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Implementing regional blue economy research and innovation strategies: a case study for the Black Sea

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The Black Sea is a vital resource with vast potential to boost the societal value of the Blue Economy for its surrounding countries. Improved knowledge and enhanced infrastructure together with better coordination and alignment of research and innovation efforts are critical for the better management of the deteriorated Black Sea ecosystem to help restore and maintain its resilience and enable sustainable use of natural resources. In 2019, the Black Sea Strategic Research and Innovation Agenda (Black Sea SRIA), was developed by the Black Sea experts, in cooperation with European marine institutes and organizations, with the support of the European Commission. Black Sea SRIA presents the priorities and ecosystem-based management options needed for a healthy, sustainable, and resilient Black Sea. Since 2019, efforts focused on developing concrete actions under the Black Sea SRIA Implementation Plan (IP) to contribute to the national blue economy strategies, better structuring of the relevant funding mechanisms for solution-oriented implementation and the international and regional strategies, supporting the co-funding mechanisms. In this study, we present a transnational process that has led to the development of the IP which utilized a bottom-up, co-design and co-creation-based approach. The SRIA and its IP support better governance of the blue economy principles towards sustainable development and conservation of unique Black Sea ecosystems. The Black Sea SRIA and IP address the fundamental research challenges of the region, promote the blue economy, and also build vital support

systems and innovative research infrastructure and capacity together with academia, funding organizations, industry, policy, civil society and local communities. The IP is a long-lasting guide to catalyze new ideas and innovations towards and with the Black Sea community with strong implications for other sea basins.

KEYWORDS

Black Sea, sustainable blue economy, marine policy, capacity building, sea-basin strategies, marine governance, stakeholder engagement

1 Introduction

Each sea and ocean basin has specific ecosystem features together with its own socioeconomic systems. Although global strategies help develop a framework towards the sustainable utilization of marine ecosystem services (e.g. EU Blue Growth Strategy, EU Mission Ocean, EU Green Deal, UN Ocean Decade, UN SDGs), basin-scale strategies are critical. Basin-scale strategies can also support the policy at the national level. Here we present the Black Sea as a case study and describe a systematic approach on how a regional strategy for research and innovation can be created supporting better management and governance for a sea basin.

The Black Sea is unique in many respects. It is rich in biodiversity and has a vibrant marine cultural heritage and abundant natural resources. However, many stressors have been acting on the Black Sea ecosystem during the last 50 years, such as eutrophication and deoxygenation, overfishing, and the introduction of alien species, in addition to the effects of climate change (Oguz et al., 2006; Oguz, 2017). The Black Sea proposes a unique system that serves as a natural laboratory where different combinations of stressors take place during different periods of time. To begin with, it is the largest oxygen-depleted body on earth, below an average of 100 m depth there are no detectable levels of dissolved oxygen, but the deep waters contain high levels of hydrogen sulphide (Tuğrul et al., 2014).

Black Sea borders six countries with approximately 17.5 million inhabitants that are dependent on its services (Figure 1). Despite its socioeconomic significance, the Black Sea was poorly managed. There have been limited efforts towards a strategy that addresses the sustainable use of ecosystem services.

In order to respond to this pressing need, in 2017, an initiative entitled, "The Blue Growth Initiative for Research and Innovation

FIGURE 1
Map of the Black Sea and bordering countries (Credit: Google Earth; Data: SIO, NOAA, U.S. Navy, NGA, GEBCO; Image: Landsat / Copernicus).

in the Black Sea (Initiative)" was launched with support from the European Commission to develop a joint research and innovation agenda and guide for national and EU-level policymakers. Consisting of experts from the Black Sea countries, in cooperation with marine experts from European marine institutes and organizations, the Initiative produced the Burgas Vision Paper to foster human and infrastructure capacity in coastal, marine and maritime sectors in view of unlocking unique opportunities for sustainable and environmentally friendly blue growth in the Black Sea (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2018). This process was further supported by the Ministerial Declaration towards a Common Maritime Agenda for the Black Sea (CMA), endorsed by the Black Sea countries (European Commission, 2019a) The Black Sea SRIA, developed based on the Burgas Vision paper complements the CMA as its scientific basis and provides the inputs for science-based decision-making (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023a).

The Burgas Vision Paper highlights characteristics and principles that guides the common vision and addresses the key pillars on which a new Black Sea Strategic Research and Innovation Agenda (Black Sea SRIA) is built on (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2018). Based on the characteristics and principles that will guide the common vision, a set of priorities for the Black Sea basin was produced and under four main areas these priorities were listed; "i) Addressing fundamental Black Sea research challenges, ii) Developing products, solutions and clusters underpinning Black Sea blue growth, iii) Building of critical support systems and innovative research infrastructures iv) Education and capacity building" (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023a).

A key output of the Black Sea SRIA is to help identify national-level priorities to contribute to the development of national Blue Growth agendas for better management towards sustainable practices. Furthermore, the actions proposed in the Black Sea SRIA and their implementation will generate scientific knowledge. The challenge is to convert its outputs into actions that support better governance. This required an accountable and impactful Black Sea SRIA Implementation Plan (IP) based on the key framework conditions that need the involvement of national research funders and key stakeholders concerned. The Black Sea SRIA has been updated (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023a) and its IP has been developed (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023b) as a result of a series of activities including national and international consultations and pilot activities conducted under the Horizon 2020-funded Black Sea CONNECT project (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2019).

This work aims to present the Black Sea SRIA and its IP and the process leading to the development of these documents. This process is a case study for developing a comprehensive, robust, and long-lasting marine research and innovation agenda. The steps towards the development of the IP as a tailored roadmap are presented and the future challenges and opportunities for the Black Sea with implications for other basins are discussed.

2 Methodology: development of the Black Sea SRIA

The overall methodology leading to the creation of the SRIA and its IP is a multi-stakeholder, multi-country and multi-disciplinary bottom-up co-creation process. The common challenges and multi-stressors that primarily drive the Black Sea ecosystem today served as the thread connecting various stakeholder engagement levels and the co-creation process. These were defined as a first step by the expert stakeholder community: warming, deoxygenation, acidification, overfishing, invasive species, eutrophication, pollution (including litter), and also sea and land-based sector activities. Figure 2 shows the multi-stressors acting on the Black Sea ecosystem (given in the outer blue circle). Research and innovation priorities and the main pillars of a strategic agenda were then sketched. Then, the conceptual approach was developed on how to establish a resilient ecosystem with healthy habitats while assessing and strengthening the ecosystem services that the Black Sea provides. The Black Sea SRIA and the resulting IP are not mere lists of research topics. The community identified that any agenda needs to be achieved by empowering the Black Sea societies and developing innovations and policy options to support the blue economy sectors. Understanding the boundaries of the ecosystem acting under the stressors and the approaches towards a sustainable blue economy should be supported by science-based policies. The approach paves the way towards the IP. This complex process is unpacked and described in the next sections.

2.1 Burgas vision paper and the Black Sea SRIA

The Black Sea Blue Growth Initiative (Initiative) generated a key framework document named, Burgas Vision Paper as a first step toward a common vision of a productive, healthy, resilient, sustainable, and better-valued Black Sea by 2030 (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2018). The document addresses the fundamental principles that the Black Sea SRIA can be constructed on. Also, the Ministerial Declaration on the Common Maritime Agenda (CMA) for the Black Sea was accepted by all Black Sea countries to provide further support for this progress (European Commission, 2019a; Sustainable Blue Economy Partnership, 2021).

