Assessing the Economic Value of Advancing Ecosystem Conservation and Stewardship in the Sargasso Sea

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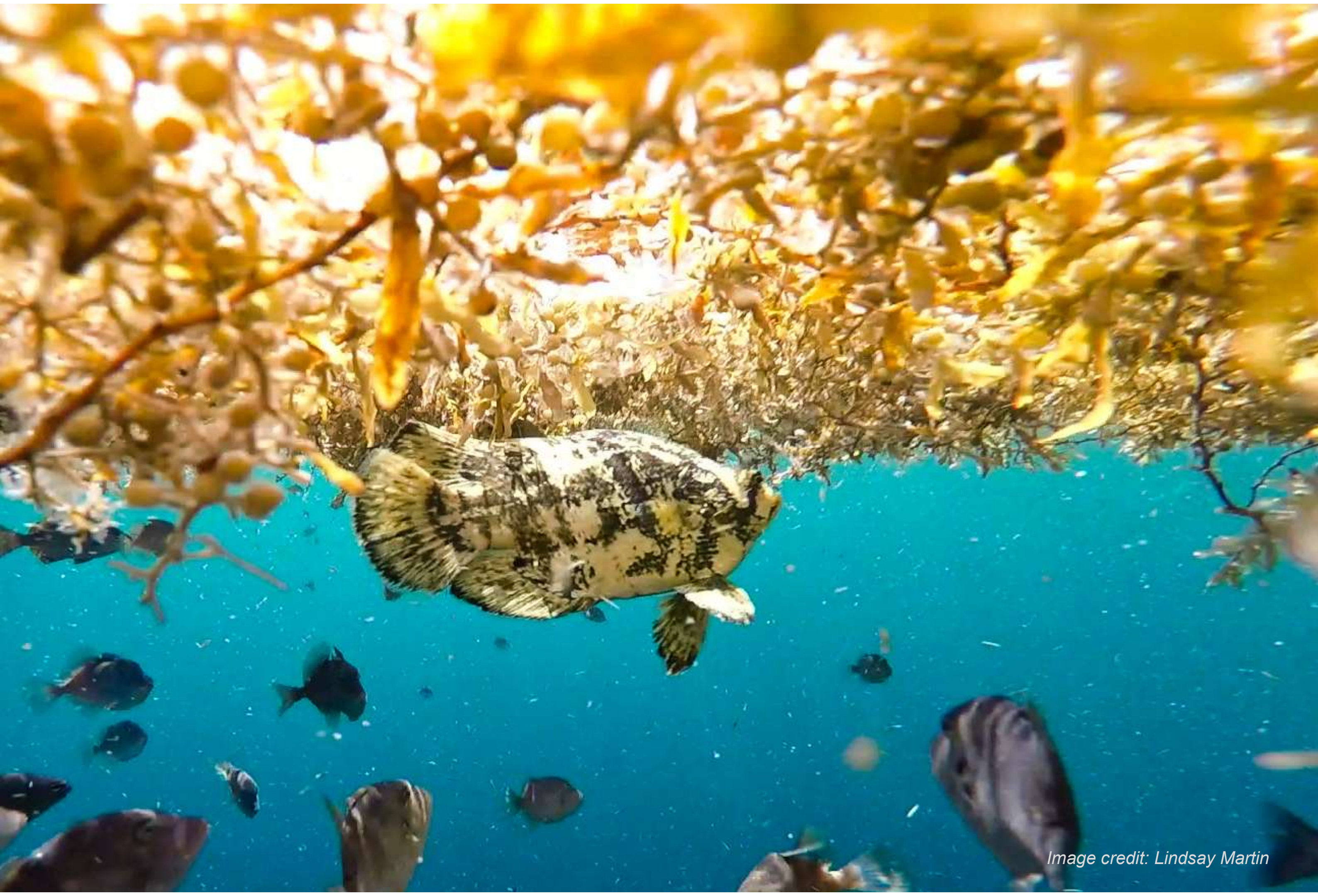

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The Sargasso Sea Commission is an Independent Group of Experts appointed by the Government of Bermuda on the recommendations of the Government Signatories of the 2014 Hamilton Declaration. This report does not necessarily represent the views, policies, or positions of the Signatories to the Hamilton Declaration on Collaboration for the Conservation of the Sargasso Sea.

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Executive Summary

The global ocean economy reached a record US$2.2 trillion in exports in 2023, supporting over 600 million jobs worldwide – without fossil resources such as oil and gas. At the heart of the growing ocean economy lies the Sargasso Sea, a unique marine ecosystem located within the North Atlantic subtropical gyre. Encompassing Bermuda and vast Areas Beyond National Jurisdiction, it is ecologically and economically significant. Its ecosystems, dominated by floating Sargassum seaweed, provide essential ecosystem services, benefitting people and organizations all around the globe. Examples include carbon sequestration, oxygen production, habitat and nursery services for a plethora of marine fish, reptile, invertebrate and mammal species, of which many are commercially important. Despite its remoteness, the Sargasso Sea´s influence extends across the Atlantic through interconnected biochemical and ecological processes.

However, the Sargasso Sea faces growing threats from overfishing, shipping, pollution, climate change, ocean acidification and deep-sea mining. Historically lacking formal protection, being an Area Beyond National Jurisdiction (ABNJ), it gained a new conservation framework through the BBNJ Agreement[1] which was open for signature in 2023 and comes into force in January 2026.

To better protect this unique ecosystem, in 2010 the Sargasso Sea Alliance was founded under the leadership of Bermuda, uniting international governmental and non-governmental organizations. Its efforts culminated in the 2014 Hamilton Declaration, signed initially by five governments (later expanded to ten). The Hamilton Declaration created the “Sargasso Sea Commission”, a voluntary, non-binding body tasked with facilitating collaboration and stewardship through education, research, and coordination rather than regulation. In 2018, the Commission launched a comprehensive Socio-Ecosystem Diagnostic Analysis to assess the Sargasso Sea’s ecological and economic value. Backed by the Global Environment Facility and UNDP, the 2022 project “Strengthening the Stewardship of an Economically and Biologically Significant High Seas Area – The Sargasso Sea” supports evidence-based management and sustainable use[2].

A part of this “Stewardship Project” is the economic valuation of ecosystem services — the direct and indirect benefits ecosystems provide to humanity. A second part is a broader assessment and cost-benefit analysis of advancing ecosystem conservation and stewardship in the Sargasso Sea.

Ecosystem services include provisioning services (food, raw materials), regulating services (climate regulation, carbon capture), cultural services (recreation, heritage), and supporting services (nutrient cycling, nursery habitats). Despite their importance, many of these services are undervalued or excluded from economic decision-making, leading to unsustainable exploitation. Assessing high-seas ecosystem services such as those of the Sargasso Sea is, however, challenging due to limited data, ecological connectivity with coastal areas, and the migratory nature of marine species. The economic valuation of the Sargasso Sea’s ecosystem services applies the GEF Guidance Document to Economic Valuation and the Total Economic Value (TEV) framework, adapted to the specific conditions of a high-seas ecosystem. The TEV approach distinguishes between use values (direct and indirect economic benefits, such as fishing or carbon sequestration) and non-use values (altruistic, bequest, and existence values). This framework ensures that both market and non-market benefits of the Sargasso Sea are captured. The valuation covers the Sargasso Sea Geographical Area of Collaboration

[1] Agreement under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction

[2] https://www.thegef.org/projects-operations/projects/10620

(SSGAC) — the high-seas portion of the Sargasso Sea, including the seabed — excluding Bermuda's coastal and EEZ waters. Ecosystem services assessed include commercial fishing, tourism and recreation, carbon sequestration, oxygen production, education and research, and existence and biodiversity values.

While the analysis focuses on ecosystem benefits, it recognizes that human activities such as overfishing, pollution, and seabed mining create ecological and economic costs that must also be considered in policy decisions.

Significant uncertainties arise from scarce data, ecosystem complexity, and spatial variability in productivity across the high-seas. The study therefore clearly communicates assumptions and limitations, noting that ecosystem service values are not uniform throughout the Sargasso Sea. For example, fisheries data drawn from global sources such as Sea Around Us may have low spatial precision due to coarse reporting by regional management bodies. Overall, the methodology emphasizes scientific rigor, transparency, and adaptability, aligning with global best practices while addressing the unique challenges of valuing ecosystem services in the high-seas.

According to the economic valuation conducted in the frame of the Sargasso Sea Stewardship Project, the directly attributable monetary value of the ecosystem services provided by the Sargasso Sea GAC ranges from 2.67 to 15.49 billion USD/year. This number, however, should be regarded as a lower boundary estimation – the real value is presumably much higher, as various services or aspects of services could not be valued, or not completely valued. These include:

- The figure does not include a value for tourism in Bermuda, which is certainly partly dependent on a healthy Sargasso Sea.
- Wider effects of the SSGAC ecosystems – for whale, bird and turtle watching in the Atlantic, or for sports fishing in Bermuda´s, the US´s or Caribbean coastal waters – are not included. Whale watching in the North Atlantic alone is valued around 500 million USD/year, while sports fishing on the US Atlantic is valued 17.3 billion USD/year.
- Also not included in the figure is the abiotic share of carbon capture and storage, worth another 12.8 billion USD/year.
- The potential value of Marine Genetic Resources and bioprospecting is not included but particularly relevant under the BBNJ framework.
- The values cited for fisheries are probably serious underestimates (e.g., in the case of eels), or include not all species caught (as in the case of the fisheries values, based on nine tuna and tuna-like fish species alone).
- The value of the ecosystem services of the deep-sea are not included in the figure.
- Values of the SSGAC for research, education and its existence value are not included either. Based on the stated preference of people asked, the "cultural value" of the SSGAC reaches 67.8 billion US/year.

Regardless, it is obvious that the Sargasso Sea GAC provides values worth millions and billions of US Dollars in Bermuda, in the wider Atlantic region, the Caribbean and US East Coast, as well as for companies and countries all around the world.

The second part of the study builds upon the economic valuation and assesses current and future pressures on the SSGAC, including climate change, habitat degradation, overfishing, shipping impacts, pollution, and potential deep-sea mining. Under a business-as-usual scenario, these pressures could lead to substantial declines in biodiversity, fisheries productivity, tourism value, and key ecosystem services by 2075. Recent international progress — particularly the 2023BBNJ Agreement— provides a new legal basis for establishing Marine Protected Areas (MPAs) and Environmental Impact Assessments (EIAs) in areas beyond national jurisdiction. However, governance of the SSGAC remains dispersed across sectoral bodies (e.g., IMO, ICCAT, ISA), leaving major protection gaps.

To guide development of a Strategic Action Programme (SAP), this analysis outlines initial management options and associated cost-benefit considerations. These include enhanced EIAs, stronger monitoring and bycatch reduction in fisheries, trade controls to reduce IUU fishing, and the creation of weak or strong MPAs depending on the level of protection sought. Stronger measures offer the greatest ecological and economic benefits but may entail higher short-term costs and political challenges.

The second part concludes with recommendations for the SAP process:

- define priority pressures and areas requiring protection;
- expand and refine the list of conservation options;
- develop step-wise socio-economic assessments of costs and benefits;
- integrate expert and stakeholder input to ensure feasibility and acceptance.

Overall, the analysis provides a foundational framework for improving stewardship of the Sargasso Sea through coordinated, cross-sectoral management and evidence-based conservation planning.

Abbreviations

ABNJ	Areas Beyond National Jurisdiction
APEIs	Areas of Particular Environmental Interest
BAU	Business As Usual
BBNJ	Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction
BT	Benefit Transfer
CBD	Convention on Biological Diversity
CICES	Common International Classification of Ecosystem Services
CE	Choice Experiment
CV	Contingent Valuation
EBSA	Ecologically or Biologically Significant Area
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIFAAC	European Inland Fisheries and Aquaculture Advisory Commission
FFEM	French Facility for Global Environment
GEF	Global Environment Facility
ICCAT	International Commission for the Conservation of Atlantic Tuna
ICES	International Council for the Exploration of the Sea
IMO	International Maritime Organization
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
ISA	International Seabed Authority
IUCN	International Union for the Conservation of Nature
KBA	Key Biodiversity Area
MA	Millennium Ecosystem Assessment
MAES	Mapping and Assessment of Ecosystems and their Services
MPA	Marine Protected Area
MARPOL	International Convention for the Prevention of Pollution from Ships
NAFO	Northwest Atlantic Fisheries Organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service

OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
POPs	Persistent Organic Pollutants
PSSA	Particularly Sensitive Sea Areas
REMPs	Regional environmental management plans
RFMO	Regional Fisheries Management Organization
SAFMC	South Atlantic Fishery Management Council
SAP	Strategic Action Programme
SCC	Social Costs of Carbon
SEA	Strategic Environmental Assessment
SEDA	Socio-Ecosystem Diagnostic Analysis
SDGs	Sustainable Development Goals
SSGAC	Sargasso Sea Geographical Area of Collaboration
TDA	Transboundary Diagnostic Analysis
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total Economic Value
UNEP	United Nations Environment Programme
UNFSA	United Nations Fish Stocks Agreement
USD	United States dollars
VME	Vulnerable Marine Ecosystems
WTP	Willingness-To-Pay

Introduction

In 2023, the “ocean economy” – total ocean trade excluding offshore oil and gas - hit a record of 2.2 trillion US Dollars in exports. It is much more than just fishing boats and cargo ships, as it powers industries from tourism and pharmaceuticals to biotechnology and clean energy, supporting over 600 million jobs worldwide. Since 1995, the ocean economy has grown 2.5 times, outpacing the 1.9-fold expansion of the overall world economy, with developing economies driving much of this growth. New UN Trade and Development (UNCTAD) data shows that while tourism (33%) and shipping (22%) remain the dominant sectors, high-tech and manufacturing industries are gaining ground, now making up 16% of ocean trade. These include pharmaceuticals, marine sports, clean energy and electrical equipment (see figure 1).

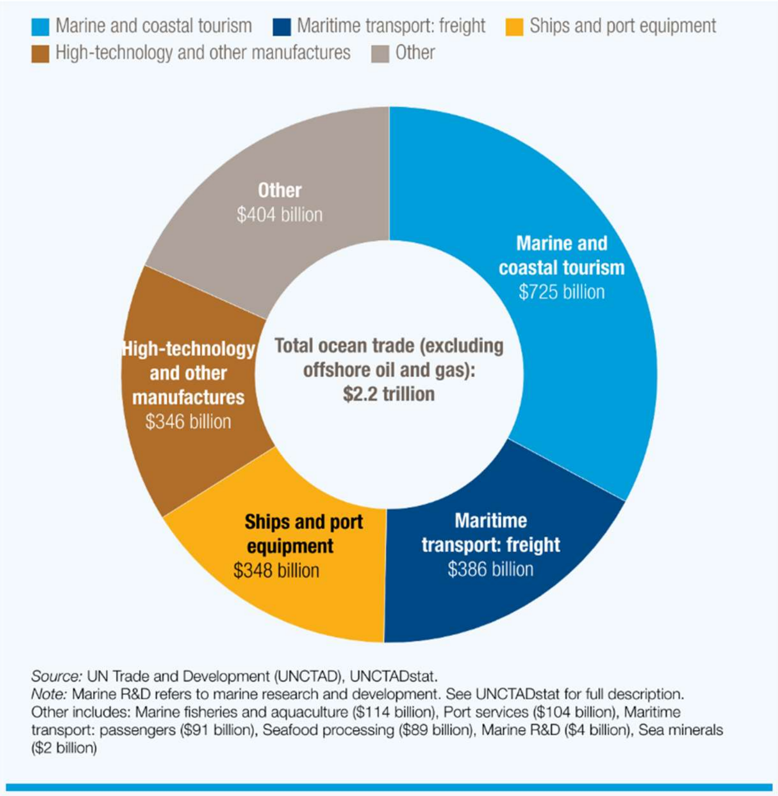

Figure 1: World ocean goods and services exports 2023 (US Dollars)

New industries are also emerging. A $10.8 billion market for marine-based plastic substitutes is taking shape, offering economic gains and environmental benefits. Marine biotechnology, a market valued at $4.2 billion in 2023 and projected to reach $6.4 billion by 2025, is expanding with innovations in low-carbon (footprint) marine foods, new antibiotics and bio-based materials (UNCTAD 2025).

The Sargasso Sea is a vital part of the world’s oceans and the “ocean economy”. It is an oceanic ecosystem (ABNJ) internationally recognized as a fundamentally important part of the global ocean because of its role in climate regulation and its unique ecology. It is bounded by the currents associated with the North Atlantic gyre, a circular ocean current. The Sargasso Sea is named for *Sargassum*, a holopelagic, golden drift algae that can aggregate to form extensive floating mats on the surface of the ocean, which has caused it to be referred to as “the golden rainforest of the ocean” (Laffoley et al. 2011). The Sargasso Sea provides habitats, spawning areas, migration pathways and feeding grounds to a diverse assortment of flora and fauna, including endemic, endangered and commercially important species. The Sea´s significance comes from the interplay of its physical structure, its ecosystems, its role in global oceanic and Earth system processes, its contributions to scientific research, and last not least the socio-economic and cultural values and ecosystem services it provides (SEDA; Laffoley et al. 2011).

Marine ecosystems provide a range of valuable goods and services – “ecosystem services” - which benefit people in various direct and indirect ways. Some of these ecosystem services have a direct, measurable commercial value, such as commercial fish stocks and tourism driven by wildlife viewing. Other ecosystem services offer both direct economic and indirect and recreational benefits, such as recreational fishing. Additionally, high-seas ecosystems support critical ecological functions essential for human life, such as oxygen production and carbon capture and storage. These ecosystems are also rich in genetic diversity and biological compounds, which hold potential for new chemical and pharmaceutical discoveries (Pendleton et al. 2014).

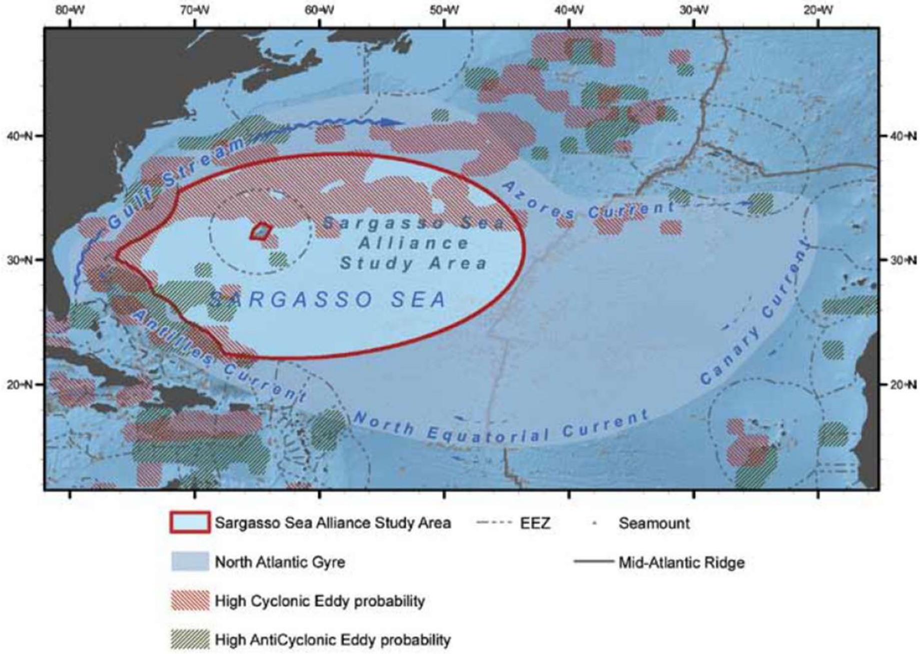

Figure 2: Boundaries of the Sargasso Sea (Ardron et al. 2011, unpublished)

Background

Despite its importance, the Sargasso Sea faces threats from various human activities that either directly harm it – like over-fishing, shipping and pollution - or pose potential risks, like climate changes and related processes (ocean acidification, for example), deep-sea mining or large-scale *Sargassum* extraction.

Bermuda lies in the centre of the Sargasso Sea and is an overseas territory of the United Kingdom. It claims a 200 nm EEZ of some 180,000 square nm. Beyond the Bermudian EEZ, however, the remainder of the Sargasso Sea is an Area Beyond National Jurisdiction (ABNJ), which includes both the "high seas" water column and the seabed "area" as defined in UNCLOS. There is no regional marine environmental treaty framework (like e.g. OSPAR in the North Atlantic), or regional fisheries agreement (like the North-East Atlantic Fisheries Commission) in place for this part of the Atlantic, although the Western and Central Atlantic Fisheries Commission (WECAFC) currently has an advisory competence and is in the process of negotiating a change of status to a management body. Two active Regional Fisheries Management Bodies have oversight on fisheries catch limits and allowable target species in the ABNJ for the Sargasso Seas, being NAFO and ICCAT. As in all ABNJ, IMO and the International Seabed Authority also maintain a level of regulatory competence and jurisdiction. In order to address concerns related to this general absence of any management authority or effective conservation measures, the Sargasso Sea Alliance was formed in 2010 under the leadership of the Government of Bermuda to bring together governments and non-government actors with a commitment to environmental protection in the Sargasso Sea (SEDA).

The Sargasso Sea Alliance aims to bring together governments and non-government actors with a commitment to environmental protection in the Sargasso Sea. Other members of the

Alliance were IUCN, Woods Hole Oceanographic Institution, WWF International, the Marine Conservation Institute and the Mission Blue/Sylvia Earl Foundation, together with the Bermuda Underwater Exploration Institute, the Bermuda-based Atlantic Conservation Partnership and the Bermuda Institute for Ocean Sciences. The small secretariat, headed by an Executive Director, was established in 2010 in the IUCN office in Washington DC. The Alliance had three key objectives:

- to build a partnership to secure international recognition of the ecological significance of the Sargasso Sea and the threats that it faces,
- to use existing regional, sectoral and international organizations to secure a range of protective measures for all or parts of the Sargasso Sea to address key threats; and
- to use the process as an example of what can and cannot be delivered through existing institutions in ABNJ (SEDA).

In 2014, five governments (Azores, Bermuda, Monaco, UK, USA) initially signed a non-binding political statement committing to collaborative conservation. The so-called Hamilton Declaration a) authorized creation of the Sargasso Sea Commission to act as steward and b) established a light institutional structure with voluntary contributions. It later expanded to ten signatories by 2018. The Hamilton Declaration was not intended to establish a new international organization with the authority to adopt binding measures, nor to include any mandatory financial commitments. The Commission to be created instead has an essentially custodial and educative role, has legal status under Bermudian law rather than international law, and receives support solely through voluntary contributions. The Declaration envisaged a light institutional structure with a regular Meeting of Signatories, a Commission and a Secretariat “to assist the Commission and the Signatories” (SEDA).

The Sargasso Sea Commission was established pursuant to the Hamilton Declaration and essentially replaced the Sargasso Sea Alliance. The Commission aim is to “encourage and facilitate voluntary collaboration toward the conservation of the Sargasso Sea.” It is an innovative structure that brings together governmental signatories of the Hamilton Declaration (Signatories) and independent scientific experts (Commissioners) to collaborate on the conservation of the Sargasso Sea. The work programme of the Commission is developed during bimonthly meetings of the Signatories and Commissioners separately, as well as joint meetings (SEDA).

In 2018, the Sargasso Sea Commission and its Members decided to review the evidence that this area constitutes one of the world’s priority oceanic ‘ABNJ’ marine ecosystems; undertake a detailed diagnostic analysis of its global significance and the impacts, threats and root causes; and develop a Socio-Ecosystem Diagnostic Analysis (SEDA) for management of this unique area through a process of mutual agreement and voluntary regulation by the various stakeholders. This plan of action was then presented to the Global Environment Facility (GEF) through the United Nations Development Programme for funding support. In August 2022 a formal project document was signed with GEF and UNDP. This project is entitled “Strengthening the Stewardship of an Economically and Biologically Significant High Seas Area – The Sargasso Sea” (SEDA).

