they place more importance on the environment and on health than policymakers do, while policymakers place more importance on the economy.

The importance placed by citizens on given activities was explored in European regional workshops<sup>27</sup> that focused on identifying trends and priorities important for OHH in the future. In each of the four sea basin workshops, the attendees were asked to agree on their top six trends for their sea basin, and the results can be seen in Figure 11 below:

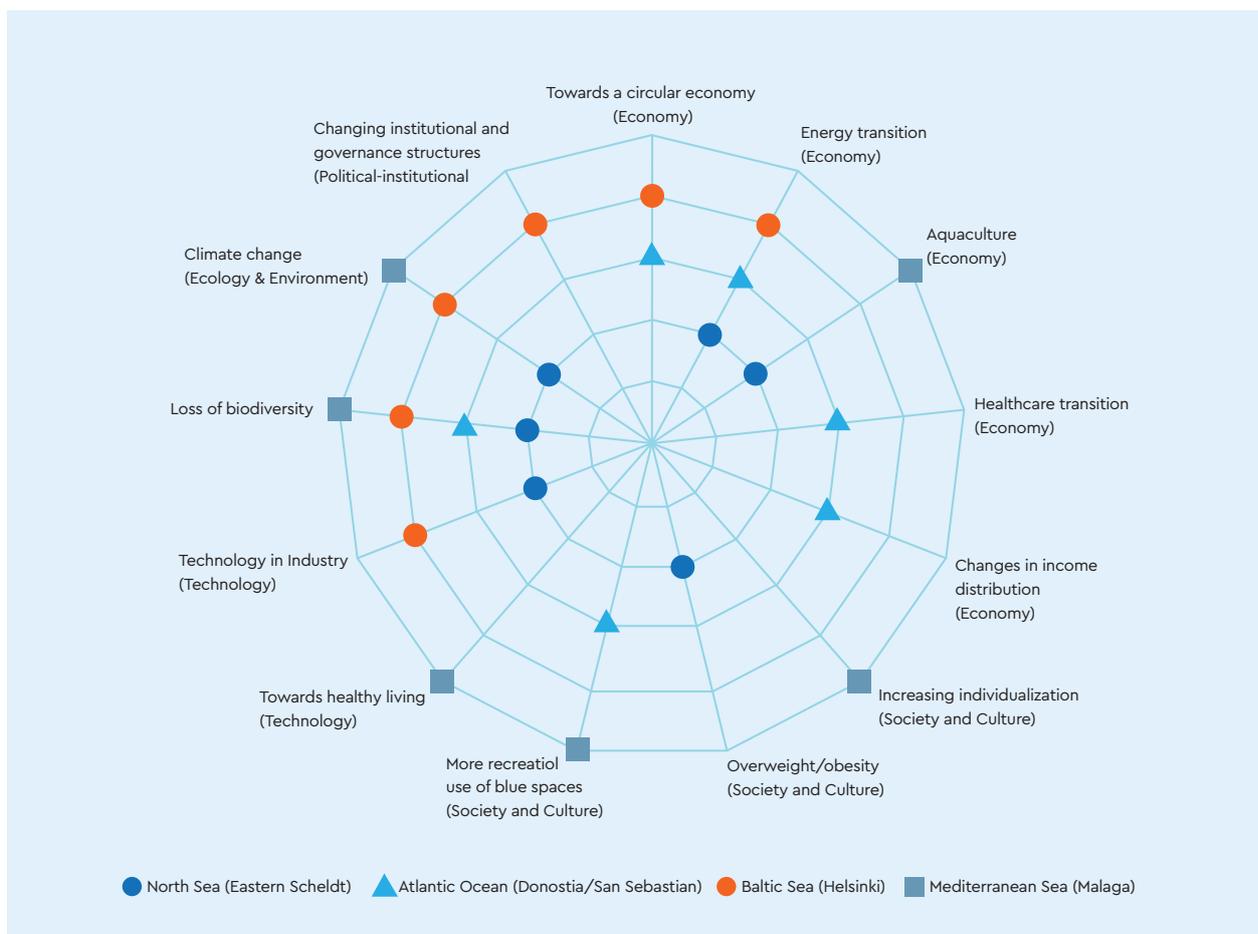


Figure 11 – Trends identified as most relevant by the participants for the sea basin being discussed

26 <https://sophie2020.eu/activities/sophie-survey/>

27 <https://sophie2020.eu/activities/innovative-solutions/>

During a case study in the Eastern Scheldt (Netherlands) the current practices of, and future challenges for, local stakeholders were investigated. Here, the level of collaboration between different stakeholders varied depending on the issue in question, but having a broad range of policies covering a particular issue was not seen as a barrier. The participants noted that they are concerned about emerging contaminants, and felt that at present, the human health implications of these contaminants were not being taken explicitly into account as existing policies do not yet address these substances. A better understanding of interactions is needed: however, gathering these data through monitoring alone could be too costly and time-consuming.

Modelling as a means to develop understanding of OHH interactions was proposed.

Clear priorities emerged from the SOPHIE inventory of innovative initiatives<sup>28</sup> that have been developed and which link to OHH. The environmental issues that were most commonly addressed by local bottom-up initiatives were marine litter and loss of biodiversity. There were also many citizen science projects, and other initiatives to enhance human health through marine ecotourism and therapies involving exercise at sea. Figure 12 highlights the numbers of initiatives that are in line with relevant SDGs and their indicators. The impact of such innovative initiatives could further increase if local initiatives collaborated in larger networks to share experiences, and collect data and resources.

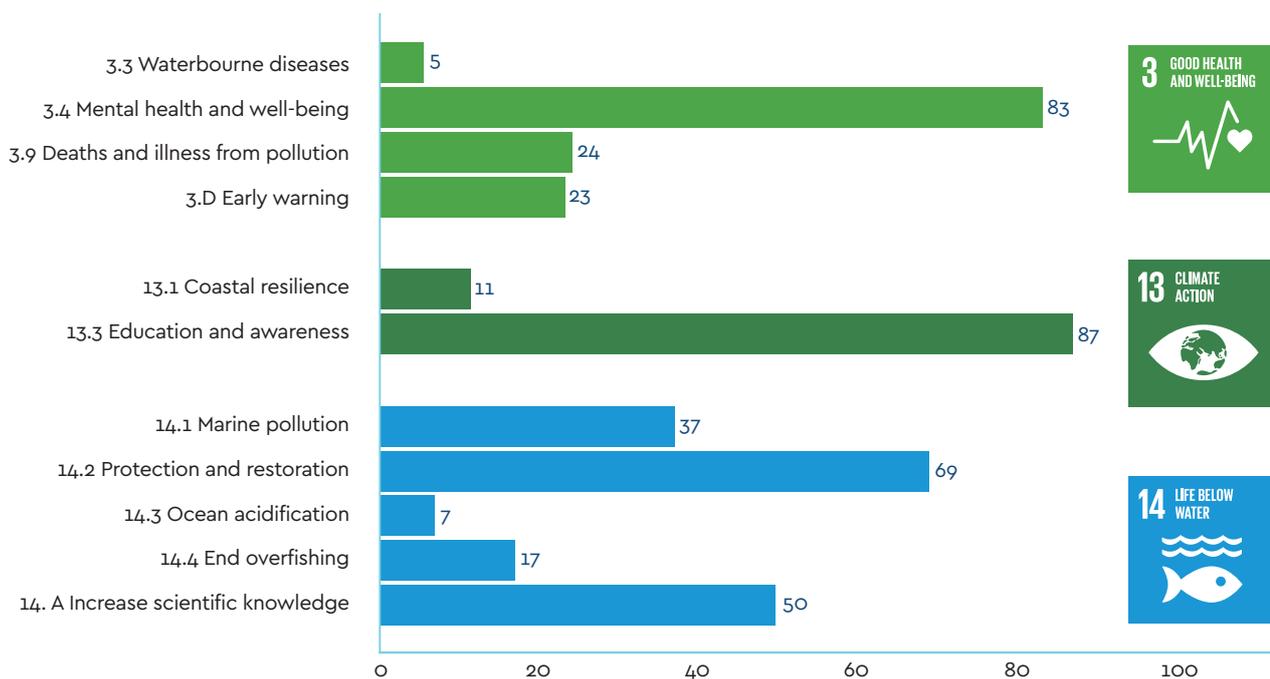
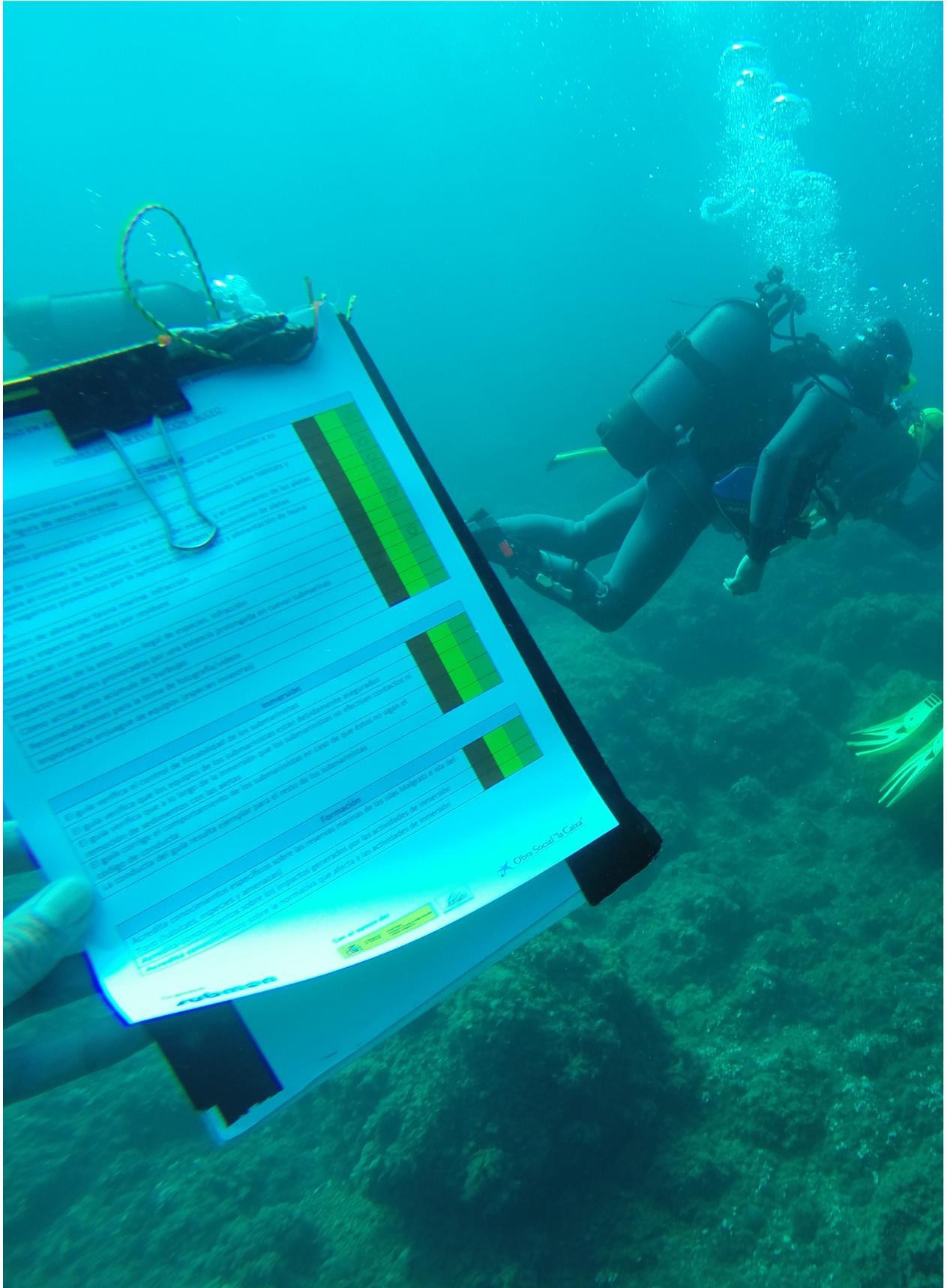