Towards the development of the Burgas Vision Paper, existing SRIAs in various sea basins, such as the Baltic Sea and the Mediterranean Sea, were assessed and used to comprise a basis. These strategies showcase the proven feasibility of achieving policy goals on a regional level, enabling collaborative solutions to shared challenges, and fostering the creation of national strategies for marine and maritime sectors that support a sustainable and thriving blue economy in a cohesive manner. Five strategic documents (SEAS ERA Black Sea and Atlantic Strategic Research Agendas (SEAS ERA SRAs) (Cordis – EU Research Results, 2014), BLUEMED Strategic Research and Innovation Agenda (BLUEMED SRIA) (Cordis – EU Research Results, 2018), BONUS Strategic

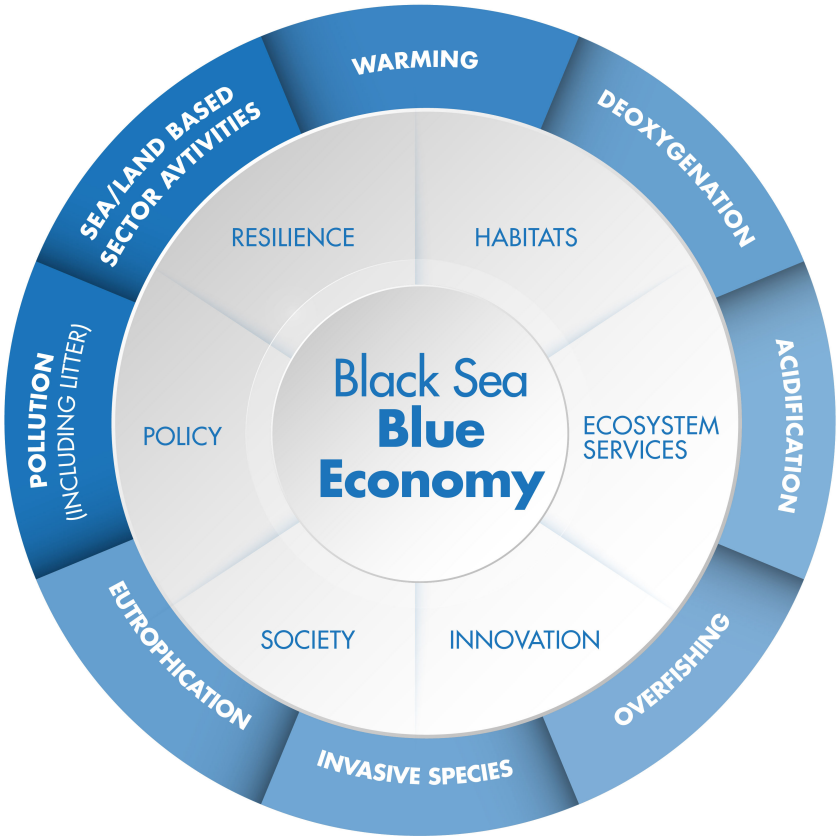

FIGURE 2
Conceptual approach towards establishing a resilient Black Sea blue economy.

Research Agenda (BONUS SRA) (Bonus Portal, 2014), BANOS Strategic Research and Innovation Agenda (BANOS SRIA) (European Union H2020 Banos Baltic and North Sea Coordination and Support Action (Grant A. No. 817574), 2021) and Sustainable Blue Economy Partnership Strategic Research and Innovation Agenda (SBEP SRIA) (European Commission, 2019b) demonstrated particular approaches.

The SEAS ERA SRAs (applied for the Atlantic and the Black Sea), BLUEMED SRIA and BANOS SRIA follow three-pillar strategy outlines (i.e. basic science, applied science, infrastructure), whereas BONUS SRA follows a five-stage strategy outline tailored towards management challenges, and SBEP strategy is based on more specifically oriented "intervention" areas. In the SEAS ERA SRAs and BLUEMED SRIA, applied research and science focusing on both the conservation of existing resources and capacities are prioritized but also sustainable development is at the forefront. The BLUEMED SRIA gives more emphasis on the European blue growth vision. In the BONUS SRA, however, the protection of existing resources and capacities is *a priori*. 'Coastal zone' is addressed differently among the SRIAs. In the Black Sea and BLUEMED, Integrated Coastal Zone Management, Maritime Spatial Planning and Marine Protected Areas are usually evaluated under one 'theme', while in BONUS SRA these subjects are treated as separate research themes. Blue economy sectors such as harvesting the oceans' non-living resources: sustainable mineral, oil and gas extraction from coastal and offshore areas take place in both the SEAS-ERA SRAs and BLUEMED SRIA, however, BONUS SRA does not focus on multi-purpose offshore platforms and its products.

Following the analyses of sea basin strategies, data on both national and international initiatives and projects in the Black Sea were collected, analyzed, and mapped based on pre-defined primary research and innovation areas in the development process of the Burgas Vision Paper (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2018) and the Black Sea SRIA to better identify the areas which need improvement (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023a). Additionally, gaps, research and innovation needs and opportunities together with the necessary justification and drivers were compiled from each Black Sea country. Finally, boundaries and framework conditions at the regional and national levels necessary for the Black Sea SRIA were identified. This work was conducted through several workshops. In addition to the expert group, certain organisations provided direct input through various activities to strengthen science and policy dialogue such as the Black Sea Commission (BSC), the Organization for Black Sea Economic Cooperation (BSEC), the International Centre for Black Sea Studies (ICBSS), Conference of Peripheral Maritime Regions (CPMR), and Black Sea Assistance Mechanism (BSAM). Additionally, other relevant past and ongoing

EU Framework and Horizon Programme projects such as SESAME, PERSEUS, EMODNET, and SeaDataNet, were scrutinized for their potential to exchange best practices, know-how, results, networks, and activities. Similarly, input from research infrastructures (DANUBIUS-RI, different ERICs, JERICO and the Centre for Marine Ecosystems and Climate Research - DEKOSIM) were also included as key enables with their potential to contribute significant data and expertise in supplying relevant baseline data for the blue growth in the Black Sea. Finally, major business stakeholders and marine and maritime clusters (Pôle Mer Méditerranée - Toulon Var Technologies (PMM-TVT), Marine Cluster Bulgaria, GALATEA, BlueInvest) were also taken into consideration for their innovation and business potential.

Based on this work, the experts of the Initiative developed: i) a common vision, ii) challenges, and iii) goals of the Black Sea SRIA based on the data collected and outcomes of these workshops. These findings were presented in the Burgas Vision Paper (Figure 3). After the publication of the Burgas Vision Paper, the efforts were mobilized to develop specific SRIA goals and actions. Further workshops, work on the existing strategies and boundary framework resulted in the Black Sea SRIA in 2019 (see Section 2.2). The Black Sea SRIA is established on the priorities and gaps defined in the Burgas Vision Paper and its frameworks, a common vision for the Black Sea.

2.2 The Black Sea strategic research and innovation agenda

Through the activities mentioned in Section 2.1, the expert group of the Black Sea Blue Growth Initiative identified the four main pillars of the Black Sea SRIA that are listed below (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023a), on which a new set of research and innovation actions can be developed. The pillars are designed to facilitate the creation of cutting-edge, purpose-built observation and data-sharing systems as shown in Figures 4, 5.

- Pillar 1: Addressing fundamental Black Sea research challenges - Black Sea Knowledge Bridge,
- Pillar 2: Developing products, solutions and clusters underpinning Black Sea Blue Growth – Black Sea Blue Economy,
- Pillar 3: Building of critical support systems and innovative Infrastructures - Key Joint Infrastructure and Policy Enablers,
- Pillar 4: Education and capacity building - Empowered Citizens and Enhanced Blue Workforce.

Overall, the Black Sea SRIA is a reference framework consisting of four pillars with specific main goals and actions

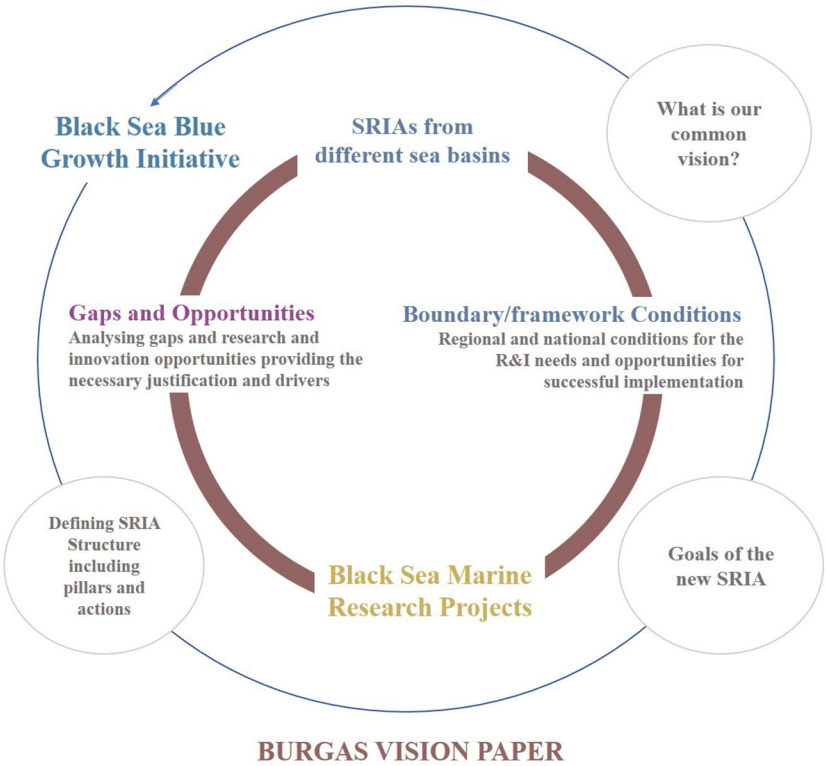

FIGURE 3
The steps taken to develop the Black Sea SRIA.