The Sargasso Sea Stewardship Project aims to facilitate a collaborative, cross sectoral and sustainable stewardship mechanism for the Sargasso Sea through improvement of the knowledge base and strengthened frameworks for collaborative governance. Part of the project is a “Socio-Ecosystem Diagnostic Analysis” (SEDA), an evolving process that has and is being modified from the existing standard Transboundary Diagnostic Analysis and Strategic Action Programme (TDA-SAP) development and implementation process, which has been tried-and-tested and refined over nearly three decades under the Global Environment Facility (GEF) International Waters focal area.

In order to effectively bridge the scientific and economic findings in the SEDA and the consequent SAP, an Ecosystem Valuation process can demonstrate the value of better management (and equally the potential loss in its absence). Hence, this report links the SEDA to the upcoming SAP for improved stewardship of this area. It has two parts:

- The first part consists of an Economic Valuation of the SSGAC´s ecosystem services.
- The second part consists of a cost-benefit analysis of potential strategies for strengthening conservation and stewardship in the Sargasso Sea. A full cost benefit analysis of conservation measures is not possible at the moment, because at this point in the process, the full details of the conservation measures which might be appropriate are not available. Instead, this part includes estimations of the impacts/changes to the value of ecosystem services and natural capital expected in an “business-as-usual” (no change in management) scenario and options for an improved conservation and stewardship strategy for the Sargasso Sea and relevant initial cost- and benefit-categories. This will serve as input to the creation of the SAP and as a foundation for a possible later more detailed quantification of the costs and benefits of more effective management and stewardship.

Part 1: An Ecosystem Valuation of the Goods and Services provided by the Sargasso Sea

What are Ecosystem Services, and why evaluate them?

"Ecosystem services" are the many and varied benefits that humans obtain from the natural environment and from properly-functioning ecosystems - for free. The present idea and concept of ecosystem services was developed and described in several important reports and publications, starting in the late 1990s with publications by, for example, Costanza et al. (1997) and Daily (1997, 2000). The concept was covered globally in considerable detail by the United Nations´ "Millennium Ecosystem Assessment" (MEA 2005), and in an increasing number of publications from that point forward. More recently, the TEEB Report ("The Economics of Ecosystems and Biodiversity"; De Groot et al. 2009), particularly the "TEEB for Water and Wetlands" (Russi et al. 2013), along with several international initiatives. These initiatives include the UN´s Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), the EU´s Common International Classification of Ecosystem Services (CICES) and the EU´s Mapping and Assessment of Ecosystems and their Services (MAES) initiative, all of which are underlining the potential of the concept for sustainable policy and decision making (Interwies/Görlitz 2019).

In the TEEB report, ecosystem services are categorized into four broad categories, representing different "services" or "goods" that are provided by different ecosystems/habitats (see figure 3).

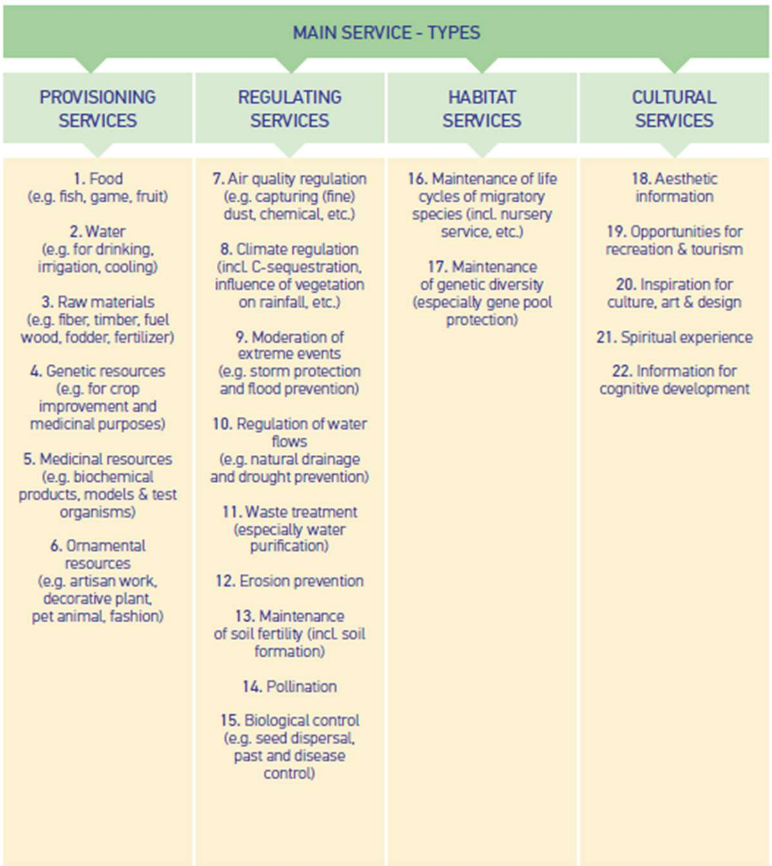

Figure 3: Ecosystem Services in the TEEB Report

Ecosystem services are crucial for the well-being of people, but their contribution to economic systems is difficult to quantify in monetary terms. Since some of them are not quantified (e.g., not traded in commercial markets), they are often given too little (or no weight at all) in decision making, e.g., in the course of the development of big infrastructure projects. Thus, final decisions may favor outcomes which do have a commercial value, turning unsustainable use of ecosystems more profitable in a short term while having considerable economic long-term costs.

Economic valuation is a tool for valuing ecosystems and their services in monetary terms. It quantifies the benefits provided by ecosystems and the impact of ecosystem changes on the wellbeing of people. However, economic evaluations can be resource-intensive, and significant expert´s knowledge is needed to conduct an analysis “from scratch” (an “original valuation study”, collecting primary data/empirical knowledge through field research).

High-Seas Ecosystem Services

The high-seas generate a wide variety of ecosystem services – Rogers et al. (n. D.) identified and defined 15 types of marine ecosystem services, building on the framework of categories of marine ecosystem services from other publications, but excluding marine ecosystem services that are exclusively coastal (see figure 4).

Ecosystem Service (ES) Category	Definition
Provisioning services	
1. Sea Food (see Case Study on High-Seas Fisheries)	All available marine fauna and flora extracted from the high seas for the specific purpose of human consumption as food
2. Raw Materials	The extraction of any biologically mediated material from the high seas, excluding material covered by ES 5
3. Genetic Resources	Any material that is extracted from the high seas for use in non-marine, non-medicinal contexts, excluding the research value associated with ES 15
4. Medicinal Resources	Any material that is extracted from the high seas for its ability to provide medicinal benefits, excluding the research value associated ES 15
5. Ornamental Resources	Any material extracted from the high seas for use in decoration, etc.
Regulating Services	**Definition**
6. Air Purification	The removal from the air of natural and anthropogenic pollutants by the high seas
7. Climate Regulation (see Case Study on Carbon Sequestration)	The contribution of the biotic elements of the high seas to the maintenance of a favourable climate via its production and sequestration of climate-influencing substances
8. Waste Treatment	The bioremediation by the high seas of anthropogenic pollutants
9. Biological Control	The contribution of the high seas to the maintenance of natural, healthy population dynamics that support ecosystem resilience by maintaining food webs
Habitat Services	**Definition**
10. Lifecycle Maintenance	The contribution of the high seas to migratory species’ populations through the provision of essential habitat for reproduction and juvenile maturation
11. Gene Pool Protection	The contribution of the high seas to the maintenance of viable gene pools through natural selection/evolutionary processes
Cultural Services	**Definition**
12. Recreation and Leisure	The provision of opportunities for recreation and leisure that depend on the state of the high seas
13. Aesthetic Information	The contribution that the high seas make to the existence of a surface or subsurface landscape. This includes informal Spiritual Experiences but excludes that which is covered by ES 12, 14, and 15
14. Inspiration for Culture, Art and Design	The contribution that the high seas make to the existence of environmental features that inspire elements of culture, art, and/or design. This excludes that which is covered by ES 5, 12, 13, and 15
15. Information for Cognitive Development	The contribution of the high seas to education, research, and learning. This includes contributions of the high seas to the research into ES 3, ES 4

Figure 4: High-Seas Ecosystem Services according to Rogers et al. (referenced Case Studies are detailed in the publication itself)[3]

However, to accurately value high-seas marine ecosystem services can be challenging. Reasons are a lack of scientific information about the provision and use of most high-seas ecosystem services and their quantity and nature, and even a lack of knowledge regarding how and where, precisely, they are produced. The high-seas support economically important species that may swim, migrate or drift beyond the physical boundaries of the area under investigation, or migrate between high-seas and coastal areas/EEZs (”connectivity”). Also, the Sargasso Sea has numerous chemical and physical interactions with surrounding marine

[3] Carbon sequestration is only a part of the climate regulation service that the high-seas provide – a far greater impact is the absorption of additional heat energy due to climate change.

areas via ocean currents and even atmospherically. This makes it difficult to disentangle the contribution of high-seas ecosystems to the services that are produced in the high-seas but are enjoyed elsewhere. Many high-seas ecosystem services are not enjoyed directly in all contexts. Instead, in some contexts, many play an intermediate role in the creation of ecosystem services elsewhere (e.g. high-seas ecosystems support prey that are consumed by commercially important fish species which are harvested elsewhere and provide migratory routes for vulnerable/endangered species and those that are of significant value to tourism such as cetaceans) (Rogers et al., n. D.).

Methodology

The economic valuation of the Sargasso Sea´s ecosystem services generally follows the approach outlined in the GEF Guidance Document (Interwies/Görlitz 2019), though adapted to the specific circumstances of the Sargasso Sea, especially with regard to it being a high-seas ecosystem.

The valuation understands "ecosystem services" in the frame of the Total Economic Value (TEV) concept. The TEV is a common approach in the field of environmental economics, a useful tool for exploring what types of values each ecosystem service provides. This helps in determining the valuation methods required to capture these values (Hoagland et al. 2006; DEFRA 2007; Plottu/Plottu 2007). It classifies ecosystem services into "use" and "non-use values":

- USE VALUES
    - Direct use value: Individuals make use of a resource in either a consumptive way (e.g., the fishing industry) or a non-consumptive way (e.g., cooling water).
    - Indirect use value: Individuals benefit from ecosystem services supported by a resource rather than actually using it (e.g., watershed protection for flood mitigation, cycling processes for agriculture or carbon sequestration).
- NON-USE VALUES
    - Altruistic value: Derived from knowing that contemporaries can enjoy the goods and services the natural environment provides.
    - Bequest value: Associated with the knowledge that the natural environment will be passed on to future generations.
    - Existence value: Derived simply from the satisfaction of knowing that ecosystems continue to exist, regardless of use made of them by oneself or others now or in future (also associated with "intrinsic value").

The TEV framework determines which concrete valuation methodology is used – or should be used – for each ecosystem service. These recommendations are being followed, though each service examined is being discussed in more detail in the respective section. If the current report deviates from the general recommendations and guidelines of the GEF Guidance Document and the TEV concept, it might be due to:

- Data restrictions: if sufficient data or information is not available to value a specific service, a benefit transfer has been used, using the GEF´s "Repository of Valuation Studies".
- Availability of other studies´ results: if results are available from former valuation exercises, and these are of sufficient quality, the results have been incorporated into the current valuation.

Scoping – spatial boundaries and ecosystem services

The geographical framework for the overarching Sargasso Sea Stewardship project is the "Sargasso Sea Geographical Area of Collaboration" (SSGAC), which is depicted in figure 2 above. It encompasses the Sargasso Sea, bounded by oceanic currents, but most importantly excludes the coastal waters and whole EEZ of Bermuda. The economic valuation of the Sargasso Sea´s ecosystem services hence examines only the services provided by the high-seas areas of the Sargasso Sea – the "Geographical Area of Collaboration". It therefore analyses the ecosystem service´s value for Bermuda, but not the value of Bermuda´s coastal waters and EEZ.

High-seas ecosystems also provide a range of ecosystem services that differs slightly from coastal ecosystems. In accordance with the GEF Guidance Document (Interwies/Görlitz 2019) and in collaboration with the GEF-UNDP-UNESCO-IOC project officer, the following ecosystem services are being examined in the current valuation:

- Commercial Fishing
- Tourism & Recreation in Bermuda and beyond
  - Tourism in Bermuda
  - Sport and Recreation Fishing
  - Whale Watching
  - Bird Watching
  - Turtle Watching
- Carbon Sequestration
- Oxygen Production
- Education & Research
- Existence Value and the Value of Biodiversity in the Sargasso Sea

Benefits vs. Costs

In this economic valuation, we assess the benefits of ecosystem services. However, this is only "one side of the medal" – the other side being the costs occurred by harmful human activities. Such activities damage ecosystems and their functions, and the ecosystem services provided with them.

Laffoley et al. (2011) discuss several of them in detail[4], without providing cost or damage estimates:

- The impacts of fishing and over-fishing.
- Shipping and shipping related impacts.
- The impacts of pollution caused by shipping.
- The commercial extraction of *Sargassum*.
- The impact of potential seabed mining.
- The impact of submarine communication cables and the potential impact of any deepwater repairs to these.

Here, the focus lies on economic benefits. However, if the "policy side" of things is concerned, harmful activities and their costs need to be assessed and discussed as well.

Assumptions and uncertainties

There are considerable uncertainties connected with economic valuations of ecosystem services, especially in low data – high-seas ecosystems. Such uncertainties, or the opaque communication of these, often hinder the uptake and use of economic valuation studies in policy making and as decision support.

The uncertainties are rooted in

- a lack of data and information;
- methodological issues surrounding assumptions and constraints, like the issue of "double counting", i.e., the fact that some ecosystem services are not complementary or influence each other (e.g. provision of fish/fisheries and spawning grounds, two values that should not be added);
- a general lack of understanding of the complex interactions between human activities, impacts on ecosystems and habitats (e.g., of infrastructure development), and their ramifications for the provision of ecosystem services. This touches on the question of

[4] The Sargasso Sea Stewardship project´s Causal Chain Analysis identifies and discuss all threats, impacts and causes in more detail.

how a given human activity impacts on the provision of ecosystem services, i.e., how a degradation of the quality of the ecosystem affects ecosystem services provision (Interwies/Görlitz 2019).

Hence, when conducting an economic valuation, it is of utmost importance to clearly describe the uncertainties involved in the exercise, and to transparently communicate any assumptions taken, for example in order to bridge data and information gaps. In this report, the uncertainties and assumptions are discussed parallel to the description of the valuation approaches to the specific ecosystem service.

In the Sargasso Sea GAC, as a high-seas ecosystem, uncertainties due to the large extent of the area, the difficulty of collecting data, the high connectivity and benefit for highly migratory species as well as low density of human use add to the general uncertainties involving economic valuations (Sapsford 2024). The high-sea domain consists of deep-sea pelagic ecosystems, epipelagic ecosystems on top, and abysso-benthic ecosystems below. The organismal density and productivity of these systems are difficult to define, as they vary significantly from one high-seas are to another, while seamounts and hydrothermal vents possessing high biodiversity. In the deep-seas, the spatio-temporal gradients are weak, except where different water masses meet. Epipelagic ecosystems are more distinctly influenced by daily and seasonal changes and ocean-atmosphere interactions; vertical gradients are thus stronger. Also, being limited to the photic zone, epipelagic ecosystems are also the most productive pelagic ecosystems of the high-seas (Bailly 2025).

Due to the large extent, low productivity, and low density of human use, the simplifying assumption that the economic value of ecosystem services provided by one hectare of high-sea at Point A equals the value of ecosystem services provided by one hectare of high-sea at Point B is difficult to maintain. The point is that all the hectares of a high-seas ecosystem do not have the same productivity, which means that increasing the size of e.g., a protected area, by the factor 10 does not mean that the value of the ecosystem services provided also increase by the same factor.

Practically applied to the economic valuation at hand, one ecosystem service that the SSGAC supplies in catchable fish. The catch data for this originates from Sea Around Us, but the spatial precision implied by the organisation´s global use of ½ degree lat./long. cells is likely problematic for offshore and high-seas cells. This is due to the catches they contain having been derived from spatially reported catch data provided by Regional Fisheries Management Organizations (RFMOs) in much larger spatial cells (1, 5, 10 or even 20 degree lat./long.). Sea Around Us´ subsequent allocation of these data to ½ degree cells within each of the RFMO cells is based on a standard allocation approach (Zeller et al. 2016). This allocation is not likely to reflect the precise location of catches being taken from each ½ degree cell within each RFMO cell in each year (Sea Around Us 2025).

Sargasso Sea ecology, ecosystems and ecosystem services

The Sargasso Sea is a refuge of life in the high-seas, characterized by a unique pelagic surface ecosystem built around floating *Sargassum*. This golden-brown seaweed hosts specific and in cases endemic ecological communities, serving as a nursery, feeding ground, and migratory corridor for numerous high-seas species, many of which are vital to Bermuda and countries across the Atlantic. The *Sargassum* ecosystem is supported by two holopelagic species of Sargassum—*Sargassum natans* and *Sargassum fluitans*. These two species evolved from benthic ancestors over 40 million years ago, and float because of small gas-filled bladders, with *S. natans* displaying delicate leaves and *S. fluitans* bearing broader, lance-shaped ones. The algae form long-lived, floating mats that often align into "windrows" running parallel to the wind - a golden, floating rainforest teeming with life (SEDA; Laffoley et al. 2011).

The size, persistence, and density of these mats support a rich and diverse array of organisms, making the *Sargassum* ecosystem distinct from other, shorter-lived coastal drift algae habitats. As *Sargassum* drifts through the gyre, it accumulates a growing variety of "passenger" species, with biodiversity varying by season, location, and the algae's age. Due to *Sargassum's* long evolutionary history in the region, many species are specially adapted to life among the floating seaweed, with 10 species that are endemic to Sargassum (among them crabs, shrimp, snails and fish) (SEDA; Laffoley et al. 2011).

Beyond these endemic species, *Sargassum* mats support over 145 invertebrate species and provide a habitat for more than 127 fish species. For many juvenile fish and invertebrates, *Sargassum* offers both shelter and a food source, while the organisms themselves enrich the water with essential nutrients. Many high-seas fish species flock to Sargassum mats a nursery, shelter or hunting grounds, among these many species of sharks and rays, tuna, and swordfish. This floating ecosystem also interacts with deeper oceanic ecological communities, connecting the surface and deep-sea food webs through vertical migrations of fish and invertebrates, and the sinking of dead *Sargassum* to the ocean floor (SEDA; Laffoley et al. 2011).

As such, the Sargasso Sea supports all of the four main classes of ecosystem services described by the Millenium Ecosystem Assessment: provisioning services such as food and fishing; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services, such as soil formation, photosynthesis, and nutrient cycling (Pendleton et al. 2015).

This economic valuation, however, only focuses on a selected set of final ecosystem services that are directly linked to the ecological conditions of the Sargasso Sea, based on the pioneering efforts done by Sumaila et al (2013) and Pendleton et al. (2015). There, final ecosystem services are defined according to Boyd/Banzhaf (2007) as "components of nature, directly enjoyed, consumed, or used to yield human well-being". For example, fish represent a final ecosystem service because they are directly harvested by people, whereas the habitat provided by *Sargassum* for these fish is considered an intermediate service—not directly enjoyed or consumed by humans. However, the Sargasso Sea supplies a wide range of important intermediate services - spawning grounds for fish, habitats and feeding areas for turtles, and potentially novel genetic resources that could greatly benefit society. These intermediate processes form a critical link between the ecological health of the Sargasso Sea, its functioning, and its broader economic value.

The valuation highlights ecosystem services that meet specific criteria: they must be ecologically tied to the Sargasso Sea, associated with identifiable user groups or constituencies, and vulnerable to clear and tangible threats from ecosystem degradation.

Ecosystems such as the Sargasso Sea are interacting and dynamic systems consisting of biotic and abiotic factors. The provision of ecosystem services by an ecosystem is the result of specific interactions, whereby only a healthy ecosystem can provide the full set of potential ecosystem services. The extraction of crude oil, sand, gravel or other mineral resources, also produces a value - a revenue/financial benefit. But this value does not derive from the living, functioning ecosystem but just happens to be derived from the same spatial area, leading more often than not to a loss of many vital and valuable ecosystem functions (negative externalities). As a result, the revenue from the extraction of non-living resources such as crude oil can in this context not be regarded as a service provided by the ecosystem. Economic valuation of ecosystem services is furthermore not about summing up the value of every economic activity in the area of investigation, but to value those goods and services that directly derive from the existence of a healthy ecosystem and its functioning.

This applies to shipping, a human activity present in the SSGAC, and to a certain extent to fisheries (a sustainable, i.e., long-term usage of fish stocks without risking depletion/extinction, is in line with the above definition of ecosystem services) (Pendleton et al. 2015; Interwies/Görlitz 2019).

Hence, in the context of this economic valuation, the extraction of mineral resources and the provision of “water for shipping” are not considered to be ecosystem services.

Economic Valuation of the Sargasso Sea´s ecosystem services

In this section, the ecosystem services selected for analysis are discussed and valued, based on existing valuation studies, market prices (in case of use values), and further methods including benefit transfers (in case of non-use values or insufficient data situations).

Existing economic valuations of marine ecosystem services

Ecosystem services of marine ecosystems have been examined and evaluated monetarily many times before, as illustrated by the 2,200 valuation studies on marine ecosystems listed in the Ecosystem Services Valuation Database (ESVD[5]), or the number of valuation studies suitable for benefit transfers listed in the GEF Repository of Evaluation Studies[6].

Most of these studies, however, focus on coastal ecosystems (e.g., Barbier et al. 2011, Costanza et al. 2008, Emerton 2014, WWF 2008), some on the deep-sea (Armstrong et al. 2010; Jobstvogt et al. 2013, Thurber et al. 2014, Ottaviani 2020). There are only a handful of studies about the economic value of high-seas ecosystem services (e.g., Xuan et al. 2021, Rogers et al. n.D.), and only two focus on the ecosystem services of the Sargasso Sea. The first - Sumaila et al. (2013) – has been developed under the Sargasso Sea Alliance Science Report Series (Report No. 12), under which a large number of authors developed a scientific case to establish the global importance of the Sargasso Sea. The report focusses on the value of fisheries, using Sea Around Us data, the value of eels, reef-associated tourism, recreational and cultural values, as well as the value of *Sargassum*. The second report, published 2015 (Pendleton et al.) builds upon the results provided in Sumaila et al. (2013), but sets a stronger focus on wildlife viewing and research and education values.

Ecosystem Service 1: Commercial Fishing

Globally, commercial fishing in the high-seas grew continuously during the second half of the twentieth century fueled by improvements in fisheries technology, vessel capacity and fisheries subsidies, only to start decelerating in the 1990’s to a landed value of 6 billion USD in 2019, the level of the mid-1980’s. At the same time, the catch volume plateaued in the early 2000s and has remained relatively stable ever since, at approximately 3 million tons of landed catches. However, high-seas fisheries catches remain a very small proportion of the total landed wild catches from the ocean of about 100 million mt per year (SEDA).

The Sargasso Sea is located almost totally in the UNFAO “Western Central Atlantic Ocean” Fishing Area (UNFAO Fishing Area 31), which is among the least fished UNFAO Fishing Areas in the world, accounting for a small fraction of total high-seas fisheries catch volume (0.53%) and value (0.49%) between 1950 and 2019. Catches consist of large pelagic species, primarily albacore tuna, swordfish and blue sharks. The large majority of the catches in UNFAO Fishing Area 31 furthermore take place within national jurisdiction (EEZs or 12-mile zones), accounting for 80% of the fisheries landed volume – only one fifth of all catches in the area are from high-seas fisheries, representing around 15% of total landed value (SEDA).

The landed volume and value of high-seas fisheries catches in UNFAO Fishing Area 31 between 1950 and 2019 have remained relatively stable since the mid-1970s, and – while varying from year to year - maintained an average landed catches of 10–15 thousand tons, with a landed value of approximately USD 30 million (see figure 5). Of this landed value, around 50% was caught by the longline fleets of Belize, China, Vanuatu, Saint Vincent & the Grenadines, USA, Spain and Taiwan (SEDA).

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[5] https://www.esvd.info/. Accessed May 2025.

[6] https://iwlearn.net/valuation/the-repository-of-economic-valuation-studies; 65 studies listed that meet certain criteria regarding quality, parameters, transferability. Accessed May 2025.