Figure 12 – Number of innovative initiatives in the SOPHIE inventory contributing to relevant sustainable development goals

28 <https://sophie2020.eu/activities/innovative-solutions/>



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WildSea divers off Isla del Toro, Spain, is an example of a marine eco-tourism initiative



## 2. Target Action Area 1: Sustainable seafood and healthy people

**Our vision for food from the oceans is for fish and seafood to be healthy, nutritious, safe and accessible to all, while ensuring sustainability of fisheries and aquaculture.**

### 2.1 Why is this important?

The ocean as a source of food is being highlighted for several reasons: the health benefits, the need to feed ever-growing populations and the increasing impact of marine pollution. We do not yet have a holistic understanding of the provision of health benefits from seafood, and this will affect our ability to adapt to future changes. Considering food chain contaminants, the SOPHIE literature and evidence review found a significant body of research on the risks of mercury to human health, with development of appropriate advisories. However, emerging threats such as persistent organic pollutants and increasing concerns about additives in plastic pollution, along with other aspects of food in a changing environment, had not yet been comprehensively addressed.

In 2015, it was estimated that the average European consumes 25.1 kg of fish or seafood per year, almost 4 kg more than the global average<sup>29</sup>. Fish and seafood are a lean form of protein and a key source of omega-3 fatty acids which are both thought to play an important role in a healthy balanced diet; these nutrients in turn can have benefits including reducing non-communicable diseases (NCD) such as obesity, diabetes, heart disease and stroke (Yashodhara et al., 2009). However more recent research is less conclusive (Abdelhamid et al.,

2018), with variations in omega-3 efficacy depending on its source, which need to be further researched.

Research also suggests that in addition to omega-3 fatty acids, a range of other nutrients found in fish are beneficial to human health (Kawarazuka & Béné, 2011); but the SOPHIE systematic map of evidence<sup>30</sup> suggested that we know relatively little about this. There is a lack of nutrient composition information for many fish species and other seafood, although new methods for prediction are increasingly being explored (Vaitla et al., 2018). The benefits of fish and seafood to nutritional security may be undervalued and there is a need to look beyond biomass and protein (Hicks et al., 2019), again indicating that further study is required. Paradigm-shifting management changes may be needed both in developed and developing countries to optimize this resource (Garcia et al., 2012).

Concerns about the impacts of meat production on climate change have led, among others, to the creation of a 'Planetary Health Diet'<sup>31</sup> which proposes the consumption of more seafood and chicken in place of red meats, alongside significantly increased amounts of plant-based foods. This does however add to the existing demand for food from the oceans.

Responding to a request by the then EU Commissioner for Environment, Maritime Affairs and Fisheries, Karmenu Vella (2014-2019), the EU Group of Chief Scientific Advisors<sup>32</sup> produced the Food from the Ocean report<sup>33</sup> on how to increase the amount of food and biomass that could be sustainably extracted from

29 [https://ec.europa.eu/fisheries/6-consumption\\_en](https://ec.europa.eu/fisheries/6-consumption_en)

30 <https://sophie2020.eu/activities/systematic-map/>

31 <https://www.sciencedirect.com/science/article/pii/S0140673618317884?via%3Dihub>

32 <https://ec.europa.eu/research/sam/index.cfm?pg=hlg>

33 <https://ec.europa.eu/research/sam/index.cfm?pg=oceanfood>

the ocean. The recommendations of this report are of great relevance here. However, natural resources are limited and overfishing beyond biologically sustainable limits continues, with only 67% of stocks worldwide estimated to be fished within sustainable levels in 2015<sup>34</sup>. These resources need to be maintained for future generations, meaning that the recommendations of Food from the Ocean and other reports (e.g. FAO, 2018) should be carefully considered, taking local contexts and trade-offs into account.

There is no perfect global solution to the challenges of feeding an ever-increasing population in a sustainable way. However, this SRA seeks to highlight the apparent lack of explicit consideration of the human component in these discussions. While both the health and marine communities in Europe and globally recognize that the consumption of high-quality fish and other seafood is an important component of a balanced human diet, there are nevertheless important questions to answer. These include:

- **What** food systems will deliver the required nutrition to humans in the future?
- **What** is the carbon footprint of the fisheries, seafood and aquaculture industries, and how sustainable are current extraction practices and projected growths in demand?
- **What** are the potential cumulative effects of chemical and microbial pollution contamination of all kinds in fish and seafood?
- **How** will this pollution affect the health of marine ecosystems, the availability of fish and seafood, and subsequently human health via consumption?
- **Who** has and is already collecting related data, and are these data sufficient to provide the required evidence for updating policy?
- **How much** will climate change affect ocean productivity and cause changes in biodiversity such as species abundance, size, and location?
- **Will** people want to eat new more sustainable foods from the ocean that become available?
- **What** impact will climate and other global changes have on the quantity, quality and diversity of key nutrients in fish and seafood?
- **What** impact will these changes in nutrients have on human health outcomes?
- **How** can we address unequal access to nutritious and safe fish and other seafood across different socioeconomic groups?

In order to balance demand with the need to ensure that seafood sources remain safe and sustainable, we need to look beyond traditional approaches, and adapt to new realities. Work exploring areas such as

sustainable production methods is already underway in projects like Seafood Tomorrow<sup>35</sup>, but more needs to be done to explore fisheries and human health issues together.

<sup>34</sup> <http://www.fao.org/sdg-progress-report/en/#sdg-14>

<sup>35</sup> <https://seafoodtomorrow.eu/>

## 2.2 Research gaps to be addressed

In order to achieve our vision of sustainable seafood for healthy people, three key research questions need to be addressed:

1. With regard to chemical and microbial pollution and seafood:
  - a) What are the combined exposures and integrated/cumulative impacts (a 'cocktail effect' or mixtures) of pollutants on both food sources and humans, and how do these exposures and impacts translate from source to consumer?
  - b) How will these exposures and impacts be affected by climate and planetary change, and by variations in human populations e.g. socioeconomic context, equity, pre-existing levels of health?
  - c) Where does the balance lie between dietary benefits and safety issues linked with pollution ingestion?
2. How do and will the nutritional content and distribution of fish and seafood change with location, climate- and global change; and how can we use this to recommend adaptable optimal sustainable harvesting and consumption patterns, in terms that can be used by health providers, fishing and marine communities?
3. With regards to sustainable and equitable provision of seafood:
  - a) How can sustainable access to, and uptake of, high-quality fish and other seafood be improved across all socioeconomic groups in Europe?
  - b) Can sustainable aquaculture increase the availability of affordable high-quality seafood, and still deliver the related health benefits for the population?

## 2.3 Research timeline

For the research gaps identified above, there is no specific chronological sequence in which the research should be done. It would be beneficial to conduct research to answer the questions in parallel, as there are interlinkages and complementarities within the different areas.

## 2.4 Linking OHH research and policy

Fisheries and aquaculture activities are already well regulated at a European level and are covered by a number of Directives and policies, most notably the Common Fisheries Policy (CFP)<sup>36</sup>, which *"... aims to ensure that fishing and aquaculture are environmentally, economically and socially sustainable and that they provide a source of healthy food for EU citizens."* However, it is not clearly specified how *"environmentally,*

*economically and socially sustainable"* and *"a source of healthy food"* is measured or ensured, as this is elaborated at Member State level.

New threats, and knowledge on monitoring and addressing them, will continue to emerge and the OHH research community should support the ongoing expansion of understanding around both these areas, to provide policymakers with implementable approaches to monitor and ensure healthy and sustainable food in line with the latest knowledge. This research should explore wider interpretations of sustainability in relation to fisheries activities. It should consider the health and nutrition benefits of the fish/seafood being captured/harvested and sold, and the current and required future equity of access to these benefits.



