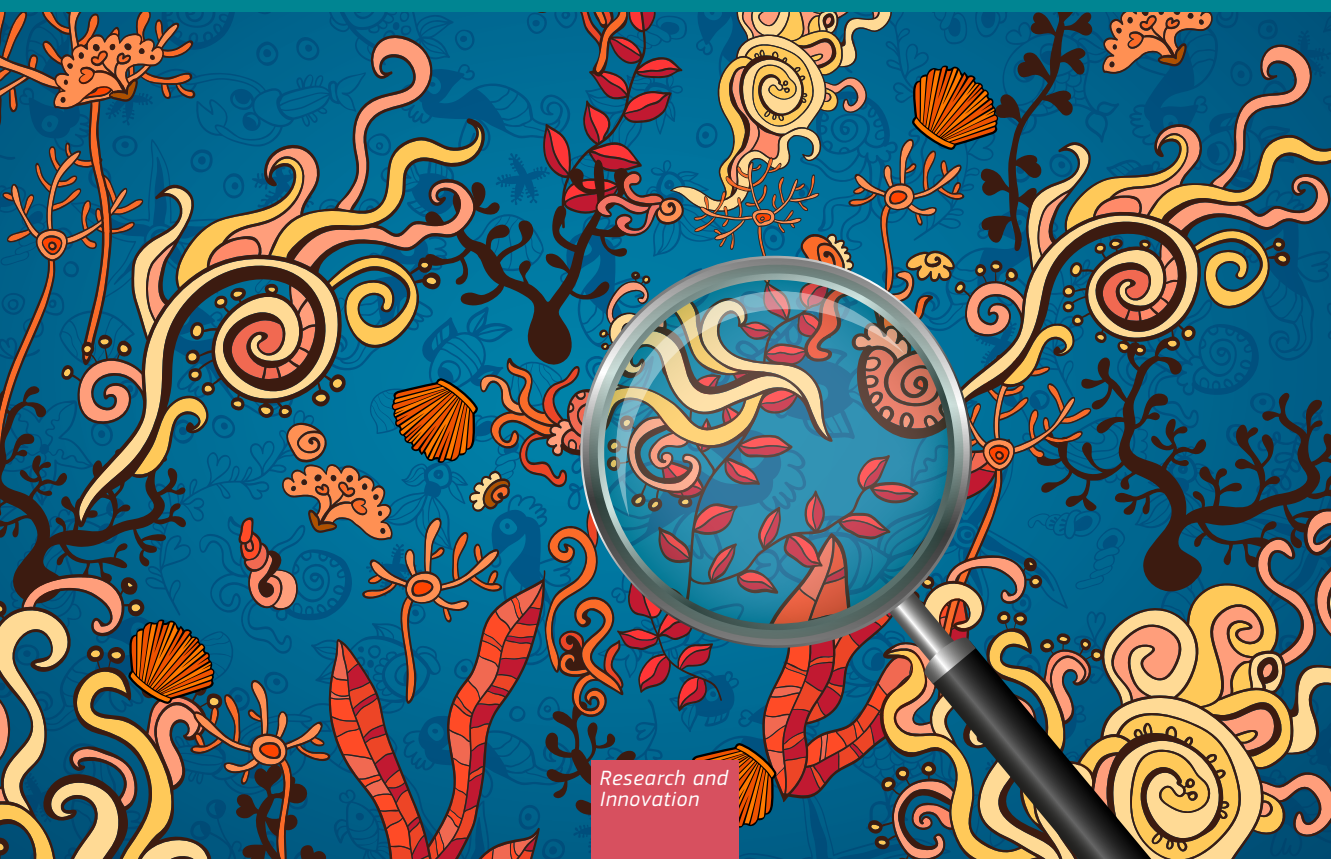
European Commission

Scientific Advice Mechanism (SAM)

Food from the Oceans

High Level Group of Scientific Advisors
Scientific Opinion No. 3/2017



Research and Innovation

Food from the Oceans - How can more food and biomass be obtained from the oceans in a way that does not deprive future generations of their benefits?

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EUROPEAN COMMISSION

Scientific Advice Mechanism (SAM)
INDEPENDENT SCIENTIFIC ADVICE FOR POLICY MAKING

Food from the Oceans

How can more food and biomass be obtained from the oceans in a way that does not deprive future generations of their benefits?

High Level Group of Scientific Advisors
Scientific Opinion No. 3/2017

(Informed by SAPEA Evidence Review Report No 1)

Brussels, 29 November 2017

2017 Directorate-General for Research and Innovation

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High Level Group of Scientific Advisors

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ACKNOWLEDGEMENTS

This Scientific Opinion (hereafter the Opinion) was delivered by the SAM High Level Group of Scientific Advisors (SAM HLG) to the European Commission on 29 November 2017. It responds to a request from the European Commission which SAM HLG accepted on 28 September 2016. The SAM HLG members in charge of developing this Opinion were Carina Keskitalo (lead), Janusz Bujnicki and Elvira Fortunato. The Opinion has been endorsed by all the members of SAM HLG.

SAM HLG wishes to thank the many contributors for their support and input in the preparation of this Scientific Opinion:

- The Science Advice for Policy by European Academies consortium (SAPEA)[1] - a key component of the Scientific Advice Mechanism. Academia Europaea, represented by Ole Petersen, assumed responsibility on behalf of SAPEA for an Evidence Review Report on the subject. This was prepared under the leadership of SAPEA Working Group Chairs Dag Aksnes (University of Bergen) and Poul Holm (Trinity College Dublin), aided by a SAPEA staff team led by Louise Edwards (Academia Europea).
- All the scientific experts and stakeholders from the science, policy, industry and civil society communities who contributed to the SAPEA Evidence Review Report, expert workshop, stakeholder meeting and other *ad hoc* meetings and consultations – the full list can be found in Annex 1.
- The European Commission's DG Joint Research Centre (Jann Martinsohn and colleagues), DG Marine and Maritime Affairs, DG Research and Innovation and DG Environment.
- The European Commission's SAM Unit support team (James Gavigan, Laura Contor and Gianluca Ferraro).

[1] SAPEA brings together knowledge and expertise from over 100 academies and learned societies in over 40 countries across Europe. Funded through the EU's Horizon 2020 programme, the SAPEA consortium comprises Academia Europaea (AE), All European Academies (ALLEA), the European Academies Science Advisory Council (EASAC), the European Council of Academies of Applied Sciences, Technologies and Engineering (Euro-CASE) and the Federation of European Academies of Medicine (FEAM)

EXECUTIVE SUMMARY

The ocean is one of the main systems of our planetary biosphere. It accounts for almost half of the planet's biological production, but a much smaller proportion of human food – about 2% of overall calorie intake and 15% of protein intake. This is no longer tenable given the nutritional needs of a growing population and over-stretched land-based resources. At the same time, with the oceans becoming warmer and more acidic, and with a larger proportion of the planet's population moving out of poverty, the global community needs to act together to ensure that the rights of future generations to a healthy and productive ocean are not compromised.

The European Commission requested scientific advice from SAM HLG on extracting more food and biomass from the oceans, in order to inform preparations for the successor of the present European Maritime and Fisheries Fund and on-going development of the overall marine policy portfolio. The question put to SAM HLG was:

"How can more food and biomass be obtained from the oceans in a way that does not deprive future generations of their benefits?"

Based on the accompanying SAPEA Evidence Review Report, an overview of the policy context, a scientific expert workshop, *ad hoc* expert consultations and a stakeholders meeting, this Opinion responds to the question. It provides a number of evidence-based policy recommendations on increasing the amount of food harvested from the ocean while maintaining healthy marine and coastal ecosystems.

The scientific evidence unambiguously points to sustainable "culture" and "capture" at lower trophic levels (*i.e.* levels in the ocean food web below the carnivore levels currently mostly exploited) as the way to bring about such an increase. Furthermore, the greatest and most feasible potential identified for expansion globally lies in mariculture (*i.e.* marine aquaculture) - notably of herbivore filter feeders (*e.g.* molluscs) for direct human consumption or, together with cultivated algae, as a more ecologically-efficient source of feed for farmed marine carnivores (*e.g.* finfish, shrimp, *etc.*). At the same time, much still needs to be done to improve the

management of capture fisheries in order to preserve this vital source of nutrition and livelihood for a significant proportion of the global population. In summary, the main recommendations are:

Mainstream a "food from the ocean" paradigm of responsible culture and capture into broad EU and global systems-level policy agendas – this includes integrating aspects of EU fisheries and mariculture policy into a food systems framework, and prioritising the food-generating capacity of the ocean in the EU's Integrated Maritime Policy as well as in EU contributions to the European Consensus for Development and to international policy initiatives such as the UN's Agenda 2030.

Take the development of mariculture in Europe to a higher and more strategic level via a comprehensive, concerted policy framework – this includes issuing guidance on the inclusion of mariculture requirements in the implementation of the 2014 EU Directive on Marine Spatial Planning and extending technological cooperation to mariculture under sustainable fisheries partnership agreements (SFPAs) between the EU and southern partner countries.

Continue to improve implementation and enforcement of existing regulations and use of best practice for sustaining wild capture – broadening as necessary the regulatory toolbox, *inter alia*, to ensure that all bycatch is recorded and landed, and optimising and fully enforcing the legal rules that facilitate or constrain the harvesting of food from the ocean.

Facilitate policy change – by optimal use of the Open Method of Coordination and initiatives such as the Blue Bioeconomy Forum, to support identification and deployment of best practice, stakeholder dialogue and the acquiring of social license to operate.

Future-proof policy and extend knowledge – by further developing the Common Fisheries Policy's science advice system, addressing key knowledge gaps and uncertainties identified in this Opinion and facilitating scientifically-motivated pilot fishing of as-yet unexploited lower trophic-level species.

Introduction: Aim, scope and methodology

1. INTRODUCTION: AIM, SCOPE AND METHODOLOGY

1.1. Introduction

The EU shares global responsibility to ensure an adequate and nutritious supply of food for all in the world, in accordance with the long-term capacity of the planet's ecosystems. In addition to security of supply, this involves ensuring optimum food distribution, health and safety, as well as solving problems of poor diet[2], hunger, micronutrient deficiencies and unsustainable use of natural resources.

While the ocean accounts for almost 50% of the earth's biological production, at present it only provides on average 2% of the daily per capita calorie intake and about 15% of animal protein intake. However, in the developing world, fish and other aquatic species account for a significantly higher proportion of food than in the developed world[3] where in fact they are a vital source of essential micronutrients for billions of people. Furthermore, to fulfil the UN Framework Convention on Climate Change, ocean-derived protein should play an increasingly important role, globally. Threats to this food supply from declining fish stocks and underdeveloped mariculture are therefore of global concern. Of equal concern is the fact that dietary preferences of developing countries tend to evolve towards less healthy and less eco-efficient habits of the developed world. There is also a tendency to view food security and nutrition issues largely through the lens of agriculture, with fisheries and mariculture often treated marginally.

