Marine Policy 163 (2024) 106132

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Building competences for researchers working towards ocean sustainability

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ARTICLE INFO

Keywords:
Sustainable blue economy
Sustainability science
Marine interdisciplinary sciences
Marine and maritime sectors
Ocean science
Transformative research
Ocean literacy

ABSTRACT

The challenges of achieving just, equitable and sustainable ocean futures require a new type of transdisciplinary and action-oriented science that integrates across disciplines and knowledge systems. Scientists and researchers in academia, industry or government, who contribute to knowledge creation, innovation, and policy development for the ocean, must be empowered with a fresh set of competences. This paper maps the knowledge, skills, and attitudes required to enable such a shift. The proposed skillset serves as a foundation for the design and operationalisation of modern training for ocean sustainability and is envisaged to be used by researchers both individually and in teams. It also highlights the potential for career diversification beyond the traditional 'blue jobs' legitimated by existing sectors. To ensure the short-term practical implementation of the competence framework, self-awareness and self-reflection are encouraged among learners and teachers, along with pragmatic actions to overcome barriers to transdisciplinarity. For long-term impact, system interventions will be necessary to improve organisations' readiness to absorb and valorise researchers trained in this new framework. This will require re-training the current pedagogical workforce as well as reframing existing knowledge systems and incentives.

1. Introduction

The ongoing expansion of human activities into the ocean [1,2] and related challenges of resource over-exploitation, pollution, habitat destruction, and continued climate change imply an urgent need for action in support of ocean sustainability [3,4]. Over the past years, researchers have formulated recommendations regarding the governance approaches that are needed to support just, equitable and sustainable ocean futures [5-9]. The UN Decade of Ocean Science for Sustainable Development 2021–2030 (Ocean Decade) reflects the highest level of international consensus and commitment regarding actions needed to move from the ocean we have towards the ocean we

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https://doi.org/10.1016/j.marpol.2024.106132
Received 11 October 2023; Received in revised form 25 January 2024; Accepted 24 March 2024

want, with the support of science [10-12]. It offers a roadmap for a much needed and more fundamental transformation of our relationship with the ocean [13]. Commitments to take up the scientific assessments have also been made in smaller groupings, for example when 18 world leaders joined together and committed to sustainably manage 100% of the ocean area under national jurisdiction by 2025 as part of a 'bold transformation' of the ocean economy, informed by the best available science and knowledge (Ocean Panel 2023) [14].

While many knowledge systems must be drawn upon to inform sustainable ocean management [15,16], the establishment of the Ocean Decade highlights the key role that sciences can play in the process of transformative change. It also emphasizes the importance of enhancing international cooperation on research and scientific programmes to better manage marine resources and reduce maritime risks [12]. This is particularly important given that transformation towards sustainability is a complex process, taking place across multiple governance scales [6, 17-19].

The urgency and complexity of the challenge call for a new type of science. One that embraces systems thinking [20] as well as inter- and trans-disciplinary approaches [21]. This requires scientists to not only integrate knowledge and methods across academic disciplines [22], but also to co-produce knowledge with societal actors beyond academia, including those whose livelihoods depend on the ocean or those whose actions impact the ocean [23-27,16].

To enact this new type of transdisciplinary and action-oriented science, we need scientists with a fresh set of competences [28], working in academia, industry or government, and contributing to the advancement of knowledge and innovation through their investigations, analysis, or policy development in relation to the marine environment. Humans drive transformations, be that by affecting structures, behaviours, relations or knowledge-production processes [29]. Any fundamental change in these domains concurrently takes place also at a personal level, i.e. at the scale of individual and collective beliefs, values, and worldviews [30]. Thus, if we are to move towards a sustainable ocean as opposed to conducting business as usual, we need to ask: what competences are required by researchers to enable that shift?

We focus on competences as a broad term that encompasses knowledge, skills and attitudes (Box 1).

Our approach builds upon and complements a wealth of literature dealing with education for sustainability, including the identification of 'sustainability competences'. However, to generate impact, existing sustainability competence frameworks (e.g., [36]) need to be grounded in empirical justifications and real-world contexts [36,37]. Their deliberate intention to serve any domain of relevance to sustainability [38,39] may present a limitation for ocean sustainability science since this scientific domain is still in the process of integrating previously disconnected disciplines, approaches and methods into a coherent whole [40-43]. The attractiveness of specific ocean-related concepts, such as blue economy [44] or ocean literacy [45,46] are a testimony of the appetite for a holistic consideration of the ocean. Arguably, the formation of ocean sustainability sciences as an interrelated interdisciplinary discourse is only partially integrated into the sustainability science. There is of course a strong link between the general sustainability competence framework and the interdisciplinary marine sciences. However, this link will be more easily recognised when competences are less abstract and more specifically tailored to the marine contexts.