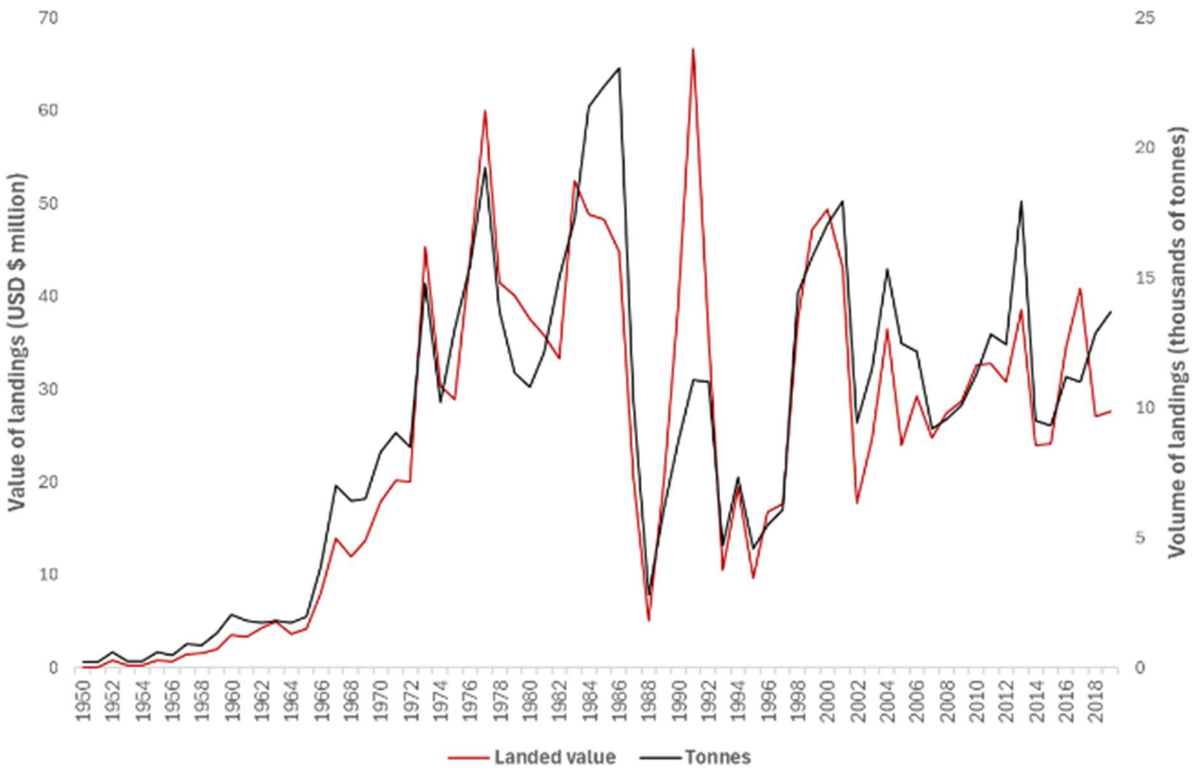

Figure 5: Trends of fisheries landings volume (tonnes) and landings value (USD) in the high-seas portion of UNFAO Fishing Area 31 between 1950 and 2019 (Source: Sea Around Us).

Several tuna species – albacore tuna (*Thunnus alalunga*), yellowfin tuna (*Thunnus albacares*), and Atlantic bluefin tuna (*Thunnus thynnus*) - represent the commercially most significant fish stocks that are associated with the Sargasso Sea GAC. These species are known to spawn here and migrate across both the high-seas and the Exclusive Economic Zones of the Atlantic, facing intense pressure from commercial fisheries. Spanish mackerel and other, smaller pelagic species are also caught in significant numbers (Sumaila et al. 2013).

Swordfish (Xiphas gladius) is one of the most widely caught species of large pelagics in the North Atlantic, and areas immediately south of the GAC, across the southern US East Coast, Gulf of Mexico and northern Caribbean have been identified as important spawning grounds for this and other species of swordfish. Telemetry data shows that swordfish can be found within the Sargasso Sea GAC throughout the year (SEDA).

Eels are another key group of commercially important fish whose life cycle is closely linked with the Sargasso Sea (Ringuet et al. 2002). The area serves as the only spawning ground for both European and American eels, marking the starting and end point of an astonishing migration. Larval development occurs in the Sargasso Sea, after which both species migrate along the Gulf Stream back to freshwater habitats in North America and Europe. While migrating, they metamorphose into their juvenile forms, referred to as “glass eels.” While both eel species are not directly harvested within the Sargasso Sea, they are targeted by large – mostly artisanal - fisheries in North America, Europe, and Africa—for both food markets and seed stock in capture-based aquaculture (SEDA; Sumaila et al. 2013).

In the Sargasso Sea Alliance Science Report Series, the value of the Sargasso Sea to fishery operations has been assessed for the first time (Sumaila et al. 2013), to be later reviewed and reproduced by the economic valuation of Duke University (Pendleton et al. 2014). Sumaila et al. (2013) used spatially explicit data for the whole Sargasso Sea, extracted from the expansive Sea Around Us database. They concluded that the value of commercial fishing of pelagic species in the Sargasso Sea is around 100 million USD/year (gross value of landed catches) (Sumaila et al, 2013, Pendleton et al. 2014).

This estimate seems quite accurate, as it is spatially explicit, targeting only fish caught in the Sargasso Sea, and includes all fish species caught, including bycatches and smaller pelagic species. It includes, however, landed catches from the EEZs, which represent around 80% of landed catches, and 85% of the value. The value of the catches in the high-seas Sargasso Sea GAC would then amount to 15 million USD/year.

Eel fishing was estimated to be worth 66 million USD/year (gross value), though both species of eel are not caught in the Sargasso Sea, but in continental waters of range states, to a large part (Sumaila et al. 2013, Pendleton et al. 2014, CITES 2022).

The number cited from Pendleton and Sumaila is estimated using data from Europe, the United States, and Canada, however, important northern African and Caribbean eel fishing States are not represented. Hence, the number seems to rather be an understatement. Also, illegal trade of eels is not accounted for in this figure (Sapsford 2024).

The Socio-Ecosystem Diagnostic Analysis (SEDA) undertook the most recent task of calculating the value of landed catches explicitly from the Sargasso Sea GAC. To accomplish this, the price estimates per ton of the nine tuna and tuna-like species reported by ICCAT within the Sargasso Sea were used - bluefin tuna (8,205 USD/ton), swordfish (5,043 USD/ton), Albacore tuna, yellowfin tuna, bigeye tuna, sailfish, blue marlin and white marlin (between 2,434 and 3,676/ton) and skipjack tuna (1,490/ton). However, since the high-seas portion UNFAO Fishing Area 31 encompasses an area larger than the extent of the Sargasso Sea, only some of the landing volume and value estimates for the region could be linked exclusively to the Sargasso Sea. The authors used the value estimates per ton of catch derived from the Sea Around Us dataset in conjunction with the landings volume of the 9 tuna and tuna-like species in ICCAT's CATDIS database to obtain estimates of landings value for CATDIS datapoints that overlapped with the Sargasso Sea. Using this, the total value of the nine CATDIS target species was calculated for the Sargasso Sea between 2010 and 2021, resulting in an annual catch value of 116 million USD (see figure 6).

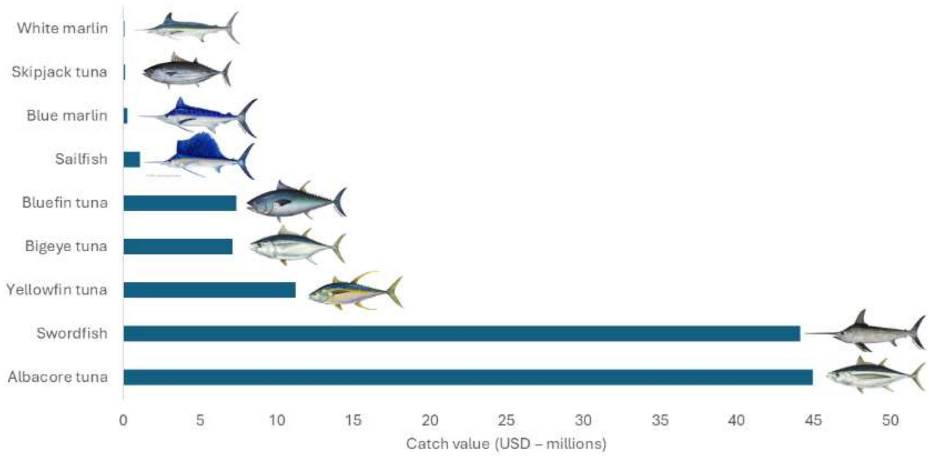

Figure 6: CATDIS landings multiplied by average price per ton according to Sea Around Us data in UJNFAO Fishing Area 31 high-seas of these species caught by ICCAT longline fleets (2010–2021) (SEDA).

This estimate represents the gross value of landed catches, meaning that the costs of the fisheries operations are not included yet. Recent studies suggest that fishing in the high-seas is presently enabled by large government subsidies, without which as much as 54%of the present high-seas fishing grounds would be unprofitable at current fishing rates. The patterns of fishing profitability vary widely between countries, types of fishing, and distance to port. However, it is obvious that much fishing by the world's largest fishing fleets would largely be unprofitable without subsidies and low labor costs (Sala et al. 2018).

While the estimate represents the best approximation of the value of fisheries explicitly for the Sargasso Sea GAC, it has one major limitation in that it includes only the nine ICCAT target species, providing no information about other targeted species such as blue sharks or bycatch species.

Data on American and European Eel catches are available from FAO, reaching back to the 1950ies. Catches declined for both Eel species, from high levels in the 1960s (2,000 tons/year for the American Eel, mainly in Canada and the United States, and 10,000 tons/year for the European Eel) to lower levels since the 2000s. In the last decade, catches of American Eel averaged around 900 tons/year. Catches of the European Eels averaged 2,000 tons/year. This catch data includes all life stages (glass eels, yellow eel, silver eel). Eel fisheries were estimated to be worth 8.8 million USD/year for the American Eel (reference years 2010-2019), and 44.7 million USD/year for the European Eel, using Sea Around Us catch and price data (gross) (SEDA). Data from three Caribbean range states – Cuba, Haiti and the Dominican Republic – hint at annual export values in the range of 25 million USD in 2021 (Cuba and DR) and 2016-17 (for Haiti) (GEF/UNDP 2022), while the global eel market – i.e., sales from wild catches and aquaculture, all age groups – is estimated by independent market research institutes to be at 4 to 5 billion USD/year (Kaifu et al. 2025; Spherical Insight[7]).

Against this background – the global value of eel trade being this high - the estimate cited in the SEDA seem rather low. Even the figures for only three Caribbean states – 25 million USD export value annually – hint at much larger values. Nevertheless, as the data is based on concrete catch and price data, it seems rather valid, and roughly in the same range as the value calculated by Sumaila et al. (2013). However, illegal trade in the species is not accounted for in this number.

Ecosystem Service 2: Tourism & Recreation

Tourism is an important expression of the relationship between nature and societies. As is often noted, tourism is one of the world's largest industries, contributing approximately 9.9 trillion U.S. dollars to global GDP in 2023, making up a 9.1 percent share of the total global GDP. However, like all economic sectors but probably even more so, tourism is heavily dependent on ecosystem services to develop its activity. The tourism industry needs provisioning services to provide tourists with food, water, or energy, among other things. In addition, regulating services are important because ecosystems regulate the weather, for instance, which is fundamental when tourists choose a destination. Moreover, many tourism activities are located in areas affected by natural hazards, such as floods or hurricanes. Therefore, ecosystems are able to mitigate risks that could affect tourism activity, risks which are expected to grow in the future due to climate change. Last but not least, cultural ecosystem services are crucial to visitor satisfaction, as tourists are attracted by different cultural ecosystem services, such as aesthetic appreciation, recreational experiences, or spiritual and religious experiences. Expressed in these terms, tourism's dependence on ecosystem services is obvious (Pueyo-Ros 2018).

Tourism in Bermuda

Bermuda is a booming international maritime and sports destination, with international arrivals exceeding 700,000 in 2024, almost catching up with high arrival numbers prior to the Corona

[7] https://www.sphericalinsights.com/reports/eel-market (Accessed September 2025).

pandemic, which saw numbers dropping globally. Most visitors presently arrive by cruise (72%), and air (27%) (see figure 7).

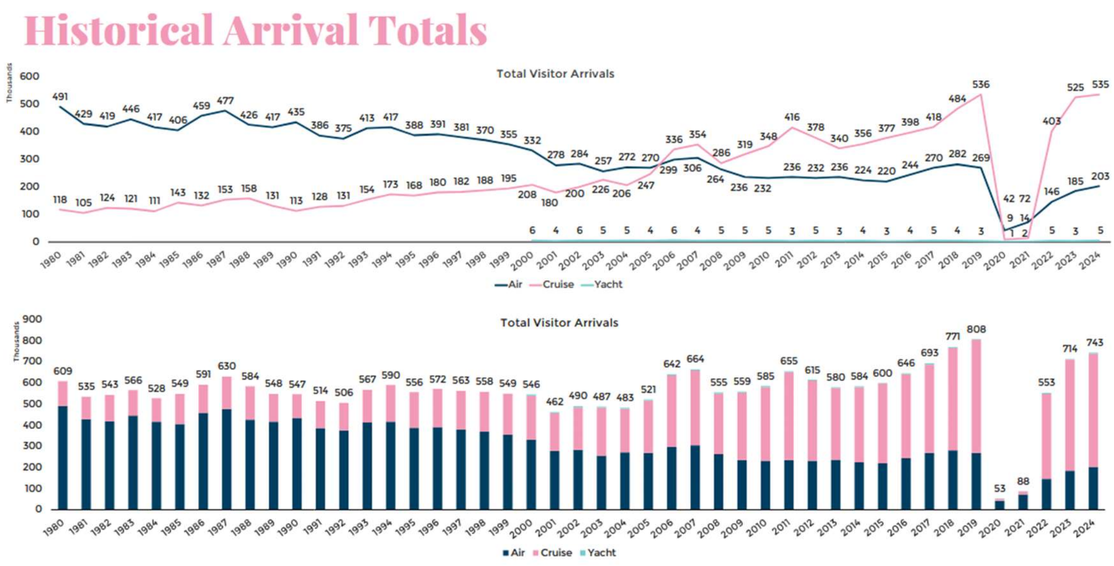

Figure 7: International Arrivals in Bermuda 1980-2024 (Bermuda Tourism Authority 2025)

Most international visitors arrive to Bermuda for vacation/leisure activities – 100% of the arrivals via cruises and 69% of all air arrivals (around 140,000 in 2024). Cruise visitors spent an average of 214 USD per visit, for a total of 114 million USD in 2024, while vacation/leisure visitors arriving by air – and staying an average 6-7 days – spent an average of 2,150 USD per visit, totaling 300 million USD in 2024.

Estimated Average Per Person Spending

Air Visitors

	All Visitors							Vacation & Leisure						
	2020	2021	2022*	2023	2024	# Δ vs 2023	% Δ vs 2023	2020	2021	2022	2023	2024	# Δ vs 2023	% Δ vs 2023
Lodging/accommodations	$790.81	$872.20	$973.68	$974.68	$1,206.83	$232.15	23.8%	$907.21	$942.64	$1,060.21	$1,057.35	$1,289.79	$232.44	22.0%
Restaurants & dining out	$397.92	$402.60	$440.33	$425.62	$441.41	$15.80	3.7%	$424.00	$408.98	$448.76	$435.99	$443.36	$7.37	1.7%
Entertainment & sightseeing	$108.70	$120.14	$118.46	$122.41	$113.29	-$9.12	-7.5%	$121.77	$126.20	$125.03	$133.04	$118.15	-$14.89	-11.2%
Shopping/any retail purchases	$107.51	$105.47	$117.82	$122.08	$106.90	-$15.18	-12.4%	$111.74	$104.46	$118.74	$122.14	$110.75	-$11.39	-9.3%
Groceries	$100.04	$70.41	$66.94	$69.70	$53.01	-$16.68	-23.9%	$95.12	$64.99	$63.24	$67.79	$52.65	-$15.14	-22.3%
Gas, Parking & local transportation	$82.32	$81.43	$81.32	$77.92	$86.36	$8.44	10.8%	$92.21	$83.55	$86.13	$81.51	$90.77	$9.27	11.4%
Other	$51.48	$46.76	$53.00	$49.07	$43.05	-$6.01	-12.3%	$56.67	$47.04	$55.14	$52.70	$45.29	-$7.41	-14.1%
TOTAL	$1,638.78	$1,699.00	$1,851.55	$1,841.47	$2,050.86	$209.39	11.4%	$1,808.72	$1,777.87	$1,957.25	$1,950.50	$2,150.75	$200.25	10.3%

	Business							Visiting Friends & Relatives						
	2020	2021	2022	2023	2024	# Δ vs 2023	% Δ vs 2023	2020	2021	2022	2023	2024	# Δ vs 2023	% Δ vs 2023
Lodging/accommodations	$868.92	$979.48	$1,168.54	$1,227.42	$1,480.97	$253.55	20.7%	$223.32	$306.32	$274.12	$284.41	$293.90	$9.49	3.3%
Restaurants & dining out	$381.41	$471.17	$504.85	$478.97	$525.59	$46.61	9.7%	$301.13	$318.51	$320.01	$322.12	$315.15	-$6.97	-2.2%
Entertainment & sightseeing	$77.84	$104.62	$107.76	$96.21	$112.48	$16.27	16.9%	$83.30	$81.45	$87.13	$89.39	$83.08	-$6.32	-7.1%
Shopping/any retail purchases	$84.35	$81.16	$100.04	$117.59	$92.23	-$25.36	-21.6%	$112.64	$125.77	$130.10	$128.95	$102.32	-$26.63	-20.7%
Groceries	$69.23	$66.43	$37.51	$37.57	$22.47	-$15.09	-40.2%	$152.80	$114.30	$120.88	$115.51	$97.71	-$17.80	-15.4%
Gas, Parking & local transportation	$64.35	$102.78	$74.91	$87.54	$90.16	$2.63	3.0%	$57.52	$54.01	$56.76	$49.00	$52.59	$3.59	7.3%
Other	$32.61	$39.21	$39.55	$36.08	$33.40	-$2.68	-7.4%	$48.05	$48.43	$52.95	$42.30	$41.88	-$0.42	-1.0%
TOTAL	$1,578.72	$1,844.85	$2,033.16	$2,081.37	$2,357.29	$275.93	13.3%	$978.75	$1,048.79	$1,041.95	$1,031.68	$986.62	-$45.06	-4.4%

Cruise Visitors

Average Cruise Visitor Per Person Spending	2020**	2021	2022	2023	2024	# Δ vs 2023	% Δ vs 2023
Restaurants & dining out	$14.52	$33.68	$31.47	$45.85	$42.27	-$3.58	-7.8%
Entertainment & sightseeing	$25.94	$61.64	$56.86	$53.26	$52.64	-$0.62	-1.2%
Shopping/any retail purchases	$39.63	$74.91	$62.12	$65.16	$59.04	-$6.12	-9.4%
Groceries	$2.07	$5.71	$2.90	$5.58	$2.52	-$3.07	-54.9%
Gas, parking & local transportation	$7.39	$20.35	$14.04	$15.30	$16.08	$0.79	5.2%
Excursions/Package Tours (purchased through cruise line)	$1.61	$11.21	$7.16	$10.93	$8.83	-$2.09	-19.1%
Other	$14.36	$38.21	$37.70	$38.45	$32.77	-$5.68	-14.8%
TOTAL	$105.51	$245.72	$212.23	$234.52	$214.16	-$20.37	-8.7%

Figure 8: Estimated average per person spending in 2024 (Bermuda Tourism Authority 2025)

Undoubtful, most of these visits are at least partly motivated by the ocean´s beauties and natural riches, such as pristine beaches, diving opportunities, sailing, and recreational fishing – which at least in parts depend on healthy ecosystems providing the necessary ecosystem services.

As this report focusses on the ecosystem services provided by the Sargasso Sea GAC – a high-seas ecosystem – coastal ecosystem services such as erosion prevention and protection, as well as coastal and reef-based activities are not valued. Instead, in the following sub-chapters, high-seas related tourism activities are discussed – recreational fishing and wildlife watching (marine mammals, birds and turtles). It follows the assumption expressed by Pendleton et al. (2014) that a healthy Sargasso Sea benefits human activities and people who live within the Sargasso Sea region, especially in Bermuda, but also beyond. That country receives direct economic benefits from tourism, via wildlife watching and recreational/sport fishing.

Sumaila et al. (2013) estimate the total value of recreation (including sport and recreational fishing), culture and reef-based tourism of the Sargasso Sea (coastal areas, EEZ and high-seas) to be around 440 million USD/year. To which degree these activities are directly (e.g., high-seas fishing) or indirectly (e.g., through providing habitat and spawning areas) dependent on high-seas ecosystem services will be discussed for the selected activities in the respective sections below.

Sport and Recreational Fishing

Bermuda is a prime location to catch rare large pelagic fish species, such as the Blue Marlin, and various other large billfish species. Anglers, mainly from the United States, visit Bermuda during the summer for international billfish tournaments, and sport fishing vessels often spend several weeks based out of the island for these tournaments, contributing to local economic activity. Estimates of the economic contributions of international anglers visiting Bermuda are available. For example, a study by Hellin (1999) estimated the annual gross revenues of the Bermudan recreational fishery for pelagic species at 311,000 USD, while Hallett (2011) estimated that the total expenditure by foreign anglers participating in seasonal tournaments in 2010 was 880,000 USD (adjusted to 2025 USD) (Pendleton et al. 2014).

Such fishing activities, however, take place almost exclusively inside Bermuda´s EEZ, and not, technically, in the high-seas (Sumaila et al. 2013). However, these fishing activities in the Bermuda EEZ are most likely strongly linked to the Sargasso Sea GAC. Furthermore, the Sargasso Sea ecosystem is likely to be economically important for recreational fishing beyond the Bermuda EEZ, as recreational fishing and sport fishing events generate revenues in regions such as the Americas as well as in Europe (e.g., the Azores) - recreational fishing in the Atlantic is a well-developed activity that generated as much as 17.3 USD billion of gross revenues in the Atlantic region of United States alone. In the Eastern Caribbean, direct expenditures of over USD 6.8 million per year are recorded for recreational/sport fishing, but these represent only the payments to the operators themselves, while there are likely to be many associated expenditures (OECS 2020).

The economic contribution of the Sargasso Sea GAC to recreational fishing inside the Bermuda EEZ as well as the wider Atlantic ocean, especially as a key spawning area for recreationally important fish, has not yet been quantified (Pendleton et al. 2014).

International visitors to Bermuda – those coming for vacation/leisure activities and staying at least one night (e.g., excluding cruise arrivals) – spent 300 million USD in 2024. At least a part of these surely arrive to engage in sport and/or recreational fishing as well as other activities that strongly depend on a healthy Sargasso Sea to provide nurturing grounds and habitat for the priced target species.

Under the assumption that sport and recreational fishing could not take place properly in Bermuda´s waters (coastal and EEZ) without a healthy Sargasso Sea, a part of the total spendings of international vacation/leisure arrivals could be reliably attributed to the ecosystem services provided by the Sargasso Sea GAC. However, there is no data on the percentage of international vacation/leisure arrivals that come to Bermuda primarily because of sport and recreational fishing.

The estimation of Hallet – 880,000 USD/year –represents slightly below 0,3% of the spending of international vacation/leisure arrivals (excluding cruise arrivals). There is no indication of whether this number is an under- or overestimation of the actual number of visitors arriving at least partly to indulge in sport and recreational fishing.

Some investigation into the motives of visiting the region could be easily obtained by a survey of international arrivals going beyond the broad categories "vacation/leisure" and "business" that are presently surveyed by the Bermuda Tourism Authority.