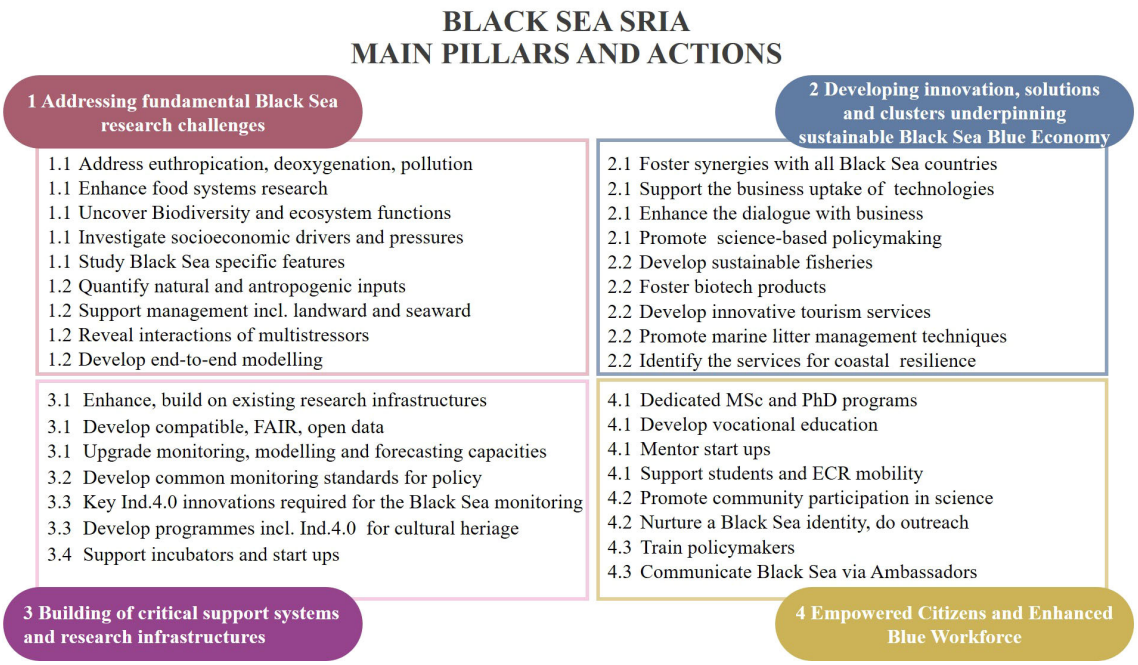

FIGURE 4
Goals of the Black Sea SRIA based on the Burgas Vision Paper.

under each pillar. The document also includes the Burgas Vision Paper principles and annexes dedicated to explaining the process leading up to the development of the strategy, relevant projects and initiatives identified in the preliminary work mentioned in Section 2.1 to support the Black Sea SRIA. The Bucharest Declaration marked the launch of the Black Sea SRIA in May 2019, addressing the Black Sea countries' governments and the European Commission for further support on the process of implementation (Sustainable Blue Economy Partnership, 2021).

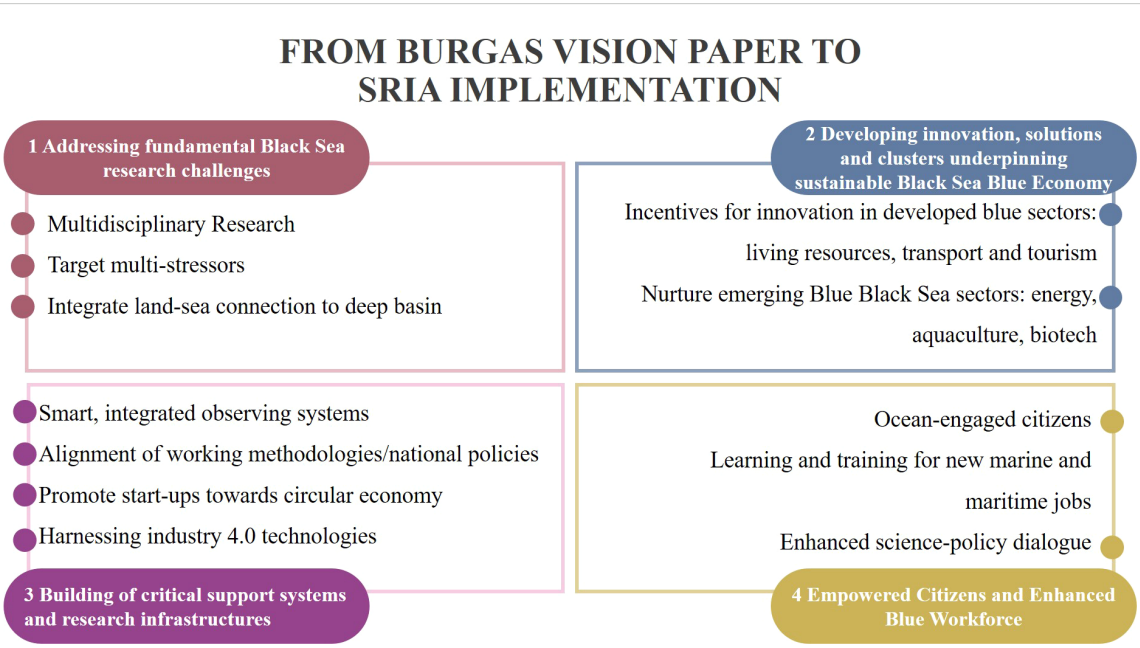

FIGURE 5
Examples of actions based on the pillars and goals given in the Burgas Vision Paper and the Black Sea SRIA that later the IP built on.

2.3 Black Sea CONNECT project for the Black Sea SRIA update and implementation plan

A major difficulty following the development of the Black Sea SRIA was transitioning from strategy to implementation. Considering the challenges and priorities defined in the Burgas Vision Paper and also the Black Sea SRIA, the primary task for the basin is developing solutions for the ecosystem as well as the economy under a wide range of human-induced stressors.

In 2019, Black Sea CONNECT (2019-2023) Coordination and Support Action (CSA) was funded under the European Union's Horizon 2020 Programme to consolidate the SRIA and develop its IP (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2019). The specific goals of the CSA are as follows:

1. Support the Black Sea Blue Growth Initiative to consolidate and update the SRIA
2. Develop the SRIA Implementation Plan
3. The establishment of an operational network for the Black Sea Region
4. Support the design and implementation of new transnational joint activities
5. Making the Black Sea visible through empowered Black Sea societies

With these goals, the Black Sea CONNECT CSA aimed to take further the process that started with the Burgas Vision Paper to the Black Sea SRIA Implementation Plan (IP). For this purpose, the Black Sea CONNECT focused on gathering national-level input from a wide range of stakeholder groups, including policymakers, regulatory agencies, and researchers to define key framework conditions for the SRIA implementation with the contribution of the various stakeholders (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023a).

In this regard, two rounds of national Black Sea SRIA consultation workshops in all of the Black Sea countries were organized in addition to other international activities to collect input to feed the Black Sea SRIA Update and its IP.

2.3.1 1st round of consultations

The first round of the consultations was carried out in September-October 2020, engaging more than 600 attendees in the seven Black Sea countries virtually or in hybrid formats due to the COVID-19 pandemic. During the consultations, the participants were asked to score the Black Sea SRIA actions under each main goal in the corresponding pillar on a scale of 1 (lowest) to 5 (highest) together with suggested actors and timeframes foreseen for the actions. The participants were also provided with the opportunity to make new suggestions in addition to the Black Sea SRIA actions.