In this article, we synthesised a large amount of recent work at the intersection of ocean sustainability and science, drawing on published research, expert discussions and perceived trends, to provide an initial attempt at a competence framework to support "the science we need for the ocean we want" [47]. We combined scientific rigor, societal relevance and experiential learning [48] to identify the knowledge, skills and attitudes needed to transform current practices towards a thriving ocean. The results do not represent a final competence framework, but a workable structure to encourage the design and operationalisation of modern trainings for ocean sustainability. We go beyond current discussions that have argued for the responsibility and capacity of social sciences to contribute to sustaining ocean health for the benefit of humans and ecological systems [40,49-52]. These discussions have often treated 'science' as a single unit and looked at its ability to influence change in the system without outlining the potential and capacity of the individuals operating in it [28]. While practical advice has been developed for researchers on how to achieve interdisciplinarity in ocean sustainability sciences in practice [22], here we provide a concrete toolbox for individuals and teams to realise their objective.

The paper proceeds as follows. First, in Section 2 we briefly portray the existing educational landscape for building ocean sustainability, which is inviting a transformation in how ocean challenges are addressed. Section 3 outlines the methodological approach we used to build the competence framework for ocean sustainability, which is then presented in Section 4. Section 5 provides case studies of the competence framework. Finally, Section 6 considers the implications of such a framework in the process of building the missing capacities into the ocean leaders, practitioners, and scientists of tomorrow.

2. The educational landscape for ocean sustainability

Marine scientists and researchers can gain competences through formal and informal education. Formal education related to the ocean is traditionally discipline-based and highly disintegrated. While many universities offer programmes related to the seas at the bachelor, master and PhD levels, they are typically focused on a single category by the International Standard Classification of Education (ISCED), UNESCO's standard for organising education programmes and qualifications [53]. A review of the ISCED categories reveals that marine sciences fall under Physical sciences, which are separate from Social and behavioural science and from Environmental sciences (containing environmental conservation, control and protection, air and water pollution control, labour protection and security). An interdisciplinary approach to ocean science, as deemed fit for addressing ocean sustainability challenges [54,49,55], is at odds with the established organisation of study programmes. Since programme and course curricula are typically not publicly available for

Box 1
Competences in education.

The term 'competence' underlines the guiding paradigm for training and education, which in the early 21st century has shifted from advocating an encyclopaedic type of training that teaches definitions, texts and established categories to an outcome-based, student-centered form of instruction that actualises the student's or trainee's real potential, including from a critical perspective [31-34]. The insistence on competences and competence-based pedagogy is related to the goal of knowledge application, in contrast to that of knowledge acquisition from content-based pedagogy. At the heart of the learning process is the promotion of the student's responsibility and autonomy in performing a task, related to professional and personal development [35]. From a system perspective, the focus on competences points to multiple objectives of educational efforts, which are directed towards both the individual and the broader society, with a focus on personal development as well as competitiveness, employment and social cohesion [35].

review, it is unclear whether this structural barrier has systematically been overcome in actual programme design or study processes.

The persistence of traditional siloes is reflected in the online platform Marine Training, which maps study programmes in the wide domain of 'marine training'. As of May 2023, the portal revealed 3078 programmes on marine training, at the Bachelor (1337), Master (1268) and PhD level (393). In absence of access to programme curricula, an important indicator of interdisciplinarity would be the relevance to multiple ISCED categories. However, most programmes have a focus within a single ISCED broad field of education (i.e., Natural sciences, mathematics and statistics; Engineering, manufacturing and construction; or Agriculture, forestry, fisheries and veterinary) and only a few transgress the single entry, such as Marine spatial planning or Conservation and environmental management.

More recently, higher education institutions have started diversifying their programmes. Over the past years, an increasing number of ocean-related short trainings and seminars have been offered. The Marine Training portal contain 545 of them, which have run as one-off or recurring courses, workshops, trainings, seminars, webinars etc. both in physical and online versions. Characterised by a considerably faster chance to respond to new demand, short courses offer both strong specialisations (e.g. on 3D data visualisation, maritime security, animal behaviour) and interdisciplinary curricula. They describe a dynamic educational landscape where topics can interrelate in new ways.

These trends follow the development of the job market. A growth in marine professionals and interest in marine careers is reflected in the proliferation of the term on 'blue jobs' and establishment of new dedicated online portals, targeting specifically those specialised in the marine and maritime sectors. For instance, the Blue Jobs platform established in 2022 promotes jobs not according to the disciplines or sectors (e.g. BlueGeneration project), but according to the type of work from the functional perspective, such as climate change, naval and marine engineering, water and hydrology, management and consultancy, marine policy. This categorisation seems to better reflect the kind of ocean sustainability positions that are currently entering the job market and seems more adequate to respond to the range of associated challenges.

3. Methodology

We situated our task of mapping the competences for the 'ocean science we want' against the need for these competences to accomplish visions of a desirable ocean future. The approach of merging established visions, ongoing trends and key challenges at play in the ocean has been effectively used in previous studies to propose plausible scenarios for action [56-58].

Specifically, to address the aims of this study we adopted a mixed-method approach that was designed to draw upon, and integrate, published scientific evidence and the experiential knowledge of topic experts [59]. Such mixed-methods approaches have proven meaningful for ensuring that results provide a broad understanding of the focal topic (i.e. breadth via literature review) as well as a deeper contextual understanding of the key points [60]. We do so through three discrete but interconnected steps; (i) A global literature review of the published scholarly literature and policy documents, (ii) a survey of topics experts working on related but diverse topics in different geographic regions, and (iii) the presentation of case studies (Fig. 1).