Whale Watching

As many as 30 cetacean species have been observed in and around the Sargasso Sea. In spring, humpback whales (*Megaptera novaeangliae*) migrate from breeding habitat to feeding grounds located throughout the Gulf of Maine, eastern Canada (including the waters off of Newfoundland and Labrador), West Greenland, Iceland, and the Barents Sea, passing through the Sargasso Sea. Sperm whales (*Physeter catodon*) - classified as vulnerable in the IUCN Red List of Endangered Species - and other whale species that attract whale watchers are commonly observed as well (SEDA).

While a significant number of visitors to Bermuda certainly engage in whale watching activities during their stay, the value and hence economic importance of whale watching for Bermuda´s economy is unknown.

Globally, though, whale watching as an economically significant part of tourism has been growing steadily. The report by O´Connor et al. (2009) is still the most recent estimate of the global scale of the industry. It concludes that whale watching generated a total global revenue amounting to 2.1 billion USD while supporting around 13,200 jobs in 2008. These numbers are likely to be considerable underestimates compared with the potential current revenue of whale watching, as they were calculated more than a decade ago. Assuming a steady rate of increase and ignoring inflation, whale watching could have a current global revenue of roughly 3.6 billion USD, of which at least 500 million are attributed to the North Atlantic (Ouled-Cheikh et al. 2023, Pendleton et al. 2014). Recent figures from an economic analysis of whale watching in the Strait of Gibraltar (Ouled-Cheikh et al. 2023) suggest that this number is rather an understatement, as three whale species alone generated an economic income on the Spanish coast of more than 6 million USD per year.

Nevertheless, the proportion of these revenues that are dependent on the ecological condition of the Sargasso Sea can still not be estimated. As Sapsford (2024) writes, "all the researcher can do is acknowledge that the Sargasso Sea supports these species in their life cycles, and so contributes a portion of the revenue derived from them".

Under current data limitations, it is not possible to calculate an economic value for the contribution of the Sargasso Sea GAC to Bermuda´s and other countries revenues generated through whale watching. However, as is the case with sport and recreational fishing, it seems not unrealistic to assume that these species would not be there to be watched if the Sargasso Sea became totally degraded.

Birdwatching

Birds living in oceanic habitats can be found worldwide, from the Arctic to the Antarctic. These birds have adapted to life in the open ocean, where they face challenges such as storms, long-distance migrations, and a scarcity of food. Despite the challenges, oceanic birds have carved out a niche for themselves and play important roles in marine ecosystems. They help cycle nutrients, control populations of smaller marine animals, and serve as indicators of changes in the ocean environment.

Many species of oceanic birds are also popular among birdwatchers and ecotourists, attracting visitors from around the world. High-sea regions are generally low on bird species on a per hectare scale, though it is estimated that at least 26 different seabirds are associated with aggregations of Sargassum, with bird densities being up to 32–43 times greater in areas with Sargassum than in areas without (SEDA; Laffoley et al. 2011). Various shearwater species are commonly observed in the open ocean areas around Bermuda and include the Cory's Shearwater (*Calonectris Diomedea*), greater Shearwater (*Puffinus gravis*), and the Audubon's shearwater (*P. lherminieri*). When mats of Sargassum are particularly dense, certain species of terns, including bridled tern (*Sterna anaethetus*) and sooty tern (*S. fuscata*), have been known to roost on these at-sea aggregations. Bermuda is also home to the endangered endemic Cahow, or Bermuda petrel (*Pterodroma cahow*), which has a resident geographic extent that overlaps with most Sargasso Sea region (SEDA; Laffoley et al. 2011).

Although birdwatching is considered one of the fastest growing nature-based tourism sectors in the world (Schwoerer/Dawson 2022), there is no comprehensive information on the value of the bird-watching industry globally, or for the Sargasso Sea GAC.

However, tourists who identify as birdwatchers tend to be well-educated and wealthy travelers with a specific interest in the places they visit, and on average are able and willing to spend more per trip/per visit that other visitors (Schwoerer/Dawson 2022). Figures for specific countries are available, though: in the UK, annual spending on birdwatching surpasses 500 million pounds; in the US, approximately 46.7 million people observed birds around the home and on trips in 2011, according to the U.S. Fish and Wildlife Service (FWS) national survey, and birdwatchers spent over 40 billion USD on birdwatching (including trips, travel expenditures and equipment). In Alaska alone, nearly 300,000 birdwatchers spent 378 million USD in 2016, supporting approximately 4,000 jobs. The Caribbean Tourism Organizations (CTO) reports that 3 million international trips (worldwide) are taken each year for the main purpose of bird watching, and many more trips combine birding with other activities (National Audubon Society 2015, Schwoerer/Dawson 2022). A Meta-Analysis conducted by Bonacquist-Currin (2020) looked at 27 stated preference WTP surveys to measure consumer surplus per person, per day for bird watching. The mean was 56.74 USD per day, but as the measurement is consumer surplus (i.e., the value of the enjoyment gained by individuals from birdwatching above and beyond what they pay), it cannot be directly applied or compared with other income-based measurement (Bonacquist-Currin 2020).

Most birdwatching occurs on the coast, or close to the coast, where the abundance of birds in generally higher, it is quite probable that no direct income is generated by birdwatching activities in the high-sea Sargasso GAC. However, the Sargasso Sea certainly has important ecological functions also for sea birds (nesting and feeding areas, for example), contributing indirectly to any value generated through coastal birdwatching in Bermuda, but mainly beyond – the United States and the Caribbean, for example.

Under current data limitations, it is not possible to calculate an economic value for the contribution of the Sargasso Sea GAC to Bermuda´s and other countries revenues generated through birdwatching. However, as is the case with whale watching, it seems not unrealistic to assume that these species would not be there to be watched if the Sargasso Sea became totally degraded.

Turtle Watching

Several species of sea turtles use the Sargasso Sea as a sheltering habitat from predators, feeding area and nursery habitat, e.g., green turtles (*Chelonia mydas*), hawksbill turtles

(*Eretmochelys imbricate*), loggerhead turtles (*Caretta caretta*), and Kemp's Ridley turtles (*Lepidochelys kempii*). These species are all endangered or critically endangered, and Sargassum represents for some of them – especially Loggerheads – a critical habitat (Laffoley et al. 2011, SEDA).

Though not as significant as whale watching, turtle watching generates revenues in the region - Central and South American communities as well as the Caribbean nations benefit from revenues generated by turtle watching, which are estimated at around 15 million USD per year. This value is based on surveys at a few selected locations, and is hence quite probably an underestimation (Pendleton et al. 2014). Globally, in the early 2000s some 175,000 people took sea turtle tours to more than 90 sites in more than 40 countries. At the biggest and most established site in Tortuguero National Park in Costa Rica, marine turtle tourism generates revenues worth more than 7 million USD annually (Troëng/Drews 2004). However, as with whale watching and birdwatching, the share of this value attributable to the Sargasso Sea remains unquantified.

Under current data limitations, it is not possible to calculate an economic value for the contribution of the Sargasso Sea GAC to Bermuda´s and other countries – such as the Caribbeans - revenues generated through turtle watching. However, as is the case with whale watching and birdwatching, it seems not unrealistic to assume that these species would not be there to be watched if the Sargasso Sea became totally degraded.

Ecosystem Service 3: Carbon Sequestration

The global oceans have historically been responsible for the capture and storage of more than a third of the total CO_2 produced by humankind. The ability of the ocean to capture and store carbon reduces atmospheric CO_2 and thus slows changes in global temperature and other consequences associated with climate change. Carbon capture and storage occurs through both physical processes, which do not involve living organisms (and which would not qualify as an "ecosystem service"), and biological processes in which living organisms play the dominant role. Physical processes include carbon dioxide dissolving in the ocean and - depending on the depth reached by the dissolved carbon and hydrographic and biological processes - it can be again transformed into CO_2 in a layer with direct exchange with the atmosphere, or it can be stored in-depth for thousands of years to geological times in a process called carbon sequestration. Biological processes include the "fixation" of carbon by photosynthesis in the surface layers of the ocean (<200m depth) by phytoplankton, which grows like other plants by fixing carbon and other nutrients, then they die and sink or are consumed by zooplankton and other organisms that eventually die and become particulate organic carbon (POC), a portion of which sinks into the deep ocean where it is lost from the atmosphere (captured and stored) over long timescales (SEDA, Rogers et al. n. D.). Historically, the Sargasso Sea has thus absorbed huge amounts of carbon, with approximately the same effectiveness as the global oceans (i.e., its share of the 30% of the total carbon emitted by humans), which would amount to a cumulative total carbon sequestration value for the Sargasso Sea of 495 billion USD, assuming a Social Costs of Carbon (SCC) of 90 USD/ton CO_2[8]. Taking present-day annual CO_2-emissions – 41.6 billion/a – and again assuming the

[8] According to Ritchie/Roser 2020 (amended 2024), since 1751 the world has emitted over 1.5 trillion tons of CO2, of which one third – 500 billion tons – have been captured by the world´s oceans. The Sargasso Sea GAC represents a share of 1.1% of the global oceans. Assuming that the rate of carbon capture is similar to the rest of the oceans, the Sargasso Sea would have captured a total of 5.5 billion tons of those emissions, resulting in the above calculated 495 billion USD, assuming a SCC of 90 USD/ton CO_2 (Ritchie/Roser 2020).

SSGAC absorbs CO_2 at about the same rate as the global oceans, the contribution of the SSGAC to CO_2 sequestration via absorption of CO_2 would be 12.8 billion USD/year[9].

Rogers et al. (n. D.) tried to estimate the amount of carbon captured by living organisms – the "biological capture" - and stored by high-seas ecosystems by calculating the net primary production of the ocean´s surface layer, and then apportion this amount between high-seas and EEZs. While coastal ecosystems are more productive, the high-seas cover such huge areas that almost 50% of all carbon fixation by phytoplankton takes place in the high-seas (around 23 billion tons), of which 0.448 billion tons - the equivalent of over 1.5 billion tons of carbon dioxide - annually are biologically captured and stored in the Deep-sea. The authors note, however, that their estimations are preliminary, and subject to a great deal of uncertainty. Using the Social Costs of Carbon (SCC) estimates of 90 USD/ton CO_2, the total social benefit of "biological" carbon capture and storage by the high-seas amounts to 218.93 billion USD a year in 2025 dollars (with a range of 109 to 328 billion USD for mid-estimates) (Rogers et al. n. D.).

The Sargasso Sea is characterized by low macronutrient concentrations that support primary production (i.e., fixation of carbon dioxide into organic matter) and marine phytoplankton growth and biomass. Hence, net primary production is limited. Nevertheless, the Sargasso Sea has absorbed anthropogenic CO_2 from the atmosphere, with the amount of anthropogenic CO_2 in the upper waters almost doubling over the last 40 years (SEDA). The size and significance of the carbon stocks in Atlantic *Sargassum* is being disputed in scientific literature, with estimates ranging from relevant (Gouvêa et al. 2020) to insignificant (on the Atlantic scale) (Hu et al. 2021). Sapsford (2024), citing Lomas et al. (2011) estimates that the Sargasso Sea represents a net carbon sink of around 7% of the global net biological carbon pump, which seems quite significant, given that the Sargasso Sea represents around 1.1% of the global oceans.

Using the figure calculated by Rogers et al. (n. D.) as basis - 218.93 billion USD a year for "biological" carbon capture, using the SCC and a price of 90 USD/ton for calculating the cost of emitted CO_2 – it is possible to apportion this value between the high-seas globally and the Sargasso Sea GAC. The global oceans cover an area of approximately 360 million km², of which the Sargasso Sea GAC represents ca. 1.1% (roughly 4.1 million km², although the boundaries shift with the currents, and are notoriously difficult to determine). Assuming a similar rate of carbon sequestration as in other high-sea areas, the Sargasso Sea would biologically capture and store atmospheric CO_2 worth ca. 2.4 billion USD in avoided damage costs per year. Assuming higher absorption rates – not unrealistic, given the productivity of Sargassum – and using the 7% value provided by Lomas et al. (2011), the value rises to 15.3 billion USD per year.

The amount of CO_2 absorbed and sequestered/stored by the Sargasso Sea GAC is disputed. However, we provide some preliminary numbers and value estimations, based on global ocean anthropogenic CO_2 absorption rates and on phytoplankton biomass production globally and apportioned to the Sargasso Sea. Although subject to assumptions and uncertainties, the value provides a first insight into the economic significance of both abiological and biological carbon capture and storage provided by the Sargasso Sea GAC.

Ecosystem Service 4: Oxygen Production

Plants produce oxygen as part of their metabolism – photosynthesis. Without this, higher life on Earth would be impossible, at least in its current form. Nevertheless, how it should be valued

[9] 41.6 billion tCO_2/yr x 0,33 (percentage of CO_2 absorbed by oceans) x 90 USD/ton SCC x 0.011 (percentage of SSGAC of global oceans) = 12.8 billion USD/year.

is controversial and depends on several factors. One of the newest publications regarding that topic - Chen at al. (2022) - concludes that the flow of oxygen produced by ecosystems should not be valued in a general, all-encompassing way, but rather in three very specific cases only:

- If high levels of atmospheric oxygen at specific micro-scale areas (e.g., a park in an urban environment) provides additional benefits to local human health and additional attraction to tourists[10].
- If micro-scale aquatic oxygen production (e.g., in a pond or aquafarm) avoids potential loss of aquatic products.
- When macro-scale aquatic oxygen production (e.g., in global oceans) maintains marine contributions to humans (e.g., fishery resources).

The third case would apply to the Sargasso Sea, however, whether macro-scale atmospheric oxygen production should be valued is uncertain, because the effects of declining global atmospheric oxygen, especially in the short term, remain unclear (Chen et al. 2022). The changes in atmospheric oxygen levels being discussed are also almost trivially small (Andrew Hudson, personal communication). Also, it can be argued that nearly all of the oxygen that phytoplankton produces in the ocean is also consumed in the ocean, and that little of it gets into the atmosphere. Since global oxygen levels are extremely stable at 21%, presently there is no net production of oxygen on earth, only gross production - all of which is equally consumed by total global respiration to maintain the overall oxygen level at 21% (Andrew Hudson, personal communication).

While recognizing the essential service that all plant life on Earth provides in terms of oxygen production, we follow the argumentation that the conceptual situation is yet too uncertain and undefined to allow for an answer to whether oxygen production should be valued as an ecosystem service, or not.

Ecosystem Service 5: Education & Research

The educational and research values of ecosystems or natural areas in general are important, but usually not fully appreciated assets of the natural environment, and rarely valued monetarily as independent, specific services. Instead, most often education and research are summarized with other non-use values such as aesthetic information, inspiration or spiritual experience (Interwies/Görlitz 2019). This is due to the fact that it is extremely difficult to quantify the monetary value of education, or the benefit we derive from understanding the functions of ecosystems. Normally, educational and research values are understood as both biotic and abiotic features of the natural environment, which can be potentially used to acquire knowledge about the structure and functioning of the current and past natural environment. Those features include, e.g., rock and soil outcrops, landforms, water bodies and plant communities as well as other effects of environmental processes, occurring in different combinations (Mocior/Kruse 2016).

The economic value of the Sargasso Sea for research and education, or the economic benefits society obtains from education and research taking place in the Sargasso Sea, could not be quantified. It can be assumed, however, that a part of such values is included in the existence value of the Sargasso Sea, which is discussed below.

Pendleton et al. (2014) attributed a monetary value to the economic impact the research and education sector has on the Bermudian economy, i.e., the money spent by research organizations and their scientists working in Bermuda, amounting in the case of the Bermuda

[10] This notion has to be regarded with skepticism, as there is so much oxygen in the atmosphere that an air-breathing creature would not notice the difference in oxygen levels on a local level (Andrew Hudson, personal communication).

Institute of Ocean Sciences to 12-13 million USD per year. Such expenditures should be part of the visitor statistics discussed in the section on tourism and recreational benefits above. The Bermuda Tourism Authority also raises data on “business trips”, under which the visit of a scientist would certainly fall, but the data does not distinguish between the purposes of such business visits. With more differentiated data, the values by Pendleton et al. (2014) could certainly be improved.

Also, U.S. Government bodies including the National Science Foundation, NOAA, NASA, the U.S. Department of Energy as well as other research foundations have spent nearly 100 million USD over the last fifty years for better understanding the Sargasso Sea and the global oceans. Taken together with earlier studies of marine biology, this research effort makes the Sargasso Sea one of the best studied ocean regions in the world, providing unparalleled information on a changing ocean and its responses to global issues such as climate change (Laffoley et al 2013).

Existence Value and the Value of Biodiversity in the Sargasso Sea

Existence values are a class of ecosystem services that reflect the benefit people receive from knowing that a particular environmental resource, such as the Sargasso Sea, an endangered species, or any other organism or thing exists. Existence value is a prominent example of a non-use value, as they do not require that a utility be derived from direct use of the resource: the utility comes from simply knowing the resource exists. The considerable importance which the wider public attach to maintaining diverse marine life is revealed through the continuing interest in marine based media presentations, such as the BBC ‘‘Blue Planet’’ TV series or, for example, news features on penguins in Antarctica, despite the fact the majority of the general public will never see a wild penguin, but they are nevertheless interested in them and benefit from their existence.

The existence value is difficult to grasp, and difficult to distinguish clearly from other non-use values, e.g., the value of biodiversity, of aesthetic information etc. The TEEB groups the existence value under “cultural services”, in the same category as tourism and recreation, spiritual experience and aesthetic information (De Groot et al. 2012). In the GEF Guidance Document, four of the Cultural Services of the TEEB - aesthetic information, inspiration, spiritual experience and education – are grouped into one category, for reasons of simplicity – the existence value is not included as a single category.

There are different ways of valuing the existence value of an ecosystem, or – as it is mostly done – specific elements of ecosystems (such as certain species or habitats). Mostly, a Contingent Valuation study (CV) is being used, in which a representative number of people is being asked about their Willingness-To-Pay (WTP) to, for example, prevent an ecosystem from being destroyed (e.g., through protection measures), or a species from being extinguished. There are many methodological caveats to a CV study, and many uncertainties remain even if a study is methodologically sound. For the Sargasso Sea, such a study does not exist. However, if there were a study about another high-seas area, one could use these results and apply them via a Benefit Transfer (BT) to the Sargasso Sea. Unfortunately, to our knowledge there is no such study – i.e., one that places a value per hectare or per km² to a high-seas ecosystem.

Hence, to put an existence value to the Sargasso Sea via the usual methodologies – an CV study, or a Benefit Transfer – is not possible at the moment. To conduct such a study could be a further focus of research.

Another option would be to assess the sums that national or international organizations invest into the protection of a certain area. The amount of money spent by such organizations for conservation and preservation is a loose lower bound on the value of these species/habitats to society (Martin et al. 2016). For example, the Sargasso Sea Commission has recently been awarded two separate but complementary grants, one from the Global Environment Facility (GEF), called the Sargasso Sea project, and one from the French Facility for Global Environment (FFEM) called “SARGADOM”, worth 3 and appr. 1 million USD, respectively. Also, Greenpeace, NOAA and others, among them philanthropic organizations, spent millions of Dollars and a lot of time investing into the conservation of the Sargasso Sea.

Existence value is also closely linked to biodiversity. Endangered and threatened species have been shown to hold significant value through different economic surveys, but these are not specific to the Sargasso Sea. In general, the fewer individuals there are of a species, the higher the existence value. In the GEF Guidance Document, biodiversity is understood to be part of the value of provisioning services (e.g., food), regulating services (e.g., carbon sequestration), habitat services (e.g., nursery service) and cultural services (tourism/recreation). The intangible existence value of biodiversity is included in the “grouped” service “aesthetic information, inspiration, spiritual experience and education” (Interwies/Görlitz 2019).

Again, there are very few studies putting a value on the biodiversity of the open sea. Costanza et al. (1997) do not list “biodiversity” as an individual value or service, but instead list “cultural services”, which includes the existence value of biodiversity besides, for example, aesthetic, artistic, educational, spiritual, and scientific values of ecosystems. The value stated is 76 USD per hectare per year (in 1994 USD), representing a present value of 165,4 USD/ha/a. The Sargasso Sea has an approximate area of 4.1 million km², or 410 million hectares, which – using the values of Costanza et al. (1997) – generates an annual value of 67.8 billion USD in cultural services, including the existence value of biodiversity, and also the waters belonging to the EEZ. The TEEB report (De Groot et al. 2012) also does not list “biodiversity” as a single category. Instead, it is understood to underpin many other ecosystem services – provisioning, regulating, habitat and cultural services. The overall value of these services for the open ocean is 491 International Dollars per hectare per year (2007 price level), representing 756 International Dollars in 2025. The overall value of the Sargasso Sea´s ecosystem services in the open ocean – putting the size of the Sargasso Sea at 410 million hectares – would then be 310 billion International Dollars per year. This staggering amount includes the EEZ, and all services listed in the TEEB – the existence value of biodiversity is a small part of it.

Putting a monetary value to the existence of the Sargasso Sea, or an overall value to the region´s biodiversity, in a methodologically sound way, seems not possible considering the present data situation. Rather, there a methodologies that can be used to approximate these values, from the expenditures of international organizations to protect the Sargasso Sea, to overall value estimates from the literature – which yield results that differ by several orders of magnitude. Hence, to get a better understanding of the value of biodiversity, and to better communicate its importance, it is recommended to understand biodiversity as a necessary, crucial factor that underpins all other ecosystem services – which would not exist without it.

Ecosystem Services of Deep-Sea Ecosystems

As outlined above, there is growing evidence that the ecosystem services provided by the high-seas are of high social and economic value (Rogers et al., n. D.). The bigger part of the literature assessing high-seas ecosystem services focus on pelagic and epipelagic ecosystems. The deep-sea – marine waters below 200 m, where sunlight does not penetrate or is so dim that the environment does not allow photosynthesis - is often viewed as a remote and inhospitable environment, yet the deep ocean and seafloor are crucial through the services that they provide (Bailly 2025; Ottoviani 2020).

The deep-seas provide many resources, including commercial fish stocks targeted by deep-sea fisheries, precious corals for the jewelry industry, substances used as pharmaceuticals, as well as oil, gas and minerals that can be extracted from the seabed. The deep-seas play a key role in many processes, including climate regulation and carbon dioxide transport and storage, water temperature regulation, and regeneration and circulation of nutrients in the water column. The deep-seas constitute a remote, highly pristine environment, that is still largely unknown, where exploration and research are ongoing for both scientific and commercial purposes. Its role in driving nutrient regeneration and global biogeochemical cycles is essential for sustaining primary and secondary production in the oceans. In addition, it supports a high diversity of habitats and species as well as huge mineral resources. Furthermore, the buffering capacity of the deep ocean is vital for mitigating the climatic changes caused by anthropogenic emissions (Thurber et al. 2014; Ottoviani 2020).

The deep-sea is home to diverse – and often strange - fish species and large, little known pelagics like giant squid. It serves as a foraging or hunting ground for surface predators and, while mostly cold, dark, and oxygen-rich, also includes unique environments such as “oxygen minimum zones”, hydrothermal vents, and cold seeps. These areas are hosts to key biogeochemical processes and a high diversity of microbes. The deep-sea floor consists mainly of soft sediments – the remnants of organisms slowly raining down from above - and is divided into continental margins (200–4000m) and abyssal plains (4000–6000m). Other important features include mid-ocean ridges (mostly volcanic) and deep ocean trenches reaching depths of 11,000m (e.g., the Mariana Trench). Smaller but ecologically significant habitats—like seamounts, canyons, fjords, vents, and seeps—contribute to the ocean’s biodiversity and productivity. Seamounts and canyons are hotspots of biodiversity, while chemo-synthetic habitats like hydrothermal vents support unique and often endemic flora and fauna. Biogenic habitats, i.e., habitats formed by organisms such as cold-water corals, sponges, tube worms, and burrowing animals, add structural complexity and enhance biodiversity by providing refuge and nursery grounds (Thurber et al. 2014).