A broad range of stakeholders from research, industry, and civil society communities took part in the workshops. The outputs have shown that the Black Sea SRIA and its goals are still very relevant as a significant amount of actions were ranked as high priority (Figure 6). It is also observed that some Black Sea SRIA areas that

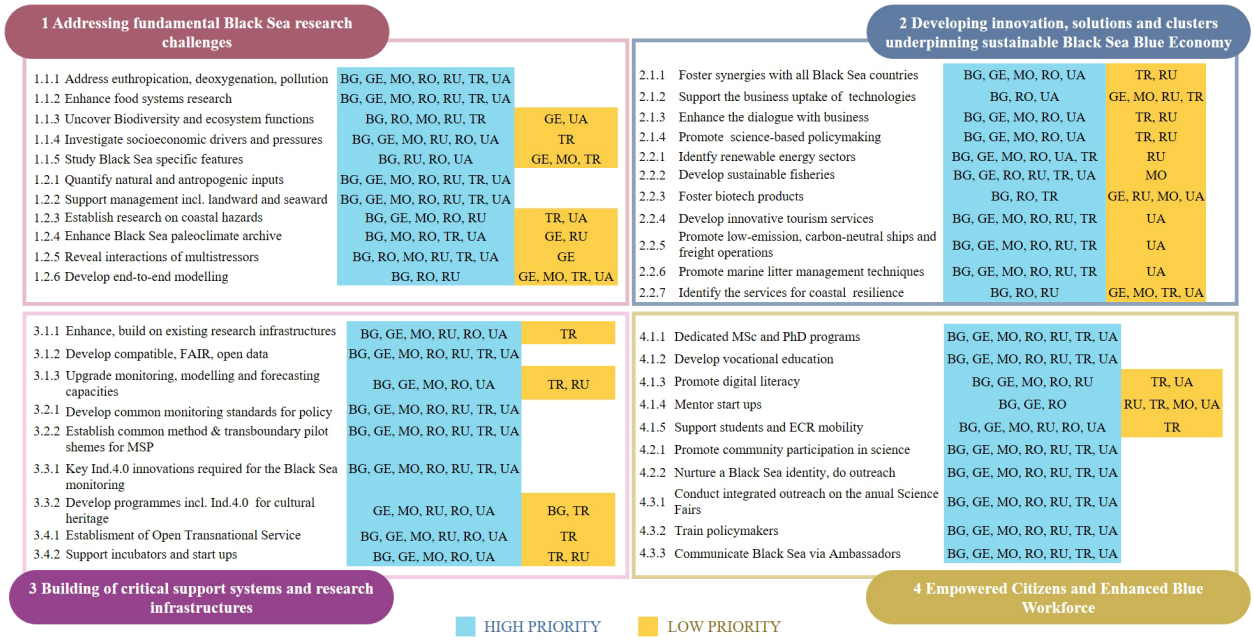

FIGURE 6
Results of the First Black Sea SRIA National Consultations (2020). Bulgaria: BG; Georgia: GE, Moldova: MO, Romania: RO, Russia: RU, Türkiye: TR, Ukraine: UA. The graphs reflect the result of the first round of consultation that took place in 2020. The European Council on 24 February 2022 condemned Russia's military aggression against Ukraine. The Council of the European Union adopted subsequently far-reaching restrictive measures in response to this aggression including the termination of the participation of Russian beneficiaries in the EU funded-projects. The termination has taken effect from 19 May 2022.

are, for example, related to the blue economy are given lower priority which can be linked to the fact that the blue economy in the Black Sea remains rather underdeveloped, and less awareness exists in the region. There were also new suggestions to Black Sea SRIA especially regarding digitalization, the need for new knowledge to mitigate the impacts of global climate change and the multiple environmental and anthropogenic stressors (Pillar 1), innovative and sustainable marine and maritime solutions within blue economy sectors (Pillar 2), conservation and valorization of marine cultural heritage (Pillar 3), various training needs and educational programs, campaigns for behavioral change in the Black Sea (Pillar 4). These outputs were consolidated into the first update of the Black Sea SRIA, the CSA has analyzed the results and mapped the high-ranked actions and recurring themes in the new suggested actions.

2.3.2 Activities conducted to develop the IP

The Black Sea CONNECT CSA conducted certain activities before the 2nd round of consultations that provided input to the development of the IP.

2.3.2.1 Mapping activities

The CSA collated information on past and ongoing national and EU projects. It was shown that in all funding streams, there was a gap in terms of support for emerging research and innovation areas. Most Black Sea countries lack underlying infrastructure such as observing and monitoring systems, relevant marine-related policies and implementation instruments. More funding is needed both at the national and EU levels for projects and programs tackling areas such as marine ecosystem services, human health and seas, also interconnections of the basins. National projects mostly focus on living marine resources, marine pollution and litter, biodiversity and operational oceanography, observing systems and monitoring projects. Multinational EU-funded projects targeted operational oceanography, observing systems and monitoring, training and technology transfer, tourism and surrounding economy, socioeconomic and policy research and biodiversity. climate change was addressed as a secondary area. Emerging challenges such as bioinvasions, deep-sea ecosystems, seas, and human health are less addressed in monitoring programs. Additionally, the CSA identified the relevant projects to engage in the IP, building on the initial mapping activity conducted during the Black Sea SRIA development (see Section 2.1). A handbook of relevant Black Sea projects, initiatives and entities was developed as a database of past and ongoing projects that are relevant to Black Sea CONNECT.

2.3.2.2 Innovation workshop

Black Sea CONNECT CSA organized an Innovation Workshop to showcase the best practices of marine cluster initiatives in the Black Sea and beyond for the eventual formation of a marine and maritime cluster of the Black Sea. The outputs of this workshop showed that different challenges exist including the transition from research to the market and the shortage of public and private funding for the formation of a maritime cluster for the Black Sea. These inputs are also used in the updated Black Sea SRIA and its IP.

2.3.2.3 Joint actions

Black Sea CONNECT CSA has piloted three joint actions which are integrated into the IP. Firstly, Marine Litter Action Forum was organized, focusing on innovative solutions to combat marine litter pollution in the Black Sea. Secondly, the Black Sea Young Ambassadors Programme (BSYAP) has been launched. The third joint action focused on the assessment of the impact of risks on the Black Sea ecosystem, pandemic, sea level rise, extreme weather, and harmful algal blooms – also one health approach, that considers both human health and the ecosystem health and resilience with specific strategic joint actions underneath. It has been integrated as a separate theme to the IP. The impact of military activities is also added as part of this joint action, especially after the unjustified war on Ukraine as this impact is expected to increase. Available monitoring activities need to be upgraded to better understand these impacts. Inputs received through these actions and activities are also integrated into the IP draft.

2.3.2.4 Synergistic activities

The Black Sea CONNECT project was involved in synergistic activities with the relevant policies and initiatives. Close cooperation was ensured with the Common Maritime Agenda for the Black Sea (CMA) and its steering group and national hubs throughout the lifetime of the project. The political steering committee of the CMA endorsed the Black Sea SRIA priorities and the main events carried out under the presidencies of Bulgaria (2020), Türkiye (2021) Georgia (2022) and Romania (2023) gave floor regularly to SRIA updates from the Black Sea CONNECT coordination on the developments of the Black Sea SRIA and IP. The CMA high-level ministerial event hosted by Türkiye's Minister of Transportation and Infrastructure was moderated by the CSA coordinator in 2021, where SRIA priorities were brought to the attention of Ministerial delegates of the Black Sea countries.

Additionally, through Black Sea CONNECT, the Black Sea SRIA is integrated into the Sustainable Blue Economy Partnership (SBEP) as the sea basin strategy for the Black Sea. Alignment with the Mission Ocean priorities is also enabled throughout the CSA activities. This way, many more stakeholders are engaged beyond the CSA-organized activities, and input is gathered to be integrated into the final Black Sea SRIA and its IP.

2.3.2.5 Operational network of funders

Under the Black Sea CONNECT CSA, the Operational Network of Funders (ONF) was also established. Consisting of funding agencies (ministry representatives) of Black Sea countries (Bulgaria, Georgia, Romania, Moldova, Türkiye, Ukraine) and European Commission officials from the Directorate-General for Research and Innovation, the Directorate-General for Maritime Affairs and Fisheries, and European External Action Service, the objective of the ONF is to streamline funding for the implementation of the Black Sea SRIA IP joint actions. Through

1 https://bridgeblacksea.org/

2 https://www.doorsblacksea.eu/

online, onsite and hybrid meetings organized under the CSA, the representatives of relevant ministries contributed greatly to the development of the IP.