3.1. Step 1. Literature review

As outlined above, the first step in our study was to undertake a review of the published scholarly literature and policy documents. The process of combining diverse literatures faced the challenge of terminological differences and multiple formulations and categorisations of knowledge. Rather than identifying differences in emphasis, our aim was to build bridges across bodies of literatures and distil the key concepts for the specificities of the ocean. Thus, to arrive at competences, we deployed elements of sustainability education and pedagogy [61-65], cross-sectoral engagement by science [13,27,19,50,66,67], 21st century learning and lifelong learning [68-70], and the concepts relating to the relationship between human activities and the health of the ocean and coastal areas [71]. On the latter, we drew on publications with various conceptions and terms, including ocean sustainability [72,73], ocean health [74,75], ocean futures [57,58] and often overlapping terms related to blue economy, blue growth, maritime economy, marine economy and ocean economy [44,76,77]. While there may be differences in emphasis and scope of these concepts, they seek to capture the needs and wants of multiple users, and encompass both a concern for equitably distributed benefits from the economy [78-80] and a concern for sustainability and resilience of marine ecosystems while balancing overall economy [81].

To achieve this, we screened and collected publications from Web of Science and Google Scholar databases, published in English through to the end of 2022. We searched the databases, using a combination of

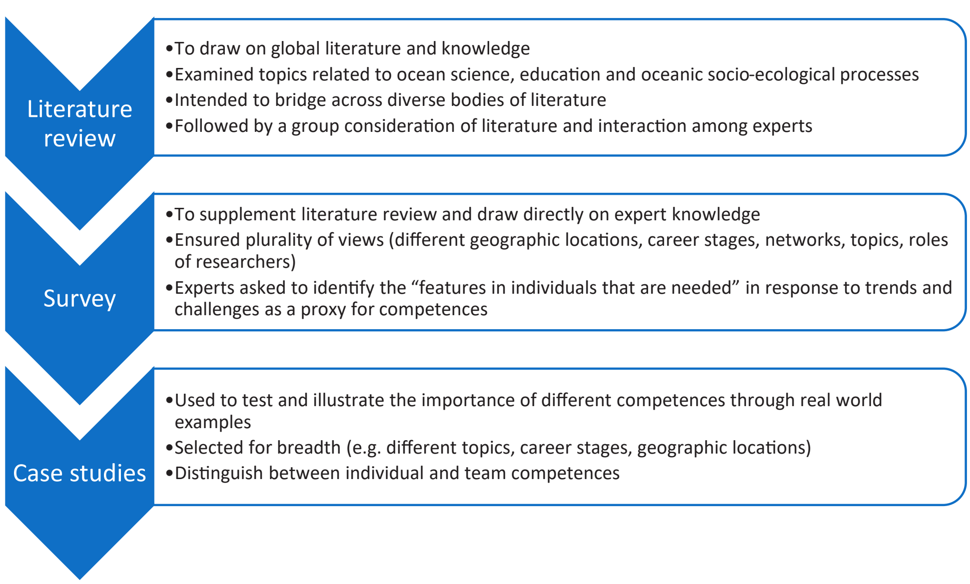

Fig. 1. Summary of the mixed-methods approach used in this study.

keywords of ’competence(s)’, ’competency’, ’skill(s)’, ’ocean’, ’sustainability’, ’blue economy’, ‘maritime economy’. The screening of the full text was implemented to ensure that such skills and competences were identified, or their features described, based on their relevance to the research question. Relevant extracts (paragraphs, sentences) from the publications were extracted. Additionally, we also relied on cross-referencing in key publications. We reflected on the literature review in a simple group workshop in June 2022.

3.2. Step 2. Expert survey

The second step in our approach was to supplement the results of the literature review with expert knowledge, to help ensure the completeness of the list of competences. To do so we used an online survey that asked respondents to identify the key challenges and trends in support of ocean sustainability, and 7–10 key features in individuals needed to resolve the challenges, as a proxy for competences. To foster free thinking and creativity, the survey intentionally did not ask the experts to name the competences or to differentiate between knowledge, skills and attitudes.

The survey was conducted between June 2022 and August 2022, and sent to 12 respondents who were known to the lead author as having extensive knowledge of, and experience with, the focal aims of this study. The respondents were academics and practitioners and were selected to ensure social plurality and a diverse set of perspectives to be drawn on [82]. For example, the 12 individuals all came from different countries (i.e. geographic diversity), represented 12 different institutes, spanned a range of career stages (early-, mid- and later-career) and different disciplinary backgrounds (i.e. ranging across social sciences, life sciences and engineering).