Thurber et al. (2014) and Ottoviani (2020) list several key services[11] provided by the deep-sea and it´s ecosystems:

- Fisheries/nutrition: One of the most tangible ecosystem services from the deep-sea are fish stocks, which are increasingly finding their way into human diets. Recent work in the twilight (or mesopelagic) zone between 200m and 1,000m depth has revealed unexpected biomass and diversity that may provide a new and largely untapped resource for fisheries harvest – but one that first needs to be understood, before being exploited. Also, a key knowledge gap is how mesopelagic food webs support foraging activity by commercially valuable, highly migratory top predators such as bigeye tuna, swordfish and yellowfin tuna (Disa et al. 2024; Willis et al. 2025).
- Water circulation and CO2 exchange/sequestration: Gigantic masses of water are transported in the ocean´s “global conveyor belt” also known as the “thermohaline circulation” – cool, salty water in northern latitudes sinks below the photic zone, where they are cut off from the atmosphere for approximately 1000 years. This creates more than one billion square kilometers of water separated from direct contact with the atmosphere, allowing an incredible buffering capacity for nutrient and carbon cycles. In 2014, the deep-sea stored approximately 37,000 Gton of carbon and has already absorbed a quarter of the carbon released from human activities.

[11] The authors also list oil and gas and other mineral resources, but these are not considered ecosystem services for the purpose of this evaluation, according to the GEF Guidance Document (Interwies/Görlitz 2019).

- Nutrient cycling and the biological pump: As organic matter and particles sink through the water column, they are stripped of their easy-to-digest compounds, releasing nutrients and energy into the deep-sea. This process, termed the "biological pump", both sequesters atmospheric carbon and releases nutrients that eventually fuel production. A part of this sinking biomass is stored and the carbon stored in it will be kept out of the atmosphere until the water rises to the surface again and releases the carbon back (1000-year timescales). However, if this carbon is buried in sediments, the CO_2 is removed from the atmosphere for geologic timescales (thousands to millions of years). Besides carbon, the deep-sea environment plays a key role in the cycling of other nutrients such as nitrogen, silica, phosphorus, hydrogen and sulfur.

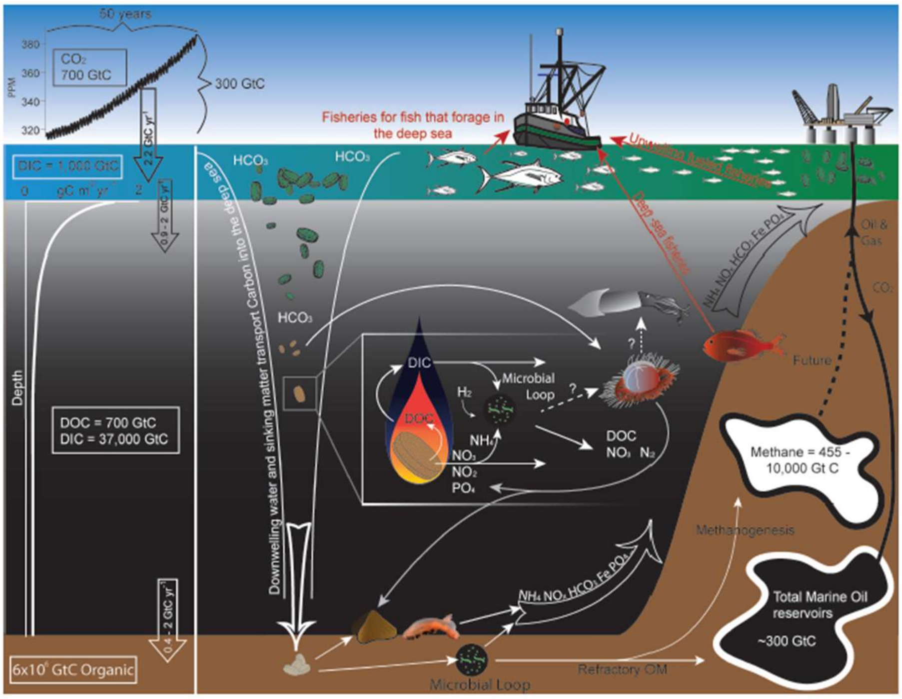

Figure 9: Schematic of carbon flow and a subset of the resources and functions of the deep-sea (Thurber et al. 2014)

- In situ primary and secondary production: The formation of biomass fueled by organic carbon degradation and assimilation, resulting in the provision of biomass for human consumption, most notably finfish, shellfish, and cetaceans.
- Waste absorption and detoxification: The deep-sea provides an area where waste products are stored as well as detoxified through biotic and abiotic processes.
- Genetic resources: The use of substances of marine origin as e.g., pharmaceuticals.
- Precious corals being harvested.
- Cultural Services: Cultural services can range from the valuable scientific knowledge that can be obtained from deep-sea environments, the educational value and the economic benefits generated by science, exploration and discovery (and the technological development that accompanies these), to the more purely aesthetic and inspirational services, including literature, entertainment, ethical considerations, tourism (e.g., touristic activities with submersibles to visit sites such as the Titanic shipwreck), and spiritual wealth and well-being.

Putting a monetary value on deep-sea ecosystem services faces severe challenges. As Jobstvogt et al. (2013) write, science has a limited understanding of how biodiversity is affected by human impacts in general (i.e., even on land), and how changes in biodiversity bring about changes to the supply of ecosystem services. In the deep-sea, this factor is aggravated by the fact that the major part of the deep-sea remains unknown. The available information on deep-sea ecosystem services is mostly of a descriptive nature – see the description provided above - and the majority of experts would be reluctant to put numbers on the changes in ecosystem service provision that we have to expect due to changes in the natural environment.

Furthermore, one of the biggest challenges of attaching economic values to deep-sea ecosystem services and biodiversity is the unfamiliarity of the general public with the deep-sea environment. This is relevant given the likelihood that researchers will need to use stated preference methods – i.e., a Contingent Valuation study, or similar methodologies - to estimate values for deep-sea biodiversity (Jobstvogt et al. 2013).

Hence, there is an extremely limited number of studies trying to assign a value to deep-sea ecosystem services. Ottoviani (2020) attributed a Total Economic Value of 267 billion USD per year to global deep-sea ecosystem services. However, the biggest share – 92% - of this value originates from abiotic resources (oil and minerals), which are not considered to be ecosystem services for the purpose of this study (Interwies/Görlitz 2019). 5% of the value originates from biotic resources (fish, corals and pharmaceuticals of marine origin), 2% from cultural services (scientific research and tourism/recreation), and 1% from carbon sequestration. The latter value of course would sharply increase if valued with a higher unit price, reflecting both market prices in the carbon market and incurred social costs from increased carbon emissions (Ottoviani 2020). Jobstvogt et al. (2013) conducted a choice experiment survey in which Scottish households were asked for their Willingness-To-Pay for additional marine protected areas in the Scottish deep-sea, investigating public preferences for the protection of deep-sea ecosystems. The choice experiment focused on the elicitation of economic values for two aspects of marine biodiversity, which were the existence value for deep-sea species and the option-use value of deep-sea organisms as a source for future medicinal products. The WTP for the highest levels of protection was 70-77 British Pounds per person (in 2012 price levels), reflecting a willingness to invest in deep-sea marine protection even if not directly profiting from deep-sea resources (Jobstvogt et al. 2013).

In the Sargasso Sea, the information about deep-sea ecosystems is also very limited, with our knowledge of the seafloor diversity of the Sargasso Sea limited to a handful of studies. Entire ranges of seamounts remain unexplored. This lack of knowledge represents a significant threat to the Sargasso Sea given the increase in human exploitation including past activities such as fishing and shipping but also with new human activities being considered such as deep-sea mining and marine carbon dioxide removal (SEDA).

The lack of knowledge on deep-sea ecosystems, biodiversity and ecosystem services makes deep-sea ocean management extremely difficult, especially with regards to managing the exploitation of marine resources, as it is presently impossible to know the full “cost” that we will have to pay for exploiting a specific resource. More science is needed, to better understand the cost versus benefit of exploitation, especially in the Sargasso Sea, with its crucial role in marine life cycles in the Atlantic ocean.

Summary and Conclusion

The Sargasso Sea is a vital part of the world's ocean ecology. It is located within the North Atlantic subtropical gyre, and its boundaries shift with the surrounding currents. The Sargasso Sea´s significance comes from the interplay of its physical structure, its ecosystems (mainly the floating carpets of *Sargassum*, the world's only holopelagic seaweed), its role in global oceanic and Earth system processes, the socio-economic and cultural values, and its contributions to scientific research (SEDA; Laffoley et al. 2011).

The Sargasso Sea is also an important part of the global "ocean economy", as it provides a range of valuable goods and services – commonly known as "ecosystem services" - which benefit people in various direct and indirect ways. Some of these ecosystem services have a direct, measurable commercial value, such as commercial fish stocks and tourism driven by wildlife viewing. Other ecosystem services offer both direct economic and indirect and recreational benefits, such as recreational fishing. Additionally, high-seas ecosystems support critical ecological functions essential for human life, such as oxygen production and carbon capture and storage. These ecosystems are also rich in genetic diversity and biological compounds, which hold potential for new chemical and pharmaceutical discoveries (Pendleton et al. 2014).

The economic valuation of the Sargasso Sea´s ecosystem services set out to examine the ecosystem services provided by the high-seas areas of the Sargasso Sea – the "Geographical Area of Collaboration". It therefore analyzed the ecosystem service´s value for Bermuda, but not the value of Bermuda´s coastal waters and EEZ. Such high-seas ecosystems provide a range of ecosystem services that differs from coastal ecosystems. The following ecosystem services were being examined in the current valuation:

- Commercial Fishing
- Tourism & Recreation
    - Tourism in Bermuda
    - Sport and Recreation Fishing
    - Whale Watching
    - Bird Watching
    - Turtle Watching
- Carbon Sequestration
- Oxygen Production
- Education & Research
- Existence Value and the Value of Biodiversity in the Sargasso Sea

However, quantifying the economic contribution of ecosystem services to economic systems is challenging especially in a high-seas areas such as the Sargasso Sea GAC. Reasons for this are the lack of "official" boundaries and its remote location, being far from most human settlements, a lack of scientific information about the provision and use of most high-seas ecosystem services and their quantity and nature, and even a lack of knowledge regarding how and where, precisely, they are produced. The high-seas support economically important species that may swim, migrate or drift beyond the physical boundaries of the area under investigation, or migrate between high-seas and coastal areas/EEZs. This makes it difficult to disentangle the contribution of high-seas ecosystems to the services that are produced in the high-seas but are enjoyed elsewhere. Many high-seas ecosystem services are not enjoyed directly in all contexts. Instead, in some contexts, many play an intermediate role in the creation of ecosystem services elsewhere (e.g. high-seas ecosystems support prey that are consumed by commercially important fish species which are harvested elsewhere) (Rogers et al., n. D.).

Hence, a valuation of high-seas ecosystem services is certain to suffer from a number of uncertainties. The uncertainties are rooted in

- a lack of data and information;
- methodological issues surrounding assumptions and constraints, like the issue of “double counting”, i.e., the fact that some ecosystem services are not complementary or influence each other (e.g. provision of fish/fisheries and spawning grounds, two values that should not be added);
- a general lack of understanding of the complex interactions between human activities, impacts on ecosystems and habitats (e.g., of infrastructure development), and their ramifications for the provision of ecosystem services. This touches on the question of how a given human activity impacts on the provision of ecosystem services, i.e., how a degradation of the quality of the ecosystem affects ecosystem services provision (Interwies/Görlitz 2019).

Nevertheless, the valuation assessed a set of high-seas ecosystem services. Values have been derived, wherever possible, under the limitation imposed by the lack of data. The table below summarizes these results, and describes the most significant gaps in data, to possibly inform an “original” ecosystem services valuation (which, according to Interwies/Görlitz 2019, would include local data generation via surveys and collaboration with local authorities).

Activity	Estimated Annual Value derived locally (Bermuda and SSGAC) from SSGAC to this activity (USD/a)	Estimated Annual Value derived globally from SSGAC to this activity (USD/a)	Most significant data gaps
Commercial Fishing	15 million (Pendleton et al. 2014) to 116 million (SEDA)[12].		SEDA value only represents 9 tuna-like species. Other target species (e.g., blue shark) not included.
Eel Fisheries	53.5 million (SEDA) to 66 million (Pendleton et al. 2014). Possibly much higher, as three Caribbean states state export values of 25 million USD/annually (in 2016-17 and 2021).		Parts of global trade (e.g., in glass eels) not included. No data on costs (value if gross value). Very dynamic prices.
Tourism in Bermuda	No estimates available.	n.a.	Motives of visits to Bermuda unknown.
Sport and Recreational Fishing	0.88 million (Hallet 2011).	17.3 billion (US Atlantic) 6.8 million in Eastern Caribbean.	Number of visitors coming for fishing to Bermuda unknown. Contribution of high-seas to fishing in EEZ unknown. Contribution of SSGAC to fishing in wider Atlantic unknown.
Whale-Watching	No estimates available.	500 million in the North Atlantic (estimate). 2.1 billion (O´Connor et al. 2009) to 3.6 billion (estimate) globally.	Number of visitors coming for whale-watching to Bermuda unknown. Contribution of SSGAC to whale-watching in wider Atlantic or globally unknown.

[12] This estimate represents the gross value of landed catches, meaning that the costs of the fisheries operations are not included yet. Recent studies suggest that fishing in the high-seas is presently enabled by large government subsidies, without which as much as 54%of the present high-seas fishing grounds would be unprofitable at current fishing rates. The patterns of fishing profitability vary widely between countries, types of fishing, and distance to port. However, it is obvious that much fishing by the world’s largest fishing fleets would largely be unprofitable without subsidies and low labor costs (Sala et al. 2018).

Bird Watching	No estimates available.	Spending on bird watching 650 million in UK, 40 billion in US.	Contribution of SSGAC to bird watching in coastal areas around the Atlantic unknown. Number of visitors coming for bird watching to Bermuda unknown.
Turtle Watching	No estimates available.	7 million in single NP in Costa Rica (Troëng/Drews 2004).	Number of visitors coming for turtle watching to Bermuda unknown.
Carbon Sequestration	2.4 billion to 15.3 billion in "biological" CCS. 12.8 billion in abiotic absorption of anthropogenic CO_2		CCS rate in SSGAC unknown. Storage in *Sargassum* unknown.
Oxygen Production	No estimates available.		Unclear whether oxygen production should be valued as ecosystem service.
Education and Research	12-13 million in related expenditures (Pendleton et al.)	No estimates available.	Number of visitors coming for research/education to Bermuda unknown.
Existence Value/Biodiversity	67.8 billion in "cultural services" based on Costanza et al. (1997).		Stated preference study for SSGAC. Expenditures by international organizations to protect the SSGAC unknown.
Ecosystem Services of the deep-sea	No estimates available, though the deep-sea has an important part in other ecosystem services, such as carbon sequestration, fisheries etc.		Contribution of deep-sea to other ecosystem services unknown.

Table 1: Ecosystem Services of the SSGAC

According to the economic valuation conducted in the frame of the Sargasso Sea Stewardship Project, the directly attributable monetary value of the ecosystem services provided by the Sargasso Sea GAC ranges from **2.67 to 15.49 billion USD/year**. This number, however, should be regarded as a lower boundary estimation – the real value is presumably much higher, as various services or aspects of services could not be valued, or not completely valued. These include:

- The figure does not include a value for tourism in Bermuda, which is certainly partly dependent on a healthy Sargasso Sea.
- Wider effects of the SSGAC ecosystems – for whale, bird and turtle watching in the Atlantic, or for sports fishing in Bermuda´s, the US´s or Caribbean coastal waters – are not included. Whale watching in the North Atlantic alone is valued around 500 million USD/year, while sports fishing on the US Atlantic is valued 17.3 billion USD/year.
- Also not included in the figure is the abiotic share of carbon capture and storage, worth another 12.8 billion USD/year.
- The potential value of Marine Genetic Resources and bioprospecting is not included but particularly relevant under the BBNJ framework.
- The values cited for fisheries are probably serious underestimates (e.g., in the case of eels), or include not all species caught (as in the case of the fisheries values, based on nine tuna and tuna-like fish species alone).
- The value of the ecosystem services of the deep-sea are not included in the figure.
- Values of the SSGAC for research, education and its existence value are not included either. Based on the stated preference of people asked, the "cultural value" of the SSGAC reaches 67.8 billion US/year.

Regardless, it is obvious that the Sargasso Sea GAC provides values worth millions and billions of US Dollars in Bermuda, in the wider Atlantic region, the Caribbean and US East Coast, as well as for companies and countries all around the world.

Part 2: A Cost-Benefit Analysis of Potential Strategies for Strengthening Conservation and Stewardship in the Sargasso Sea

The Importance of the Sargasso Sea

The Sargasso Sea is a vital part of the world's oceans and the "ocean economy", worth billions and billions of Dollars per year. The Sargasso Sea´s significance comes from the interplay of its physical structure, its ecosystems (mainly the floating carpets of *Sargassum*), its role in global oceanic and Earth system processes, the socio-economic and cultural values, and its contributions to scientific research (SEDA; Laffoley et al. 2011).

The Sargasso Sea as a critical habitat for threatened marine species

The Sargasso Sea is part of the central North Atlantic Ocean, with Europe and Africa to the east, North America to the west and the Caribbean to the south (figure 10). The island of Bermuda constitutes the only landmass, and the Sargasso Sea has abyssal depths of 4,000 meters or more, with notable eroded seamounts. The Sargasso Sea is an anticyclonic gyre with the surface currents of the North Atlantic Current to the north, the Canaries Current to the east, the North Equatorial Current and Antilles Current to the south, and the western boundary current Gulf Stream to the west (SEDA).

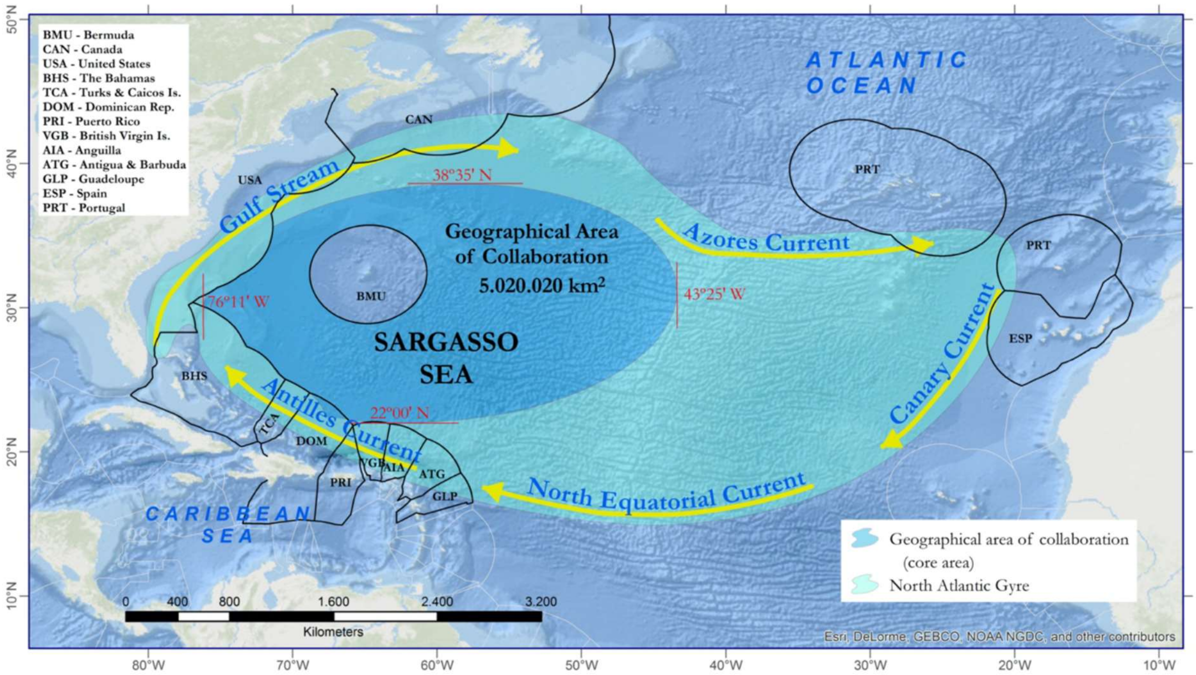

Figure 10: Geographic location of the Sargasso Sea and its major surface currents

Black lines delimit the EEZs of international stakeholders. Source: Marine Geospatial Ecology Lab, Duke University, and MarViva and SARGADOM FFEM, http://www.sargassoseacommission.org/our-work/projects/ffem.

The Sargasso Sea is one of five oceanic gyres that cover about 60% of the global ocean. The upper ocean of the North Atlantic Subtropical Gyre has distinct seasons and a mixed layer depth that is deeper in the winter time and shallower in the summertime. The northern part of the sea is strongly impacted by seasonality, whereas the southern part of the gyre is warmer and permanently stratified. The Sargasso Sea is an oligotrophic gyre that supports a "spring bloom" of marine phytoplankton photosynthesis and biomass growth. This, in turn, supports a rich microbial community of ocean bacteria and viruses and higher trophic level communities of zooplankton, fish, marine mammals and pelagic seabirds. Additionally, the free-floating pelagic plant *Sargassum* and the mats it forms provide an essential ecological niche for glass shrimps, *Sargassum* fish, and protection for juvenile turtles, shade protection for young fish, and resting places for pelagic seabirds (SEDA).

The Sargasso Sea provides a valuable habitat for several pelagic fish species such as Atlantic bluefin tuna (*Thunnus thynnus*) and Atlantic swordfish (*Xiphias gladius*), both of which are economically important and support regional commercial fisheries. The Sargasso Sea acts primarily as a stopover and temporary foraging site for tuna species; Atlantic bluefin tuna, yellowfin (*Thunnus albacares*), and bigeye (*Thunnus obesus*) have been known to migrate through the Sargasso Sea and Albacore tuna (*Thunnus alalunga*) are believed to spawn in and around this feature. In fact, this feature acts as a nursery and spawning habitat for other species such as dolphinfish (*Coryphaenidae spp*.), flying fish (*Exocoetidae spp*.), and blue marlin (*Makaira nigricans*). Sharks and rays also occupy the Sargasso Sea, inhabiting or migrating through the feature seasonally. Basking sharks (*Cetorhinus maximus*) regularly move through this area during winter months at depths of 200–1,000 m. Large female porbeagle sharks have been tracked migrating over 2,000 km from Canadian waters to the Sargasso Sea, potentially for pupping. A female white shark (*Carcharadon carcharias*) was also observed traveling from Massachusetts to the Sargasso Sea during the winter months, suggesting that this area may serve as critical nursery habitat for threatened shark species, including blue sharks (SEDA).

As many as 30 cetacean species have been observed in and around the Sargasso Sea. Humpback whales (*Megaptera novaeangliae*) routinely pass through this area during annual migrations. Sperm whales (*Physeter macrocephalus*) are commonly observed as well, with adults and calves likely feeding at the frontal convergence and around the boundaries of the Gulf Stream (SEDA).

Several species of turtles, all of which are endangered or critically endangered, spend time as hatchlings and juveniles in the protective layer of the Sargasso Sea. Green turtles (*Chelonia mydas*), hawksbill turtles (*Eretmochelys imbricata*), loggerhead turtles (*Caretta caretta*), and Kemp’s Ridley turtles (*Lepidochelys kempii*), all use the Sargassum as a nursery habitat). For these, as well as many other species, the Sargassum mats provide a stable structure habitat with a rich food supply, protection from predators and thermal regulation that promotes growth and feeding.

It is estimated that at least 23 different seabirds are associated with aggregations of Sargassum. Various shearwater species are commonly observed in the open ocean areas around Bermuda and include the Cory’s Shearwater (*Calonectris Diomedea*), greater Shearwater (*Puffinus gravis*), and the Audubon’s shearwater (*P. lherminieri*). When mats of Sargassum are particularly dense, certain species of terns, including bridled (*Sterna anaethetus*) and sooty (*S. fuscata*) terns, have been known to roost on these at-sea aggregations. Bermuda is also home to the endangered endemic Cahow, or Bermuda petrel (*Pterodroma cahow*), which has a resident geographic extent that overlaps with most Sargasso Sea region (SEDA).