2.3.3 Second round of consultations

Based on the input from the 1st and other CSA activities (see Section 2.3.2), the steering committee of the CSA drafted 12 themes as a first draft of the Black Sea SRIA IP and with strategic joint actions (SJAs) under each theme. The second round of national Black Sea SRIA consultations was organized in February – March 2023, to discuss these themes and define further feasible and necessary actions under these themes.

Different from the first round, an international consultation also took place in March 2023. This event was organized with significant support from the Horizon 2020-funded BRIDGE-BS[1] and DOORS[2] projects with also other relevant EU-funded project coordinators included to reflect the input from their respective projects into the IP.

The goal of the second round of consultations was to identify common SJAs that different Black Sea countries find feasible and necessary. During the consultations (both national and international) draft IP's themes and actions were assessed in terms of their feasibility and necessity on a scale of 1 (not feasible/necessary) to 5 (most feasible/necessary). The main questions guiding this process were: i) The most feasible actions within the current infrastructure, policies, capacity etc.; ii) Actions that are not feasible with the current framework conditions but necessary to implement by and beyond 2030; iii) Overall comments and feedback. English and translated versions of national languages were used during the consultations.

A total of 203 distinct Black Sea national stakeholders responded to a joint online questionnaire before, during or after the consultations in the period of February-March 2023. The stakeholders included central, regional and local authorities of littoral countries (national focal points and advisory group members; maritime, fisheries and environment agencies; maritime academies, universities and marine research institutes from national capitals and coastal cities; Horizon 2020 and Horizon Europe projects (e.g. BRIDGE-BS, DOORS, ARSINOE); international, regional and national NGOs; Black Sea Young Ambassadors (BSYAs); blue economy sector representatives, SMEs, start-ups and innovation agencies.

Based on the first round of the consultations, and all other CSA activities draft IP was developed with the steering committee of the CSA (Figure 7). It is important to note that all these activities provided great input to the constant development of the Black Sea SRIA IP and to be relevant in the current policy scene at the international and regional levels.

3 Actionable recommendations: the Black Sea SRIA implementation plan

The Black Sea SRIA IP aims to set in motion the research, innovation and policy streams to protect the unique habitats of the Black Sea while supporting the development of sea-based sectors. These in return will boost the sustainable blue economy and help generate more employment in the region. It will involve participants from academia, funding organizations, industry, policy, civil society and local communities to address the fundamental challenges of the Black Sea, promote the blue economy, build vital support systems and innovative research infrastructure, enhance education, and build capacity. IP aims to serve as a long-lasting guide to catalyze new ideas and innovations towards and with the Black Sea community and beyond with adjacent regions, actors, and instruments for a better-managed, healthy, resilient, and sustainable Black Sea.

The IP is an action plan based on the Black Sea SRIA Pillars (Figure 4), translating Black Sea SRIA goals into concrete and feasible action to contribute to the national blue economy strategies, better science-based decision-making and governance

FIGURE 7
Process for the Black Sea SRIA update and development of the implementation plan.

and better structure the relevant funding mechanisms. This way it aims to implement national, international and regional strategies; while at the same time, supporting the co-funding mechanisms.

The IP consists of 12 Themes and 25 Strategic Joint Actions (SJA) as shown in Figure 8. Under each theme, there is a preamble that explains the overall concept of the theme. The SJAs under each theme (there are two SJAs under each theme except Theme 6, where there are 3 SJAs) have the timeframe during which progress on the implementation of the action needs to start, relevant policy and programs (both national and international), and existing Funding Opportunities and Research Infrastructures (both national and international). Below, the Implementation Plan theme and actions

FIGURE 8
The Black Sea SRIA Implementation Plan Themes and Strategic Joint Actions (SJAs).

are presented based on the final SRIA IP. The preambles of the IP themes are shortened and paraphrased in this paper.

3.1 Theme 1: digital twin of the Black Sea

This theme suggests the development of the Digital Twin of the Black Sea to better understand the ecosystem dynamics, help predict its state under changing climate and environmental stressors, test alternative socio-economic scenarios, and support decision-making. SJAs suggest advancing AI-based decision support tools for ecosystem-based management in the Black Sea with real-time information from available database systems, high-resolution models of the sea and the Black Sea watershed supported by socio-economic models.

3.2 Theme 2: effect of multiple stressors on the Black Sea ecosystem

Understanding the impact of various stressors on the ecosystem individually and how they interact with each other in complicated dynamics (such as climate change, fisheries and invasive species) is critical for the management of the fragile Black Sea ecosystem. This needs to be addressed in the wider context of the special Black Sea's unique genesis, evolution and characteristics. SJAs suggest integrated and synergistic activities and pilot studies to determine the impact of these stressors and identify and forecast the hazards arising from their interaction that will support the governance options.

3.3 Theme 3: changing Black Sea biodiversity and ecosystem resilience under climate change and multi-stressors

Ecosystem resilience affected by changing environmental conditions and the impact of biodiversity ecosystem's health, production, and resistance to stresses is important. The SJAs suggest the utilization of cost-effective mapping of the Black Sea with e-DNA, acoustic, optical, and chemical sensing to understand the resilience of the ecosystems better. They also focus on mapping biodiversity to assess and forecast their impact as a basis for prevention, mitigation and adaptation policies.

3.4 Theme 4: ecosystem based fisheries, high-tech aqua- and mariculture

Despite the existing fish stock studies, studies on the effect of fisheries on the overall ecosystem and the primary production of the Black Sea have been limited. The SJAs promote ecosystem-based fisheries management by focusing on understanding fish production zones and expanding the Black Sea's extremely small protected areas. Additionally, zero carbon practices towards attaining alternative methods of utilizing proteins and other nutritional products from the sea are suggested.

3.5 Theme 5: blue biotechnology

The Black Sea has a unique biogeochemical structure and therefore has a large potential for new bioinspired products and solutions. Also, seasonal algal blooms in the basin present an opportunity for fuel and protein products. The SJAs in this theme focus on the documentation and sustainable use of this potential in an interdisciplinary approach, connecting results from different points of view (oceanographic, geochemical, physical, and environmental processes).

3.6 Theme 6: one health approach and improved safety for the Black Sea coasts

This theme promotes the One Health Approach for the health, well-being and resilience of marine systems and local coastal communities against the increasing frequency of disruptive activities such as climate-driven extreme events and the potential risk of marine geohazards. The SJAs under this theme suggest mobilization of monitoring, research and innovation tools to detect the impact of these disruptive activities such as long-term and episodic (storm-related) sea level rise and coastal floods, estimation of geohazard-related coastal risks, the impact of pollution accidents, the impact of armed conflict-related activities (effects of ammunition, noise and episodic pollution events - unexploded ordnance) and estimation of free-floating hazards such as mines.

3.7 Theme 7: marine litter

Addressing the marine litter problem at the source is of high importance for long-term solutions. Awareness-raising activities through citizen science initiatives and facilitating already existing platforms such as the Black Sea Marine Litter Action Forum and the Black Sea Young Ambassador Programme are suggested as SJAs under this theme.

3.8 Theme 8: marine renewable energy

The Black Sea has a high potential for offshore wind and wave energy. Now a more robust roadmap and detailed feasibility studies will be needed, but the community will also need to start testing prototype renewable energy solutions that potentially integrate other blue carbon solutions such as macroalgal cultivation and hydrogen generation from biofuels.

3.9 Theme 9: innovative observing systems

Observation in support of MSFD criteria through fixed and mobile platforms generates a wealth of observations on the state of marine physical and ecosystem processes and it provides a great potential for filling the scientific gaps and supporting the policymakers. SJAs promote coordinated and targeted actions that focus on cost-effective instrumentation, open data and open innovation.

3.10 Theme 10: Black Sea underwater and coastal heritage

Both the coastal zone of the Black Sea countries and the deeper waters safeguard uniquely preserved wooden shipwrecks that pave the way for discoveries. These provide a ground for international scientific cooperation and a sustainable blue economy for the coastal cities and communities. The SJAs address both of these aspects.

3.11 Theme 11: innovative approaches to connect scientists, policymakers, industry and society

This theme addresses the need for innovative and coordinated approaches to engage stakeholders to sustain their commitments in the long term without creating stakeholder fatigue. World cafes, living labs, multi-actor stakeholder forums and mechanisms to continue Black Sea SRIA priorities are suggested under the SJAs.