In other words, the value of seafood is at present not properly understood, protected or integrated into global food security and nutrition policy considerations (see for example Béné et al., 2015). Such a blind spot is all the more worrying in view of the global need for 70% more protein by 2050.

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[2] Such as the tendency in developed countries to consume less nutritious and much less eco-efficient produce causing chronic conditions

[3] *"Around 1.25 billion (10^9) people worldwide rely on fish as their primary source of animal protein, and 4.3 billion people derive at least 15% of their animal protein intake from it"* ((SAPEA, 2017): Chapter 1)

Food harvesting from the ocean to date has mostly focused on top predators (fish) and much less on the vast amounts of potential food at trophic levels below those of carnivorous fish such as herbivores and algae. This is despite the fact that these latter species have already given rise to economically viable and nutritious products. However, they could in the future provide a substantially increased contribution to human food systems.

Development of traditional and newer forms of mariculture - *e.g.* going to lower trophic levels of farmed species and feed sources - given their huge potential and resource efficiency, is particularly attractive from both size and sustainability points of view (see (SAPEA, 2017): 2.4, 3.2 & 5). Such developments could also help to put traditional fisheries and potential future lower-trophic wild capture onto a sustainable footing (see (SAPEA, 2017): 3.1.3). Public policies are crucial in this regard as they determine the conditions which either permit or forbid certain ocean-based activities. They also shape the market and incentive conditions needed to enable the harvesting of such species to account for a significant rather than marginal proportion of food for human consumption.

1.2. Aim

The question on Food from the Oceans put to SAM HLG by Commissioner Vella on behalf of the Commission was:

"How can more food and biomass be obtained from the ocean in a way that does not deprive future generations of their benefits?"

SAM HLG began its work early in 2017 following agreement in December 2016 with the Commission on a scoping paper[4].

The aim of this Opinion is to answer the question in terms of where the potential increase lies, how feasible is its exploitation, over what timescale, and what factors could influence potential use. The Opinion should present

[4].https://ec.europa.eu/research/sam/pdf/meetings/hlg_sam_052016_scoping_paper_oceanfood.pdf#view=fit&pagemode=none

a number of policy recommendations, drawing on the best available scientific and technical evidence, knowledge and expertise in the area.

1.3. Scope

The scope of the Opinion is to some extent given by the different components of the question as specified by the SAM HLG early in the process. These components range from natural and engineering sciences perspectives on biological potential and ecosystem impact to social sciences and humanities perspectives on economic feasibility, consumer acceptance, governance systems, social licence, impact on coastal communities of different potential pathways as well as the implications of increasing production through alternative routes. More food from the oceans is thus seen both in terms of potential biological production capabilities and the implementation and governance of this production.

Even though this Opinion should inform the development of public policy in the EU, another feature of its scope is that it draws on scientific evidence and knowledge pertaining to the global ocean and not just European waters and harvesting activities. Indeed, the resources of the ocean, whether inside or outside waters under the jurisdiction of individual sovereign states, are connected to one another - what happens to a component of the food web in one part of the ocean can affect the whole system. Furthermore, while all EU policies invariably take into consideration the global context, in matters concerning food and the ocean, this broad perspective is seen to be an imperative.

Note however that inland capture and fresh water aquaculture are outside the scope of this Opinion and the scientific evidence reviewed.[5] In addition, the Opinion is also limited to food considerations and does not, for instance, cover ocean-derived biomass and only touches on pollution issues such as

[5] it is nonetheless important to acknowledge that freshwater capture and culture account for one third of the tonnage of harvested aquatic species and especially that they be factored into broad policy considerations concerning sustainable food supply, health and nutrition

microplastics, heavy metals or eutrophication, to a cursory extent (SAPEA, 2017).

1.4. Methodology

The investigation of this question was undertaken within the framework of the Scientific Advice Mechanism of the European Commission (SAM) which includes the SAM HLG and the SAPEA Consortium.

Following the above-mentioned initial specification by the SAM HLG of component sub-questions, SAPEA set up two working groups to review published scientific evidence. This gave rise to the accompanying Evidence Review Report (SAPEA, 2017). This report drew on: the knowledge of the 19 working group members; the results of a literature search conducted by SAPEA; a compilation of relevant grey literature and other key academic publications by the SAM Unit; a peer review process; a scientific expert workshop and *ad hoc* expert consultations.

SAM HLG also requested the SAM Unit to undertake a number of fact-finding missions[6] and to prepare an overview of the relevant policy context (summarised in section 2 of this Opinion) in consultation with relevant Commission Directorates General.

Based on a first draft of the SAPEA Evidence Review Report, in August 2017 the SAM HLG drew up a list of questions regarding feasibility of potential actions.[7] A group of 24 experts, 14 of whom had not been involved in the SAPEA report, addressed these questions in a one-day expert workshop in

[6] For the seminar **"***How much can we increase sustainable harvest from the ocean?*", Bergen, 7th March 2017, see the full set of presentations at: http://www.imr.no/forskning/utviklingssamarbeid/nyheter/presentations_from_day_zero_of_nasf_2017/en; and for *"The Ocean Conference",* UN, New York, 5th – 9th June 2017 see the Resolution adopted by the UN General Assembly in July 2017 (United Nations, 2017) at: http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/71/312&Lang=E

[7] The questions covered the following issues: improved fisheries management; reduction in and improved utilisation of discards; redirection of reduction fisheries to human consumption; harvesting and/or farming of under- or un-exploited species such as macroalgae and marine herbivores; improved and increased mariculture; integrated multi-trophic aquaculture; rights-based management; financial strategies such as limiting direct subsidies or providing support for start-ups; potential coastal engineering; social license [consumer information, social responsibility, and citizen involvement] and other social goals such as employment

Brussels on 14 September 2017 – see the Expert Workshop Report (Scientific Advice Mechanism, 2017a)[8].

Subsequently, on the basis of the workshop discussions, additional information of relevance to both the SAPEA report and this Opinion was identified and collated (much of which is referenced in this Opinion). Further expert consultations were held on issues related to potential policy recommendations including, amongst others, an *ad hoc* expert consultation meeting on 13 October 2017 with six experts. On 13 November 2017 the SAM HLG held a stakeholder meeting in Brussels to collect views and comments from representatives of interest groups in response to the presentation of the main draft elements of the Opinion. The reactions and comments received largely supported an increased focus on mariculture and more integrated, participative, knowledge- and systems-based approaches to policy and planning, with some disagreements in particular on quota and subsidy issues[9]. All contributing experts are included in the list in Annex 1.

In parallel, after the September expert workshop, the draft SAPEA Evidence Review Report underwent anonymous peer review followed by revision, finalisation and adoption by SAPEA at the same time as the delivery of this Opinion to the Commission. This report should be referred to for detailed definitions of scientific terms used (which are otherwise briefly explained in this Opinion) (SAPEA, 2017: Annexes 5 and 6). Note also that, as part of its work, SAPEA organised a number of outreach events across Europe to engage with the public on the subject of this Opinion.[10]

[8] https://ec.europa.eu/research/sam/pdf/food_from_oceans_expert_workshop_report.pdf#view=fit&pagemode=none

[9] See summary report of Meeting with Stakeholders at: http://ec.europa.eu/research/sam/index.cfm?pg=oceanfood (Scientific Advice Mechanism, 2017b)

[10] These included events at: The UNESCO Sustainable Gastronomy Day, Bergen, NO on 18 June 2017 http://ec.europa.eu/research/sam/index.cfm?pg=oceanfood; The Annual Cardiff International Food and Drink Festival, Cardiff, UK,14 - 15 July 2017 http://ec.europa.eu/research/sam/index.cfm; and The German Science Year 2016/17, Hamburg, Germany, 5 October 2017 www.sapea.info/events

Policy Context

2. POLICY CONTEXT

The primary policy context for this Opinion is given by policies in Europe and worldwide concerned with fisheries and mariculture linked to the sustainable production and consumption of food from the ocean. Broader policy frameworks are also relevant. These include marine-specific policies which give integrated consideration to all or several ocean functions.[11] Other relevant broad frameworks deal with issues such as food security and nutrition, equity, human health, the bioeconomy, development cooperation, trade, ecosystem resilience or sustainable development (*e.g.* the UN's Agenda 2030) - see Table 1.

Most immediately relevant for this Opinion is the preparation of the Commission's post-2020 EU Multi-annual Financial Framework for which formal proposals are due in 2018. The Opinion should inform how "food from the ocean" concerns are taken up in Commission proposals for the planning of future EU political priorities and resource allocation and, more particularly, the successor to the current European Maritime and Fisheries Fund. The Opinion should also inform relevant on-going policy implementation (*e.g.* the Blue Growth Strategy, Agenda 2030, ocean governance and development cooperation) as well as emerging policy discourses such as a systems-based approach to food policy.

The European Commission's Environment, Maritime Affairs and Fisheries policy portfolio most relevant to "food from the ocean" includes responsibility for developing the European maritime economy, securing sustainable fisheries, a stable supply of seafood, healthy seas and prosperous coastal communities. Its main components are the Integrated Maritime Policy and Common Fisheries Policy (CFP). The EU has treaty-endowed exclusive competence for wild-capture fisheries policy, while primary competences affecting mariculture reside at national and sub-national (see (European Committee of the Regions, 2015) levels in the EU.

[11] *e.g.* Food, climate regulation, materials, energy, transport, leisure, cultural identity, biodiversity, habitat reservoir

Table 1 - Overview of policy areas and initiatives for which this Opinion is potentially relevant

	EU level	*International level*	*Emerging*
Fisheries management	→ Common Fisheries Policy[A]	→ FAO Code of Conduct for Responsible Fisheries[B]	→ Post-2020 Multi annual Financial Framework[C]
Mariculture[D]	→ Common Fisheries Policy → Open Method of Coordination[E]	→ FAO Code of Conduct for Responsible Fisheries	→ Post-2020 Multi annual Financial Framework
Maritime and marine affairs	→ Integrated Maritime Policy[F] → Blue Growth Strategy[G]	→ UN Convention on the Law of the Sea[H]	→ Blue Bioeconomy Forum[I]
Food and feed health and safety	→ General Food Law[J] → Common Agricultural Policy[K] → Novel foods[L] → Animal health[M]; veterinary medicines[N] → Feed & feed additives[O]	→ FAO/WHO - Codex Alimentarius[P]	→ "Food 2030"[Q]
Sustainable development	→ Marine Spatial Planning Directive[R] → Bioeconomy Strategy[S] → Circular Economy Action Plan[T]	→ Agenda 2030 Sustainable Development Goals[U]	→ Ocean governance Communication[V] → Bioeconomy Strategy[W] → Sustainable Europe paper[X]
Environmental protection	→ Marine Strategy Framework Directive[Y] → Water Framework Directive[Z] → Birds & Habitats Directives[AA] → Strategy on Adaptation to Climate Change[BB] → 2030 Climate and Energy Framework[CC]	→ Convention on Biological Diversity[DD] → HELCOM & General Fisheries Commission for the Mediterranean[EE] → UN Framework Convention on Climate Change[FF]	
Territorial/International cohesion and cooperation	→ Atlantic & Baltic Strategies[GG] → Development cooperation[HH]	→ Galway Statement[II] → Committee on World Food Security[JJ]	→ European Consensus on Development[KK] → Belem Statement[LL]