All in all, the Sargasso Sea supports various life stages of a wide range of threatened marine species. Based on criteria outlined by the IUCN Red List of Threatened Species, there are currently around 100 threatened marine fish, invertebrate, marine mammal, and sea turtle species that are listed as “critically endangered,” “endangered,” or “vulnerable” within the Sargasso Sea region. In the SSGAC, there are 29 species listed as being part of one of these status classes. Additionally, 31 species within the SSGAC are listed in the appendices of the Convention on Migratory Species of which 16 are also classified as threatened under the IUCN Red List (SEDA).

The Sargasso Sea´s Ecosystem Services

The Sargasso Sea provides a range of valuable goods and services – commonly known as "ecosystem services" - which benefit people in various direct and indirect ways. Some of these ecosystem services have a direct, measurable commercial value, such as commercial fish stocks and tourism driven by wildlife viewing. Other ecosystem services offer both direct economic and indirect and recreational benefits, such as recreational fishing. Additionally, high-seas and associated seabed ecosystems support critical ecological functions essential for human life, such as oxygen production and carbon capture and storage. These ecosystems are also rich in genetic diversity and biological compounds, which hold potential for new chemical and pharmaceutical discoveries (Pendleton et al. 2014).

The economic valuation of the Sargasso Sea´s ecosystem services conducted in the frame of the Stewardship Project set out to examine the ecosystem services provided by the the Sargasso Sea ABNJ – the "Geographical Area of Collaboration". Such open ocean ecosystems beyond national jurisdiction provide a range of ecosystem services that differs from coastal ecosystems. The valuation assessed a set of oceanic ecosystem services provided by the Sargasso Sea GAC for which values have been derived, wherever possible, under the limitation imposed by the lack of data. The table below summarizes these results.

Activity	Estimated Annual Value derived locally (Bermuda and SSGAC) from SSGAC to this activity (USD/a)	Estimated Annual Value derived globally from SSGAC to this activity (USD/a)	Most significant data gaps
Commercial Fishing	15 million (Pendleton et al. 2014) to 110-120 million (SEDA)[13].		SEDA value only represents 9 tuna-like species. Other target species (e.g., blue shark) not included.
Eel Fisheries	53.5 million (SEDA) to 66 million (Pendleton et al. 2014). Possibly much higher, as three Caribbean states state export values of 25 million USD/annually (in 2016-17 and 2021).		Parts of global trade (e.g., in glass eels) not included. No data on costs (value if gross value). Very dynamic prices.
Tourism in Bermuda	No estimates available.	n.a.	Motives of visits to Bermuda unknown.
Sport and Recreational Fishing	0.88 million (Hallet 2011).	17.3 billion (US Atlantic) 6.8 million in Eastern Caribbean.	Number of visitors coming for fishing to Bermuda unknown. Contribution of high-seas to fishing in EEZ unknown. Contribution of SSGAC to fishing in wider Atlantic unknown.
Whale-Watching	No estimates available.	500 million in the North Atlantic (estimate). 2.1 billion (O´Connor et al. 2009) to 3.6 billion (estimate) globally.	Number of visitors coming for whale-watching to Bermuda unknown. Contribution of SSGAC to whale-watching in wider Atlantic or globally unknown.
Bird Watching	No estimates available.	Spending on bird watching 650 million in UK, 40 billion in US.	Contribution of SSGAC to bird watching in coastal areas around the Atlantic unknown.

[13] This estimate represents the gross value of landed catches, meaning that the costs of the fisheries operations are not included yet. Recent studies suggest that fishing in the high-seas is presently enabled by large government subsidies, without which as much as 54%of the present high-seas fishing grounds would be unprofitable at current fishing rates. The patterns of fishing profitability vary widely between countries, types of fishing, and distance to port. However, it is obvious that much fishing by the world's largest fishing fleets would largely be unprofitable without subsidies and low labor costs (Sala et al. 2018).

			Number of visitors coming for bird watching to Bermuda unknown.
Turtle Watching	No estimates available.	7 million in single NP in Costa Rica (Troëng/Drews 2004).	Number of visitors coming for turtle watching to Bermuda unknown.
Carbon Sequestration	2.4 billion to 15.3 billion in "biological" CCS. 12.8 billion in abiotic absorption of anthropogenic CO_2		CCS rate in SSGAC unknown. Storage in *Sargassum* unknown.
Oxygen Production	No estimates available.		Unclear whether oxygen production should be valued as ecosystem service.
Education and Research	12-13 million in related expenditures (Pendleton et al.)	No estimates available.	Number of visitors coming for research/education to Bermuda unknown.
Existence Value/Biodiversity	67.8 billion in "cultural services" based on Costanza et al. (1997).		Stated preference study for SSGAC. Expenditures by international organizations to protect the SSGAC unknown.
Ecosystem Services of the deep-sea	No estimates available, though the deep-sea has an important part in other ecosystem services, such as carbon sequestration, fisheries etc.		Contribution of deep-sea to other ecosystem services unknown.

Table 2: Ecosystem Services of the SSGAC

The results of the economic valuation should be regarded as a lower boundary estimation – the real value is presumably much higher, as various services or aspects of services could not be valued, due to a lack of data. Nevertheless, it is obvious that the Sargasso Sea GAC provides income worth millions and billions of US Dollars in Bermuda, in the wider Atlantic region, the Caribbean and US East Coast, as well as for companies and countries all around the world.

Connectivity and the Sargasso Sea

Dynamic oceanographic processes play a crucial role in the environmental variability of the ocean over a wide range of scales and consequently have a major influence on marine biodiversity. These open ocean processes also link ABNJ to coastal environments as well as the communities which depend on the latter for their livelihoods. According to the formal definition adopted by the Convention on the Conservation of Migratory Species of Wild Animals "Ecological Connectivity is the unimpeded movement of species and the flow of natural processes that sustain life on Earth". This is similar to other definitions of connectivity as the flow of energy, materials, organisms and gene across space (e.g., habitat patches or regions of interest) (SEDA).

It is clear that marine ecosystems are connected through different pathways. Vertical connectivity is assumed to mean ecological and/or food web connectivity between the surface ocean (epipelagic zone from 100 m depth), through the mesopelagic zone (generally considered as 200–1,000 m depth), bathypelagic (1,000– 4,000 m depth), abyssopelagic (4,000–6,000 m depth) and hyperbenthic zone (varying distances above bottom) down to the seafloor. Another form of connectivity occurs at the level of biological communities and relates to the vertical and horizontal distribution of assemblages of species. This is linked to patterns of intraspecific population connectivity which are maintained by adult migration and larval dispersal and is generally estimated in the present day by tagging adult individuals of e.g., sharks as well as indirect assessment via analysis of patterns of genetic variation across geographically separated samples. These forms of connectivity are relevant to the management of ecosystems in ABNJ.

Vertical connectivity is pervasive across the entire Sargasso Sea, specifically through the production of food, via primary production at the surface, which then "feeds" all the ecosystems of the deep sea (depths below 200m) including both pelagic (water column) and benthic (seafloor) ecosystems. Thus, the gravitational sinking of organic material from the surface to the deep sea is a form of directed connectivity (SEDA).

One of the notable features of the northwest Sargasso Sea is the generation of mesoscale eddies resulting in complex rotational flows. Eddies are highly relevant to trophic connectivity within the Sargasso Sea. These mechanisms leading to upwelling of nutrients or downwelling of nutrient depleted surface water are known as "eddy pumping" and can also interact with near surface winds. In the Sargasso Sea eddies are likely a net contributor to primary production, possibly contributing up to 35–50% of new production and also enhance zooplankton biomass. They therefore also enhance food supplies and increase trophic connectivity between the epipelagic zone and deeper waters (SEDA).

Given the transboundary nature of the Sargasso Sea, which straddles both the ABNJ and the EEZs, the co-occurrence of species within and beyond national jurisdiction may be interpreted as an indicator of ecological connectivity in the region. Of the 6,793 species known to occur within and around the Sargasso Sea, at least 58.2% have observation records within the national jurisdiction of adjacent coastal and island nations. The biological connectivity of the Sargasso Sea Large Marine Ecosystem is exemplified by several species, one of which is the highly migratory species the humpback whale (*Megaptera novaeangliae*). The iAtlantic project documented the importance of areas around Bermuda as important for humpback whale vocalization on the species' wide, sometimes trans-Atlantic, migratory route. Combined with the reconstructed time series analyses of humpback whale abundances and their re-sightings, this new information evidences the role that the Sargasso Sea plays in maintaining populations throughout their life histories. To further contextualize the importance of the Sargasso Sea to broader biological connectivity, the humpback whale feeding grounds are found in the Barents and Norwegian Sea off and around Iceland, west off Greenland, off Newfoundland and Labrador, in the Gulf of St. Lawrence and the Gulf of Maine. Breeding grounds are thought to be located in the northwest and southeastern Caribbean but also and the Cape Verde Islands (SEDA).

Thus, humpback whale re-sightings, their increasing abundance over time, and the occurrence of transient whales later re-sighted elsewhere in their feeding and/or breeding grounds strongly suggest the SSGAC is a key oceanic stopover ground for this species, with the wider Sargasso Sea being one of the most important to the biological connectivity for this species in all the Atlantic Ocean. The inclusion of migratory connectivity in the design of conservation and management measures is critical to ensure they are appropriate for the level of risk associated with various degrees of connectivity (SEDA).

The importance of the Sargasso Sea for international shipping

The high seas are host to a wide range of maritime traffic types, from cargo and tanker ships to fishing and passenger vessels. The Sargasso Sea experiences this same vessel variety, with traffic ranging from highly concentrated shipping routes across the middle North Atlantic to the less intensively occupied fishing grounds around the Gulf of Maine and the coast of Labrador. Notably, there are several major shipping lanes that connect ports in North America, the Caribbean, South America, and Europe that overlap with the Sargasso Sea. These routes are primarily occupied by cargo and tanker vessel traffic.

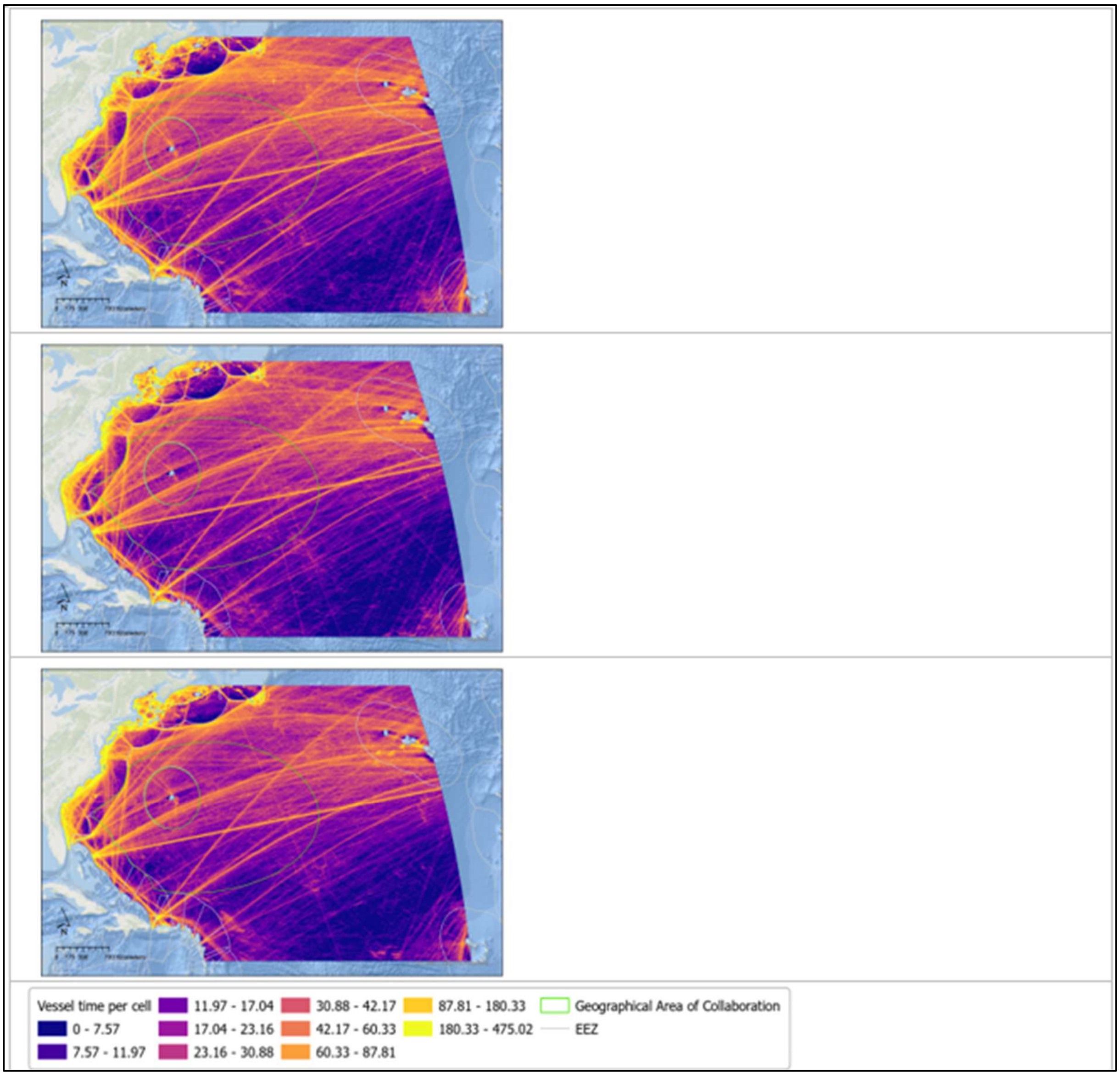

Figure 11: Annual summary of vessel traffic (vessel time in hours) in 2019 (top), 2020 (middle) and 2021 (bottom) (SEDA).

Cargo and tanker vessels transit most of the Sargasso Sea region however aggregations of location data derived from automatic identification system (AIS) shows that these vessels routinely move up and down the eastern coast of the U.S., sometimes along the continental shelf break, in addition to transiting the North Atlantic to distant water ports. In addition to significant cargo and tanker vessel traffic across the Sargasso Sea region, large passenger vessels, such as cruise ships, routinely transit this feature. These passenger vessels concentrate on narrow transit lanes, with ships aggregating into several central routes after congregating from destination/origin ports. Passenger vessel activity peaks during the spring and late fall/early winter, corresponding with increases in tourism to the Caribbean (SEDA).

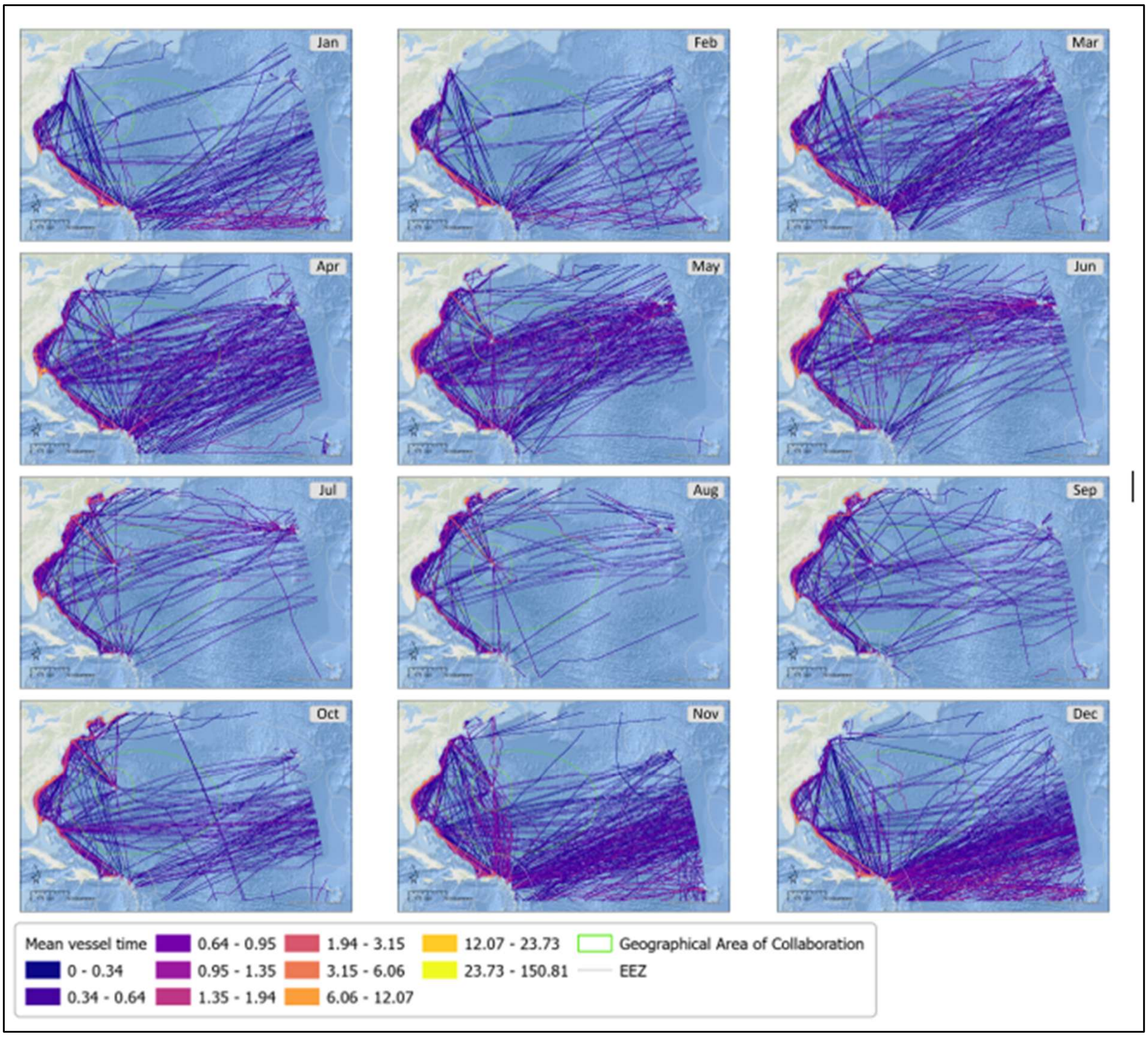

Figure 12: Monthly average of passenger vessel time in hours across three years (2019, 2020, 2021) (SEDA).

Sea-bed activities in the Sargasso Sea

Large mineral deposits, rich in valuable metals, including manganese nodules, cobalt crusts, massive sulphide deposits, are distributed in the deep ocean across the globe. Deposits of these materials occur on abyssal plains and at the upper continental shelf slopes in addition to forming at hydrothermal vents and seamounts. In the north Atlantic, the mid-Atlantic ridge is the location of aggregations of polymetallic sulphide deposits. Closer to the U.S. coastline and Caribbean, there are deposits of polymetallic nodules and cobalt-rich crusts, both of which overlap with various jurisdictional waters. The ISA has entered into 15-year contracts with twenty-one contractors for exploration of polymetallic nodules, polymetallic sulphides and cobalt-rich ferromanganese crusts in the international seabed area (the Area). This region is defined as “the seabed and ocean floor and the subsoil thereof, beyond the limits of national jurisdiction”. In the North Atlantic, ISA has granted three contracts for exploration of the Mid-Atlantic Ridge as a site for polymetallic sulphide extraction (SEDA).

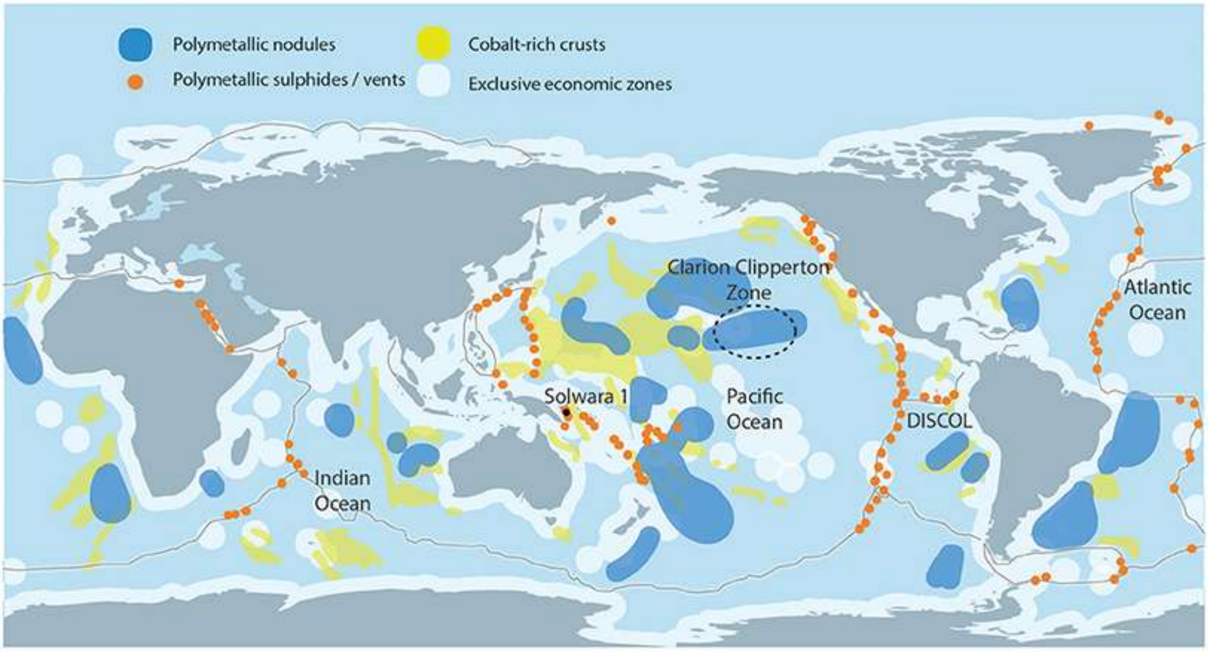

Figure 13: Location of three principle marine mineral deposits (SEDA).

Some potential areas of deep seabed mining exploration in the future are located in the EEZs of neighbouring states which overlap with the SSGAC.

Some submarine cables also cross the Sargasso Sea (see figure 14). Submarine optical cables are responsible for transmitting the vast majority of the world’s data and telecommunication traffic. These cables are either laid upon the seafloor or buried into the seabed and extend across the Atlantic between land-based stations. While their location on the seafloor limits the scope of impact to a pelagic ecosystem such as the Sargasso Sea, submarine cables are subject to regulations by managing nations including management protocols pertaining to installation, maintenance, repair, and removal, all of which can have effect the surrounding marine ecosystem (SEDA).

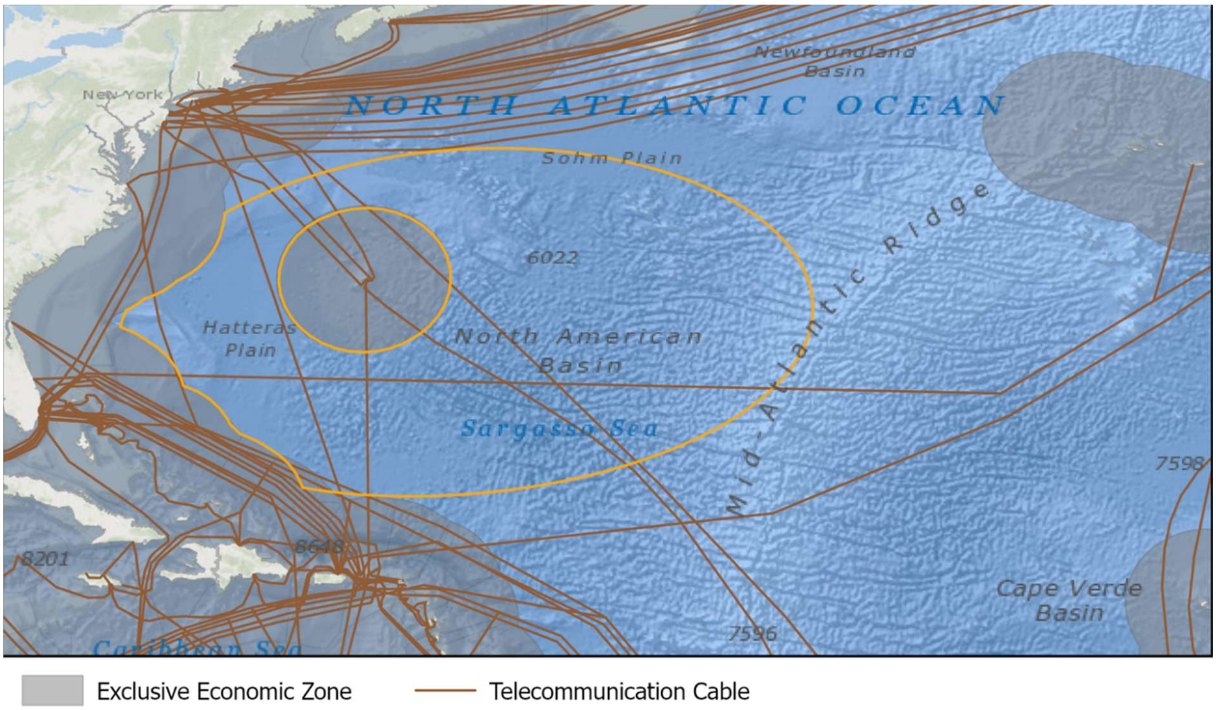

Figure 14: Undersea telecommunications cables and approximate locations (SEDA).