The written responses were analysed by a group of three co-authors (JP, JBJ, CC) to remove the potential for researcher bias, and ensure the validity and reliability of the coding process. Each of the three analysts first independently coded the surveys to identify individual skills, using inductive approach and knowledge of framing competences from the initial literature review [83]. We looked for listing as many competences as possible but did not duplicate (when different respondents provided the same response). Where appropriate, responses were broken down into separate competences. The lead author combined the results with those of the literature review into one integrated list and eliminated the duplicated competences. This list was then reviewed at first by the three individuals who undertook coding, and then by the broader author group, to ensure that the grouping of competences was appropriate. Competences were further grouped into a higher level of coding (following the approach used by [22]) to increase their usefulness and applicability. Specifically, we grouped competences into *knowledge*, *skills* and *attitudes*. The allocation of each competence to a higher-level theme was reviewed by all co-authors, both independently and in group discussion, to ensure that competences were allocated to themes in the most appropriate manner. See Annex 1 for the final list of competences.

While steps were taken (as outlined above) to ensure that respondents to the survey represented a diversity of knowledge bases and experiences, the small sample size may have influenced the nature of the results derived through the surveys. While there is no universally accepted ‘best practice’ sample size for such an approach, previous studies seeking to identify individual competences have done so successfully with similar sample sizes. For example, Tuohy et al. [84], with a sample size of 14, elucidated the skills and attributes that are required for research funders and managers to be successful knowledge brokers. Similarly, Kelly et al. [22] drew on the experiential knowledge of 13 internationally recognised interdisciplinary experts from around the world to generate practical advice for early career researchers and their mentors for achieving interdisciplinary research, including the identification of individual skills and attributes. Thus, given the diversity of backgrounds possessed by our experts, the combination of survey results with a comprehensive literature review, and the fact that such as study can never be fully representative, we feel confident in our approach.

3.3. Step 3. Case studies

The third and final step in our methods was to use case studies to test the feasibility of the resulting competence framework and illustrate the application of our results in real world settings. Case study research methods involve an in-depth and comprehensive examination of a specific instance or situation within a real-life context [85]. In doing so, researchers can provide a rich and detailed understanding of a phenomenon, allowing a more holistic view of the subject under investigation. This approach is particularly useful for gaining insights into real-world situations and increasing the practical utility of research findings [85]. Such approaches have previously proven effective, for example, in the highly cited paper by Norström et al. [27] that combined a survey with case studies to articulate the key principles that support the effective and efficient co-production of sustainability science. Here, five co-authors were invited to write case studies to test the competence framework based on their own experience. The authors of the cases, which were selected for diversity in terms of topic and location, were asked to describe their working research approaches and link the actual work to the competences from the list to help demonstrate the application of the competence framework. In listing competences, they were asked to draw freely on knowledge, skills and attitudes, but differentiate between individual and team competences – competences that they possessed as an individual and those they relied on as part of a team.

4. Results: Competences for ocean sustainability

There is a high level of agreement among scientific and policy literature over the background against which competences should be build. The *visions* that drive activities and actions emphasizes the objectives of equity and sustainability dimensions (UNCLOS, Part XII; [86,11,87,12,88]). These visions must overcome real problems or *challenges,* which can be framed in 10 specific Ocean Decade Challenges [11] as understanding and beating marine pollution; protecting and restoring ecosystems and biodiversity; sustainably feeding the global population; developing a sustainable and equitable ocean economy; unlocking ocean-based solutions to climate change; increasing community resilience to ocean hazards; expanding the Global Ocean Observing System; creating a digital representation of the ocean; building skills, knowledge and technology for all; and changing humanity’s relationship with the ocean. These challenges can also be framed at a smaller scale and in more practical ways, such as the need to close the life cycle of sea vessels (Solakivi et al., 2021), preventing the spread of invasive species to destabilize ecosystem (Molnar et al., 2008), or ending harmful fishing subsidies (Sumaila 2021). What emerges is that almost all the challenges arising at sea apply to multiple marine or ‘blue’ sectors at once and require coordinated interventions across interacting sectors [89], rather than implementing solutions in isolation. This reinforces the observation that ocean-related challenges are far from being fully captured in the ocean-centered SDG 14, but in fact interrelate with multiple SDGs ([90,91]; Lee, Noh, and Khim 2020).

Trends also have an impact on the future. The ongoing patterns and shifts in behaviours or attitudes relating to ocean sustainability are partly a reflection of more general ones, sometimes called megatrends [92-94]. These relate to the continued rise of activities at sea, with a geo-strategic and political outlook; digital and technological trends (e.g. automation, advanced robotics, AI, big data, 3D printing, smart grid and smart sensors, advances in material science); rising environmental regulation; increased demand for greening solutions by the industry as well as by the public. These trends can be further tailored and adjusted to the specific geographical context of regions [95,96] or countries [97] (Norwegian Ministry of Trade, Industry and Fisheries 2019; Fisheries and Oceans Canada 2021), or an economic or marine sector [98,99]. The trends impact all the sectors, albeit in specific ways, and thinking in terms of sectors does not appear particularly helpful in capitalizing or responding to these trends. An adequate strategy for anticipating ocean sustainability, and indeed creating conditions for it, requires a systemic view of visions, challenges and trends, including the interplay between them. Policy documents are gradually replacing their focus on sectors with a need for cross-sectorial coordination [95,100-102] and this is where scientists can play a role, if trained accordingly.