Footnotes to Table 1

[A] https://ec.europa.eu/fisheries/cfp_en
[B] http://www.fao.org/docrep/005/v9878e/v9878e00.HTM
[C] Forthcoming – see (European Commission, 2017b)
[D] See a complete set of links to related policies at https://ec.europa.eu/fisheries/cfp/aquaculture/policy-areas_en
[E] https://ec.europa.eu/fisheries/cfp/aquaculture_en
[F] https://ec.europa.eu/maritimeaffairs/policy_en
[G] (European Commission, 2012, 2017c)
[H] http://www.un.org/depts/los/convention_agreements/convention_overview_convention.htm
[I] Forthcoming – see https://ec.europa.eu/maritimeaffairs/content/call-tenders-establish-blue-bioeconomy-forum_en
[J] https://ec.europa.eu/food/safety/general_food_law_en
[K] https://ec.europa.eu/agriculture/cap-overview_en
[L] https://ec.europa.eu/food/safety/novel_food_en
[M] https://ec.europa.eu/food/animals/animalproducts/aquaculture_en; https://ec.europa.eu/food/animals/live_animals/aquaculture_en
[N] https://ec.europa.eu/health/veterinary-use_en
[O] https://ec.europa.eu/food/safety/animal-feed_en
[P] http://www.fao.org/fao-who-codexalimentarius/en/
[Q] (European Commission, 2016a)
[R] https://ec.europa.eu/maritimeaffairs/policy/maritime_spatial_planning_en
[S] (European Commission, 2017d)
[T] http://ec.europa.eu/environment/circular-economy/index_en.htm
[U] http://www.un.org/sustainabledevelopment/development-agenda/ and (European Commission, 2016b)
[V] (European Commission & High Representative of the Union for Foreign Affairs and Security Policy, 2016)
[W] See (European Commission, 2017a)
[X] (European Commission, 2017b)
[Y] http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm
[Z] http://ec.europa.eu/environment/water/water-framework/index_en.html
[AA] http://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm; http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm
[BB] https://ec.europa.eu/clima/policies/adaptation/what_en
[CC] https://ec.europa.eu/clima/policies/strategies/2030_en
[DD] https://www.cbd.int/
[EE] http://www.helcom.fi/about-us/convention; http://www.fao.org/gfcm/en/
[FF] http://unfccc.int/2860.php
[GG] See https://ec.europa.eu/maritimeaffairs/policy/sea_basins/atlantic_ocean_en; https://ec.europa.eu/maritimeaffairs/policy/sea_basins/baltic_sea_en
[HH] https://ec.europa.eu/europeaid/node/22_en
[II] https://ec.europa.eu/research/iscp/pdf/galway_statement_atlantic_ocean_cooperation.pdf
[JJ] http://www.fao.org/cfs/cfs-hlpe/reports/report-7-elaboration-process/en/
[KK] https://ec.europa.eu/europeaid/policies/european-development-policy/european-consensus-development_en
[LL] http://ec.europa.eu/research/iscp/pdf/belem_statement_2017_en.pdf#view=fit&pagemode=none

Noteworthy in the Integrated Maritime Policy's Blue Growth Strategy is the prioritisation of aquaculture along with four other maritime economy sectors (European Commission, 2012, 2017c). Also of significance is the 2014 Maritime Spatial Planning Directive which, in requiring Member States to take into account land-sea interactions, holds the promise of enabling coastal and off-shore mariculture and fisheries development in balance with other ocean-based activities.

In the area of environmental policy, beyond broadly-relevant initiatives such as the EU Strategy on Adaptation to Climate Change and the 2030 Climate and Energy Framework, more directly-relevant measures include: the 2015 Circular Economy Action Plan which addresses elimination of waste from fisheries and aquaculture; the 2008 Marine Strategy Framework Directive seen as the Integrated Maritime Policy's environmental pillar; and the 2000 Water Framework Directive as applicable to transitional (estuaries) and coastal waters. A guidance document addressing the requirements of the Marine Strategy Framework Directive and the Water Framework Directive in relation to aquaculture (European Commission, 2016c) *inter alia* points out the potential value of integrating such requirements into marine spatial planning.

In the areas of food safety[12] and consumer affairs[13] most applicable measures do not distinguish between what is produced on land or in the sea. However there are a few emphases of notable relevance to food from the ocean including a concern for the safety of aquaculture products.[14] A new regulation[15] on novel foods and novel food ingredients may facilitate increased exploitation of algae and other heretofore unconsumed aquatic species.[16]

[12] https://ec.europa.eu/food/safety_en
[13] http://ec.europa.eu/consumers/eu_consumer_policy/our-strategy/index_en.htm
14 https://ec.europa.eu/food/animals/animalproducts/aquaculture_en
[15] Adopted in 2015 and which will fully apply from 1st Jan 2018 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2283&from=EN
[16] https://ec.europa.eu/food/safety/novel_food_en

In addition to the external dimensions of the Common Fisheries Policy[17], the EU also influences fisheries in partner countries through its support to development cooperation, where nutrition and food security are key priorities, and via trade policy promotion of sustainable fisheries, particularly through Economic Partnership Agreements with African, Caribbean and Pacific countries.

Policy areas currently either under development, review or implementation which may be receptive to this Opinion include:

- Implementation of the EU's 2016 agenda for international ocean governance responding to the United Nation's 2030 Agenda for Sustainable Development, particularly Sustainable Development Goal 14 (SDG14)
- Follow-up to the current European Maritime and Fisheries Fund (2014-20) – as part of the wider debate on the EU's post-2020 Multi annual Financial Framework on which formal proposals are expected to be tabled by the Commission in 2018
- On-going review (due to be completed by end 2017) of the EU's Open Method of Coordination of EU aquaculture policy under the Common Fisheries Policy, following the 2013 Strategic Guidelines for the development of aquaculture (European Commission, 2013)
- Expected revision in 2018 of the EU's bioeconomy strategy following the 2017 review (European Commission, 2017d)
- An emerging systems-based approach to food policy which is gaining traction in some academic, policy and other stakeholder circles – see food-related elements of the public consultation response on reform of the Common Agricultural Policy[18], Food 2030 (European Commission, 2016a) and (European Committee of the Regions, 2017)[19]
- The intention to establish in 2018 a Blue Bioeconomy Forum bringing together industry and the public sector to identify possible operational paths to increase production of food, feed, energy and materials deriving from the collection, cultivation and husbandry of marine life[20]

[17] https://ec.europa.eu/fisheries/cfp/international_en
[18] https://ec.europa.eu/agriculture/consultations/cap-modernising/2017_en
[19] Note also that the Commission plans to propose legislation in 2018 on improving the EU food supply under Articles 42 and 43 of the Treaty on the Functioning of the EU, the latter referring to both common agricultural and fisheries policies (European Commission, 2017b)
[20] This forum *inter alia* plans to address how to move aquaculture facilities further offshore and what needs to be done to open new markets for products from algae and other marine organisms

- Implementation of the EU's European Consensus on Development in line with the UN Sustainable Development Goals (SDGs) which commits the EU to the conservation and sustainable management of oceans and their resources.

In the international arena, on-going effort to deliver the UN's 2030 Agenda is of major significance to the aspiration to increase sustainable ocean harvest. Particularly noteworthy is the 14-point consensual Call for Action adopted at the UN Ocean Conference on 9th June 2017 (United Nations, 2017) several of which are relevant to sustainable food from the ocean for food security and nutrition. The European Commission's reflection paper "Towards a Sustainable Europe by 2030" planned for 2018 on the UN's 2030 Agenda and the Paris climate change agreement may benefit from this Opinion (European Commission, 2017b).

Also of note is the on-going series of annual ministerial-level Our Ocean conferences focused on making concrete commitments to preserve the health of the ocean. "Sustainable fisheries" has been one of the focus areas since the first 2014 edition in Washington DC. At the October 2017 edition hosted in Malta by European Commissioner Vella on behalf of the EU, many new commitments relating to food security were announced under "sustainable fisheries" and other themes. In principle, this Opinion could influence the identification of other commitments to be announced at the 2018, 2019 and 2020 editions of Our Ocean which will take place respectively in Indonesia, Norway and Palau.

Scientific Evidence and Feasibility Analysis

3. SCIENTIFIC EVIDENCE AND FEASIBILITY ANALYSIS[21]

The challenges to sustainably and responsibly derive more food from the oceans relate to wild-capture ocean harvesting and mariculture[22]. In addition to evidence from the natural sciences, the analysis on which this Opinion is based also considers evidence from the social sciences. Indeed, the social sciences have much to say about the governance, management and socio-economics of the seafood value chain from extraction to consumption and the part it plays in various, ecological, socio-cultural and political systems. Most of the evidence drawn on is contained in the SAPEA Evidence Review Report (SAPEA, 2017). The Opinion also draws on workshop discussions and *ad hoc* consultations with experts on the feasibility of realising the potential identified in the SAPEA Evidence Review Report and possible actions to take in this regard.

The SAPEA Evidence Review Report, which slightly reformulated the question to *"How can more food and biomass be obtained from the oceans in a way that maximises the benefits for future generations*" (SAPEA, 2017, p. 11), summarises the key scientific evidence and knowledge in the published literature. It describes the present extent to which food is obtained from the ocean, discusses the biological potential for increasing the amount of food harvested and points out constraints on the realisation of this potential.[23] It states that *"increased food production from the ocean may release some of the pressure that has been put on agriculture to achieve UN sustainable development goal SDG2 (end hunger, achieve food security and improved nutrition and promote sustainable agriculture) and SDG12 (protect, restore and promote sustainable use of terrestrial ecosystems). However, this needs to be achieved without compromising SDG14 (conserve and sustainably use the oceans, seas and marine*

[21] For a full glossary of key definitions and terms and a list of abbreviations, see (SAPEA, 2017): Annexes 5 and 6
[22] N.B. excluding freshwater capture fisheries and freshwater aquaculture
[23] The SAPEA Evidence Review Report defines food and biomass from the ocean as "*marine organisms that have spent most of their life in the ocean and that derive an essential part of their nutrition from the ocean*"

resources), whilst acknowledging the climate change drivers that are reflected in the SDG 13 (climate action)" (SAPEA, 2017, p. 11).