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*A fishmonger in Spain*

It is not clear how far the (longer-term) impacts of climate and other environmental changes and social pressure on fisheries are currently considered in the implementation of the CFP. The current ecosystem-based management approach to fisheries has been criticized by some for its lack of human-relevant indicators (Hornborg et al., 2019). The OHH research community could support policy by gathering data and hence developing predictions in line with future scenarios, and supporting the development of ocean-human-relevant indicators.

The quality of and levels of pollution in terrestrial and marine waters (up to one nautical mile from the coast) are covered by policies such as the Water Framework Directive<sup>37</sup>. Full implementation of the requirements of these policies is intended to (among other things) help ensure that the food produced in these waters remains safe. However, recent research shows that there is still some way to go to achieve full implementation<sup>38</sup>. Furthermore, not all pollutants (including chemicals and pathogens) in marine waters are legislated for or monitored under this Directive; and the monitoring that does take place is often on a reactive basis rather than being implemented on a preventative and early warning basis. In this regard, the OHH community should support the regular revision and/or addition of

requirements and indicators for marine pollutants in relation to food safety, especially for new and emerging pollutants and their safe consumption levels (in isolation and in combination). Improving links between research and fisheries governance mechanisms such as Regional Fisheries Management Organizations<sup>39</sup> could also help to bring information on relevant aspects (such as nutrition and pollution) into fisheries management decision-making more efficiently.

The SOPHIE project case study in the Eastern Scheldt showed that seafood is now monitored routinely for pathogens (indicated by *E. coli*), algal toxins and five chemical substances known to be harmful: mercury, cadmium, lead, polycyclic aromatic carbon (PAH) and polychlorinated biphenyl (PCB). Monitoring data on all other chemical and microbial pollutants are generally lacking and it would be very costly and time-consuming to get appropriate spatial and temporal distribution information on all relevant substances and organisms through monitoring. Modelling the use, fate and transport of potentially harmful substances would be one way to get a better understanding of human health risks and mitigation measures. However, data on the use of chemical substances (including pharmaceuticals) are also currently hard to access.

36 [https://ec.europa.eu/fisheries/cfp\\_en](https://ec.europa.eu/fisheries/cfp_en)

37 [http://ec.europa.eu/environment/water/water-framework/index\\_en.html](http://ec.europa.eu/environment/water/water-framework/index_en.html)

38 <https://www.eea.europa.eu/publications/contaminants-in-europes-seas/>

39 [https://ec.europa.eu/fisheries/cfp/international/rfmo\\_en](https://ec.europa.eu/fisheries/cfp/international/rfmo_en)

A complementary Directive at European level, which also addresses pollutants, is the Marine Strategy Framework Directive<sup>40</sup> (MSFD). The MSFD aims to provide greater protection to the marine environment in European waters. It addresses a wide range of fisheries- and aquaculture-relevant aspects such as contaminants (see Descriptor 9<sup>41</sup>, although not the environmental reality of multiple pollutants in a 'cocktail effect'), extraction of living resources (see Descriptor 3<sup>42</sup>), and biodiversity (see Descriptor 1<sup>43</sup>). At present, the Directive only directly refers to human health twice, and in both cases the statements are very general. To support the development and implementation of appropriate measures at Member State level, the OHH research community should support policy in helping to develop ocean and human health-relevant indicators that could be included within this framework.

The European Commission's Blue Growth Strategy<sup>44</sup> "is the long-term strategy to support sustainable growth in the marine and maritime sectors as a whole". It identifies five key areas that offer a high potential for growth in

the near future, including aquaculture. The Strategy calls for aquaculture that is both economically viable and environmentally sustainable, but that also enables EU citizens to have equal access to safe, nutritious and sustainable seafood, as well as equitable jobs. Measuring the implementation of this Strategy may require the addition of other human health and well-being indicators alongside those of economic growth and job creation, such as those discussed in Coulthard & Britton (2015).

From a health and nutrition perspective, there are also a number of relevant European-level policies such as Food 2030<sup>45</sup>, and the Strategy on Nutrition, Overweight and Obesity-related Health Issues<sup>46</sup>, which led to the formation of the high level group on nutrition and physical activity<sup>47</sup>. Further research is required into understanding to what extent these health-driven aims are linked to requirements for safe fish and seafood, and to highlight any additional or differing needs in resource provision. This research will be especially relevant at a national level, given the significant variations across Europe in terms of resource access and levels of consumption.



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Working on board a trawler

40 [http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index\\_en.htm](http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm)

41 [http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-9/index\\_en.htm](http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-9/index_en.htm)

42 [http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-3/index\\_en.htm](http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-3/index_en.htm)

43 [http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-1/index\\_en.htm](http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-1/index_en.htm)

44 [https://ec.europa.eu/maritimeaffairs/policy/blue\\_growth\\_en](https://ec.europa.eu/maritimeaffairs/policy/blue_growth_en)

45 <https://ec.europa.eu/research/bioeconomy/index.cfm?pg=policy&lib=food2030>

46 [https://ec.europa.eu/health/nutrition\\_physical\\_activity/policy/strategy\\_en](https://ec.europa.eu/health/nutrition_physical_activity/policy/strategy_en)

47 [https://ec.europa.eu/health/nutrition\\_physical\\_activity/high\\_level\\_group\\_en](https://ec.europa.eu/health/nutrition_physical_activity/high_level_group_en)



© SUBMON

Fish on a stall in Spain

## 2.5 Public and stakeholder needs identified by the SOPHIE Project

The safety, security and sustainability of food from the ocean has been identified as a priority for OHH societal stakeholders as part of an online survey<sup>48</sup>. More than 270 societal stakeholders from across marine and public health sectors identified *food safety and supply and sustainable fisheries management* as their key priorities. *Food safety and supply* was also voted as a top priority in these deliberation workshops. The societal stakeholders also identified *promoting local and sustainable food options* as a relevant action. Citizens participating in a similar workshop came to similar conclusions, and also highlighted concerns over practices that only appear to be sustainable, or 'greenwashing'. Interestingly, this process also identified *reframing the Blue Economy* as a top priority with calls to *reframe EU policy priorities on blue growth to include social, environmental and cultural aspects*, as well as *taxation of the blue economy and penalties for polluters*. It was noted that when comparing these discussions, societal stakeholders tended to focus

on the regulatory and governance systems and social justice issues whereas citizens prioritized the need to hold industry accountable via sanctions and stricter penalties. *Sustainable fisheries management* and the need to *balance human actions with marine protection* were identified as key priority areas by a nationally representative sample<sup>49</sup> of citizens in 14 European countries through the SOPHIE Survey<sup>50</sup>.

In the SOPHIE Survey, *eating seafood* was ranked in the top five recreational activities engaged in while at the coast. It is interesting to note that when asked how good or bad they felt commercial fishing and aquaculture were for the environment and for human health and well-being, the citizens ranked both activities as neutral in both cases. This contrasts with another result from the same survey, which ranked *contamination of seafood* and *collapse of fish stocks* as 4<sup>th</sup> and 5<sup>th</sup> out of 16 respectively in terms of potential threats to public health and well-being about which respondents felt most concerned. This might be an indication that additional education and awareness of the balance between positive and negative aspects of these activities among citizens is needed.

48 <https://sophie2020.eu/resources/conversations-report/>

49 A nationally representative sample is where the sample reflects the demographics and non-demographic properties of the full national population of interest.

50 <https://sophie2020.eu/activities/sophie-survey/>

## 2.6 Capacity and training needs

In order to address the outlined research questions, the development of a dedicated community of researchers from relevant fields such as marine biology and fisheries science, public health, nutrition and diet, and climate change is essential. A human-centric perspective from the social and economic sciences should also be integrated. These researchers need to work with a view of the 'whole system' beyond their own area of expertise. Despite some examples of valuable collaborations and interdisciplinary teams already emerging, it has thus far been difficult to engage the medical and public health communities, despite the benefits that could be gained. Understanding of the reasons for this, and exploration of approaches to address it, are needed.

The development of this inter/transdisciplinary OHH community would benefit from students and graduates who leave university with experience in transdisciplinary research, along with a base of knowledge and awareness of the wider context in which their specialist subject sits. This will require an increase in opportunities for students to have exposure and experience across relevant sectors throughout their studies. For example, nutrition and public health courses should include at least one module that covers the link to marine food

resources, and *vice versa* for marine biology and fisheries science courses. These would ideally be offered as part of a comprehensive degree programme, however extracurricular options such as summer schools would also be appropriate. Specific courses in the field of Oceans and Human Health are also recommended, with existing examples being the undergraduate module offered at the University of Exeter, UK<sup>51</sup>, and the summer school held in 2019 by AZTI in Spain<sup>52</sup>.

Opportunities for lifelong learning, continuing professional development (CPD) courses, and online resources etc. are required for researchers already working in relevant sectors to gain wider knowledge and understanding of relevant topics and to keep up to date with the latest developments.

The availability of learning opportunities and general ocean literacy is equally relevant outside academia, e.g. as a professional development component for those working in marine and public health policy, fisheries management, and regional development. Having significant first-hand experiences and dialogues with other relevant actors can lead to a more nuanced understanding of the context, problems and decision implications of their roles over both a shorter and longer term. Ocean literacy development and the communication of related risks and benefits is also important for citizens.