Against this background, researchers working in ocean sustainability need a particular set of knowledge, skills and attitudes (See Fig. 2 for summary and Annex 1 for a full list). *Knowledge* is both subject-specific and interdisciplinary. We have divided it into the categories of bio-physical processes at seas, human individuals and communities, marine technologies and engineering, and planning. These categories transcend traditional disciplines and imply that apart from comprehensive subject-specific knowledge, the required expertise involves synthesizing relevant information from various disciplines. The suggested categories are in line with the expectation that any researcher in sustainability possesses knowledge of basic ecology, climate, biotic and abiotic resources, consumption behaviour, society, politics, economy, and environmental contamination [103]. This could also be framed as the need for a researcher to have knowledge of socio-ecological sustainability science, relating to complex adaptive systems, social-ecological systems, cross-scale dynamics, diversity, transformations and biosphere-based sustainability [104]. For marine scientists, this knowledge needs to be adapted to the marine environment and can be associated with some aspects of ocean literacy [45], including the close interconnections between ocean and land [105].

Skills (which relate to acquired abilities and expertise) and *attitudes* (which relate to personal beliefs and values, gained through personal experience and socialization) allow knowledge to be applied for success in the professional career. Specific skills can be clustered under the broader themes of systems thinking, research design, data analysis, communication and engagement, facilitation and coordination, management and leadership. A researcher is likely to possess skills from across these categories. Attitudes are divided into those that relate to embodying sustainability and those that support leadership for change. The former represent the prerequisite for the latter, but we find the interplay between the two increasingly essential to respond to the challenges. Attitudes are essential both in the relationship with others, e.g. to establish a positive dialogue with key actors in the ocean sustainability arena in supporting efficient and effective science-policy-society interfaces, as well as in relation to oneself for a long-term engagement with ocean sustainability. The expectation of ocean stewardship, in particular, has been advocated by the literature quite strongly [106-109, 2]. Relevant findings are also offered by the literature on sustainability-aligned values, which has highlighted the need for moving away from predominant values that currently over-emphasize short term and individual material gains [110].

While the competence framework seeks to be comprehensive, it is not a rigid instrument. First, most competences cannot be classified as either present or absent and will instead exist on a spectrum with differing levels of command within researchers. Evaluating the level of expertise is a task for each specific programme, course, individual or group. Secondly, the relative emphasis within these domains may vary among individuals. Particularly with regards to knowledge, it is expected that researchers are working on different issue areas and with different goals, and thus cannot be asked to possess the exact same competences.

With that in mind, the proposed skillset can also be regarded as a team aspiration. While we encourage individual to cover as many of the competences as possible and expect that they have reached a certain level of core knowledge, we also acknowledge that researchers usually work in a community of knowledge holders. Insofar as the individual

Fig. 2. Examples of competences fora researcher working towards ocean sustainability. See Annex 1 for the full list.

cannot cover all the knowledge and skills, the gaps are expected to be complemented through their colleagues and partners. Acknowledging that competences can adequately be covered in a team, removes the unrealistic expectation of super-researchers, and is beneficial to encouraging productive teamwork (e.g., effective communication, collaboration, leadership, and conflict resolution), and to ensuring diversity of perspectives [111]. Indeed, individuals within a team bring different sets of skills and expertise, which can complement each other and enhance the collective knowledge base of the group as well as its capacity to solve complex problems.

5. Case studies of the marine science competence framework

Building on the framework outlined above, this section draws on our practical experience to show how these competences operate in practice through five real-world scenarios. Researchers have indicated the key competences (a combination of knowledges, skills and attitudes) that they have used either as an individual or by working as part of a team. We find that the individual and the team are highly complementary in the use of knowledge and skills, while attitudes lie mainly with the individual, and it was particularly difficult to single out some of these as more important than others.

5.1. Water pollution

The Gulf of Gabès is characterized by shallow water, high temperature and high salinity. It is a spawning and refuge area for larvae and juvenile fish and is estimated to provide about 65% of Tunisia's production of marine resources. It is exposed to anthropogenic pressures from industry, agriculture, and wastewater treatment plants. Our work was the first application of marine ecotoxicology in Tunisia to measure the impact of pollution on marine organisms and to propose appropriate monitoring tools. The clam *Ruditapes decusatus* was chosen as a biological model, as it is largely distributed along the Tunisian Coasts and mollusk bivalves are known to accumulate pollutants in their tissue without showing any detrimental effect. To better understand the impact of pollution on these organisms, we had to combine various complementary approaches, including field and *in vivo* experiments, *in vitro* trials and transplantation experiments. The first step was to undergo different training courses in recognized research laboratories in the field of marine ecotoxicology to learn the different techniques that will be applied later in our local laboratory. We also had to bring samples to foreign laboratories to conduct analysis that were not available locally. Besides analyzing data, it was necessary to build new networks, develop research proposals (national and international), write scientific papers and train master and PhD students. We also organized workshops and conferences to identify the next research steps and how to disseminate the key messages to policy makers and stakeholders. In many steps, it was necessary to take courageous actions to initiate a new topic, studied for the first time in Tunisia, like marine ecotoxicology, endocrine disruptors and pollution and cancer diseases.