The SAPEA Evidence Review Report also points out that: 1. all evidence presented is subject to multiple uncertainties, including the impact of climate change on species vital for food production; 2. species-specific responses to multiple ocean stressors (*e.g.* overfishing, global warming, acidification and invasive species) are unclear; 3. changes at the base of the ocean food web and their implications for fisheries management are difficult to quantify; and 4. regional differences in impacts on fisheries and dependencies abound, where mariculture and wild catch in coastal systems strongly depend on the interaction with the land bordering the coast (see (SAPEA, 2017): 3.3.5). Microplastic pollution also has an unclear range of impacts on food production from the ocean (see (SAPEA, 2017): 3.3.7). Other activities such as reclamation and forms of seabed mining that cause permanent loss of seafloor habitat are likely to cause net losses to food production as well as to most other societal uses of the ocean. In addition, *"[t]he issues are further compounded by deficiencies of knowledge; we may have case-study evidence for some issues, but often generalised knowledge is lacking"* (SAPEA, 2017, pp. 12-13). SAPEA's assessment of the evidence suggests that *"[u]ltimately, the choices underlying such maximisation [of food from the ocean], and whether the ocean and land will be viewed in isolation or in combination, are political rather than scientific. However, science can help to map positive and negative consequences of a choice, which the present report attempts to do"* (SAPEA, 2017, pp. 11-12).

3.1. Quantification of harvest potential

The Evidence Review Report gives current tonnages of extracted fish and other biomass for food and feed as well as the trends over recent decades (see (SAPEA, 2017): Chapter 2). The most recent and best available data[24] put the total annual amount globally in 2015 at 138 Mt (million metric tons)

[24] They come with some caveats and a degree of underestimation due for instance to illegal, unregulated and unreported catches

of which 60% was wild-capture landings (including 20 Mt reduction fisheries) and 40% mariculture production.[25] Since 1990 wild-capture tonnage has been relatively stable while mariculture has been growing at 6.5% per year.

More relevant to the central question of this Opinion are estimates in the SAPEA Evidence Review Report of the additional tonnages which could be obtained annually from the ocean for ten different options considered (see (SAPEA, 2017): Chapter 5). In short, the only way to obtain significantly more food and biomass (> 100 Mt) from the ocean is to harvest on average from a lower trophic level than is the case today. Mariculture is closest to a realisation of this because macroalgae and molluscs are at the lowest trophic levels, but also because plants now make up a substantial fraction (up to 70%) of the feed of finfish and crustacean mariculture.

The SAPEA Evidence Review Report distinguishes between potential increases in food for direct human consumption and increases in feed for mariculture.

For food:

- The biggest potential increases estimated could come from mariculture – over 160 Mt achievable within some decades[26] – which, if realised, would alone more than double the current overall tonnage
- Of this 160 Mt, 100 would be filter feeders[27], 50 algae and 10 marine carnivores. At a growth rate of 6.5% per year, such expansion (from today's 56 to 216 Mt) would require 22 years
- The estimated potential wild-capture increase is 30 Mt which would be 37% above the current value which has however remained at a relatively stable level over the past 20 years
- Of this 30 Mt, 20 could come from improved management of established fisheries and 10 from more selective fishing which reduces discards and thus contributes to increased catch at a later stage. The time scale needed to obtain such improvement was not indicated but is likely to be

[25] Freshwater capture and aquaculture – not included - amount to an additional annual tonnage of over 20 Mt
[26] This number is potentially much larger over a longer time scale
[27] *i.e.* Crustaceans, aquatic molluscs and other fish that feed by straining suspended matter and food particles from water

long on the basis of low past improvement rates. If current reduction fisheries could be directed to food instead of feed, an additional 15 Mt of food would become available at the expense of feed.

For feed:

- An increase could come from currently unexploited zooplankton (krill) and mesopelagic fish. The potential for a sustainable harvest might be large but is unclear due to lack of biological knowledge. A precautionary harvest of 20 Mt was indicated. Significant estimates were proposed for other sources – more than 50 Mt from mariculture of macroalgae (and potentially of filter feeders); 30 Mt from discards and processing waste amounting to an additional >80 Mt.

No estimates are given for increased tonnage from wild algae harvesting nor from integrated multi-trophic aquaculture because of high associated uncertainties (see (SAPEA, 2017): 3.1.4 & 3.2.8).

The SAPEA Evidence Review Report takes care to point out that one should not take the above estimates as precise but rather as order of magnitude indications and illustrations of the substantial differences between the different options. It also notes that the numbers for traditional capture fisheries are upper limits for how much more food/biomass can be obtained, while the numbers for mariculture are not upper limits, but rather indicative of the potential that could be realised within two to three decades based on current growth rates.

While the estimates are based on business-as-usual scenarios, the SAPEA Evidence Review Report points out that *"[r]adical innovations involving more fundamental changes in how we exploit the ocean which may become important are not accounted for"* (SAPEA, 2017, p. 19) in such scenarios. For wild capture and mariculture, such innovations could include harvesting with a higher ecological efficiency than today, *i.e.* utilising the much higher natural biological production capacity at the lower trophic levels.

Overall, the estimates paint a positive picture of a combined potential increase between 300-400 Mt of biomass for food or feed - a three to four-fold increase on current levels of extraction. Compared to the current tonnage for traditional fisheries this number is high. However, a large fraction of this potential is at the lowest trophic levels where the natural

production is several orders of magnitude higher than for the trophic level of the fish predators constituting today's fishery catch (see (SAPEA, 2017): 2.4).

In terms of feasibility, the "lowest hanging fruits" globally lie in mariculture development. In a business-as-usual scenario, continued investment and annual growth rates of 5-8% for the main organism groups (algae, filter-feeders and carnivores) would permit the short, medium, and long-term realisation of this potential. What is more in doubt is the part that mariculture in the EU might play in this.

Concerning traditional fisheries, the estimated potential increases are not only lower than for mariculture, they are also more uncertain. History demonstrates that improvements in traditional fisheries as a sector with long established institutions can take a long time.

Most uncertain of all is the potential increase from zooplankton and mesopelagics wild-capture. This is therefore deemed to be a long-term option. However, as academic research alone will not fill the knowledge and understanding gaps needed to test this potential, the case can be made for pilot/ experimental fisheries of such species on the basis of a precautionary approach as has already been done in some countries such as Iceland, Norway, Russia, South Africa (see (SAPEA, 2017): 3.1.3 & Chapter 5).

3.2. Cross-cutting issues

3.2.1. An integrated perspective

Harvesting more "food from the ocean" needs to be considered in an integrated perspective linked to a broad conception of food security and nutrition in which related trade-offs are carefully balanced (Blanchard et al., 2017; Scientific Advice Mechanism, 2017a). The importance of food from the oceans in the context of a growing world population and as a source of micronutrients and lipids is seen as potentially more important than that of

supplying protein, notably in developing countries (Golden et al., 2016, 2017)[28].

An integrated perspective is needed to understand complex synergies and interrelated challenges. For instance, as different species interact with each other within ecosystems, it is too simplistic in fisheries matters to treat species separately (see (SAPEA, 2017): 3.1). Such interactions take place in a dynamic context of ecosystem change. They need to be taken into account when devising the regulatory system for different type of fisheries, as well as in considering the effects of climate change. Account also needs to be taken of differences between the North and the South, and between small- and large-scale fisheries. The majority of world fisheries are small scale and are not well represented in the political and economic development agenda and imbalances between developed and developing world are well-known (Béné et al, 2015).

3.2.2. Knowledge uncertainties[29]

Current knowledge in many areas of science relevant to food from the ocean is severely lacking, as already noted in the introduction to this chapter. There is a large uncertainty in the potential for growth in the exploitation of new (*i.e.* heretofore unexploited) species. New evidence and understanding could change the perspective on what constitute sustainable solutions. Current scientific assessments that are characterised by inherent uncertainty include the variable effect of climate change on each species and life stage (as with impacts of other ocean stressors[30] on marine ecosystems), resulting in changes at the base of the food web - *e.g.* impact of ocean acidification on molluscs (see (SAPEA, 2017): 3.3); impacts of diseases and parasites on food-producing organisms (see (SAPEA, 2017): 3.3.6); and the poor understanding of the effects of microplastics (see (SAPEA, 2017): 3.3.7) and invasive species. Many such factors can

[28] Africa and the Pacific Islands, for instance, would greatly benefit from the introduction and development of less intensive mariculture aimed at domestic consumption
[29] Uncertainty is discussed through all sections of the SAPEA Evidence Review Report (SAPEA, 2017)
[30] Acidification, pollution, changing ocean currents, stratification, sea-level rise, *etc*.

influence the harvesting possibilities, and would need to be included in for instance determining Maximum Sustainable Yields (MSY) (see (SAPEA, 2017): 3.1). It is also relevant to look into alternative, ecosystem-based approaches for determining fishing yield such as Bpa (biomass precautionary approach reference point) (Kvamsdal et al., 2016) or the emerging so-called balanced harvesting approach (International Union for Conservation of Nature, 2015). The best-possible approach to scientific-advice-to-policy in such circumstances of uncertainty should include providing transparency on trade-offs between options when incomplete knowledge precludes total clarity (Ramírez-Monsalve et al., 2016)(van Hoof & Kraus, 2017).

Experts also point out that institutional inertia can give rise to lock-in of fisheries management and practices which may have become redundant or obsolete as a result of on-going change in many spheres – *e.g.* technical change or ecosystem change (see (SAPEA, 2017): 3.3.1 & 4.3). A case in point is climate change which can lead to changes in the location and distribution of marine species (SAPEA, 2017: 3.3.1). Changes in for instance fish location and migration can also lead to the consequence that fishers need a way to capture what is in their waters rather than what used to be there, posing a need for adaptive change in fisheries management and practices.

3.3. Mariculture[31]

3.3.1. Potential[32]

Mariculture, as a relatively underdeveloped sector, is deemed to have the largest capacity to increase food harvested from the ocean (see (SAPEA, 2017): Chapter 5). The increasing number of species farmed in mariculture include primary producers – *e.g.* seaweed and herbivores such as bivalves[33]

[31] For relevant evidence and references see (SAPEA, 2017): 3.2
[32] Relates to (SAPEA, 2017): Chapter 5) – Options 7,8,9 and 10
[33] Bivalves or bivalve molluscs *e.g.* clams, oysters, mussels, scallops

- which, by volume, represent the largest share of current mariculture production (as most finfish are produced in freshwater aquaculture).

Molluscs (including shellfish species) and macroalgae (marine plants), near the bottom of the food chain, extract their feed and nutrients directly from the sea (extracting mariculture). Mollusc and macroalgae production has already reached relatively large volumes. The evidence points to the possibility of accelerating this increase thereby providing the largest potential tonnage increase in food and biomass from the ocean. Global annual growth is around 5%, but expansion in many countries is constrained by obstacles such as lack of suitable nutrition (for macroalgae), environmental legislation, inaccessibility of suitable coastal space and immature management routines.