3.12 Theme 12: blue skills and capacity building on marine sciences

Raising awareness among the general public, through ocean literacy activities, and thus contributing to a more ocean-literate and empowered society is crucial for the sustainability of the region. Theme 12 addresses the need to continue citizen science efforts through the engagement of early career ocean professions (ECOPs) such as the Black Sea Young Ambassadors Programme. SJAs also focus on informal and innovative approaches to increase the capacity and create cascading effects through training the trainer approach.

3.13 Final Black Sea SRIA IP and the launch event in the European Parliament

As given in Section 2.3.3, the IP's strategic joint actions (SJAs) under 12 themes are ranked in terms of feasibility and importance in national and international consultations. The results indicated that all the Black Sea SRIA IP actions of the themes are relevant, and they all scored above 3.5 on a scale of 1 to 5 in terms of feasibility and importance (See Figure 8 for SJAs). Therefore, all actions of the draft Black Sea SRIA IP are integrated into the final version the comments received during the consultations are also integrated into the final Black Sea SRIA and IP (Figure 9).

The IP has been launched in a dedicated event entitled "Launch of the Black Sea SRIA IP" that took place on 04 May 2023, at the European Parliament in Brussels, Belgium which was hosted and chaired by Member of the European Parliament Marian-Jean MARINESCU (in the framework of the European Parliament's SEArica Intergroup) and provided an occasion to have international stakeholders in the process, showing the different levels of complexity in the IP document but also inform them on the process and actions that have taken place with the view to the future for Black Sea research and innovation[3].

The discussions of the event have shown that the Black Sea SRIA and the IP are very much supported at national, regional and European levels. Participants included high-level representatives of the European Commission (Director of Directorate General of Maritime Fisheries, Head of Units of Directorate General of Research and Innovation), regional organizations and research-performing organizations, and more than 110 high-level stakeholders from policymaking, research, and innovation communities from the European Union member states and Black Sea littoral countries including the Operational Network of Funders who made pledges to implement the Black Sea SRIA in their countries.

4 The Black Sea SRIA and implementation plan input to policy

Both the Black Sea SRIA and its IP considered the existing international and EU policies and frameworks such as the European Green Deal, European Missions: Restore our Ocean and Waters, Sustainable Blue Economy Partnership, and United Nations Decade of Ocean Science. In this section, we discuss how the Black Sea SRIA and its IP have supported and will support policy agendas at the national, European and international dimensions, with a focus on selected policy frameworks for each level. It also underlines how SRIA priorities provide input to the national agendas.

4.1 National Policies

At the national level, Black Sea SRIA and IP priorities that are derived from the stakeholder input to the Black Sea SRIA have resonated with the national stakeholders while also creating strong links with country priorities. For example, based on the pledges made in the Launch of the Black Sea SRIA IP event by the ONF members, Bulgaria is greatly interested in wind energy and blue carbon (Theme 8) whereas Georgia is moving towards integrating more citizen science and marine litter activities (Theme 12). Ukraine is already planning the recovery of biodiversity and resilience of the marine ecosystem (Theme 6). Furthermore, SRIA priorities are integrated into the national agendas for Moldova in the code on research and innovation, enhancing the overall status of research and innovation in the country. Similarly, Romania already included a specific sub-program dedicated to the blue economy in the Black Sea under the National Plan for Research, Innovation and Technological Development under which dedicated calls are expected. Moreover, SRIA priorities and IP actions are already integrated into Türkiye's National Climate Summit Decisions of 2022 under which the Ministry of Industry and Technology launched specific calls. Integration of SRIA priorities into the national agendas can be considered as a success story of the Black Sea CONNECT Project.

3 Press release and event photos, recordings and presentations are availablehttp://connect2blacksea.org/press-release-onthe-launch-of-the-black-sea-sria-implementation-plan/

4.2 Common maritime agenda

Common Maritime Agenda for the Black Sea is "a sea basin initiative to enhance regional cooperation for achieving a sustainable blue economy in the Black Sea". The CMA acknowledges the necessity of a unified strategy to tackle shared maritime and blue economy issues. This marks the first effort of its type in the region, stemming from a grassroots initiative initiated by the participating countries and supported by the European Commission (2019a). The CMA goals which are based on the Black Sea SRIA as its scientific pillar also include priorities such as the health of marine and coastal ecosystems, competitive, innovative, and sustainable blue economy and fostering investment in the Black Sea which are closely linked with the Black Sea SRIA and its IP's actions and goals.

4.3 The EU blue growth strategy and EU blue economy reports (2014 to latest update 2023)

In 2012, the EU launched the EU Blue Growth Strategy to sustainably harvest the potential of oceans and seas for economic recovery. EU considers "the sea and the coasts are drivers of the economy" (EUR-Lex: EU law, 2012) and defines the blue economy as "all economic activities related to seas, oceans and coasts and covers a wide range of interlinked established and emerging sectors" (Publications Office of the EU, 2018). The blue economy has great potential for the Black Sea countries and Europe as a whole. The Black Sea SRIA aims to foster cooperation between countries but also to enhance the concept of achieving tangible results at the basin-scale in the Black Sea region. With the blue economy dedicated pillar and actions, the Black Sea SRIA and IP aim to generate scientific knowledge as a key element towards science-based and well-informed decision-making. Such policymaking will pave the way to a sustainable blue economy. The Black Sea SRIA and IP support the EU blue economy by "creating incentives for maritime innovation in existing and new, emerging blue economy sectors, such as renewable energy, sustainable fisheries, high-tech aquaculture, biotechnology, underwater heritage, carbon-neutral shipping" (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023a).

4.4 Paris agreement (2015)

The Conference of the Parties adopted "the Paris Agreement to strengthen the global response to the threat of climate change, in the

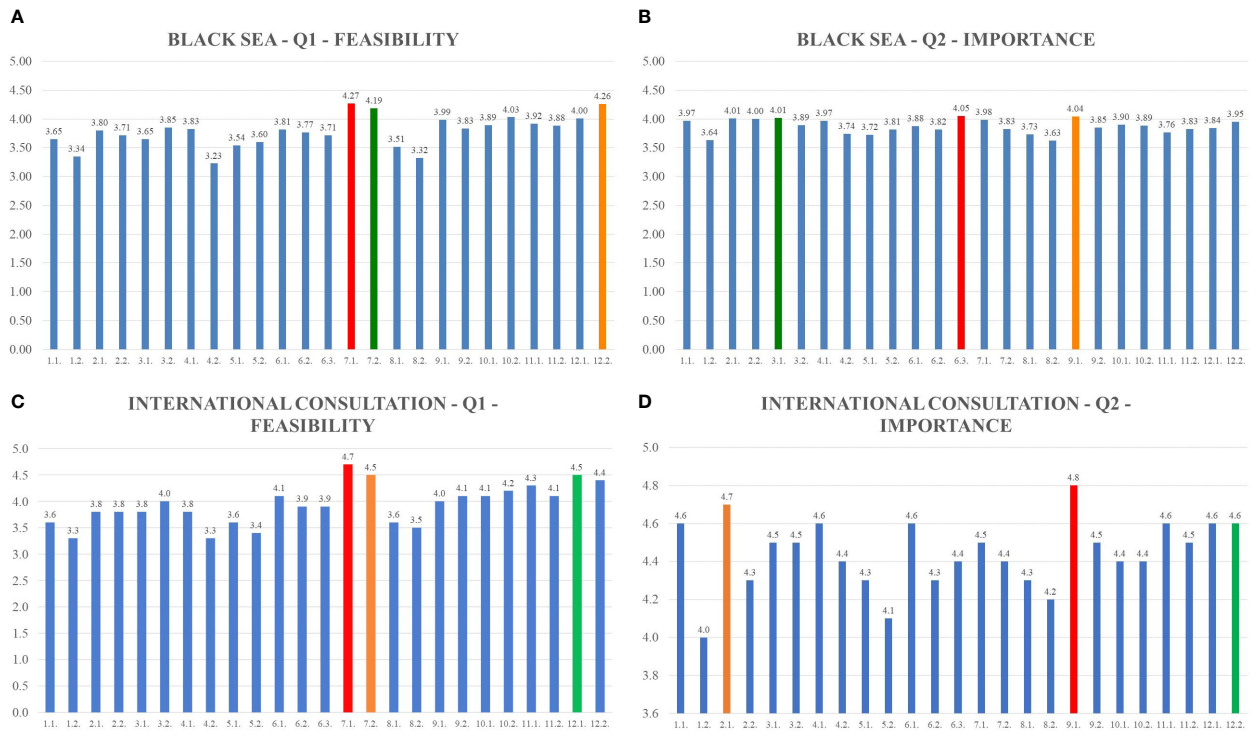

FIGURE 9
Ranking of Implementation Plan Strategic Joint Actions (SJAs) by the average scoring out of 5 (colour codes indicate top three ranked SJAs; red 1st, orange 2nd and green 3rd) (SJA numbers are provided in Figure 8) **(A)** Ranking by feasibility (Q1) – Black Sea Stakeholders **(B)** Ranking by importance (Q2) – Black Sea Stakeholders **(C)** Ranking by feasibility (Q1) – International Stakeholders **(D)** Ranking by importance (Q2) – International Stakeholders.

context of sustainable development and efforts to eradicate poverty" (United Nations Framework Convention on Climate Change (UNFCCC), 2016). The Black Sea SRIA supports this policy by producing predictions on how the marine ecosystem will be affected under different IPCC predictions such as the SSPs, to help understand and reduce the risks and impacts of climate change. Both the Black Sea SRIA and the IP suggest actions to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production.