51 <http://medicine.exeter.ac.uk/programmes/programme/modules/module/?moduleCode=CSC2010M&ay=2018/9>

52 <https://www.azti.es/en/eventos/azti-sophie-project-summer-school-2019-does-human-health-and-wellbeing-depend-on-a-healthy-ocean/>



© Photo by Annie Spratt on Unsplash

Lobster pots



## 3. Target Action Area 2: Blue spaces, tourism and well-being

**Our vision is for improved individual and community physical and mental health and well-being through enhanced interactions with healthy blue spaces that are sustainably managed.**

### 3.1 Why is this important?

A European study of the Epidemiology of Mental Disorders found that 25.9% of European participants reported the presence of a mental health disorder (including anxiety and depression) during their lifetime (Alonso et al., 2007). A 2015 estimate suggested that more than €600 billion a year are spent on mental health care in EU Member States (OECD/EU, 2018). In addition, the World Health Organization (WHO) estimated that 77% of the disease burden in Europe arises from non-communicable diseases (NCDs) including obesity, diabetes, heart disease and stroke, many of which can be preventable. These are clearly huge public burdens, and new solutions to these issues will need to be found.

It has been shown that physical activity can impact positively on both NCDs and mental health; and engaging with natural environments may improve mental health indicators (Bowler et al., 2010). This has led to the consideration of 'nature' as an alternative or adjunct to medication for some mental health conditions<sup>53</sup>; and in some countries the concept of 'nature prescriptions' is already being applied. In Papathanasopoulou et al. (2016), the physical health benefits of water-based recreation were estimated to have a value to society of approximately £176 million per year in England alone. The SOPHIE inventory

of innovative initiatives<sup>54</sup> showed many examples of therapies improving mental health through exercise near the sea. The health benefits of these therapies have not yet been thoroughly scientifically researched. Better understanding of these health benefits would allow their optimization (e.g. as part of integrated coastal zone management and marine spatial planning practices). Studies for the entire adult population of England concluded that good health and comparatively improved mental health is more prevalent the closer one lives to the coast (Garrett et al., 2019; Wheeler et al., 2012). They also found that the positive effects of coastal proximity were greater among more socioeconomically deprived communities. Similar studies in other parts of Europe should also be conducted.

To date the vast majority of the research looking at the natural environment and human health/well-being has focused on 'green' rather than 'blue' spaces, meaning that the potential benefits of interacting with ocean, coastal and inland waterway areas are less well understood for most European countries. Some work has been conducted looking at the differences between interaction with green and blue spaces including studies in urban areas in Germany (Völker & Kistemann, 2015), some review articles (Britton et al. 2018) and work conducted within the scope of the BlueHealth Project<sup>55</sup> (Gascon et al., 2017; Grellier et al., 2017). This research now needs to be expanded to cover the rest of Europe, as it is not yet clear whether the same findings will apply for different regions.

53 <https://www.ecehh.org/research/nature-prescription/>

54 <https://sophie2020.eu/activities/innovative-solutions/>

55 <https://bluehealth2020.eu/>

There are both risks and benefits involved in any interaction with a blue space, e.g. jellyfish stings, effects of HABs, pollutants and water-borne diseases versus the benefits of physical activity and sea air (Fleming et al., 2019). Research around the benefits has developed in recent years, however just 7.4% of research identified through the SOPHIE systematic review<sup>56</sup> had some focus on human well-being outcomes. This lags far behind research on risks associated with coastal recreation and living. Assessments of how these benefits and risks trade off to inform scenarios of future change are even less well explored. Relevant studies are also heavily focused on mental health or metrics of overall well-being. While numerous other health benefits such as cardiovascular, neurological and respiratory health have been speculated on and inferred, the scale and context of these impacts is not well understood.

The balance of risks and benefits should not only extend to humans but also to the marine environment, ensuring that in generating greater benefit for humans, the additional pressures of increased coastal human activity do not further degrade the environment. Additionally, interaction with degraded environments may in turn reduce the derived benefits, meaning that both humans and the ocean gain from appropriate compromises and innovative initiatives. Using tourism as a driver to improve ocean literacy levels among citizens could dramatically improve their understanding of the risks and benefits to their health from interacting with the ocean; and raise awareness of the actions that they can undertake to mitigate pressure on marine ecosystems, habitats and species. The SOPHIE case study in the Eastern Scheldt demonstrated that this does work. We now need to understand:

- **What** are the different physical and mental well-being benefits that can be gained from interacting with coastal and ocean areas?
- **Why** do we gain these benefits, and what are the mechanisms at play?
- **Where** do we gain these benefits, and are there significant variations between interacting with different kinds of spaces, e.g. with blue spaces in different European regions?
- **Who** could benefit the most from these interactions, and do they have equitable access to these environments throughout the year?
- **How much** exposure or what dosage is required to gain the benefits, taking into account the quality of the exposure, and the risks that may also be present?
- **How** will this balance of benefits and risks be affected by the impacts of climate and other global change?
- **How** do we balance ensuring access to blue spaces with increasing and diverse pressures on coastal and marine ecosystems, and how might that vary regionally?

It is critical to ensure that blue spaces do not carry the burden of additional human activity pressure and consequently suffer further degradation, so ongoing monitoring and protection are needed. However, if appropriate compromises are applied, there could be significant potential realized from this existing

natural capital, with health and monetary benefits. Innovation will be critical; it would be unrealistic to bring everyone to the coast, but can we bring the ocean to them e.g. through art, soundscapes, virtual reality experiences, and simulated blue environments?<sup>57</sup>

<sup>56</sup> <https://sophie2020.eu/activities/systematic-map/>

<sup>57</sup> <https://bluehealth2020.eu/blog/virtual-blue-healthcare/>

## 3.2 Research gaps to be addressed

In order to achieve our blue spaces, tourism and well-being vision, four key research questions that need to be addressed are:

1. Based on existing and ongoing UK studies and green health<sup>58</sup> research, what is the evidence for blue health<sup>59</sup> and well-being impacts across Europe?
2. With regards to mechanisms and pathways:
  - a) Through which interactions (type of activity, duration etc.) with different types of coastal environments and blue spaces does human health and well-being improve?
  - b) Through which interactions does the risk of disease and/or physical issues increase?
3. How does increasing the human use of blue spaces affect the coastal and marine ecosystems and biodiversity?
4. How can we optimize OHH interactions in order to obtain physical and mental health and well-being benefits in a sustainable manner for all people and species?

## 3.3 Timeline

These research questions should be addressed in a clear and logical sequence. In order to ensure understanding before progressing, the first three questions should be addressed together, before the fourth question can be addressed. This will allow a representative body of evidence to be gathered on the component aspects before optimizing the OHH benefits.

## 3.4 Linking OHH research and policy

The European Commission's Blue Growth Strategy<sup>60</sup>, which identifies five key areas that offer a high potential for economic growth in the marine and maritime sectors in the near future, includes coastal tourism as a key sector. The focus within this strategy is on economic growth and job creation, and these are certainly important for human health and well-being.

However, the Strategy does not clearly express consideration of other human or environmental benefits or risks from pursuing this growth. For coastal tourism, typically still a very seasonal activity, the Strategy does specify a need for *"measures that help to improve the tourism offer for low-season tourism and reduce the high carbon footprint and environmental impact of coastal tourism"*, but it is not clear how this should be achieved. The OHH research community has a role to play in highlighting the human health benefits of blue activities that could also promote ocean interactions outside of the traditional tourist season (e.g. walks, surfing, diving, sea kayaking, wild swimming etc.).

As previously identified, there are also risks associated with human interactions with blue spaces, and several marine-based policies cover these. One is the Bathing Water Directive<sup>61</sup>, which addresses some acute health problems that may arise from swimming in

58 Green health – benefits to human physical and mental health and well-being through interaction with land-based natural environments

59 Blue health – benefits to human physical and mental health and well-being through interaction with coastal and marine environments, and land-based natural environments which incorporate water

60 [https://ec.europa.eu/maritimeaffairs/policy/blue\\_growth\\_en](https://ec.europa.eu/maritimeaffairs/policy/blue_growth_en)

polluted waters. As long as this Directive is implemented as intended, it will support and enhance safe, healthy and beneficial interaction to some extent. However, at present, given the findings of a recent study by the European Environment Agency<sup>62</sup> that showed that there are still a high proportion of "problem areas" in European waters in relation to contamination, there is still some way to go. The Directive only covers official bathing sites and does not include sites such as those within cities that people are increasingly using as a way to cope with climate change-induced heatwaves. In addition, problems such as antimicrobial resistance (AMR) are not currently addressed under the Bathing Water Directive, although the EU One Health Action Plan against AMR<sup>63</sup> does refer to the Water Framework Directive (of which the Bathing Water Directive is a component) more generally. AMR is where microorganisms such as bacteria and parasites develop a resistance to anti-microbial substances

such as antibiotics. In the case of marine waters, there is evidence of a risk of exposure to antibiotic-resistant strains of E.coli (Leonard et al., 2015). The European Environment Agency has published findings on knowledge developments in relation to chemicals in European waters<sup>64</sup>. Further research is needed to identify additional appropriate risk indicators, data collection and monitoring needs, additional sources of pollutants (e.g. sailing yacht flotillas), and regional or seasonal implementation challenges (e.g. local sewage infrastructures becoming overwhelmed by visitors in peak tourist season). This should take into account the requirements for pollutants that already exist under the Marine Strategy Framework Directive<sup>65</sup>.

Maritime spatial planning<sup>66</sup> already includes considerations for tourism and allows for a multi-stakeholder approach that could be expanded to include health and well-being. The OHH research community should further explore this opportunity.