A benefit of plant- and herbivore- mariculture compared to agriculture is that it is independent of industrial fertilizers, feed, and large supplies of freshwater and there is a very large unrealised worldwide biological potential for producing more. Modern "feeding mariculture" - *e.g.* salmon and shrimp - using pelleted feeds produced by large feed companies, has high conversion efficiencies and low environmental footprints. Today, the largest fraction of pelleted feed consists of terrestrial plant material, but around 20% marine ingredients (oil and meal originating from reduction fisheries) are required (see (SAPEA, 2017): 3.2.5). If terrestrial plants in feed could be substituted by material from increased mariculture of underutilised marine plant and herbivore species, the pressure on agriculture would be released. In addition more fish could be produced independently of today's reduction fisheries[34] as marine plants, herbivores and oils from cultured microorganisms could cover the need for marine oil in the feed. As well as releasing pressure on capture fisheries and agriculture, this also moves farmed fish down the food chain to lower trophic level as has already been achieved with salmon using terrestrial plant material (see (SAPEA, 2017): 3.2.5).

[34] *i.e.* Fisheries where the catch is "reduced" to fish meal and oil for feed rather than being for human consumption

Important lipids (LC n-3 fatty acids) for nutrition of farmed fish, as well as for humans, could also be obtained from previously underutilised sources such as fish-processing waste (discards and offal) as well as from zooplankton, mesopelagic fish, micro- and macro-algae, mollusc and other filter feeders, and also from agricultural waste if used as a growth substrate for unicellular organisms producing LC n-3 fatty acids[35]. All these sources could provide important avenues for feed to "feeding mariculture" (see (SAPEA, 2017): 3.2.6).

Given the constraints on getting more food from the ocean (*e.g.* social concerns relating to coastal communities), farming macroalgae and molluscs (oysters, mussels) seems to be one of the best candidates to increase harvest in the short term (see (SAPEA, 2017): Chapter 5). Given its labour intensity, such development would create valuable local employment.

In addition to traditional mariculture focused on single species, integrated mariculture systems focused on several species is also possible (so called Integrated Multi-Trophic Aquaculture *e.g.*, rope cultures with macroalgae or shellfish close to fish cages) (see (SAPEA, 2017): 3.2.8, 4.1.2 & 4.3.2).

Open sea mariculture has high potential though largely requires substantial investment and is only achievable at a large scale in the long term. However technologies for open sea farming of fish and shrimp are becoming established in some places in recent years (see (SAPEA, 2017): 3.2.4; (Buck & Langan, 2017)).

3.3.2. Challenges and concerns

For mariculture expansion, important considerations relate to *competition for space in coastal areas* (including space for other commercial purposes, for recreation and protection of biodiversity, among other things) and the

[35] However, there is no evidence to suggest that any of these sources (*e.g.* krill and mesopelagics) will be used in the short term for direct human consumption other than in the form of derived food additives such as omega-3 in the case of krill and Calanus and nutraceuticals – See (SAPEA, 2017): 3.1.3

lack of offshore production techniques (*e.g.* structures to allow seaweed or fish cages to survive open-ocean conditions).

Regarding macroalgae and mollusc production, water quality in coastal areas is sometimes insufficient, and there are concerns about possible negative effects of such mariculture on wild shellfish populations as well as uncertainty concerning the future impact of ocean acidification on shellfish. Harmful algae blooms that increase with climate change could have large negative effects on shellfish production.

For macroalgae, concerns include: insufficient seed quality and related risks regarding maintenance of native genetic resources[36]; lack of low-cost, high efficiency harvesting systems; varying nutritional content seasonally; and food acceptability. The fact that alginates bind heavy metals also results in large uncertainties with regard to food safety of increased seaweed consumption.

For finfish mariculture, environmental concerns relate to release of organic material (surplus feed and fish waste) and pharmaceuticals. Poorly regulated finfish mariculture may have strong environmental footprints in locations with poor water renewal.

For Integrated Marine Trophic Aquaculture, the implementation of such approaches has so far been limited in Europe (less so in Asia) due to the increased probability of harmful interactions, escapees and losses of fish during bad weather, and immature technology (see (SAPEA, 2017): 3.2.8). This raises the possibility of considering incentives to promote this and other types of eco-friendly mariculture.

Open or deep sea farming needs clear regulatory frameworks and the means to implement them.

An important obstacle to mariculture is public acceptance (see (SAPEA, 2017): 4.2). As the view that wild catch is "better" than mariculture

[36] *e.g.* To limit disease and also possibly managing non-native genotypes – at present mostly prohibited in seaweed aquaculture - avoiding invasive species risks and providing selective breeding programmes

products remains dominant in Europe, this may require benefits of mariculture to be made known among consumers.

Start-up conditions for new mariculture production in Europe are in general difficult (see (SAPEA, 2017): 4.1.5). Capital is needed to start new activities, but banks and other investors are holding back, potentially linked to the complicated procedures for licensing mariculture. Less intensive mariculture struggles with productivity compared to alternative proteins. Facilitating start-up investments in this sector thus requires clear, transparent, and harmonised regulation and rules for granting mariculture firm licences - which presently vary widely between jurisdictions (Innes, Martini, & Leroy, 2017).

In order to develop offshore multi-use in a spatially efficient way, certain preconditions need to be fulfilled and streamlined to reduce the risk for offshore entrepreneurs. For example, there is a need to clarify the specific functions and siting of marine installations, but also the overall regulatory conditions (*e.g.* working rules), allocation of responsibilities, as well as commercial arrangements or actuarial regulations and questions of ownership and liability in Exclusive Economic Zones (see (SAPEA, 2017): 4.3.2).

3.4. Wild capture[37]

3.4.1. Improved management of current fisheries[38]

The SAPEA Evidence Review Report clarifies that more food can be obtained from current fisheries by improved management of overfished stocks (*e.g.* allowing fish to grow more and to contribute more to the next generation) and by waste reduction (increased utilisation of discards and post-harvest wastes). Concerning overfishing, the most important obstacles include: a lack of adequate assessment and management systems for many stocks; "Too little, too late" reduction in fishing pressure when stocks are in

[37] For relevant evidence and references see (SAPEA, 2017): 3.1
[38] Relates to (SAPEA, 2017): Chapter 5 – Option 1

decline; Lack of enforcement; and added complications due to the fact that rebuilding of overfished stocks require reduced fishery landings for several years (SAPEA, 2017): 3.1.1) - see also (Bell, Watson, & Ye, 2017; Marchal et al., 2016). The SAPEA Evidence Review Report also states that *"maximum sustainable catches cannot be obtained from all species simultaneously, or from whole functional groups or trophic levels, or for individual species. This is because of changes in habitat quality and availability, climate variations and change, and because of resulting changes in trophic interactions and vital rates"* (SAPEA, 2017, p. 22). Presently, many stocks are subject to overfishing (including at levels above the estimated MSY [maximum sustainable yield] for some stocks where such MSY estimates exist. Establishment of MSY estimates is critical in a first instance with some evidence suggesting that, once MSY capacity of a stock has been reached, precautionary fishing below MSY levels could increase yields by more than 50% (SAPEA, 2017: 3.1.1).

3.4.2. Re-direction of reduction fisheries and bycatch[39]

The option exists to redirect reduction fish – *i.e.* catch reduced to fishmeal and oil for use in processed feed used as direct feed, bait fish, pet food, or fertilizer – towards direct human consumption at the expense of mariculture and agriculture feed. This would decrease the production capacity of finfish and crustacean mariculture if alternative marine lipids are not made available. The potential to redirect reduction fish to human consumption also depends on factors such as consumer preferences, the nutritional strategies in different countries and market dynamics - including global demand for fish meal (notably in China).

3.4.3. Discards and bycatch[40]

An increase in the efficiency of current catch is potentially achievable through reduction of wasted biomass in the form of discards, viscera and other offal across the processing chain.

[39] Relates to (SAPEA, 2017): Chapter 5 – Option 4
[40] Relates to (SAPEA, 2017): Chapter 5 – Options 2 and 3

There are two ways to reduce discarded bycatch[41]: 1. land it and utilise it as food or biomass; or 2. implement management systems (including more selective fishing gear) aimed at reducing bycatch that would be discarded. The 2013 reform of the European Common Fisheries Policy (CFP) enacted a landing obligation, or discard ban, for European fisheries, aimed at decreasing bycatch by making it more onerous on fishers. The CFP specifies that landed bycatch (former discards) cannot be used for human consumption and therefore cannot lead to the creation of new markets except for fish oil and fishmeal. The landing obligation should increase the amount of fish that is landed from the total catch and thus increase fish available for fishmeal/fish oil. It should also serve as an incentive to fish selectively and thus reduce bycatch of undersized or under-aged fish of the same or other species. This can help to increase the future yield from these stocks.

The Expert Workshop and *ad hoc* expert consultations stressed that the complexity and geographical variability of different situations call for a case-by-case assessment of fishing gear and management systems for reducing bycatch. In other words, the mechanisms for decreasing unwanted bycatch and collateral damage need to be tailored to specific areas and species. This could include banning poorly-selective fishing gear in specific cases and areas. While experts concur on the need to eliminate discards as legislated for under the discard ban, it was acknowledged that compliance is difficult to control. The expert view is that financial/ market "incentives to land" also need to be put in place to help achieve the expected positive effects of the landing obligation.

Experts also pointed out that action in the area of eliminating waste from harvested wild stocks is hampered by a lack of data and the lack of independent control methodologies for traceability and labelling. With regard to some of these issues, it was suggested that the EU data collection framework could be used. In addition, more capacity is needed for: on-

[41] Unwanted species or undersized fish that are dumped back into the ocean

board storage; delivery and processing of discards and offal; and assessing the suitability for feed ingredients further down the value chain.

3.4.4. Zooplankton[42]

Zooplankton from micrometre-sized ciliates to large jellyfish is so far rarely used as human food[43]. However, the Norwegian Directorate for Fisheries has recently set up plans for precautionary trial fishery of one such species, Antarctic krill which has already been fished to a limited extent under the Commission for Conservation of Antarctic Marine Living Resources. It constitutes *"a potentially large underexploited resource which could provide >10% (by mass) of all current global marine landings"* (SAPEA, 2017, p. 26). However, the ecological consequences of removing large amounts of krill are so far not known. Today's biological and technical constraints for harvesting more zooplankton include lack of efficient harvesting and preservation methodologies leading to high energy costs particularly for organisms smaller than krill. Moreover fishing bans and precautionary approaches apply in order not to reduce the output of traditional fisheries but to avoid the risk of ecosystem damage.

3.4.5. Mesopelagic fish[44]

Mesopelagic fish that feed on zooplankton and which are not exploited today also could have large potential for increasing food harvested from the sea (see (SAPEA, 2017): 3.1.3). However, fundamental knowledge gaps and technical deficits raise doubts about the short-term techno-economic viability of this potential. The most recent estimate[45] of an exceptionally high mesopelagic fish biomass remains uncertain due to inadequate sampling methodology and other factors. Extensive utilisation of this resource, which consists of a large number of species, would require improved biological knowledge of these stocks (species composition, abundance, spatial distribution, vital rates, and improved sampling and

[42] Relates to (SAPEA, 2017): Chapter 5 – Option 5
[43] See footnote to section 3.1.1 above
[44] Relates to (SAPEA, 2017): Chapter 5 – Option 5
[45] While this high estimate of 10,000 Mt is uncertain, an older conservative estimate of 1000 Mt is still considered to be a minimum

harvesting methodologies). It would also require the distribution of fishing over large ocean areas to avoid local depletions. Due to such constraints, the undertaking of limited and strongly-regulated precautionary trial fisheries could be justified.