4.5 The European green deal (2019)

The European Green Deal sets out to make Europe become the first climate-neutral continent by 2050 and to transform the EU into a fairer, cleaner and greener society. Through the EU Green Deal, the European Union aims to foster a sustainable economy by converting climate and environmental obstacles into advantageous prospects, ensuring that the transition is fair and encompasses everyone. The Black Sea SRIA supports the EU Green Deal strategy with its specific goals related to "boosting and efficient use of resources by moving to a clean, circular economy, restoring biodiversity and cutting pollution" (European Commission, 2019c) such as "mitigating the impacts of global climate change in the Black Sea from land-sea interface to the deep basin" and "promoting low-emission, carbon-neutral ships and freight operations in line with the international safety standards and circular economy principles to achieve sustainable and green shipbuilding, repair and retrofit" (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023a). The IP supports the green deal with its carbon-zero aquaculture and fisheries practices, and renewable wind and wave energy demonstrator (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023b).

4.6 United Nations sustainable development goals (2015)

The 2030 Agenda for Sustainable Development provides "a shared blueprint for peace and prosperity for people and the planet, now and into the future" (United Nations Sustainable Development Golas, 2015). While the document includes a dedicated goal for water "SDG14 Life below water - Conserve and sustainably use the oceans, seas and marine resources for sustainable development", there are different targets that have direct links with seas and oceans. The Black Sea SRIA and IP support all ten targets of SDG14 and also the other targets concerning the seas and marine resources as SDG1-T5 No Poverty – Build Resilience to Environmental, Economic, and Social Disasters, SDG2-T3 Zero Hunger – Double the Productivity and Incomes of Small-scale Food Producers or SDG8-T6 Decent Work and Economic Growth – Promote Youth Employment, Education and Training.

4.7 United Nations decade of ocean science (2021-2030)

The United Nations proclaimed the decade from 2021 to 2023 as the Decade of Ocean Science for Sustainable Development. The Decade "provides a common framework to ensure that ocean science can fully support countries' actions to sustainably manage the Oceans and more particularly to achieve the 2030 Agenda for Sustainable Development" (UNESCO Digital Library, 2020). The Black Sea SRIA and the IP support Ocean Decade in terms of the generation of data, information and knowledge needed to move from the 'ocean we have' to the 'ocean we want'. SRIA Pillar 1 and IP Theme 2 and 3 aim better understanding of the effects of multi-stressors, assessment of the biodiversity and the resilience of the Black Sea and the innovative observing systems for example directly support this priority. The Black Sea SRIA and IP supports Ocean Decade and its seven outcomes (clean, healthy and resilient, productive, predicted, safe, accessible and also inspiring and engaging ocean) in the basin region and beyond with its goal-driven actions for a productive, healthy, resilient, sustainable and better valued Black Sea.

4.8 The European missions: restore our ocean and waters (2022-2030)

One of the EU Missions aims to "restore the health of our ocean and waters by 2030 (Mission Ocean). The Mission Ocean is designed to deliver on the European Union's 2030 quantified and measurable targets for protecting and restoring ecosystems and biodiversity, for zero pollution, and the decarbonization and reduction of net greenhouse gas emissions towards climate neutrality, within the EU's ocean, seas and waters" (European Commission Research and Innovation, 2021). The main goal of the Black Sea SRIA is closely associated with Mission Ocean as "advancing a shared vision for a productive, healthy, resilient, sustainable and better valued Black Sea by 2030". The Black Sea SRIA and IP aim to generate the knowledge needed to increase ecosystem resilience and mitigate the impacts of global climate change and multi-stressors including pollution in the Black Sea which is the direct objective of Mission Ocean (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023a; European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023b). Science and innovation that will be produced with the guidance of SRIA is the key element towards good governance - as one of the objectives of this mission - for a sustainable, healthy, and resilient Black Sea. With this vision, Black Sea SRIA supports the Mission Lighthouses that aim to foster regional engagement and cooperation in major sea and river basins: Atlantic-Arctic, Mediterranean Sea, Baltic-North Sea, and Danube-Black Sea. In fact, with the role of ensuring the Black Sea SRIA and its IP to the Mediterranean, the Black Sea CONNECT Coordinator is involved in the BlueMissionMed CSA funded under Horizon Europe to

support the Mediterranean Lighthouse (European Union Horizon Europe BlueMissionMed (Grant A. No. 101094073), 2022).

4.9 Horizon Europe sustainable blue economy partnership

The European partnership for "A climate neutral, sustainable and productive blue economy" is a co-funded partnership under the Horizon Europe Research and Innovation (framework program 2021-27). The SBEP also developed an overarching SRIA based on the existing sea basin strategies and SRIAs from the EU sea basins and builds on them, including the Black Sea SRIA, and it offers "demonstrated achievability of policy targets at sea basin-scales, allowing common issues to be jointly addressed and facilitate the development of national marine and maritime strategies for a climate neutral, sustainable and productive blue economy" consistently (European Commission, 2019b). The SBEP SRIA focuses on "actions where joint national and EU support can generate momentum and impact well above what could be achieved by a single country or region and thus contributes significantly to a high-performing European Research Area in the blue economy domain" (European Commission, 2019b). The Black Sea SRIA and IP are a part of this big picture and contribute to partnership on a regional level. The main commonalities between the Black Sea SRIA, its IP and the SBEP include the economic development within safe boundaries (resilient ecosystems), reduction of pollution, digital twin and innovative observing systems, upscaling of renewable ocean energy, development of multi-use offshore platforms, green and smart ports, quantifying of the impact of climate change and increasing the resilience of the ecosystems, one health approach, development of methodologies for blue biotech, innovative aquaculture and ecosystem-based fisheries, sustainable tourism, circularity and job creation, blue skills and capacity building, new opportunities in the blue economy.

5 Discussion

Black Sea SRIA IP is finalized based on the input received through two rounds of national consultations and certain Black Sea CONNECT CSA activities (see Section 2.3). Moreover, the original Black Sea SRIA that was developed in 2019 was revised with the new priorities (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023a). The Black Sea SRIA of 2019 identified the national priorities of the time and responsible actors and initiatives to implement these. It also supported the development of these priorities into the national blue economy agendas to lead the way for science-based decision-making and well-informed governance. The Black Sea SRIA 2023 modified these priorities to align them with the conditions in the region following the pandemic and ongoing or post-war circumstances. Similarly, actors and initiatives are also revised accordingly. New actions were added, and existing ones were revised based on the input from consultations (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023a).

Black Sea SRIA serves as a reference document for marine and maritime strategies and can be used as a programmatic tool for defining national, European, and sea basin strategies. The 2023 version brought a new vision with new aspects that can be implemented by other basins as well. For example, new research activities under Pillar 1: Black Sea Knowledge Bridge actions on the deep-sea ecosystem of the Black Sea, ecosystem services and their resilience and One Health Approach, investigating climate-related impacts and geohazards including military activities are added (European Union Horizon 2020 Black Sea Connect (Grant A. No. 860055), 2023a). Under Pillar 2: Black Sea blue economy, innovation focus has been further emphasized. This includes exploring renewable energy pilots such as wind, wave, solar, green hydrogen, and carbon capture in marine and coastal areas. Additionally, there is an investigation into the potential of responsibly exploring gas hydrates using artificial intelligence and decision-support tools infrastructures for policy-making and marine spatial planning. Other focus areas involve sustainable ecosystem-based fisheries and high-tech aquaculture, a Marine Litter Forum as a regular event, biotechnology, and the establishment of multi-actor forums and living labs to foster synergy. Under Pillar 3: Key Joint Infrastructure and Policy Enablers, Critical Infrastructures and Enablers were also further reinforced. This reinforcement includes the establishment of a unified database, as well as the deployment of both mobile and fixed marine observation instruments. Finally, under Pillar 4: Education and Capacity Building, actions were added focusing on Formal and Informal, intergenerational Programs including staff exchanges and mobility and continuing the Black Sea Young Ambassador Programme (BSYAP). While the Black Sea SRIA 2023 stands as a general strategy document for the Black Sea beyond 2030, the IP focuses on concrete actions that are feasible by 2030.