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*Enabling the younger generation to interaction with and enjoy blue spaces*

61 [http://ec.europa.eu/environment/water/water-bathing/index\\_en.html](http://ec.europa.eu/environment/water/water-bathing/index_en.html)

62 <https://www.eea.europa.eu/publications/contaminants-in-europes-seas/>

63 [https://ec.europa.eu/health/amr/sites/amr/files/amr\\_action\\_plan\\_2017\\_en.pdf](https://ec.europa.eu/health/amr/sites/amr/files/amr_action_plan_2017_en.pdf)

64 <https://www.eea.europa.eu/publications/chemicals-in-european-waters>

65 [http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index\\_en.htm](http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm)

66 [https://ec.europa.eu/maritimeaffairs/policy/maritime\\_spatial\\_planning\\_en](https://ec.europa.eu/maritimeaffairs/policy/maritime_spatial_planning_en)

### 3.5 Public and stakeholder needs identified by the SOPHIE Project

More than 14,000 citizens participating in the SOPHIE survey<sup>67</sup> listed *beach/coastal walking, watching the view, sunbathing/picnics and swimming* as the top four recreational activities in which they engage that relate to the sea or coast. The survey also demonstrated significant variation by country in how regularly citizens visit the coast. In terms of concern for potential threats to public health and well-being, *sewage in bathing water* was ranked comparatively highly (6<sup>th</sup> out of 16) whereas *jellyfish swarms, drowning and sunburn/sunstroke* were ranked lowest (14<sup>th</sup>, 15<sup>th</sup> and 16<sup>th</sup> respectively). This is important information for defining policy options, and for public outreach and awareness campaigns.

European citizens<sup>68</sup> identified the need to *understand public health impacts of the marine environment* as a key priority area, and they also felt that improving water quality to lower the risk of skin infections and other infections in humans and the risks posed to human health from degraded and polluted marine environments were important. They also showed concern for the environment in their responses: *Reduce tourism – problems such as pollution or plastic deposits in the sea often arise from overuse / people at sea*. As a solution, they proposed to *create a Culture of Care and pro-environmental practices and encourage the responsible use of oceans and rivers – to ensure the use of the oceans does not harm them*. The research to understand how to encourage this responsible use now needs to be done.

It should be noted that public support for more research funding directed to better understanding the health and well-being effects of living by the sea, and of spending

leisure time in and around marine environments, was comparatively low, placing them 12<sup>th</sup> and 13<sup>th</sup> out of 16. In general, citizens appeared to support reducing risks over demonstrating benefits.

Conversely, based on a survey and deliberation workshops<sup>69,70</sup>, societal stakeholders from a diverse mix of backgrounds relevant to OHH agreed that *access and experience of blue space and recognizing human health benefits from the ocean* were key priority areas. This demonstrates differences in the priorities of societal stakeholders and citizens. The reason and implications of these differences for both research and policymaking should be further studied.

### 3.6 Capacity and training needs

Ocean literacy<sup>71</sup>, or the understanding of the ocean's influence on people and people's influence on the ocean, is particularly relevant here because coastal tourism or living by the coast are likely to be the main ways in which the public knowingly interacts with the ocean. Improving ocean literacy levels among citizens could also help to improve their understanding of the risks and benefits to their health from interacting with the ocean. Resources to support ocean literacy development are required, and approaches that engage and then inform the public have been found to be more effective than simply providing information (Owens, 2000). To date it has not been demonstrated that increased knowledge will result in behavioural change, thus awareness alone is not enough, and further research is needed to better understand how interest can be turned into action, such as through relevant experiences. There is a need to share examples of meaningful actions, solutions and best practices in order to help create a culture of care.

67 <https://sophie2020.eu/activities/sophie-survey/>

68 <https://sophie2020.eu/activities/stakeholder-discussions/>

69 <https://sophie2020.eu/activities/stakeholder-discussions/>

70 <https://sophie2020.eu/resources/conversations-report/>

One such approach is citizen science, where the general public collaborates with scientists on research projects, generally by supporting data collection and/or analysis (Garcia Soto et al., 2017). In the case of mental and physical well-being and coastal interaction, such projects (along with relevant supporting resources) could improve ocean literacy but they could also help to highlight both the risks and benefits of interacting with the ocean and blue spaces. Many of the innovative initiatives found in the SOPHIE inventory<sup>72</sup>, which included citizen science projects, contributed to improved education and public awareness on OHH issues.

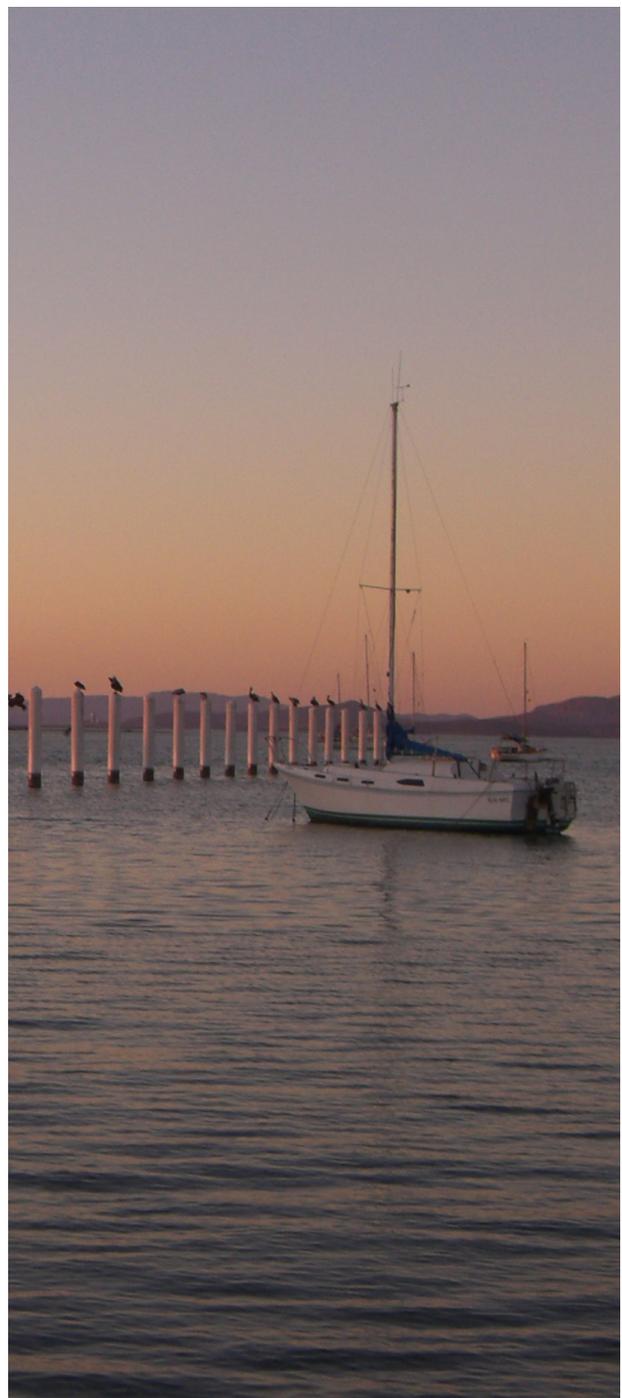
In a SOPHIE pilot project<sup>73</sup>, ocean-related ecotourism operators offered their clients an opportunity to engage in a citizen science project about their well-being in relation to participating in an activity by or on the sea. The pilot project showed that this is a good way to spread information and increase ocean literacy across a wider audience, with the operators serving as multipliers and advocates. In addition, the tourism operators noted that this approach was also beneficial for their business, where scientific findings showing that the activities were beneficial for health could also help boost their business. To take this further, approaches to engage a wider diversity of blue space users should be explored, in particular those targeting the younger generation who are already demonstrating greater environmental awareness and a willingness to participate.

While some citizens may appreciate the health risks associated with interaction with the ocean (e.g. drowning, jellyfish stings), this awareness can be limited, and may be entirely lacking for some issues (e.g. pollution of water and sand, exposure to water-borne diseases). Further research is needed to find effective ways to pass on these important messages, helping the public to be more aware of the risks and helping communities to reduce negative incidents.

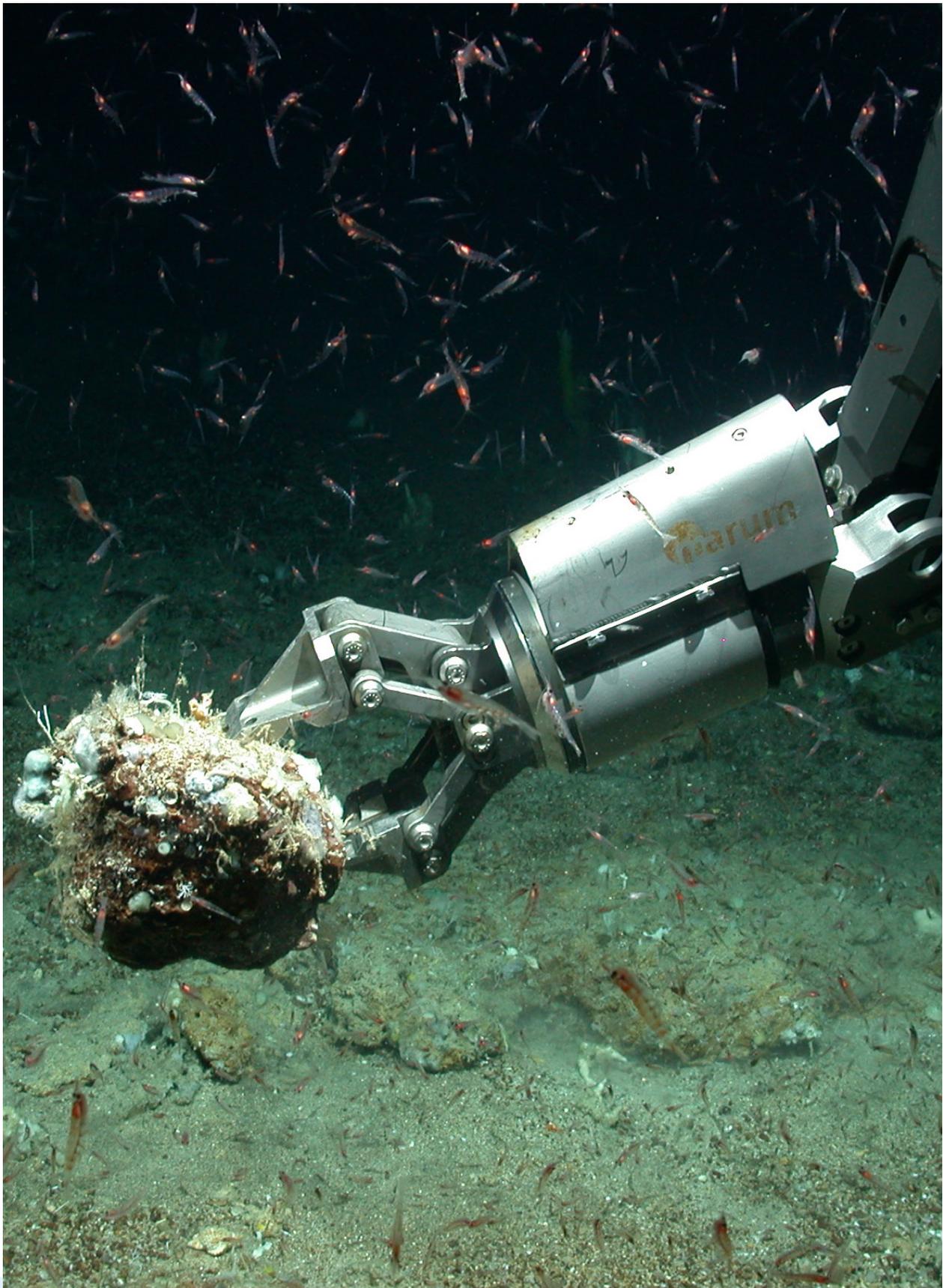
71 <http://oceanliteracy.wp2.coexploration.org/>