3.4.6. Macroalgae[46]

Macroalgae such as seaweed and kelp constitute an important source of ocean biomass with food potential. Small scale hand harvesting is considered sustainable whilst large scale industrial mechanised harvesting has often had negative impacts on shore ecosystems (harvesting or killing species of plants or animals other than those targeted or resulting in disease risks). Improved technologies and management are needed to increase sustainable mechanised harvesting of wild populations which is currently one thirtieth the size of cultivated macroalgae (see (SAPEA, 2017): 3.1.4).

3.5. Management and governance[47]

The SAPEA Evidence Review Report states that *"[g]overnance change presents probably the single largest opportunity for growing food production from the sea"* (SAPEA, 2017, p. 77). The many complex governance arrangements and considerations that come into play call for context-specific measures and the possibility of drawing upon different potential approaches.

3.5.1. A Regulator's tool box[48]

To manage many aspects of fisheries and mariculture, there is a need for a "regulator's tool box" with a clear role for the juridical system. Complex difficulties need to be acknowledged in areas with a lack of political will and control of fishing activities. Perverse incentives need to be eliminated and illegal fishing stifled, for instance through improved legal action. There is

[46] Relates to see (SAPEA, 2017): Chapter 5 – Option 6
[47] For relevant evidence and references see (SAPEA, 2017): Chapter 4 and SAM (2017)
[48] (Scientific Advice Mechanism, 2017a); Relates to see (SAPEA, 2017): Chapter 5 – Option 11

also a need to reconcile both environmental and social policy aims (as further discussed below under 3.5.2 and 3.5.3). Harmonisation of standards, quality and traceability is also essential, in relation to both the licensing of mariculture firms and the establishment worldwide of a fair and level competitive playing field.

There is also a need to streamline licensing requirements in the mariculture sector, and especially to facilitate farming permits for molluscs/macroalgae where most growth potential lies.[49] Note in this regard that an international study of over 40 national and sub-national licensing and regulatory systems shows a negative correlation between aquaculture growth rate and administrative burden - see (Abate, Nielsen, & Tveterås, 2016; Innes et al., 2017).

In relation to the Common Fisheries Policy, there is also evidence for short comings and inefficiencies such as the mismatch between the lead-time to prepare and enact EU decisions and the pace of change on the ground or the efficacy of regulatory implementation and control exercised (Self, 2015; Ørebech, 2015; European Court of Auditors, 2017).

3.5.2. Implementing effective catch restrictions[50]

There is wide agreement among economists that rights-based management – an approach whereby fishers own some type of individual fishing right that reduces the "race to fish" – leads to higher quality fish, better selection for age classes and species, and smooths out supply over time.[51] This aim, however, need to be coupled with the equally widely-recognised need to reconcile and integrate both social aims and efficiency considerations in the careful design and application of *ad hoc* fisheries policies and management

[49] In addition, specific action and identification of best practice may be needed in relation to: minimizing the use of chemicals in some cases; improving vaccines; improving understanding of pathogen transmission mechanisms; *etc*. - with an eye to an integrated way of reviewing/ assessing risks and developing regulation.
[50] For relevant evidence and references see (SAPEA, 2017): 4.1.1 - Relates to Option 11
[51] Individual Transferable Quota (ITQs) could help to increase food from the ocean. Furthermore, they are economically beneficial, almost doubling the profitability of fisheries compared to the situation prior to their introduction. However, an ITQ system in fisheries works only if effective catch restrictions are set in place by the regulating authorities. Moreover, it leads to a restructuring of fisheries that is often socially undesirable, both in terms of increasing inequality among fishermen and in terms of concentrating fisheries in fewer ports.

measures. Specific measures to do so, as identified in the SAPEA Evidence Review Report and discussed in the Expert Workshop, include removing subsidies that reduce the long-term yield from a stock whilst potentially replacing some with investment grants, tax reduction or other incentives and tailoring quota systems to include a broad range of environmental and social goals. Effective examples include, trading efficiency for community development in community-based quotas or Territorial Use Rights in Fisheries (TURFs) and mechanisms for buy-back of quotas. Regulating fisheries by means of catch taxes or annually auctioned fishing permits may circumvent these problems while maintaining the benefits of a rights-based fishery management (see (SAPEA, 2017): 4.1.1). For wild-capture fisheries with decreased stocks, there is need for investment to increase long-term yields during the reduced-catch phase as stock are rebuilding. During this investment phase, fish consumption and employment in the fisheries will decrease and needs to be managed through other policy measures. However, as ecosystem viability constitutes the basis for fishing, it is important to highlight and manage for both the environmental and long-term positive economic net effects of rebuilding overfished stocks.

3.5.3. Market-based instruments[52]

Studies suggest that direct subsidies for marine food production should be used with caution, as they can have detrimental indirect effects. In particular, they can incentivise over-use of the natural environment thus decreasing ecosystem productivity. Today, as highlighted in the SAPEA Evidence Review Report, there is a broad consensus among scientists that most subsidies for wild capture fisheries should be abandoned. On the contrary, tailored taxation, meaning a tax (or fee) on fish catches could increase the efficiency and yields of fisheries, in particular if appropriately delineated according to the structure of fish populations. The reason is that a tax on fish catches sets the incentives to reduce fishing effort to more efficient levels that sustain the productivity of fish populations. Taxes may

[52] For relevant evidence and references see (SAPEA, 2017): 4.3.4 – relates to Option 17

be an appropriate regulation instrument when they are applied to increase the private costs of actions that harm the marine environment – such as over-exploitation of marine resources, but also marine pollution.

For activities that benefit the natural environment, remuneration payments may also be appropriate. Specifically, it makes economic sense to remunerate (not subsidise) the water purification service of the farming of filter feeders.[53] There may also be a case for subsidising research and technology development in different parts of the marine food production sector. Greening payments could play a limited role in promoting responsible fishing in terms of the implementation of the discard ban. Subsidies that would facilitate the purchase of new gear that allows for the better separation of target species from other species that are not being targeted but that have high survivability rates, could be beneficial as long as the gear to be replaced is permanently removed. In terms of mariculture, some form of green payment system could be developed. Similar to the greening of the Common Agricultural Policy, this would act as compensation for the additional environmental benefits that arise as a result of improved but more expensive marine farming approaches. Similar to wild fishing, subsidies and grants have been employed for decades to compensate for the high level of risks in the start-up of aquaculture farms, again with the aim of increasing overall production growth. An option could be to reorientate these payments toward green payments for innovation to reduce waste from production processes and to compensate producers for employing more expensive feed that uses fewer marine resources in its composition. Alternatively, reduction in tax liabilities for those operators who move to more responsible forms of mariculture is an option that could also be explored rather than green payments.

3.5.4. Improving social licence[54]

[53] *i.e.* Crustaceans, aquatic molluscs and other fish that feed by straining suspended matter and food particles from water
[54] For relevant evidence and references see (SAPEA, 2017): 4.2.2 – relates to Option 14

The growing literature on individual transferable quotas (ITQs) and on intensive salmon mariculture and its negative impacts on the environment and other users of related marine space has been little connected to the developing literature on financialization and to the literature on ocean grabbing within fisheries. However, specific neoliberal processes - including privatisation and marketisation (in herring fleet ITQs and mariculture lease systems), (re)regulation, financialization and globalisation - have interacted to support the reshaping of regional fisheries from mixed small-scale, family based, petty commodity fisheries towards vertically-integrated, corporate, financialized fisheries - to some extent characterised by ocean-grabbing. The term "social licence" is defined as the ongoing acceptance and approval of a development – such as a business enterprise – by local community members and other stakeholders, and stresses the central importance of obtaining public acceptance of bio-economic activity. In this understanding, large food corporations play a decisive role in determining the sourcing and provisioning of the food market and must develop further their public responsibility for sustainable marine foods. Industrial actors along the value chain of seafood need to identify crucial nodes of social responsibility and integrate adequate consultations.

External to the regulatory system, experts acknowledge the value of certification and eco-labelling as useful systems of signalling and social licence (see (SAPEA, 2017): 4.2).

3.5.5. Integrated planning and assessment[55]

Proponents of any nearshore or offshore marine activity – mariculture or other – must demonstrate that its environmental impact can be justified compared to the benefits of a no-take zone or alternative activities in the same place. Of course, different types of actors are involved in the offshore realm compared to nearshore areas.

[55] For relevant evidence and references see (SAPEA, 2017): 4.3 – relates to Options 12 and 15; see also *e.g.* Alexander et al, 2016; Ertör & Ortega-Cerdà, 2017

Established and emerging instruments (environmental impact assessment (EIA), certification, *etc*. - see Sim-Smith & Forsythe, 2013), can be crucial to transparent communication concerning the legitimacy of activities in terms of: who decides what, when, and what will be the likely short- to long-term consequences and trade-offs. Prominent in this regard in the EU is the on-going implementation of the Maritime Spatial Planning (MSP) directive, recognised in the literature as the best-available – even if not ideal – collective option available in this domain ((Flannery et al., 2016). In addition, (Brennan, Fitzsimmons, Gray, & Raggatt, 2014) stress that the practical orientation of MSP makes it a preferable instrument from a welfare perspective than the Marine Strategy Framework Directive (MSFD) which is primarily focused on conservation. MSP aims to facilitate efficient management, avoid conflict and create synergies between the different sectors and uses of the marine ecosystems. It is a key instrument of the Integrated Maritime Policy (IMP), given the increasing competition between various maritime sectors and increasing environmental concerns. It is relevant to: Integrated Coastal Zone Management (ICZM); regionalisation of marine governance to address land-sea interactions; and the need to integrate across sectors and levels of governance. It constitutes a welcome participatory knowledge-based approach involving increased cooperation between EU member states and neighbouring third countries.

Such processes should enable quick and effective decision making regarding approval or rejection of certain activities, and ensure a fair and level playing field for all stakeholders. Mariculture development, for instance, depends on the availability of sufficient appropriate[56] space where the costs of exploitation and regulatory compliance are compatible with the running of a competitive business. The sizes of protected reserve zones where commercial fishing is prohibited need to be carefully considered if dual benefits of population rebuilding and spill-over of specific species are desired.

[56] In terms of bio-physical characteristics (Gentry et al., 2017; Klinger, Levin, & Watson, 2017)

As Europe has long established fishing and coastal communities, a challenge with regard to multiple social and economic European aims is to find ways to boost ocean food production, by building upon rather than subverting existing expertise, manpower, and community structure. As most of available biomass that can be used for food production is concentrated in coastal areas within reach of existing fishing populations, labour-intense forms of harvesting - so called "technological subsidiarity" - are possible[57]. There are also opportunities for restoration and enhancement of coastal marine ecosystems, *e.g.* through the development of breakwaters, sea walls and other man-made structures along coastlines which is increasing worldwide to sustain commercial, residential and tourist activities as well as for protection from coastal erosion and sea level rise[58].