Individual competencesvas

- Ability to coordinate a team
- Ability to design workshops, facilitate and moderate dialogues, and run participatory processes
- Being courageous to challenge the status quo and take action
- Ability to produce diverse outputs, practices and activities that maximise impact
- Ability to research and analyze information from a variety of sources to identify and synthesize relevant knowledge
- Ability to listen actively, comprehend and interpret other people's messages

Team competences

- Physical, chemical, and biological aspects of marine environments
- Interactions between processes at land and sea
- Spatial and temporal cross-scale dynamics
- Marine policy and regulatory framework (processes, goals, tools, indicators) at local, national and regional scales
- Ability to consider the interconnectedness of elements within complex adaptive socio-ecological systems, identify their feedback loops, and understand the impact of changes.

5.2. Ocean literacy for the blue economy

Although the ocean is crucial for life on this planet, most people are not aware of its importance. To effectively protect, conserve and sustainably use marine resources and ecosystems, society needs to be ocean literate and understand the relationship between people and the sea. Coastal communities are directly connected with the sea, but they are often unaware of the impact that people have on the sea. Inland communities are often even more disconnected from the sea. Ocean literacy empowers people to recognize their connection to the sea and to make informed and responsible decisions related to marine resources and ocean sustainability. As a marine biologist, I work on ocean literacy at different levels – research, education and citizens engagement. Each of these levels need a different approach and way of communication. Collaboration between scientists and society is crucial for approaching different societal groups. Working at the international level helps to identify priorities and methods of work. My work in the field of ocean literacy is oriented towards the Mediterranean Sea. Through the coordination of the regional ocean literacy network, I worked on the process of identifying the steps needed for ocean literacy in this region, also addressing the importance of ocean literacy for a sustainable blue economy. Working at the Mediterranean level means working in an intercultural environment which needs to be inclusive, and where many different perspectives overlap. In the ocean literacy research, I mostly focus on the education system, identifying the level of ocean literacy knowledge among school students by using validated methods (questionnaires). Recently, I collaborated in the study on ocean literacy levels in the blue economy workforce. I presented the research results and activities on different events and conferences. I also give courses at the university to future teachers and marine science students. To ensure financial resources for performing all the activities, I have successfully written project proposals. Through the work at the international level, I organized online and physical events which enabled participants to share their experience and knowledge and led to some new collaborations.

Individual competences

- Physical, chemical, and biological aspects of marine environments
- Social-ecological dynamics, human-ocean interactions
- Ability to consider the interconnectedness of elements within complex adaptive socio-ecological systems, identify their feedback loops, and understand the impact of changes
- Ability to clearly communicate with impact with different scientific, policy, and public audiences verbally and visually
- Ability to plan and organize events
- Ability to coordinate a team
- Ability to organize resources, tasks, and people in order to complete a project
- Ability to work in international contexts
- Being humble and open minded
- Being inclusive and collaborative

Team competences

- Marine policy and regulatory framework (processes, goals, tools, indicators) at local, national and regional scales

- Ability to consider the interconnectedness of elements within complex adaptive socio-ecological systems, identify their feedback loops, and understand the impact of changes
- Ability to integrate various disciplines and ecological, social and economic aspects in order to gain a holistic understanding of a situation and to consider the long-term implications of decisions
- Ability to think across geographical, theoretical and disciplinary boundaries
- Ability to identify and solve problems by using critical thinking, creativity, and multiple knowledge
- Being inclusive and collaborative

5.3. *Local fishing traditions and products*

In the northern Adriatic region, the identity of towns is closely linked to the fishing tradition, but fishers report ever smaller catches, their profession is disappearing and most of the seafood for local consumption is imported. I have been working on this issue to find viable solutions within the existing system of the market. There are many explanations for what is at stake: overfishing, inadequate policies hindering small-scale fishers, historical jurisdictional changes, EU policies, changing consumer tastes, inadequate enforcement of regulations and illegal fishing, insufficient attention to ecological connectivity etc. Based on the personal accounts of professionals working in the sector at national and international level, I had to identify the viable points for intervention. I conducted several individual and group sessions with the stakeholders in which we jointly defined how the different factors are interrelated and manifest themselves in the relationships between producers and consumers, but also how they can be changed. We identified solutions that were applied to the problem in different local environments in Europe and the Mediterranean. Since the problem cannot be solved at the level of a single country, we also identified regional organisations that have an interest or the power to influence outcomes. We have found that the policy discourse on 'sustainable food systems' is much more holistic and appropriate than the narrower framework of 'catching and selling fish'. Our research points to the interplay of numerous social and environmental factors and identifies various points at which established practices and structures can be changed. As a direct result, we have developed and disseminated recommendations for fishermen, consumers and policy makers. I continue working on the issue of ecological connectivity as this is another factor affecting fishing opportunities in this region.