72 <https://sophie2020.eu/activities/innovative-solutions/>

73 <https://sophie2020.eu/activities/citizen-science/>



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Obtaining samples with the submersible vehicle MARUM-QUEST in 620 meters of water in the Atlantic



## 4. Target Action Area 3: Marine biodiversity, biotechnology and medicine

**Our vision is a more targeted approach to explore, identify and obtain what marine biodiversity can provide to biotechnology, medicine and disease prevention, while demonstrating the critical importance of marine biodiversity and its protection.**

### 4.1 Why is this important?

The ocean is the last great frontier of planetary discovery, with up to two-thirds of marine species still to be discovered. With so much still unknown, the unique diversity of the marine environment is the largest untapped source of chemical compounds and other biotechnological products including food supplements, enzymes, and biomaterials such as artificial bone from corals and silica, chitin, and collagen from sponges. With species extinction increasing at a rate unprecedented in human history (IPBES, 2019) it is critical to describe and protect marine biodiversity as soon as possible to promote a healthy and resilient ocean and to ensure conservation of these environments, as well as the provision of ecosystem services for human health into the future.

The quest for new drugs is more urgent than ever before due to the rise in antibiotic resistance<sup>74</sup>, and marine organisms are important in providing new chemical diversity for the drug development pipeline. While more than 34,000<sup>75</sup> molecules of pharmaceutical or cosmetic interest have been discovered (Blunt et al., 2018) there are only 10 pharmaceutical products<sup>76</sup> of marine origin currently on the market, including four anti-cancer drugs and one anti-viral drug (Collins et al., 2019; Jaspars et al.,

2016; Mayer, 2012). There are a further 28 drugs in clinical trials globally. There are several challenges in bringing marine-derived compounds to market, including very high costs and a time investment of approximately 20 years. The vast majority of these compounds are synthetically produced since there are major technical difficulties in sustainably supplying enough biomass from marine organisms to scale up production of target compounds, which generally exist in very small quantities in nature (Newman, 2016), although new -omics tools are opening up possibilities. While there is a tendency to focus on the discovery of new treatments for the most prevalent health conditions such as cancer and HIV, marine organisms offer unique genetic resources with potential to also treat rare diseases (Bhatia & Chugh, 2015) that typically receive limited attention (Sharma et al., 2010).

Although only small quantities of biological resources are harvested, exploration of the ocean for new biotechnological products often involves environmental disturbance with potentially adverse effects, particularly in highly sensitive ecosystems such as coral reefs or the deep sea. Access to biological resources within exclusive economic zones (EEZs) of countries is regulated and near-shore collections typically fall under national regulations, requiring environmental impact assessments and permits, and imposing collection limits. There are however no regulations for bioprospecting in areas beyond national jurisdiction, including the majority of the deep sea. As such, it is important to use caution and to establish appropriate regulations for bioprospecting.

74 <https://www.pewtrusts.org/en/research-and-analysis/data-visualizations/2016/the-critical-need-for-new-antibiotics>

75 <http://pubs.rsc.org/marinlit/>

76 <https://www.midwestern.edu/departments/marinepharmacology/clinical-pipeline.xml>

Biobanks, such as the European Blue Biobank<sup>77</sup>, enable the storage of biological specimens and facilitate sustainable access to marine biodiversity. They are an important component of the biodiscovery pipeline and can be consulted as part of a bio-prospecting campaign. If used properly, these infrastructures can help reduce over-collection of the same species. Biobanks can be an approach to conserve biodiversity, but they need to be expanded to become a more comprehensive representation of marine biodiversity and to not only represent cultivatable marine organisms.

A targeted approach to biodiscovery is needed to maximize the chances of finding specific compounds of interest. This calls for improved knowledge of marine chemical and molecular ecology to enable the identification of promising sites and organisms. Sites of interest may include extreme or unique environments such as the deep sea or coral reefs, 'blue zones', highly stressed or polluted areas, or areas with high competition between species. Organisms to focus on include sessile species that depend on 'chemical warfare' for their survival, and specific organisms in which the majority of marine-derived compounds have previously been discovered (i.e. invertebrates, algae and marine microorganisms). There is a need for close collaboration between the marine science, biotechnology, medical and pharmaceutical communities to streamline the biodiscovery process and share expertise. Previous and current collaborative projects have demonstrated this can be successful e.g. FP7 and Horizon 2020

projects SPECIAL<sup>78</sup>, BluePharmTrain<sup>79</sup>, PharmaSea<sup>80</sup>, MarPipe<sup>81</sup> and TASC MAR<sup>82</sup>.

Interest in marine species also extends beyond compounds purely for medication and treatments. Marine biodiversity is also important in fundamental biological research, e.g. green fluorescent protein (GFP) first isolated from jellyfish is used extensively in cell and molecular research, and the molecular basis of memory was discovered in sea slugs. Marine species have specific adaptations, patterns of behaviour and lifestyles that may present beneficial applications in human health and well-being. To enable this exploration into the future, the protection of the marine environment and its biodiversity should be guaranteed. Trawling prohibitions and the protection of coral reefs and the deep sea by increasing the extent and number of marine protected areas (MPAs) are examples of positive actions that could be incentivized by the OHH community.

Biotechnology research accounted for 46% of the original research identified through the SOPHIE literature and evidence review<sup>83</sup>. However, biotechnology research is time and resource intensive so the numbers of research articles alone are not necessarily representative of the extent to which marine compounds have been investigated. The majority of this research relates to the development of supplements and other applications for marine-derived omega-3 fatty acids.

77 <https://www.bluebiobank.eu/project/>

78 <https://cordis.europa.eu/project/rcn/97042/factsheet/en>

79 <https://www.bluepharmtrain.eu/en/bluepharmtrain.htm>

80 <http://www.pharma-sea.eu/>

81 <http://www.marpipe.eu/>

82 <http://www.tascmar.eu/>

83 <https://sophie2020.eu/activities/systematic-map/>

Outstanding questions not yet fully answered by current research include:

- **What** are the fundamental links between healthy, biodiverse marine environments and human health?
- **How** can we best demonstrate the importance of preserving marine biodiversity, ecosystem functioning and ecosystem services for ensuring human health?
- **Where** should we look for species with a high likelihood of possessing compounds or properties of medical interest?
- **How** can we overcome challenges in the sustainable supply of target organisms and compounds in order to scale up production of useful products?
- **What** can marine biodiversity contribute to fundamental biomedical research and bioinspired applications for human health and well-being?



© Zaferkizilkaya

*Marine sponges produce many interesting compounds for medicine and human health*

## 4.2 Research gaps to be addressed

In order to achieve our biotechnology and medicine vision, there are three key research questions that need to be addressed:

1. A better understanding of marine ecosystems is needed to enable a more targeted approach to biodiscovery in the ocean. Continued research on how, why and where marine organisms produce bioactive compounds and other products will improve the identification of habitats and species that will contain products useful for human health. This should take into account threats to marine biodiversity in a holistic manner to account for ongoing and future shifts in the abundance and distribution of marine species due to both human pressures and climate- and global change.
2. Continued development of new technologies is needed to overcome bottlenecks in the marine biodiscovery pipeline. These include -omics technologies, culture methods, advanced screening techniques, chemical synthesis techniques, and synthetic biology approaches. Improved fundamental knowledge is needed for species from which medically relevant products originate and of the environmental conditions under which they are produced, in order to facilitate scaling up of products under controlled conditions. An interdisciplinary approach is needed, drawing on expertise from marine scientist, chemists, molecular and synthetic biologists, pharmaceutical scientists, and SMEs.
3. Research is needed on the unique characteristics of marine species and applications to fundamental biomedical research and bioinspired applications that sustainably benefit human health and well-being.

## 4.3 Timeline

The research questions identified in this vision should be dealt with in parallel. The second question – of how to bring the communities together for a strategic approach – will support the more technical aspects of the other two questions, but all three are intrinsically linked and involve multiple sectors with significant innovation potential.

## 4.4 Linking OHH research and policy

The links between this vision and policy are complex, as this topic spans various different policy and ethics fields.

On the health and medical side, the marine biodiscovery pipeline is by necessity heavily regulated, with safety considerations meaning that the burden of proof of a compound's efficacy

and safety is significant. The European process is concisely outlined by the European Medicines Agency (2016), and similar processes are used by the US Food and Drug Administration (FDA). Of note, environmental sustainability is an important but underemphasized aspect of this pipeline, and the marine science community could provide additional input and advice.