3.5.6. Benchmarking and deploying best practice[59]

In relation to uncertainties and cross-jurisdictional and geographical variations, there is potential for reviewing and extending (via new platforms and fora) best-practice examples across Europe and the globe, such as regarding the use of closed and open fishing areas, emulating best mariculture practices and regulation, and employing non-European integrated multi-trophic aquaculture practices and alternative feed development approaches (including *e.g.* the potential of food waste, insect-based systems). Education, information availability and co-management (see (SAPEA, 2017): 4.3.1) is essential to help bring about behaviour change in what people are prepared to eat. In this regard there is disconnect between those in the developing world who have little choice in what they eat and the fact that when they become richer, they tend to consume more land-produced protein, thus making it meaningless to deal with "food from ocean" separately from the rest of the food system.

[57] Relates to (SAPEA, 2017): Chapter 5 – Option 16
[58] Relates to (SAPEA, 2017): Chapter 5 – Option 18
[59] Relates to (SAPEA, 2017): Chapter 5 – Option 13

Recommendations

4. RECOMMENDATIONS

4.1. Mainstreaming "Food from the Oceans" into systems-level and global policy agendas

The relative neglect of "food from the ocean" considerations in key overarching policy frameworks is something of a policy blind spot. The EU can contribute to rectifying this via a combination of actions and advocacy taken within its own jurisdiction, in global policy forums and through its international programmes.

A necessary part of this is putting wild-capture (current fisheries and future capture of as-yet unexploited species) on a sustainable footing. However, this alone on the part of the EU, would correspond to an overall declining contribution to the proportion of human food harvested from the ocean. In the long run, the significance of Europe's role on the world stage will depend on the extent to which both its fishing and mariculture activities becomes leading sustainable sectors globally. To achieve this, notably in mariculture, important social and ecological conflicts need to be resolved. This requires fair and fully-inclusive decision and planning processes and sustained technical progress as well as drawing on the continent's strong innovation and investment capacities. Furthermore, such progress in the EU would create jobs and growth and reinforce regional cohesion.

Fisheries and mariculture development and the policy coherence and trade-off issues they raise, need to be optimised in broad policy approaches such as the Blue Growth Strategy in the EU (European Commission, 2012, 2017c) or along the lines described in the OECD's Green Growth in Fisheries and Aquaculture (OECD, 2015). But they also must be afforded full consideration in broader "food system", "ocean system" and "bioeconomy" contexts. This means, *inter alia*, joint system-level treatment of several sectors and policy objectives in conjunction with drivers of change such as climate and other such influences on sustainable development. It also means acknowledging that more food from the ocean to meet the need of present and future generations necessarily entails local changes in biodiversity just as agriculture does.

The HLG recommends:

To integrate the aspects of EU policy which touch on fisheries and mariculture into a cross-policy sustainable "food systems" framework

For this, seafood, agriculture and the intersections between the two systems (along the respective production cycles, in a circular economy rationale) should be optimised in terms of outcome with regard to ecosystem sustainability and the needs of producers and consumers. In particular, the development of a strong consumer focus alongside the traditional focus on production calls for policy attention to factors which promote or constrain changes in consumer choice – *i.e.* what they are willing to eat as food from the ocean moves to lower trophic levels. Steps towards such a food policy framework could be provided for in the EU's post-2020 Multiannual Financial Framework in which the budgets and objectives of the next phases of the Maritime & Fisheries Fund, the Common Agricultural Policy and other spending programmes in support of EU policy priorities will be determined.

To accentuate the food-generating capacity of the ocean in the EU's Integrated Maritime Policy (IMP)

To do so, within the frame of IMP, the EU should periodically rebalance the competing uses and trade-offs between the amenity values of marine and maritime resources and shift policy priorities in light of the evolving context and emerging needs, as well as other public-good considerations.

To apply the same integrated approach (as for food policy and Integrated Maritime Policy) to the EU's contribution to the attainment of the Sustainable Development Goals, its advocacy in other international arenas, and in supporting other regions of the world to strike a balance between competing socio-economic and ecological goals which touch on food and the marine environment

To ensure concerted action by the EU and its Member States in relation to food, fisheries and aquaculture development cooperation as foreseen in the European Consensus for Development

4.2. Integrated planning, assessment and informed decision making for a vibrant mariculture sector

Fostering fishing and mariculture, beyond food and ecology implications, should also take into account the human health, economic, social and cultural values of such activities for coastal communities, stakeholders (*e.g.* fishers, seafood industries) and society at large. This requires fair and inclusive application of Marine Spatial Planning and similar mechanisms (such as the Marine Strategy Framework Directive aimed at attaining "Good Environmental Status") for detailed holistic assessments of the full range of marine-based or marine-dependent activities including mariculture. Such integrated planning and assessment should give equal consideration to the social, ecological and economic implications of different – sometimes conflicting – uses and abuses of marine space[60] as well as to changes in response to related stressors[61]. This not only leads to trade-offs, but can also identify win-win multi-use and co-location options. To enable rapid growth of mariculture in Europe, it is essential for entrepreneurs and investors that sufficient amounts of appropriate space be made available. This applies in the short term to near-shore sites, and in the longer term to off-shore as mariculture in such locations becomes technically and economically viable. On-shore space availability is also required.

The EU Common Fisheries Policy emphasises wild capture but only partially addresses mariculture, where most potential growth in sustainable food supply lies. From a policy vantage point, subsidiarity must be respected and basic differences between wild capture and mariculture in terms of property rights, legislative and regulatory competences recognised. Notwithstanding this, there is scope and value in deploying stronger and proportionate effort

[60] Including fishing and mariculture and others – *e.g.* tourism, transport, pollution, energy
[61] Ocean temperature increase, acidification, sea-level rises, invasive species

at EU level to support a level playing field and increased attention to mariculture along with other aspects of Food from the Ocean - akin to agricultural policy or a broader food policy.

The HLG recommends:

To put in place a comprehensive and concerted policy framework for the development of sustainable mariculture in the EU which facilitates, amplifies and complements primary action and control at national and sub-national levels

This should aim to bring the sector in the EU up to a level and rate of growth commensurate with other leading countries in the world. It should position the sector to lead global expansion in new directions (*e.g.* Integrated Multi-Trophic Aquaculture, off-shore, moving down the trophic level).

The policy framework should take into account the full range of enabling factors which need to be addressed – investment, innovation, addressing cumulative effects and negative externalities, identification and designation of zones for mariculture through marine spatial planning, differences between different mariculture activities in terms of requirements and space, developing social licence and informing consumer acceptance[62] and cross-border effects - with due regard to subsidiarity.[63]

This approach should also consider establishing an EU-wide mariculture or "food from the ocean" platform, including public and private actors, consumer organisations and dialogue between fisheries and mariculture. It could emulate and build on best practices of similar initiatives.[64] Any existing or emerging trans-boundary cooperative actions, especially those involving regional and local authorities, should be integrated into this platform.

[62] Plus harmonisation of: standards, assessment time scales; basis for assessment; and quality and traceability requirements, according to which a mariculture licences are granted
[63] It should capitalize on the substantial efforts which have already been deployed (such as the on-going implementation of the 2013 EU aquaculture strategic guidelines), taking them to a higher strategic priority level.
[64] *e.g.* The Ocean Energy Forum, European Innovation Partnerships, *etc*.

To issue specific guidance on the inclusion of requirements for both near-shore and off-shore mariculture development in the implementation of the 2014 EU Directive on Maritime Spatial Planning

This could be facilitated by the aquaculture "Open Method of Coordination". It would help to ensure that mariculture considerations along with EU-wide coordination[65] are fully integrated into the national marine spatial plans due in 2021. Crucial to this is the involvement of sub-national regional and local actors and authorities where decisions are often made.

To extend technological cooperation in the sustainable fisheries partnership agreements (SFPAs) between the EU and southern partner countries to mariculture

4.3. Sustaining wild-capture - ensuring implementation of existing regulations and use of best practice

At the global or EU scale, on the basis of current state-of-the-art knowledge and eco-system constraints, the potential for increased food extraction from wild capture is lower than it is for mariculture. However, from a multiplicity of perspectives (social, economic, cultural, nutritional), it is important to maintain traditional wild capture fisheries. A *sine qua non* condition for this is to attain sustainability of all exploited stocks and ensure responsible practices over the full production-processing-distribution-consumption chain. In most of the developed world – though much less so in developing and underdeveloped countries - fisheries policies and management practices aim to achieve this, in spite of some shortcomings and inefficiencies. Furthermore, we are presently throwing away a lot of food, using misplaced incentives, and allowing legal loopholes to give rise to activities which are wasteful or harmful to the ocean. Such problems point to the need for better use of a regulatory tool box. SAM HLG is fully aware of the on-going efforts under the Common Fisheries Policy to achieve sustainability. However, on the basis of the scientific evidence, analysis and

[65] Using the Directive's trans-boundary cooperation requirement (Articles 6 and 11)

expert knowledge informing this Opinion, the SAM HLG deems that accelerated or amplified action in some areas should be considered.

The HLG recommends:

To continue to increase the efficiency and flexibility of the Common Fisheries Policy by building successful regionalisation of a number of instruments under current legislation[66] and extending it to others in line with the principle of subsidiarity

To continue to promote the understanding of and compliance with scientific advice for better fisheries management. In particular, this should entail strict observance of responsible fishing practices in order to ensure preservation of healthy marine ecosystems

To develop ways to monitor and assess the full extent of bycatch for all cases where species and biomass not covered by the landing obligation, go unrecorded, and are not landed/ used in any way

To continue to develop measures, based on a broad regulatory toolbox, to minimise unwanted bycatch (via more selective gear) and support the use of fisheries waste and bycatch, learning from best-practice

To consider extending and tailoring quota systems (such as trading efficiency for community development in community-based quota or "Territorial Use Rights in Fishing"), using tradeable quotas as well as quota buy-backs.[67] Rules should support monitoring and allow fishing to be adjusted to species currently existing in the area as well as avoiding quota lock-in for species that may no longer be present

[66] *e.g.* Multiannual plans, discard plans, establishment of fish stock recovery areas and conservation measures necessary for compliance with obligations under EU environmental legislation
[67] The aim would be to avoid fishers or fishing communities having to lease from others outside to go fish and avoid fishing retained at high levels only to get quota, as a matter of food security both at each fishing location and over longer term

To eliminate subsidies that reduce the long term yield from a stock, whilst easing the transition for those affected through use of, for instance, investment or grants with social benefits

To optimise and fully enforce the legal rules that facilitate and constrain the harvesting of food from the ocean, ensuring coherence, complementarity, consistency and data transparency across different categories of ocean space[68] and the relevant jurisdictions[69]

This may entail adding to the regulatory toolbox (*e.g.* legal notices, fines, pre-prosecution powers such as vessel immobilisation or licence revocation) available to monitoring and enforcement authorities to penalise and deter non-compliance and illegal activities (*e.g.* IUU - illegal, unreported and unregulated fishing). It could also include an integrated transboundary approach to data sharing on ocean crime.