Major Regional and Global Impacts on the Sargasso Sea Ecosystem

The Sargasso Sea ecosystem and its habitats are impacted both by regional anthropogenic activities, as well as by global developments, such as climate change. In this section, such impacts are described briefly, drawing on work done in the frame of the Sargasso Sea Alliance Science Series and the SEDA process.

Climate Change

Global climate change is a significant stressor to marine ecosystems, amplifying and expanding the scope of impact from other human activities such as species extraction (fishing) or pollution. As the global climate warms, marine ecosystems experience shifts in biogeochemical characteristics with broader implications for species assemblages. In the Sargasso Sea, models reveal patterns of intense warming across the region and within the GAC. E.g., the cumulative intensity - duration, frequency, and intensity - of regional heatwaves is projected to increase in both short and long-term future timelines, reflected wider global ocean trends predicted across future climate change scenarios (SEDA).

As a result, the physical oceanographic and environmental variables such as temperature, salinity, and pH levels that define the Sargasso Sea have been seen to have changed (SEDA) and are likely to change further, with both direct and indirect impacts for biological communities and ecosystem structure. Impacts on sensitive species can be drastic, changing breeding and migratory patterns and potentially threaten species with (regional) extinction. For example, both the European and American eel require water temperatures within a narrow range of 22–24°C to successfully breed, and elevated temperatures impact the survival of a Sargassum algae (*S. swartsii*). Climate-induced stressors, such as changes in ocean temperature and increased CO_2 levels as well as changes in dissolved oxygen levels, can alter the community composition of phytoplankton and reduce overall primary productivity, affecting the entire food chain. Given the evidence of strong ecological connectivity within the Sargasso Sea, declines in primary productivity within this feature and related changes to species assemblages will likely have cascading effects on broader regional biodiversity (SEDA).

Habitat Deterioration and Loss

Of relevance to the Sargasso Sea region is the promising hope that even under the worst-case future emission climate change scenarios, some cold-water corals could potentially persist in the Sargasso Sea. In contrast, other coral species, such as *Lophelia pertusa* and *Acanthogorgia armata*, are unlikely to persist here. In it hoped, therefore, that some habitats relying on the reef framework-forming ecosystem engineers such as *M. oculate* could also persist in some ways.

Impacts of fishing and over-fishing

Fish stocks of many key species in the North Central Atlantic, including the Sargasso Sea, have declined significantly in the last 50 years. With the exception of swordfish, all targeted tuna and tuna-like species regulated by ICCAT are now on the IUCN Red List. According to ICCAT, yellowfin and bigeye tuna, white marlin and blue marlin, the northern albacore, western stocks of bluefin tuna and sailfish have all been overfished in the past (the 2025 bigeye stock assessment indicated that this species is not overfished or subject to overfishing presently), and swordfish may have been. At present, several species are still being overfished, with the status of several others being unclear (SEDA).

In addition to direct fishing impacts on the targeted species, the type of fishing gear used has potential impact upon by-catch and habitats. While longline fisheries can generate low levels of by-catch compared to other commercial fishing methods, purse seines and gill nets can take significant amounts of by-catch. Bottom trawling destroys corals and associated benthic faunas, while both the Corner Rise and New England Seamounts are home to numerous endemic and novel species of coral which in turn host specific commensal invertebrates[14]. Also, there is potentially some illegal, unregulated and unreported (IUU) fishing in the Sargasso Sea, but this has not been evaluated. Finally, lost and abandoned fishing gear can also have negative impacts.

Impacts of shipping

The Sargasso Sea lies within one of the world's busiest international shipping areas and is crossed by a large number of vessels each year (see figures above). Although there have not been major accidents involving vessels in the SSGAC yet, taking into account the volume of shipping traffic that crosses the area each year, it is obvious that the potential for adverse impacts certainly exists.

There are various ecological impacts associated with maritime traffic which can be categorized into two primary groups including a) pollution and b) physical harm and disturbance. The latter includes disturbance from underwater noise and direct interaction between animals and ships (known as ship strikes) or ships and the ecosystem. Large whales are particularly vulnerable to ship strikes and the North Atlantic has some of the highest recorded rates of interactions between whales and vessel traffic globally (SEDA). While more research is needed to establish concrete evidence directly linking maritime vessel traffic in and around the Sargasso Sea to increased ship strike and behaviour alteration among native cetacean populations, the spatial overlap of high vessel traffic routes together with the distribution of critical habitat for several cetacean species may suggest increased likelihood of interactions between the two (SEDA). In addition to physical interaction, noise pollution from vessel traffic impacts many vocalizing marine species, impeding their ability to communicate during key life stages, sometimes having chronic and long-term impacts for certain populations. Commercial shipping activity contributes significantly to underwater noise and the propulsion systems of commercial ships are a dominant source of low frequency radiated underwater noise (SEDA).

The principal source of shipping pollution is routine operational discharge, which can comprise of oil, chemicals, and polycyclic aromatic hydrocarbons, although illicit and accidental discharge of contaminants continues to occur on the high-seas. Ballast water discharge is widely considered one of the primary vectors for the spread of introduced and invasive species (SEDA).

Pollution

Despite its remote location in the Atlantic, the Sargasso Sea is not immune from the impacts of polluting human activities. While impacts of pollution caused by shipping are not as obvious in the Sargasso Sea, pollution from debris that accumulates amongst the floating *Sargassum* is evident as it is trapped by the oceanic gyre, as the same oceanographic processes that draw drift algae together and form *Sargassum* mats also concentrate pollutants and human waste. An estimated 56,000 tons of floating plastic existed in the Sargasso Sea in 2014, which has almost certainly grown since. Today, the North Atlantic gyre has a patch of floating debris akin to the more famous North Pacific garbage patch. The 2024 Greenpeace cruise through the Sargasso Sea retrieved hundreds of pieces of plastic from within the sargassum mats. On close inspection, every clump of seaweed contained a panoply of plastic pollution, from bottle

[14] As of September 24th, 2021, the NAFO Commission agreed to continue the existing protection of seamounts in the NAFO Regulatory Area (NRA) from bottom fishing for the next 5 years - meaning protections will be in place until 2026. This builds upon the 2016 decision by NAFO to close all seamounts in the NAFO area to bottom trawling through 2020, which was a direct result of the work of the Sargasso Sea Commission at NAFO meetings. The extended protections will now include all seamounts in the NRA at a fishable depth (less than 4000 meters deep).

caps to disposable cutlery. Marine animals may become entangled in this plastic debris – as well as in discarded or lost fishing gear - leading to choking and strangulation. Also, the SSGAC is impacted by small particles of plastic, which may be eaten by birds, turtles and fish, compromising their nutrition, and possibly exposing them to toxic chemicals in the plastics (SEDA).

Beside waste, chemical pollutants have also been recorded in the SSGAC, mainly in or around *Sargassum*. These include arsenic, mercury and germanium, polychlorinated biphenols and other persistent organic pollutants, which tend to “stick” to floating plastic resin pellets at sea, adding another level of risk when or if they are ingested by marine species (Laffoley et al. 2011).

Impacts of sea-bed mining

The impact of potential seabed mining is another concern. Within or on the seabed there are a number of mineral resources that are potentially important including polymetallic sulphides, manganese nodules and cobalt-rich crusts, gas hydrates, and, in the thick sediment deposits in the west of the area, hydrocarbons. None of these resources is presently exploited in the Sargasso Sea region but the potential for future mining and extraction remains. The ISA has entered into 15-year contracts with twenty-one contractors for exploration of polymetallic nodules, polymetallic sulphides and cobalt-rich ferromanganese crusts in the international seabed area (the Area). In the North Atlantic, Three ISA contracts exist for exploration of the Mid-Atlantic Ridge as a site for polymetallic sulphide extraction. While not overlapping directly with the SSGAC, it could be impacted indirectly, e.g., by sediment drift.

SSGAC Improved Conservation and Stewardship Measures

Legal framework for management of the high-seas

Nearly two-thirds of the ocean (representing approximately 95% by volume) exists in "areas beyond the national jurisdiction" (ABNJ) of coastal States (comprising the high seas and the international seabed area) (see figure 15).

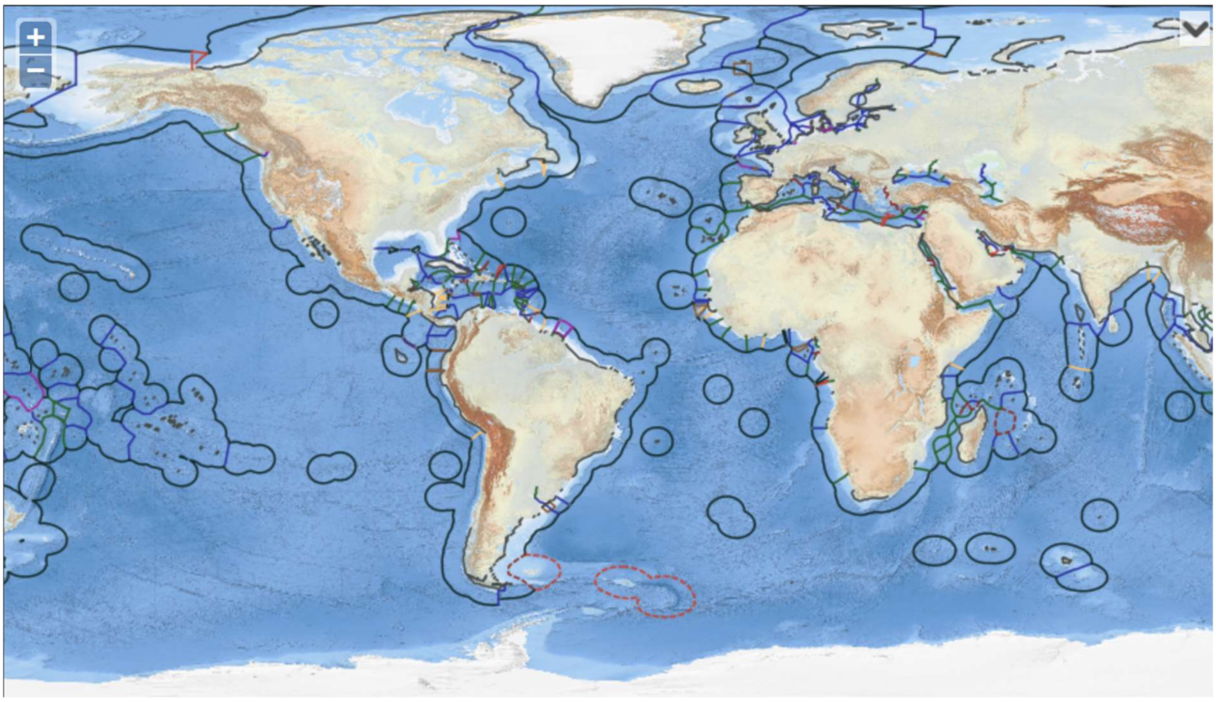

Figure 15: Exclusive Economic Zones and the High-Seas (Source: https://www.marineregions.org/eezmapper.php)

The basic legal framework for ocean governance is provided by the 1982 UN Convention on the Law of the Sea (UNCLOS), which defines the various jurisdiction zones that coastal states may claim (i.e., Territorial Sea, Contiguous Zone, Exclusive Economic Zone (EEZ), Continental Shelf, etc.) and which sets out the regime of the high seas and the deep seabed (called the "Area"). The high seas regime is based on the concept of freedom of the high seas; UNCLOS sets out six high seas freedoms (navigation, overflight, laying of submarine cables and pipelines, construction of artificial islands, fishing and scientific research). It has been called an "unfinished agenda" (Freestone, 2016) because while these freedoms are all subject to limitations, those limitations are not fully developed in UNCLOS itself. In particular, it does not recognise the importance, and provide means for the protection, of high seas and deep-water ecosystems and the biodiversity that they harbour.

These area beyond national jurisdiction contain unique species and ecosystems which, through scientific and technological advances and increasing economic pressures, are subject to increasing interest and exploitation, including through fishing, mining and bioprospecting in the deep sea. In 1995 the UN concluded an Implementing Agreement which sought to develop and clarify the regime for highly migratory species and straddling fish stocks (UN Fish Stocks Agreement (UNFSA)) and to introduce more modern management concepts such as the Ecosystem Approach to Fisheries and the Precautionary Approach, however until recently, there existed no global legal framework for the conservation and sustainable use of biological diversity in these areas. Existing global instruments apply only to specific species (e.g. tuna and tuna like species) or are of limited application to ABNJ (e.g. the Convention on Biological Diversity (CBD)), or like UNCLOS itself contain only general provisions related to the protection of rare and fragile ecosystems or threatened or endangered species.

In 2023, after nearly two decades of discussions and negotiations, the UN adopted another implementing agreement to UNCLOS on “the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction” (BBNJ Agreement). The BBNJ Agreement aims to ensure better protection and management of biodiversity in ABNJ and in particular covers issues relating to marine genetic resources, including questions on the sharing of benefits, measures such as area-based management tools, including marine protected areas, environmental impact assessments, including strategic environmental assessment, and capacity-building and the transfer of marine technology. It is designed to reflect the developments and to address the challenges that have occurred in relation to marine biodiversity since UNCLOS was concluded in 1982. The BBNJ Agreement also has the tools to contribute to the goals and targets set under the CBD’s Global Biodiversity Framework (GBF), notably the target to ensure effective conservation and management of at least 30% of the world’s lands, inland waters, coastal areas and oceans by 2030. It may also support other global agendas, such as the implementation of the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement, and the achievement of the 2030 UN Agenda for Sustainable Development, in particular its Sustainable Development Goal 14 (“Life Below Water”).

To achieve the objectives of conservation and sustainable use of marine biodiversity in ABNJ, the Agreement contains two important new instruments: and environmental impact assessments under Part II of the Agreement and area-based management tools (ABMT), including marine protected areas (MPA) under Part III. Part III provides a methodology for the establishment and international recognition of ABMTs within ABNJ. The text prescribes a process of submission, review, publicity, and consultation with stakeholders, with decisions taken at the COP by consensus (or two-thirds majority). This process is open to proposals from any one or more States Party to the Agreement. It potentially provides an important new conservation tool for ecosystems such as the Sargasso Sea.

The situation in the Sargasso Sea

Because of the difficulties of establishing legally binding protection mechanisms in the high-seas, it is obvious why no one has undertaken an in-depth effort for a stewardship and conservation mechanism for a marine ecosystem beyond national jurisdiction. Despite the large number of international organizations with an interest in ABNJ, there are only a handful with actual management competence in the SSGAC and none with a core focus on comprehensive conservation of marine biodiversity or ecosystems (SEDA).

Instead, each sectoral regime with competence over activities in the SSGAC has its own distinctive protection mechanisms. The result is a patchwork of sectoral area-based management tools designed to protect specific marine areas from specific sectoral threats. For example, the IMO has the power to adopt MARPOL Special Areas and Particularly Sensitive Sea Areas (PSSAs) to limit some shipping impacts, non-tuna RFMOs have the power to protect vulnerable deep seabed ecosystems (VMEs), and the ISA has designated nine no-mining “Areas of Particular Environmental Interest” in the Clarion Clipperton Zone based on “design principles for representative networks of marine protected areas” (SEDA).

Several areas in and around the Sargasso Sea have been recognized as critical habitat for marine communities. These areas, including habitat associated with breeding, feeding, development, and migration are important to the life history stages of a wide range of species. Designated critical habitat areas include two EBSAs and two vulnerable marine ecosystems (VMEs) are within the SSGAC. In the Bermuda EEZ there are also one important bird area

(IBA), one marine key biodiversity areas (KBAs), and seven coastal or marine protected areas (PAs) that exist within Bermudan jurisdiction (figure 16) (SEDA).

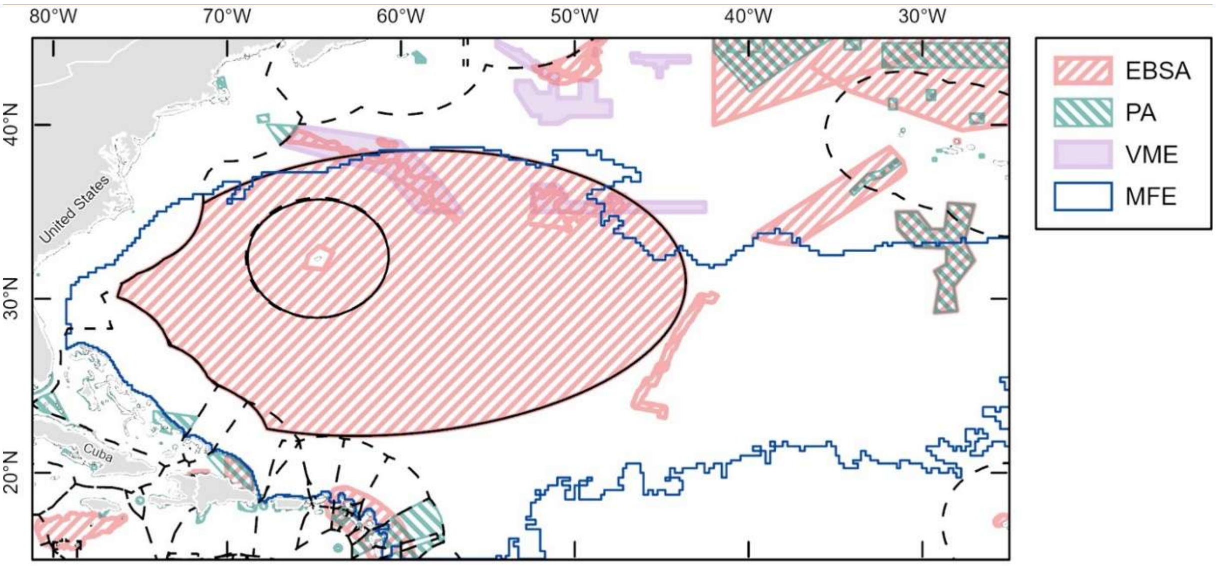

Figure 16: Recognized areas of importance in the Sargasso Sea (SEDA).

The Sargasso Sea EBSA overlaps almost completely with the SSGAC while the New England and Corner Rise Seamounts overlap with relatively little area in the northern region. VMEs designated by the Northwest Atlantic Fisheries Organization (NAFO) are areas that are particularly susceptible from damage caused by bottom fishing. The two VMEs that overlap the SSGAC (New England Seamounts and Corner Rise Seamounts) both contain a chain of seamounts with highly diverse deep-sea biological communities. Both VMEs overlap the two EBSAs that intersect with the SSGAC (SEDA).

IMO has implemented spatial based conservation measures called PSSAs. These areas are recognized for ecological, socio-economic, scientific reasons and may be vulnerable to damage by maritime activities. Currently, there are no PSSAs that include the Sargasso Sea GAC (SEDA).

Conservation Measures

While significant challenges and gaps exist with regard to the conservation of biodiversity in ABNJ, several mechanisms – “conservation measures” – exist which could offer respite to high-seas ecosystems, if implemented.

Environmental Impact Assessments

The institutional and legal fragmentation described above are a clear hurdle to holistic and effective management of the high-seas. In this context, one notable gap being discussed is the lack of standardized rules for conducting Environmental Impact Assessments (EIAs) and Strategic Environmental Assessments (SEAs). Such assessments would have a legal basis in two poorly implemented elements of UNCLOS: to “observe, measure, evaluate and analyse, by recognized scientific methods, the risks or effects of pollution on the marine environment” and to “keep under surveillance the effects of any activities which they permit” (Art. 204). States are likewise bound to “publish or provide such reports at appropriate intervals to the competent international organizations” (Art. 205). Potential impacts of planned activities are subject to the same reporting obligations (Art. 206) (Blasiak/Claudet 2024).

Further specifics on the format, content, or details of these assessments are not provided by UNCLOS, although the text of the respective Articles 204-206 is similar to the definition of EIAs provided by UNEP. In 1991, the Convention on Environmental Impact Assessment in a Transboundary Context was adopted, which obligates Member States to conduct EIAs in the context of impacts that cross borders, but it remains limited to national jurisdictions. Whereas EIAs are widely used by regulatory bodies to align approval of projects with environmental policy, SEAs generally extend beyond individual projects to consider a broader set of development objectives for a region or location over time – but their application in ABNJ becomes even patchier than within national jurisdictions. Also, such assessments are often sectoral in nature, e.g., assessing the impact of fishing on a specific fish population (Blasiak/Claudet 2024).

Nevertheless, if conducted with good faith, EIAs and SEAs are an effective tool to assess negative environmental impacts on the one hand, and on the other communicate such impacts to the broader public and stakeholders.

High-seas Marine Protected Areas

Another notable gap in ABNJ is the lack of a coherent mechanism for establishing MPAs on the high-seas or associated seabed area. The International Union for the Conservation of Nature (IUCN) defines a protected area as a "clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values." Hence a single sectoral designation simply preventing fishing or vessel traffic activities does not in itself meet these criteria. The management regime ideally needs to be multisectoral (Freestone 2018; Blasiak/Claudet 2024;).

The importance of MPAs as effective conservation measures is underlined by obligations and targets included in the Global Biodiversity Framework of the Convention on Biological Diversity (CBD) and, subsequently, in the Sustainable Development Goals (SDGs) – to conserve 10% of marine areas by 2020. The 10% target was followed in late 2022 with the Kunming– Montreal Global Biodiversity Framework Target 3, to "ensure and enable that by 2030 at least 30 per cent of terrestrial and inland water areas, and of marine and coastal areas…are effectively conserved". This target is nearly impossible to reach without a mechanism for establishing MPAs in ABNJ, as only around 36% of marine water are situated within national jurisdictions (Blasiak/Claudet 2024).

Within the context of IMO, spatial-based conservation measures called Particularly Sensitive Sea Areas (PSSAs) can be implemented, although there are none that overlap with the Sargasso Sea. In fact, presently only one PSSA is (partly) situated in the high-seas at all, the North-Western Mediterranean PSSA (SEDA; see figure 17 below).