Individual competences

- Marine policy and regulatory framework (processes, goals, tools, indicators) at local, national and regional scales
- Cross-scale dynamics
- Human-ocean interactions
- Ability to research and analyze information from a variety of sources to identify and synthesize relevant knowledge
- Ability to listen actively, comprehend and interpret other people's messages
- Ability to facilitate and moderate dialogues, and run participatory processes
- Ability to coordinate a team
- Ability to produce diverse outputs, practices and activities that maximise impact
- Being open to making the most of opportunities, overcoming setbacks and learning from them

Team competences

- Physical, chemical, and biological aspects of marine environments
- Marine resource valuation & management
- Human behaviour in relation to marine resources
- Ability to consider the interconnectedness of elements within complex adaptive socio-ecological systems, identify their feedback loops, and understand the impact of changes

5.4. *Marine plastic pollution*

Currently, my research projects are focusing on monitoring and assessments of the marine environment quality including the quantification of marine microplastics, blue carbon sequestration rates estimation and heavy metals pollution measurement in coastal lagoons sediments. While diverse, all three topics enable me to combine my analytical capacities and skills from the lab with my interest in the wider ecological, social and economic aspects. In addition, they allow me to think across geographical and disciplinary boundaries and pursue a holistic understanding of a situation and scientific questions. In the area of marine plastic pollution, I wish to address the lack of data concerning plastic pollution in Moroccan waters. I have been able to overcome this gap by using available data related to microplastic interaction with biodiversity and land systems. I combined laboratory techniques of radioactive and chemical analytical methods, and my abilities to interpret and analyze available data in a reliable and effective way with the social aspects and human behavior toward managing plastic waste. I found that human actions are the key factor affecting the marine environment through overusing plastic items and discarding their related waste in nature. Next to research, I give university courses to master students on sustainability as part of my engagement to offer extracurricular content. I also give talks in national and international meetings to sensitize different stakeholders including other scientists, governmental employees, communities, and associations to ocean sustainability and to promote scientific findings.

Individual competences

- Nutrient, chemical, oil, plastic, noise, heavy metals pollution
- Human behaviour in relation to marine resources
- Environmental impact assessment
- Ability to integrate various disciplines and ecological, social and economic aspects in order to gain a holistic understanding of a situation and to consider the long-term implications of decisions
- Ability to think across geographical, theoretical and disciplinary boundaries
- Ability to interpret and analyze data
- Ability to coordinate a team

Team competences

- Ability to research and analyze information from a variety of sources to identify and synthesize relevant knowledge
- Ability to identify and solve problems by using critical thinking, creativity, and multiple knowledge
- Ability to write scientific papers and identify target journals
- Ability to plan and organize events

5.5. *Transboundary marine spatial planning*

I was involved in the preparation of maritime spatial plans in my country. First, we had to understand and discuss with decision-makers the relevant boundary conditions (e.g. formal obligations, governance mechanisms, key actors involved, starting points and expected timeframes), the level of feasibility and ambition of the plans and which operational approach to use (e.g. which spatial scales and resolutions, who to involve, how to ensure a continuous and productive dialogue between scientific and institutional parties). The inception phase considered most international guidelines, experiences and best practices, also thanks to a well-established dialogue with the European and international MSP community. We then established a core multidisciplinary working group of about 20 people, which I co-led, and defined roles and working modes to guarantee a coherent contribution of each expert to the final outcome. The next step was a detailed initial assessment of the existing marine and coastal uses and marine ecosystems in the planning area, followed by an analysis of interactions and conflicts among uses and of potential effects and impacts on ecosystems. Then, the actual planning started, from the definition of visions and planning objectives to the allocation of appointments to the different planning units identified. Many different policies (e.g. regional, sectoral, environmental, climate) and their ongoing implementation processes had to be considered, to ensure coherence within the plans. We also had to consider the transboundary dimension of MSP, looking at the Mediterranean situation and trajectories of ecosystems and sea uses, and analysing the arrangements in neighbouring countries. The process required a continuous dialogue with ministries and regional administrations, and with many stakeholders (e.g. other public administrations, academia, private operators and their associations, NGOs and the civil society in general). Our objective was to steer their views and expertise into scientific and technical-based proposals and management measures to reach the plan's objectives and balance trade-offs (e.g. conflicts between offshore wind farms or oil and gas platforms and fisheries or seascapes, conflicts between conservation and bottom trawling or maritime transport). We had to learn here not only how to identify problems and risks, and propose solutions, but also how to convince all the actors around the table that the MSP process is for their benefit and can bring real added value for the future. After the planning phase, a monitoring plan was prepared, to ensure the ability to reach socio-economic and environmental objectives. The final proposal was then opened to a formal public national and transboundary consultation.