The Black Sea SRIA and its IP, a robust, stakeholder-driven roadmap, available for all citizens and countries, is already being used in national and international programs. European Commission and other national and international bodies have started to use the Black Sea SRIA and the IP in dedicated calls. At the national scale, Black Sea countries started to integrate the priorities into their research and innovation agendas with dedicated calls being launched.

In 2020, "Towards a productive, healthy, resilient, sustainable and highly-valued Black Sea" (BG-11-2020) was announced under the Horizon 2020 program specifically referring to the Burgas Vision Paper and Black Sea SRIA. Two research and innovation actions are funded under these calls. While "BRIDGE-BS: Advancing Black Sea Research and Innovation to CoDevelop Blue Growth within Resilient Ecosystems" (2021-2025) focuses on ecosystem resilience, services, and development of the blue economy; "DOORS: Developing Optimal and Open Research

Support for the Black Sea" (2021-2025) project aims to develop integrated observing systems, land-sea interactions, and the deep sea. With close links to Black Sea CONNECT (the Coordinator of Black Sea CONNECT, also coordinates BRIDGE-BS, and the Coordinator of DOORS is a WP leader in the Black Sea CONNECT), both projects adhere to the implementation of the Black Sea SRIA, and they significantly contributed to the development of the IP through consultations and scientific activities. Funding of these projects is a great first step towards the implementation of the actions of the Black Sea SRIA and IP and these projects also provided significant support to the development of the IP as mentioned in Section 2.3.3.

How Black Sea SRIA contributed to the Sustainable Blue Economy Partnership is another good example of how the Black Sea approach is used in other policy contexts. Black Sea SRIA is used by SBEP when forming the overarching SBEP SRIA which drew on different sea basin strategies such as Black Sea SRIA based on which dedicated calls are already launched.

The Black Sea SRIA and its IP priorities are also integrated into Horizon Europe-funded Mission Ocean's Mediterranean Lighthouse through the BlueMissionMed CSA which is another good example of how the transfer to the different basins can be achieved (European Union Horizon Europe BlueMissionMed (Grant A. No. 101094073), 2022).

The Black Sea Young Ambassador Programme[4] (BSYAP) which is one of the three SJAs that the Black Sea CONNECT CSA piloted engaged two distinct groups of Young Ambassadors with over 30 individuals, who are acting as multipliers and legacy carriers in their professions and countries brought together and trained to continue the legacy of the SRIA and IP. BSYAP also continues to link with similar youth groups and programs from different basins to foster collaboration in the forms of opportunities and calls.

In addition to the linking with other sea basins, the processes and activities towards the Black Sea SRIA and IP development served as a standing example of successful cooperation and science diplomacy within the region, where the power of science and visions of innovations bound the community's youth, scientists and policymakers. One of the major impacts of the Black Sea CONNECT CSA was the success in consolidating the Black Sea SRIA as the "scientific pillar" of the Common Maritime Agenda (CMA). Through the endorsement and representation of the Black Sea SRIA in many events including the high-level ministerial event hosted by Türkiye's Minister of Transportation and Infrastructure, which was moderated by the CSA coordinator in 2021, Black Sea SRIA priorities were brought to the attention of Ministerial delegates of the Black Sea countries. Additionally, the establishment of the Operational Network of Funders which consists of the ministry representatives from the Black Sea countries and their active contribution to the co-creation of the development of the Implementation Plan has been a further step signifying the integration of the Black Sea SRIA and IP at the national level.

4 http://connect2blacksea.org/outreach-introduction-youth-ambassadors/

6 Conclusion

Since 2017, there have been significant efforts to tap into the blue economy potential of the Black Sea with expanding research and innovation in the region. The processes that started with the Black Sea SRIA development and continued with the creation of the IP, have brought the community together across different countries and regions in the Black Sea as well as put the Black Sea on the map of the European seas.

Despite this outstanding progress in the Black Sea during the past years, the activities conducted demonstrated that there are still major challenges. Understanding the Black Sea-specific processes and how the services that the Black Sea provide will be affected by various stressors is yet to be understood. There is a strong need for further collaborative scientific programs as existing ones are limited across countries. Although the unjustified war adds an extra challenge, new ways towards a holistic understanding of the Black Sea ecosystems are still possible. Smart, harmonized monitoring technologies and innovative ways towards monitoring biodiversity such as eDNA are potential pathways. Digital Twin of the Black Sea, AI-fed monitoring and forecasting and other data processing techniques to enable integrated planning and decision support stand as promising future opportunities. Scientific understanding of the Black Sea ecosystems under changing environmental conditions is vital to support science-based decision-making and management. While achieving these, links with the industry should be reinforced and start-ups should be supported to benefit from scientific feedback. Young entrepreneurs should be equipped with the knowledge to fully benefit from the latest scientific findings to create science-based innovative sustainable blue economy solutions. Increased investments in the blue economy will lead to the creation of sustainable and high-quality jobs, reducing unemployment rates and fostering social and economic development in the region. The long-term connections made with the SBEP, CMA and related initiatives will ensure the opening of new avenues of implementation in this direction.

As a first step to overcome some of these challenges, there are already crucial developments. In 2021, two Horizon 2020-funded Research and Innovation Actions were funded named BRIDGE-BS and DOORS. These projects already implement some of the joint actions of the IP. Both BRIDGE-BS and DOORS projects support the Digital Twin of the Black Sea and already implemented Theme 1: Digital Twin of The Black Sea. DOORS with the Black Sea System of Systems that offer access to the data which will support a better understanding of the complex composition and dynamics of the human-induced impacts and climate change from river mouths to its deeper parts. BRIDGE-BS on the other hand is already developing advanced AI-powered decision support tools building on innovative models at regional and basin scales that simulate climate change and multi-stressors and integrate them with socioeconomic trends, blue economy scenarios and system of systems approaches. The work on these projects feeds into the European Digital Twin. They are also jointly running the Black Sea Accelerator Program to support the innovative blue economy solutions in the region in support of the Black Sea SRIA and IP.

By aligning efforts across the European Union, national, and regional levels and by facilitating knowledge sharing and fostering cross-sectoral collaboration, the IP will further accelerate technological advancements, leading to the creation of new products, services, and processes that drive sustainable economic growth and competitiveness in the region. To achieve that, links are ensured with major global policies such as the UN Decade of Ocean Science for the implementation and European policies such as the European Green Deal and European Missions (Mission Ocean) as well as co-funding structures at the European and regional scale (Sustainable Blue Economy Partnership-SBEP) through contributing to the dedicated calls and supporting projects implementing these policies (BlueMissonMed) Additionally, at the national level, the commitment of the ministry representatives (Operational Network of Funders) also paves the way for multilateral actions for co-funding mechanisms supporting the Black Sea SRIA and IP priorities and already dedicated calls are integrated highlighting these priorities are launched in the countries. It will also be important that cooperation efforts that are tasked to bring together the communities also continue the legacy of the Black Sea SRIA and IP.

Author contributions

BS: Project administration, Methodology, Conceptualization, Writing – review & editing, Writing – original draft. MY: Writing – review & editing, Project administration, Methodology, Conceptualization. PU: Writing – original draft, Methodology, Conceptualization. EŞ: Writing – original draft, Visualization, Conceptualization. EP: Writing – review & editing. DT: Writing – review & editing. AS: Writing – review & editing. IS: Writing – review & editing. SM: Writing – review & editing. ND: Writing – review & editing. KB: Writing – review & editing. VK: Writing – review & editing. TC: Writing – review & editing. KB: Writing – review & editing. VM: Writing – review & editing. MG: Writing – review & editing. SK: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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