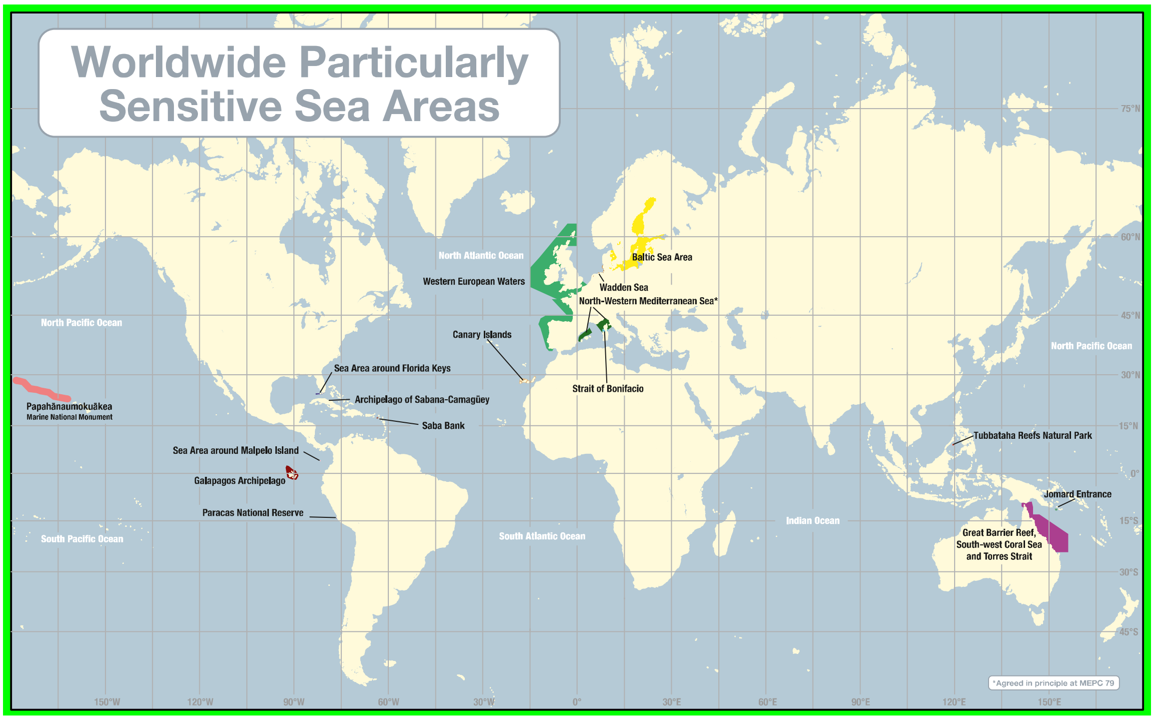

Figure 17: A map of global PSSAs designated by IMO (Source: IMO)

MPAs can also be established in other legal frameworks or contexts. In the case of fisheries, RFMOs can designate vulnerable marine ecosystems (VMEs) and impose restrictions on fishing activities. This potential remains only partially realized, not least because of the absence of RFMOs from large parts of the ocean, due to limitations on the assessment of marine biodiversity, and weak application of this tool (e.g., implementation of VMEs in regions where fishing is not viable). The ISA can describe APEIs and "preservation reference zones" in line with REMPs to limit harmful impacts of seabed mining (Blasiak/Claudet 2024).

In the OSPAR region (the NE Atlantic), eight MPAs in ABNJ have been established (OSPAR 2025), but they are binding only for signatories (currently 15 MS and the European Union). There is also an opinion that they may offer low levels of protection, and may be inadequately implemented and managed (Sullivan-Stack et al. 2024). Likewise, the establishment of large-scale MPAs through the Commission for the Conservation of Antarctic Marine Living Resources has nominally resulted in close to 3% of the high-seas being covered by MPAs, although this percentage falls below 1% when one considers only MPAs that are implemented as fully or highly protected (Blasiak/Claudet 2024).

This latter point highlights one significant factor in the effectiveness MPAs can offer: it is completely dependent on the management plan and it´s ambition (i.e., defining the level of protection, with fully or highly protected areas offering the greatest benefits in terms of ecology and economy), as well as the level of control and enforcement possible – a challenging issue in remote ABNJ.

Fishing Management Options

Management options that lessen the environmental impact of fishing activities mostly target the following main topics:

- Impacts of fishing on fish populations (introduction of an Ecosystem Approach to Fisheries);
- IUU fishing activities,
- impacts of fishing activities on benthic habitats, and

- specific measures to protect the American and European Eel.

The key objectives of the UNFSA with regard to conservation are to “ensure the long-term conservation and sustainable use of straddling fish stocks and highly migratory fish stocks” (Art. 2) and to “apply the precautionary approach” and “protect biodiversity in the marine environment” (Art. 5). Considering the current status of global fish populations – with only 61% at healthy levels of abundance according to the International Seafood Sustainability Foundation – it must be stated that these objectives are not reached or realized by the current governance regime. While some RFMOs – notably tuna RFMOs – have established some form of monitoring the impacts on their target species, there are gaps in monitoring bycatch species (other fish, mammals, birds) and impacts on trophic relationships and habitats. Most RFMOs do not have any bycatch mitigation measures in place, which would be important, as pelagic shark and ray populations have declined by 71% since 1970 and 21 of the world’s 40 albatross and petrel species are classified by the International Union for Conservation of Nature as vulnerable, endangered, or critically endangered. One aspect of monitoring activities is the presence of observers on fishing vessels, which is at well under 10% of vessels in the most important fleets fishing the SSGAC (Taiwanese, US, and Spanish). In the SEDA, it is reported that the US Atlantic pelagic longline fishery has required an electronic monitoring program since 2015 to ensure compliance with individual bluefin tuna quotas and monitor the catch of other species, such as shortfin mako sharks. The electronic monitoring system, mandatory for all PLL vessels regardless of size, includes video cameras, sensors, and GPS to record fishing activities, particularly during gear retrieval, to verify the accuracy of reported catches and species identification. Data from these systems are reviewed by a government-contracted EM service provider, with 10% of fleet-wide sets reviewed annually.

With regard to illegal, unregulated and unreported (IUU) fishing, controls on the trade in large pelagic species managed by ICCAT has reduced IUU activity targeting these species. Although the present state of the stocks of many of the species managed by ICCAT is below historical levels, ICCAT has in the past imposed time-limited closed areas and moratoria on fishing near floating objects in efforts to protect juvenile bigeye, yellowfin and skipjack. However, they recognize the present closed areas are too small to be very effective and are also in an area of low fishing effort. However, time/area closures aimed at protecting certain species is very effective and should be encouraged (Laffoley et al. 2011).

Deep pelagic and bottom trawling can cause extensive destruction of the benthic fauna. As a precautionary management measure, 12 fishable seamounts in the northwest Atlantic in ABNJ in the NAFO Regulatory Area were closed to demersal fishing from January 1, 2007, including the seamounts in the SSGAC. Different fisheries measures have been put in place by NAFO to protect these seamounts and associated species since 2007, e.g., in 2016, NAFO requirements for mid-water trawl gear modification were introduced to avoid bottom contact when fishing in seamount areas (NAFO 2025).

Measures are in place to protect the critically endangered European Eel, as well as the American Eel. Such measures are primarily within their coastal and freshwater ranges states but some also apply to the Sargasso Sea. These include:

- Integrated management approaches across the geographic range of the species.
- Habitat restoration and improved river connectivity by removing or modifying barriers like dams and weirs and installing effective eel passages, as well as restoration of inland eel habitats.
- Strengthen fisheries regulation and traceability by enforcing science-based quotas and size limits for glass, yellow, and silver eel fisheries, e.g., through licensing systems, reporting requirements and electronic catch documentation and transaction cards.

- Enhanced surveillance, including multi-agency enforcement operations, is essential to combat IUU fishing and to prevent the illicit export of eels.
- Reduce non-fisheries pressures by reducing water pollutants that are known to accumulate in eels and impair their reproductive success.
- Understand and address climate change impacts on eel larval survival in the Sargasso Sea.
- Close critical data gaps and enhance research.
- Improve governance, enforcement, and public awareness.

Shipping Management Options

Management options that lessen the environmental impact of shipping activities mostly target the following main topics:

- Pollution (substances),
- Noise pollution
- Introduction of invasive species
- Ship strikes/collisions.

As the principal source of shipping pollution is routine operational discharge (comprised mostly of oil, chemicals, and polycyclic aromatic hydrocarbons), stricter regulations on discharging oil have been successful in reducing oil and tar pollution, evident in lesser and lesser findings of tar balls in the SSGAC since the mid-1990ies. “Bilge dumping” entails the disposal of contaminated bilgewater by large vessels in ABNJ as a way to circumnavigate guidelines on treatment and disposal of routine operational waste. IMO has established regulations to control dumping of contaminated water above a certain contaminant concentration threshold, requiring additional onboard treatment and backup alarm/stopping systems for larger vessels to ensure environmentally responsible discharge. To avoid costs of implementing treatment and disposal protocols, illicit and accidental discharge of contaminants continues to occur on the high-seas, but can be detected using satellite imagery, and there are online mapping resource for oil slick and spill detection[15] (Laffoley et al. 2011; SEDA).

Invasive species are a form of pollution (any form of contaminant that is not normal present and is considered harmful). Invasive species can be introduced to non-native waters through ballast water or bilge discharges and from the presence of biofouling on ships hulls and other features in regular contact with the ocean.

Noise pollution and ship strikes can effectively be prevented only by introducing area-based management tools, which could impose speed limits, certain vessel technologies or even temporal closures.

[15] E.g., Sky Truth’s Project Cerulean (https://skytruth.org/Cerulean/).

Cost-Benefit Categories of improved Conservation Measures

In this section, a set of selected conservation measures for improved conservation of the SSGAC is analysed, setting up a framework for the assessment in terms of their effectiveness, costs, and benefits. To accomplish this, initial estimations are drawn up of the impacts/changes to the value of ecosystem services expected in a "business-as-usual" scenario (i.e., no change in management, existing scenarios e.g., of climate change effects, changes in physical and chemical oceanographic status, fisheries trends). Based on this, an initial list of conservation measures for an improved conservation for the SSGAC and the relevant cost- and benefit-categories influenced by the selected options (as a starting point for the development of management scenarios of the SAP).

BAU-Scenario and associated Loss of Ecosystem Services

The Sargasso Sea – as well as the global oceans - faces significant future threats and challenges. The impacts section above lists the most significant ones:

- Climate Change,
- Habitat Deterioration and Loss,
- Impacts of fishing and over-fishing,
- Impacts of shipping,
- Pollution, and
- Impacts of sea-bed mining.

Assuming a timeframe of 50 years (until 2075), the above pressures could cumulate in the following scenario[16]:

- Climate Change
    - Warming and stratification: The SSGAC, which is already warm and nutrient-poor, experiences further rising sea surface temperatures. Increased stratification limits nutrient upwelling, reducing productivity and shifting plankton communities. Possible effects on temperature-sensitive migratory species.
    - Ocean acidification: Calcifying organisms (pteropods, coccolithophores) that form the base of the food web will be strongly impacted, weakening energy transfer to higher trophic levels. Negative impacts also on various metabolic and reproductive functions of various species, some of them economically important.
    - Altered currents: Changes in the current regime (Gulf Stream, AMOC etc.) disrupt transport pathways for larvae etc., threatening species that rely on the SSGAC for spawning (e.g., American and European eels). Weakened AMOC could result in colder temperatures in Western Europe, altered precipitation patterns across the globe, potential disruptions to ocean ecosystems, and could even contribute to more extreme weather events.
    - Climate change driven changes in these parameters all related to surface ocean production could lead to changes in relative abundance of selected species, trophic structure, and a "restructuring" of overall Sargasso ecosystem
- Habitat Deterioration and Loss
    - *Sargassum* rafts, the defining feature of the Sargasso Sea, face dual pressures through climate change and altered nutrient dynamics, which may reduce the stability and extent of *Sargassum* habitats.

[16] The BAU-Scenario is based on the Stewardship Project´s Causal Chain Analysis, as well as other expert´s opinion.

    - The degradation of *Sargassum* habitats undermines the crucial nursery functions for many fish species, turtles, and invertebrates which depend on floating *Sargassum* mats.
    - Due to the high connectivity of the SSGAC, such impacts would also seriously impact neighbouring and other oceanic regions.
- Fishing and Overfishing
    - Target species: Continued exploitation of tunas, billfishes, and other large pelagics strongly impacts populations. Already vulnerable populations face (regional) extinction. By mid-century, many fish populations could decline to ecologically and commercially unsustainable levels if management remains fragmented across jurisdictions.
    - Bycatch: Mammals, such as sea turtles, non-target fish, as well as sea birds associated with *Sargassum* mats are impacted, aggravating the already vulnerable/threatened status of many of such species.
- Shipping
    - The Sargasso Sea remains a major trans-Atlantic shipping corridor, with increased traffic due to global economic development. Almost certainly, this results on more noise pollution, interfering with cetacean communication and navigation (notably humpback and sperm whales), and more ship strikes, particularly threatening whales.
    - Pollutant discharge (oil, waste, microplastics from hull coatings) also increase proportionally, as well as the introduction of invasive species via ballast water and hull fouling.
- Pollution
    - Plastics: The North Atlantic Subtropical Gyre continues to accumulate plastic debris, making the SSGAC a persistent convergence zone for micro- and macroplastics. By 2075, plastic could outweigh plankton biomass in surface waters.
    - Chemical contaminants: Persistent organic pollutants (POPs) and heavy metals bioaccumulate, affecting top predators and vulnerable/threatened species of concern (e.g., eels, turtles, sea birds).
- Sea-bed Mining
    - Although the SSGAC itself has no licensed mining areas, adjacent deep-sea areas (notably in the wider North Atlantic) are targeted for polymetallic nodule and seamount mining, which could lead to sediment plumes, which disperse along currents, impacting deep-sea fauna and potentially reaching the SSGAC´s pelagic ecosystems.

Hence, under a BAU scenario, the unique *Sargassum* habitat could become fragmented and unstable, partly losing its role as a nursery for fish, turtles, sea birds and invertebrates. This especially impacts American and European eels and sea turtles, as well as pelagic fish species which are further threatened due to uncontrolled overfishing. The SSGAC further becomes more and more of a “plastic soup”, with plastics integrated into food webs and replacing natural *Sargassum* as a floating substrate.

These developments result in the loss of ecosystem services (or a reduced value of still existent ecosystem services):

- Reduced fisheries productivity in the SSGAC as well as the wider Atlantic.
- Reduced tourism revenues in Bermuda and beyond (e.g. Caribbean) due to rarer sightings of whales, sea turtles and sea birds.

- Reduced revenues through sports fishing in Bermuda and beyond (e.g. North America and Caribbean).
- Diminished carbon sequestration capacity in the SSGAC.
- Reduced biodiversity and existence values.

The scale of ecosystem services losses cannot be determined exactly, or in monetary terms. Instead, the following table lists the assessed ecosystem services, their monetary value as well as the estimated scale of losses (based on an initial expert assessment which needs to be developed further during the SAP-development process):

- Low/little reduction in ecosystem services provision: losses range between 0 and 25% of current provision.
- Medium reduction in ecosystem services provision: losses range between 26 and 50% of current provision.
- High reduction in ecosystem services provision: losses are higher than 50% of current provision, up to a total loss of the ecosystem service.

Activity	Estimated Annual Value derived locally (Bermuda and SSGAC) from SSGAC to this activity (USD/a)	Estimated Annual Value derived globally from SSGAC to this activity (USD/a)	Most significant data gaps
Commercial Fishing	15 million (Pendleton et al. 2014) to 110-120 million (SEDA)[17].		SEDA value only represents 9 tuna-like species. Other target species (e.g., blue shark) not included.
Eel Fisheries	53.5 million (SEDA) to 66 million (Pendleton et al. 2014). Possibly much higher, as three Caribbean states state export values of 25 million USD/annually (in 2016-17 and 2021).		Parts of global trade (e.g., in glass eels) not included. No data on costs (value if gross value). Very dynamic prices.
Tourism in Bermuda	No estimates available.	n.a.	Motives of visits to Bermuda unknown.
Sport and Recreational Fishing	0.88 million (Hallet 2011).	17.3 billion (US Atlantic) 6.8 million in Eastern Caribbean.	Number of visitors coming for fishing to Bermuda unknown. Contribution of high-seas to fishing in EEZ unknown. Contribution of SSGAC to fishing in wider Atlantic unknown.
Whale-Watching	No estimates available.	500 million in the North Atlantic (estimate). 2.1 billion (O´Connor et al. 2009) to 3.6 billion (estimate) globally.	Number of visitors coming for whale-watching to Bermuda unknown. Contribution of SSGAC to whale-watching in wider Atlantic or globally unknown.
Bird Watching	No estimates available.	Spending on bird watching 650 million in UK, 40 billion in US.	Contribution of SSGAC to bird watching in coastal areas around the Atlantic unknown. Number of visitors coming for bird watching to Bermuda unknown.

[17] This estimate represents the gross value of landed catches, meaning that the costs of the fisheries operations are not included yet. Recent studies suggest that fishing in the high-seas is presently enabled by large government subsidies, without which as much as 54%of the present high-seas fishing grounds would be unprofitable at current fishing rates. The patterns of fishing profitability vary widely between countries, types of fishing, and distance to port. However, it is obvious that much fishing by the world's largest fishing fleets would largely be unprofitable without subsidies and low labor costs (Sala et al. 2018).

Turtle Watching	No estimates available.	7 million in single NP in Costa Rica (Troëng/Drews 2004).	Number of visitors coming for turtle watching to Bermuda unknown.
Carbon Sequestration	2.4 billion to 15.3 billion in "biological" CCS. 12.8 billion in abiotic absorption of anthropogenic CO_2		CCS rate in SSGAC unknown. Storage in *Sargassum* unknown.
Oxygen Production	No estimates available.		Unclear whether oxygen production should be valued as ecosystem service.
Education and Research	12-13 million in related expenditures (Pendleton et al.)	No estimates available.	Number of visitors coming for research/education to Bermuda unknown.
Existence Value/Biodiversity	67.8 billion in "cultural services" based on Costanza et al. (1997).		Stated preference study for SSGAC. Expenditures by international organizations to protect the SSGAC unknown.
Ecosystem Services of the deep-sea	No estimates available, though the deep-sea has an important part in other ecosystem services, such as carbon sequestration, fisheries etc.		Contribution of deep-sea to other ecosystem services unknown.

Table 3: Ecosystem Services Provision and potential Losses under the BAU-Scenario

Conservation Measures for an improved Stewardship of the SSGAC

Of the conservation measures addressing important pressures present in the SSGAC, as presented above, an initial selection is presented in this section (in the following table), along with the relevant cost and benefit categories associated with these options. Due to the fact that presently, there are no specific conservation measures planned in the SSGAC, the conservation measures presented here are an initial list of options developed in the frame of this report, without assessing in detail their feasibility. In the ongoing SAP-developments process, these measures (as well as others) need to be assessed and planned more specifically and in more detail. Based on this more specific planning, the costs and benefits of the potential measures can also be assessed in more detail in order to support the selection process.

The cost and benefit categories selected have also been developed in the frame of this report. They cover the most obvious aspects of the conservation measures, such as implementation costs (e.g., for personnel, equipment etc.), ongoing costs (mostly in form of enforcement and controls), and the benefits they derive in terms of addressing the main pressures and reducing their negative impacts. The effectiveness of the conservation measures refers to preventing these impacts, and "improving" on the BAU-Scenario outlined above.

The content of the following table represents an initial assessment, which is not to be considered either definitive or comprehensive. It is the idea of this table to kickstart the discussion early on what the options are; it can serve as a base to solicit expert´s opinion and thus to improve its content during the SAP-development. After the key measures options to be considered are set, further work is needed to specify their effectiveness, as well as the estimation of the related cost categories, where additional categories could be added.

Management Option	Short description	Pressures addressed	Effectiveness against BAU-Scenario	Cost categories	Benefit categories
EIA/SEA for RFMO stock assessments	Mandatory EIA/SEA for RFMOs to assess the status of fish populations when planning quotas.	Fisheries	Medium	Implementation costs incurred at RFMOs	Increasing fish populations and larger catches in the medium-term Biodiversity benefits Increased sports/recreational fishing
EIA/SEA for deep-sea mining in adjacent areas	Mandatory EIA/SEA for issuing ISA licenses to mining companies.	Deep-sea mining	Medium	Implementation costs incurred at ISA	Biodiversity benefits Increased carbon sequestration
"Weak" MPA	MPA targeting only one sector, with unambitious management plan, a small area or other factors that hinder effectiveness.	Fisheries, shipping	Low	Potential short-term losses to exploiting industries Costs for drafting management plan Controls & Enforcement	Increasing fish populations and larger catches in the medium-term Biodiversity benefits Possibly increased whale-watching/turtle-based tourism Increased carbon sequestration
"Strong" MPA	MPA aiming at strong conservation effects, targeting all pressures, covering a large enough area, an ambitious management plan (that, e.g., includes time/area closures and enforcement strategies).	Could address all (regional) human pressures	High	Potential short-term losses to exploiting industries Costs for drafting management plan Controls & Enforcement	Increasing fish populations and larger catches in the medium-term Biodiversity benefits Possibly increased whale-watching/turtle-based tourism Increased carbon sequestration
Measures on fishing vessels to monitor bycatches and impacts on target species	Increased quota of observers onboard the vessels, and/or obligatory electronic monitoring and electronic reporting equipment and practices.	Fisheries	Low	Personnel costs Costs of electronic monitoring equipment	Increasing fish populations and larger catches in the medium-term Biodiversity benefits

				Controls & Enforcement	Increased sports/recreational fishing
Bycatch mitigation measures	Obligatory bycatch mitigation measures to avoid bycatches of mammals, turtles and seabirds.	Fisheries	Low	Costs of equipment Controls & Enforcement	Biodiversity benefits Increased whale-watching/turtle- or seabird-based tourism
Trade controls to reduce IUU fishing	Strict(er) controls for IUU and illegal trade in endangered fish (e.g., eels, tuna, sharks etc.)	Fisheries	Low	Controls & Enforcement	Increasing fish populations and larger catches in the medium-term Biodiversity benefits Increased sports/recreational fishing

Table 4: Conservation Measures for an improved Stewardship of the SSGAC

Summary, conclusions and recommended next steps

The report presents an initial framework for the assessment of conservation and management options for the Sargasso Sea Geographical Area of Collaboration — a high-seas ecosystem of global ecological, biological, and economic significance.

The Sargasso Sea GAC lies in Areas Beyond National Jurisdiction. The BBNJ Agreement (2023) offers a new legal mechanism for biodiversity protection, marine protected areas (MPAs), and environmental impact assessments (EIAs). However, presently the management is fragmented among sectoral bodies (IMO, ICCAT, ISA, etc.), resulting in patchy protection.

The document identifies six main categories of main human and environmental pressures:

- Climate Change: Rising sea temperatures, acidification, altered current systems, and increased marine heatwaves threaten ecosystem stability.
- Habitat Deterioration: Loss of Sargassum mats and coral decline undermine nursery and feeding habitats.
- Overfishing: Unsustainable exploitation of tuna, swordfish, and eels; bycatch of endangered turtles and birds; and possible illegal, unregulated, and unreported (IUU) fishing.
- Shipping Impacts: Ship strikes, underwater noise pollution, chemical discharge, and introduction of invasive species via ballast water.
- Pollution: Accumulation of plastics and chemical pollutants, making the Sargasso Sea a North Atlantic “plastic soup.”
- Seabed Mining: Prospective mining near the Mid-Atlantic Ridge could indirectly affect deep-sea and pelagic ecosystems through sediment plumes.

If no additional management measures are implemented by 2075, main consequences can be:

- Biodiversity collapse: Loss of nursery habitats, increased species extinction risk.
- Reduced fishery yields: Declining commercial species and bycatch of protected fauna.
- Tourism decline: Fewer sightings of whales, turtles, and seabirds.
- Weakened ecosystem functions: Lower carbon sequestration and oxygen production.
- Increased pollution: Plastics may outweigh plankton biomass.

All of the above needs to be further developed and assessed in more detail based on the ongoing SAP-development process.

In addition, and regarding the initial list of conservation measures to better protect the SSGAC´s ecosystems:

- The ongoing SAP-development needs to further elaborate the priority areas of action for which current and future pressures need to be reduced;
- The initial list of measures above needs to be further expanded with additional options, specified as far as possible and evaluated early on regarding the feasibility/political acceptability in order to focus on the most promising options;
- In this process, the (socio-)economic assessment of the options/measures should be further developed in a step-wise approach, offering supporting information regarding their effectiveness, but also their costs and potential monetary benefits. The more specific the potential measures become, the more detailed the assessment of costs and benefits can be, leading to a better decision base;
- Such an approach implies further (socio-)economic work that should be organically linked to the SAP-development process (a “work bench”-approach), accompanying the

development of measures at each specification step by providing their effects on the provision of ecosystem services and estimating the broader costs and benefits associated to them;

- This approach needs to be backed up by a substantial stakeholder interaction in order to include information based on best available expert knowledge, gain and use insights on political feasibility, but also reach the best possible estimations on costs and benefits which then are to be integrated in a systematic manner in the options assessment and consequent proposals to be included in the SAP.

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