The marine side of this topic is less regulated in comparison. At the European level, the Marine Strategy Framework Directive<sup>84</sup> (MSFD) implicitly discusses biodiversity protection and the extraction of resources without harming the ecosystem, and promotes the ecosystem-based approach to management. Extraction of resources is more directly covered by the European Biodiversity Strategy<sup>85</sup> and the Strategic Plan for Biodiversity 2011-2020<sup>86</sup> (including the Aichi Biodiversity

Targets) ), and in the EU 2030 Biodiversity Strategy which is currently under development. However, there is also competence within the Maritime Spatial Planning Directive<sup>87</sup>, the Integrated Maritime Policy<sup>88</sup> and Habitats Directives<sup>89</sup>, as well as the Blue Growth Strategy<sup>90</sup>. What is needed from the OHH research community is to develop a wider understanding of how these policies complement each other and where there may be gaps. Scientific input will also be required to provide greater understanding of the importance of marine biodiversity to ocean health, and of the links between healthy and diversely populated marine environments and healthy humans.

Internationally, the Nagoya Protocol<sup>91</sup> on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (ABS) is a supplementary agreement to the Convention on Biological Diversity<sup>92</sup>. The EU is a signatory to ABS and hence has strict regulations to ensure compliance. Member States must in turn ensure compliance in relation to sampling for marine compounds and put in place provisions that require licenses to sample within their EEZs (Lallier et al., 2014). This ensures fair and equal benefit from these resources. The process leading towards an international legally binding instrument under the United Nations Convention



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*Managing remote deep sea operations from a control container on a research vessel*

84 [http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index\\_en.htm](http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm)

85 [http://ec.europa.eu/environment/nature/biodiversity/strategy/index\\_en.htm](http://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm)

86 <https://www.cbd.int/sp/>

87 [https://ec.europa.eu/maritimeaffairs/policy/maritime\\_spatial\\_planning\\_en](https://ec.europa.eu/maritimeaffairs/policy/maritime_spatial_planning_en)

88 [https://ec.europa.eu/maritimeaffairs/policy\\_en](https://ec.europa.eu/maritimeaffairs/policy_en)

89 [https://ec.europa.eu/environment/nature/legislation/habitatsdirective/index\\_en.htm](https://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm)

90 [https://ec.europa.eu/maritimeaffairs/policy/blue\\_growth\\_en](https://ec.europa.eu/maritimeaffairs/policy/blue_growth_en)

91 <https://www.cbd.int/abs/about/>

92 <https://www.cbd.int/>

93 [https://www.un.org/Depts/los/convention\\_agreements/convention\\_overview\\_convention.htm#:~:targetText=The%20United%20Nations%20Convention%20on%20the%20Law%20of%20the%20Sea,the%20oceans%20and%20their%20resources.&targetText=The%20Convention%20also%20provided%20the,the%20law%20of%20the%20sea.](https://www.un.org/Depts/los/convention_agreements/convention_overview_convention.htm#:~:targetText=The%20United%20Nations%20Convention%20on%20the%20Law%20of%20the%20Sea,the%20oceans%20and%20their%20resources.&targetText=The%20Convention%20also%20provided%20the,the%20law%20of%20the%20sea.)

94 <https://sophie2020.eu/activities/sophie-survey/>

95 <https://sophie2020.eu/activities/innovative-solutions/>

96 <https://sophie2020.eu/activities/stakeholder-discussions/>

97 <https://sophie2020.eu/activities/innovative-solutions/>

on the Law of the Sea<sup>93</sup> on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (BBNJ) began in 2014 and is still ongoing. In order to achieve the vision set out in this topic, these marine policy and governance gaps will need to be addressed, and will require OHH research community input.

#### 4.5 Public and stakeholder needs identified by the SOPHIE Project

The public is concerned about biodiversity loss. More than 14,000 European citizens in the SOPHIE survey<sup>94</sup> ranked loss of marine species as 3<sup>rd</sup> out of 16 potential threats. Marine species and wildlife protection gained most support (ranked 1<sup>st</sup> out of 16) as an area to receive more research funding in order to better understand their public health and well-being implications.

Many of the bottom-up innovative initiatives<sup>95</sup> in the SOPHIE inventory addressed the loss of biodiversity, indicating that local stakeholders and citizens are motivated to protect biodiversity.

In terms of biotechnology specifically, citizens felt that *medicines derived from marine organisms* were good for the economy and for human health and well-being, and neutral for the environment. However, support for funding more research into *marine biotechnology and its implication for public health and well-being* was ranked 14<sup>th</sup> out of 16. This may indicate a need for greater public awareness about what marine biotechnology actually is, and where and how these compounds are and could be used. It may also indicate a prioritization of other challenges such as biodiversity conservation. This needs to be further investigated and understood.

*Protection of the marine environment* (including biodiversity and all marine life) was the most frequently cited priority category by participants in the citizen deliberation survey and workshop<sup>96</sup>.

Citizens also identified the need to *find balance between human actions and marine protection: Without a balanced natural marine environment no benefits can follow – get back to nature, man is part of nature*. However, citizens surveyed made no reference specifically to the importance of medicine from the sea or potential biotechnical benefits from marine species, etc., again suggesting that this is not yet an area widely discussed in public discourse – greater awareness-raising is required. Societal stakeholders responding to an equivalent survey did however identify marine biotechnology to advance synergies between oceans and human health as a priority area.

#### 4.6 Capacity and training needs

The SOPHIE inventory of innovative initiatives<sup>97</sup> showed that citizen science is a popular and feasible approach to collect data about marine biodiversity and at the same time raise awareness and enjoy marine spaces.

However, the narrative between biodiversity and health (medical/biotech benefits) is poorly developed. *'Medicine from the sea'* and the broader category of nature-based solutions from the ocean are not well developed in mainstream media, and are therefore not in the public consciousness. As highlighted above, this indicates a need to increase awareness of the medical and other benefits that are linked to marine species and the marine environment, and what could be lost if marine biodiversity is not appropriately 'valued' and protected.

Within the research community, it would be beneficial for students specializing in one part of the pipeline to be more aware of how the full system works sustainably, where compounds come from, how they are scaled up for production, and how they are trialed for approval. This will require dedicated interdisciplinary courses and opportunities for interaction.



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*Small samples can be collected by divers*

## 5. Enabling collaboration

**The development of OHH research will require transdisciplinary and trans-sector collaborations with all relevant stakeholder groups. No single group in isolation can address the research questions raised for the three target action areas, given their complexity and transdisciplinary nature.**

In order to enable research collaboration, different stakeholder groups need to meet on an equal footing. Traditionally, marine and health researchers have limited opportunities and/or interest to interact professionally. This needs to be encouraged and enabled, and it is important for such meetings to be held in a neutral setting. Researchers also cannot address the three target action areas alone, and so collaboration with external stakeholders is required. This means engaging and involving the community at large. Again, these interactions will need to take place in a transdisciplinary forum where all relevant groups are able to input. Interaction opportunities need to be supported by awareness-raising campaigns to highlight the importance of OHH, and the mutual benefits of interaction and eventually collaboration, with appropriate incentives for participation. It is acknowledged that engaging the community and stakeholders in bottom-up initiatives is not easy and requires dedicated building of relationships and trust over time, including through shared experiences. However, willingness and interest to engage has been evident throughout the SOPHIE Project. Once a relationship has been established, it is easier to maintain and continue collaboration.

During the SOPHIE Project members of Irish Doctors for Environment (IDE)<sup>98</sup>, public and medical health

professionals experienced their own 'blue space' immersion with local surf tourism providers and engaged in a beach-clean before joining a workshop. This kind of direct learning and trans-sectoral experience can help break down silos and bridge the (knowledge and communication) gaps.

Another important initiative is the Oceans & Health Chair<sup>99</sup> created in 2017 by the University of Girona<sup>100</sup> and the city of Roses (Spain)<sup>101</sup>, with sponsorship from the Fishermen's Association of Roses<sup>102</sup> and the Fishmongers Guild of Catalonia<sup>103</sup>. This Oceans & Health Chair is an example of how stakeholders, the marine sciences and medical disciplines can work together at a regional level.

Structured and facilitated dialogues with clear and realistic goals will also be required. It is important that all parties can share their own perspectives, aims and challenges and have those understood before moving towards research cooperation. The societal stakeholder and citizen deliberation surveys used in SOPHIE employed a Collective Intelligence<sup>104</sup> approach. Such discussions are very dependent on who is participating; therefore, it is important to ensure an equal balance of representation.

Funding calls for research in the target action areas should require the formation of inter-/transdisciplinary and trans-sectoral consortia.

They should consider longer project timescales to allow for the development of common understanding and stakeholder relationships before new research is initiated. The timeline requirements highlighted to

98 <https://sophie2020.eu/news/irish-doctors/>

99 <http://www.oceanshealth.udg.edu/en/what-is-it.html>

100 <http://www.udg.edu/>

101 <http://www.roses.cat/>

102 <http://www.confrariapescadorsroses.cat/>

103 <http://gremipeixaters.cat/>

address the different research questions should be considered, possibly requiring a series of linked or related projects. Funding for regional research and solutions will also be appropriate, as important regional differences have been demonstrated in the results obtained within SOPHIE.

There will also be a large disparity in the language used by different groups, both literally and figuratively. As an example, the term "climate change" was rarely referred to by citizens, and instead the term "global warming" was more commonly used. This is a small change in terminology, but very important in ensuring clear communication. Appropriate language and framing of a discussion should be considered when communicating with different stakeholder groups.

It is also interesting to consider who provides the information, and in what way, to ensure the greatest

uptake. As an example, within the citizen science pilot projects run within the SOPHIE Project<sup>105</sup>, key OHH messages were distilled down into 'fun' or 'interesting facts' that eco-tourism operators could share directly with their customers. Breaking down complex issues made them easier to understand, and providing eco-tourism operators with information and background knowledge they would be comfortable sharing both proved very successful. These facts also made the activities that tourists were engaging in more interesting as well as enhancing the 'knowledge authority' of the operators and the image they convey as professionals who know about and care for the ocean.