4.4. Facilitating policy change

The changes to policy recommended above would require the building of strong stakeholder coalitions, a common knowledge base, best-practice exchange and communities of practice within the EU and beyond. Regarding the recognised uncertainties and large variations between systems and preconditions for fishing, mariculture and environmental protection, scientists point out the potential benefits of reviewing and extending good practices across Europe and the globe: *e.g.* extending the use of closed and open fishing areas; best mariculture policy development and practice; non-European examples of integrated multi-trophic mariculture and alternative – insect-based and others - feed development approaches. These types of approaches could be assessed and actioned through the Open Method of Coordination whereby best practice is shared between Member States, or

[68] Internal waters, territorial seas, exclusive economic zone, high seas
[69] Coastal states, flag states and fisheries management organisations

directly implemented through new action-oriented platforms such as the Blue Bioeconomy Forum involving industry and public sector actors.

The HLG recommends:

To use the Open Method of Coordination to identify practical policy measures which link global and broad system concerns (food systems, SDGs, *etc*.) to practical fishing and mariculture challenges

To develop incentives to help deploy throughout the EU transferable best practice in sustainable fisheries and mariculture, for instance through dialogue involving different stakeholder fora in the area, and to assure appropriate risk assessment

To ensure that the Blue Bioeconomy Forum serves as a stakeholder led forum – complementary to publicly-led initiatives - to identify, plan, pilot and test practical means of increasing the quantity and quality of food and biomass which is sustainably derived from the ocean

To ensure correct and accessible knowledge for consumers such as on geographical origins and traceability of food, via quality labels, certification[70] processes and other instruments

4.5. Future-proofing policy and extending knowledge

The SAPEA Evidence Review Report reveals considerable uncertainty in our basic knowledge of marine biological resources and how to assess and preserve them, particularly under ecosystem change conditions (*e.g.* ocean acidification, temperature and sea-level rise, invasive species or pest outbreaks, microplastic pollution and other impacts). When harvesting the ocean for food in such conditions, scientists agree that it is important to take into consideration the ecosystem interdependence of species rather than consider separate catch species in isolation, as has largely been the

[70] An example with relevance to the focus in this report is a new seaweed certification standard: https://improvements.msc.org/database/seaweed-standard/

case in fisheries management practices to date. The SAPEA Evidence Review Report also shows that science can shed light on the social and economic consequences of policy choices. It would therefore make sense for scientific advice to inform on trade-off implications of policy options affecting ecological, economic and social outcomes, including the consequences of giving primacy to one or other of these. In the case of some issues addressed in the evidence review – *e.g.* ecosystem management of fisheries, potential for re-direction of reduction fish to human consumption, the potential for ecosystem-compatible harvesting of heretofore unexploited wild stocks (mesopelagics, zooplankton, *etc*.) – many important knowledge gaps need to be filled. The Common Fisheries Policy is already well placed to align itself to this approach given the built-in legal obligation to act on the best available scientific advice.

The HLG recommends:

To develop the Common Fisheries Policy's scientific advice system in a direction which, in conditions of uncertainty, sheds light on the trade-off implications - in ecological, economic and social terms - of options available as well as extending this scientific advice model to other relevant "food from the ocean" policy frameworks

To the extent permitted by the evolving state-of-the-art, ecosystem and other integrated assessment approaches should be used to future-proof fisheries management against potentially shifting species and conditions. The feasibility of quantifying risks from, and potential utilisation of, circumstantial/ unintentional invasive species or species change under evolving climatic conditions should be explored. Ecosystem change should become a more established feature of the advice system – *e.g.* basing annual quotas reviews on ecosystem level assessments at least for new species as well as take into account fishing at the lower and much more productive levels of the food web.

To review the knowledge gaps indicated in the SAPEA report and this Opinion and consider how to fill them

To explore the granting of permits for scientifically-explorative pilot fishing of as-yet unexploited lower trophic level species at quotas well below the most conservative precautionary limits, in order to learn of their true commercial and nutritional potential and in the process fill knowledge and understanding gaps in cases where this is required in addition to academic research

Annexes

Annex 1 - List of contributing Experts and Stakeholder representatives consulted

Agnew	David	Science and Standards at the Marine Stewardship Council	UK
Aksnes	Dag Lorents	University of Bergen	NO
Andersen	Michael	Danish Fishermen PO	DK
Araujo	Rita	EC Directorate-General Joint Research Centre	IT
Arnason	Ragnar	University of Iceland	IS
Balzi	Elisabetta	EC Directorate-General for Research and Innovation	BE
Bankes	Nigel	University of Calgary	CA
Barange	Manuel	UN Food and Agriculture Organization	IT
Barragan Paladines	Maria Jose	Leibniz Centre for Tropical Marine Research	DE
Bavinck	Maarten	University of Amsterdam	NL
Biermann	Frank	Utrecht University	NL
Buckhout	Marc-Philip	Seas at Risk	BE
Cabaleiro	Santiago	Galician Aquaculture Technology Centre	ES
Charvoz Lienhart	Sylvie	The Mediterranean Sea Advisory Council	IT
Cury	Philippe	EuroMarine	FR
Danovaro	Roberto	Polytechnic University of Marche	IT
Denis	Isabelle	UN Food and Agriculture Organization	BE
Fournier	Nicolas	Oceana	BE
Frieler	Katja	Potsdam Institute for Climate Impact Research	DE
Froese	Rainer	Helmholtz Centre for Ocean Research Kiel	DE
Gruber	Sieglinde	EC Directorate-General for Research and Innovation	BE
Guillaumie	Bruno	European Mollusc Producers Association	FR
Harvey	Patricia	University of Greenwich	UK
Hemre	Gro-Ingunn	National Institute of Nutrition and Seafood Research in Norway	NO
Hoermandinger	Guenter	EC Directorate-General for Environment	BE
Holm	Poul	Trinity College Dublin	IE
van Hoof	Luc	Wageningen University & Research	NL
Hough	Courtney	Federation of European Aquaculture Producers	BE
Hynes	Stephen	National University of Ireland Galway	IE
Iglesias	Marta	EC Directorate-General for Research and Innovation	BE
Ingram	John	University of Oxford	UK

Kaiser	Carl	University of Bergen	NO
Kaiser	Matthias	University of Bergen	NO
Kalesi	Kalliopi	Seafood Innovation Cluster	NO
Kaushik	Sachi	French National Institute for Agricultural Research	FR
Keatinge	Michael	Seafood Development Agency - BIM	IE
Krause	Gesche	Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research	DE
Lapegue	Sylvie	Institut Français de Recherche pour l'Exploitation de la Mer	FR
Larkin	Kate	European Marine Board	BE
Lion Vazquez	Monica	International Organization for Fisheries, Aquaculture and other Marine Proteins	ES
Linsen	Max	EC Directorate-General for Climate Action	BE
Lopez Abellan	Luis	Spanish Institute of Oceanography	ES
Mac Aoidh	Eoin	EC Directorate-General for Maritime Affairs and Fisheries	BE
MacDiarmid	Alison	National Institute of Water and Atmospheric Research	NZ
Mangan	Ciaran	EC Directorate-General for Research and Innovation	BE
Marti Dominguez	Carmen-Paz	European Parliament, DG Internal Policies of Union	BE
Martinsohn	Jann	EC Directorate-General Joint Research Centre	IT
McDonough	Niall	Irish Marine Institute	IE
Moalla	Nadia	Europêche	BE
Olsen	Yngvar	Norwegian University of Science and Technology	NO
Österblom	Henrik	Stockholm University	SE
Pastoor	Guus	Market Advisory Council	BE
Pastoors	Martin	Pelagic Freezer-trawler Association	NL
Prent	Paulien	Visfederatie	NL
Quaas	Martin	Kiel University	DE
Quintas	Mafalda	COST Association	BE
Rakels	Stephanie	Aqua Spark	NL
Reale	Paola	EC Directorate-General for Research and Innovation	BE
Robben	Geert	Aquaculture Stewardship Council	NL
Schmidt	Daniela	University of Bristol	UK
Shepherd	Iain	EC Directorate-General for Maritime Affairs and Fisheries	BE
Sipic	Katarina	Conexmar	ES
Sorgeloos	Patrick	Ghent University	BE

Sparholt	Henrik	International Council for the Exploration of the Sea	FR
St John	Michael	Technical University of Denmark	DK
Steele	Susan	Sea Fisheries Protection Authority	IE
Treinyte	Skirmanta	Good Fish Foundation	NL
Viallon	Isabelle	EC Directorate-General for International Cooperation and Development	BE
Wood	Jacqueline	JPI Oceans	BE
Zampoukas	Nikolaas	EC Directorate-General for Research and Innovation	BE
Ziemssen	Fabio	Metro Group	DE
Zito	Anna	EC Directorate-General for Maritime Affairs and Fisheries	BE

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This Scientific Opinion responds to a request from the European Commission formulated by Commissioner Karmenu Vella (Environment, Maritime Affairs and Fisheries) for scientific advice on how more food and biomass can be obtained from the oceans in a way that does not deprive future generations of their benefits.

The Scientific Opinion is based on a detailed analysis of publicly-available scientific evidence and literature as well as close consultation with the scientific community. In particular, it is informed by an accompanying Evidence Review Report produced by SAPEA, an independent, Horizon-2020-funded consortium of European scientific academy networks, which constitutes a key component of the European Commission's Scientific Advice Mechanism.

The advice takes the form of five sets of recommendations.

The first calls for mainstreaming a "food from the ocean" paradigm based on responsible culture and capture, into a broad food systems policy framework, as well as into other relevant EU and global systems-level policy agendas. Reflecting the fact that scientific evidence points to mariculture (marine aquaculture) as having the biggest potential to increase food from the ocean, the second set pertains to the development of mariculture globally. As far as Europe's part in this is concerned, this would require raising the strategic priority of mariculture and bringing all available means to bear on facilitating its development – notably marine spatial planning and other such integrated planning and assessment tools. The importance of the continued development of responsible fisheries management and maintaining marine ecosystems is reflected in a set of recommendations aimed at sustaining wild-capture. A fourth set aims at facilitating policy change by optimizing the use of instruments such as the Open Method of Coordination as well as the forthcoming Blue Bioeconomy Forum. The final set targets future-proofing policy by recommending further development of the Common Fisheries Policy science advice system and actions to fill key knowledge gaps such as scientifically-motivated pilot fishing of as-yet unexploited lower trophic-level species.

This Scientific Opinion will inform preparation for the successor of the present European Maritime and Fisheries Fund and, more broadly, policy development and implementation in the coming years to help increase responsible harvesting of food from the ocean.

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