Finally, systems thinking and behavioural change will be required to take OHH forward. The OHH community and policymakers will need to consider how to apply and operationalize the INHERIT model<sup>106</sup> in practice.



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*Wind- and Kitesurfing*

104 Collective Intelligence is a methodology that specializes in facilitating group discussion and consensus building. Participants from different backgrounds and sectors work collaboratively to reach a consensus on how best to address a complex issue, in this case the case the priorities for protecting public health and the health of the marine environment for a sustainable future, <http://warfield.gmu.edu/exhibits/show/warfield/IM/process>

105 <https://sophie2020.eu/activities/citizen-science/>

106 <https://www.inherit.eu/project/inherit-model/>



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## 6. Priorities and overarching recommendations

The following main priorities and overarching recommendations emerge from this Strategic Research Agenda in relation to research:

- A formal transdisciplinary forum and/or platform should be established to encourage collaboration between researchers from all OHH-relevant fields, building on the community established within the SOPHIE Project.
- The research community should develop best practice guidance on collaboration with stakeholders and citizens in relation to OHH research.
- Systematic reviews and longitudinal studies should be conducted to better understand the state-of-the-art in OHH research, and to identify gaps in understanding linkages.
- The benefits of designated marine protected areas (MPAs) – to human as well as ocean health – should be demonstrated.
- Inter- and transdisciplinary training and education programmes should be developed at different academic levels to support the development of OHH.
- Appropriate mechanisms for youth contribution and engagement should be established.
- Policy advice should be provided regarding the additional data collection and monitoring needs for both marine and health parameters to support the understanding of interactions and to develop a body of evidence to demonstrate these interactions. It should also consider issues of accessibility and usability of existing data and monitoring systems, and propose relevant indicators and indices.

Some more general recommendations also emerge:

- A movement is needed within healthcare towards focusing on prevention rather than cure.
- Awareness and consideration of inequalities that inevitably exist and arise should be highlighted as part of all decision-making processes.
- A culture of care that will support the implementation of OHH and sustainable use of wider ocean and coastal ecosystems should be created.
- Ultimately, health (as proposed in the Health in all Policies (HiAP) concept), sustainability and environmental considerations should be present in all policies.

## 7. How will we know that it worked?

All goals should be measurable and achievable. The following outcomes will indicate attainment of the required OHH research capacity in Europe. These are:

- Recognition of OHH as a key component within the wider planetary health concept.
- Best practice guidelines for collaboration and engagement of stakeholders in OHH research.
- A set of OHH-specific indicators that Member States are required to monitor and report on, supported by cross-policy coordination, also exploring the links with SDG indicators.
- Development of a dedicated OHH community platform that can be used to initiate contacts and launch collaborations, as well as provide access to data sources and products.
- Organization of a dedicated interdisciplinary conference series and/or similar forum to present and discuss this research.
- Research calls and subsequent jointly-funded interdisciplinary and international projects which require participation from several relevant backgrounds including at least marine science, medicine and/or public health.
- An interdisciplinary OHH-specific module(s) offered to all graduates on marine and health-related university courses, either in-house or as a massive open online course (MOOC).



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*The SOPHIE Project consortium and Advisory Board at the kick-off meeting in Dún Laoghaire, Ireland*

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# Key definitions used in this SRA

**Aquaculture:** the rearing of aquatic animals or the cultivation of aquatic plants for food

**Biotechnology:** the exploitation of biological compounds and processes for industrial and other (in this case medical) purposes, especially the genetic manipulation of microorganisms for the production of antibiotics, hormones, medicines etc.

**Blue health:** benefits to human physical and mental health and well-being through interaction with coastal and marine environments, and land-based natural environments which incorporate water

**Blue space:** a term used to refer to any space where there is visible water

**Blue zone:** regions of the world (e.g. Okinawa, Japan and Icaria, Greece) where it has been claimed that people live much longer and healthier lives than on average, with the term first appearing in a National Geographic magazine cover story called "The Secrets of a Long Life"

**Citizen Science:** the collection and analysis of data relating to the natural world by members of the public, typically as part of a collaborative project with professional scientists

**Degradation:** the process in which the quality of something is reduced

**Evidence:** any scientifically based data produced and analyzed in a way that is supported by previous study, to enable a judiciary and transparent approach to decision-making using a cumulative weight of evidence

**Exposure:** experience of or contact with something, in this case including locations, activities, and substances

**Green health:** benefits to human physical and mental health and well-being through interaction with land-based natural environments

**Greenwashing:** an unsubstantiated claim to deceive others into believing that products or practices are environmentally friendly

**Human Health:** the complete state of physical, social, and mental well-being, not merely the absence of illness, disease, or infirmity

**Interdisciplinary:** combining two or more disciplines to a new level of integration suggesting component boundaries start to break down. There is a recognition that each discipline can affect the research output of the other

**Ocean Literacy:** an understanding of the ocean's influence on you and your influence on the ocean

**Oceans:** in this document this is used as the term for any marine space, both coastal and offshore

**Optimize:** trade-offs for social, environmental and economic aspects have been considered to find the best and most balanced solution in a given context

**Pollution:** the presence of or introduction into the environment of a substance or energy that has harmful or poisonous effects

**Public Health:** the branch of medicine dealing with public health, including hygiene, epidemiology, and disease prevention

**Sustainability:** the ability to be maintained at a certain rate or level, in this case applied not only to ocean ecosystems and natural resources but also to human society

**Sustainable access:** equitable access to services and resources that is sustainable for the resource provider, and the resource user, and the resource itself

**Sustainable development:** development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987) in this case taking into account the "needs" of the ocean not just humans

**Transdisciplinary:** two or more disciplines transcend each other to form a new holistic approach. The outcome will be completely different from what one would expect from the addition of the parts

# Annex 1 – Input to the Strategic Research Agenda

The information and recommendations provided in this SRA have been gathered and/or generated in the scope of the European Union's Horizon 2020 research and innovation programme Coordination and Support Action (CSA) Project SOPHIE (Seas, Oceans and Public Health in Europe, Grant Agreement No. 774567)<sup>107</sup>. As can be seen below, this SRA was developed with direct and indirect input from a very high number of stakeholders across Europe, representing a wide variety of backgrounds.

The main visions and research questions presented in this SRA are the result of two dedicated interactive two-day workshops, which were held within the scope of the SOPHIE Project . A group of 20 experts<sup>108</sup> from Europe, the USA and Australia was selected from a diverse range of backgrounds linked to OHH, including the marine sciences, public health, medicine, economics and marine law. Workshops were held in Dublin, Ireland in April 2018<sup>109</sup> and Ostend, Belgium in January 2019<sup>110</sup>. Professional facilitator Lizzie Crudginton from Bright Green Learning<sup>111</sup> led these workshops. The outcome of these two workshops was three agreed target action areas for OHH in Europe to 2030, and a set of research questions underpinning each target action area.

The other activities of the SOPHIE Project also provided significant input into the SRA. A systematic review of the existing literature was conducted and helped to highlight gaps in current research and knowledge based on a screening of 18,000 publications<sup>112</sup>. Four regional workshops on relevant future trends and scenarios<sup>113</sup>, with a total of 101 participants, also helped to frame the top priority areas and their importance.

A detailed review of the policy landscape<sup>114</sup> in relation to OHH was conducted, and hence heavily informed the policy needs outlined in this SRA.

107 <https://sophie2020.eu/activities/strategic-research-agenda/>

108 <https://sophie2020.eu/wp/wp-content/uploads/2018/05/SOPHIE-Expert-Group-Members.pdf>

109 <https://mailchi.mp/3b5b30105e88/sophie-expert-group-workshop-1-photo-report-1047821?e=dae8e46a8f>

110 <https://mailchi.mp/8ef76d4e104e/sophie-expert-group-workshop-2-photo-report-1159497>

111 <https://brightgreenlearning.com/>

112 <https://sophie2020.eu/activities/systematic-map/>

113 <https://sophie2020.eu/activities/future-scenarios/>

114 <https://sophie2020.eu/activities/policy-review/>

115 <https://sophie2020.eu/activities/sophie-survey/>

116 <https://sophie2020.eu/activities/stakeholder-discussions/>

117 <https://sophie2020.eu/activities/innovative-solutions/>

118 <https://sophie2020.eu/activities/citizen-science/>

Information on understanding the needs of the public and stakeholders, capacity and training needs, and needs for enabling collaboration, was provided by several activities:

- The SOPHIE survey of 14,167 citizens from 14 European countries (Belgium, Bulgaria, Czech Republic, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Spain, UK)<sup>115</sup>
- Deliberation surveys of more than 800 societal stakeholders and 14,000 citizens, using the trigger question "What, in your opinion, are the top priorities for protecting public health and the health of the marine environment for a sustainable future?"<sup>116</sup>
- Two deliberation workshops with European societal stakeholders, with a total of 47 participants
- One deliberation workshop with European citizens, with a total of 15 participants
- Four regional workshops held in the North Sea (Eastern Scheldt), Atlantic Ocean (Donostia/San Sebastian), Baltic Sea (Helsinki) and Mediterranean Sea (Malaga) on future trends with a total of 101 participants
- A case study in the Eastern Scheldt area in the Netherlands investigating current practices and future challenges with local stakeholders in more detail than in the above regional workshops
- Exploration of a total of 150 examples of innovative OHH initiatives in Europe and 50 in Southeast Asia<sup>117</sup>
- Workshops and training events on citizen science held with eco-tourism operators<sup>118</sup> attended by almost 100 operators in Greece, Ireland, Portugal, Spain and the UK.



## Seas, Oceans & Public Health in Europe

Linking oceans and health research

### **A Strategic Research Agenda for Oceans and Human Health:**

Identifying priority research areas towards establishing an oceans and human health research capacity in Europe

**2020-2030**

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