Individual competences

- Single and cumulative effects of natural and anthropogenic pressures
- Interactions between processes at land and sea
- Social-ecological dynamics, human-ocean interactions
- Marine policy and regulatory framework (processes, goals, tools, indicators) at local, national and regional scales
- Marine/Maritime spatial planning - Coastal zone management
- Ability to integrate various disciplines and ecological, social and economic aspects in order to gain a holistic understanding of a situation and to consider the long-term implications of decisions
- Ability to work with, and integrate, diverse knowledge systems (e.g. indigenous knowledge, local knowledge, scientific research)
- Ability to set and manage project goals, activities, budgets and a timeline (planning and execution)
- Ability to identify, assess, and mitigate risks associated with a project (risk management);
- Ability to coordinate a team
- Ability to work in international contexts
- Ability to identify and work effectively with a wide range of stakeholders, including government bodies and agencies, businesses, NGOs, and local communities
- Ability to listen actively, comprehend and interpret other people's messages
- Being courageous to challenge the status quo and take action

Team competences

- Physical, chemical, and biological aspects of marine environments
- Spatial and temporal cross-scale dynamics
- Resource valuation, familiarity with economic principles and industries at seas
- Renewable energy technologies
- Climate change adaptation and mitigation
- Biodiversity conservation and ongoing environmental change
- Ability to research and analyze information from a variety of sources to identify and synthesize relevant knowledge;
- Ability to use specialized software to process and analyze data
- Ability to design workshops, facilitate and moderate dialogues, and run participatory processes
- Ability to clearly communicate with impact with different scientific, policy, and public audiences verbally and visually
- Being appreciative that research is only one part of a bigger system, interconnected to other individuals and systems)

6. Discussion: what next for the competence framework?

Identifying a comprehensive set of researchers' competences is an essential step towards a sustainable ocean. Our ambition with this exercise is to directly support the ongoing and future education and training programmes for researchers in the domain of ocean sciences. This requires that the listed competences are integrated into educational processes, together with adequate pedagogies.

There is growing acknowledgment that a large potential of education for sustainability lies in transformative educational approaches and interventions [112,113]. These are directed not only at the application of a skillset, but also at awakening the inner, personal capacities of learners, and combining cognitive and socio-emotional processes [114-116]. We wish to see the competences for ocean sustainability be translated into routine and novel educational process at relevant levels, including study programmes, short-term trainings, professional capacity-building programmes, science-policy interfaces, intra-organisational capacity strengthening and other opportunities for the transfer of knowledge.

In doing so, the key challenge will be to equip the current pedagogical workforce – faculty or managerial staff, who coordinate the trainings – with the required knowledge and skills. A holistic competence framework is disruptive to most current educational programs, faculty, learners, evaluators and administrators. Because the requested skill set is not commonly part of the existing preparation in education, current trainers are also not necessarily prepared to build the capacity of others in transformative directions, which we have outlined. The more recent generation of researchers working in the ocean sciences are not always engaged in systematic teaching and transfer of knowledge, although evidence suggests that they would like to be [117]. Yet it is this generation that are at the forefront of advancing the science that is needed to solve complex ocean challenges [118]. Current operating bodies and systems of knowledge are rigid, and underlying these may be personal interests, beliefs and systemic incentives.

A possible aversion to change must first be recognized and addressed before a new competence framework can be authentically realized. In the short term, this can be mitigated by techniques of self-awareness and self-reflection for learners and teachers, and pragmatic actions to reduce barriers. For example, the lack of the required interdisciplinary skillset within single trainers requires an enhanced role for moderators, who encourage reflection after disciplinary activities, and for practitioners' perspectives to complement those by researchers [119]. For impact in the long term, attention needs to be placed on system interventions to improve the readiness of research organisations to absorb and valorise researchers trained to acquire and use this competence framework. Present research institutions may not be ready for this, in terms of strategic planning, internal organisation, resources allocation, ranking systems, and metrics of science impacts [120-122].

While our approach targets education and scientific professionals in their endeavours, it also has systemic implications for how we view ocean sustainability. Our focus on competences as a way of relating the individual to ocean sustainability presents an explicit contrast to the policy rhetoric of 'building blue skills'. Policy documents and discussions are replete with a link between accomplishing a sustainable blue economy and developing adequate skills for individuals [95,11,101,123]. However, the discourse over 'skills gap' or 'skills mismatch' has often remained too general and the exact skills that are in shortage have rarely been identified [124,125]. Specific marine sectors, such as renewable energy, shipbuilding, and maritime transport, among others, have therefore focussed on filling the staff shortages and the individual needs of specific sectors [126-128]. Such a sectorial approach has perpetuated the understanding that current ocean sectors lead to established jobs. Contrary to the grounding of 'blue careers' in incumbent jobs within existing economic sectors, our focus on competences allows us to envisage the jobs and professions that are required for the transformation.

An empirically-grounded competence framework, rooted in visions of the transformations of the job market, new business models, new professions, and societal change at large, is critical in addressing the complex sustainability problems [36]. Our results overcome the fixation on the 'blue economy sectors', and instead calls for an effective coordination across them. We depart from operating within the 'blue sectors' as a self-referential system that extracts the vision of the future from existing occupancies. Instead, distilling relevant skills highlights the ways in which we need to start valuing a new skillset across different careers. This opens opportunities for thinking about future professions which involve researchers and operate at the intersection of existing sectors or work across them.

Some aspects of the blue economy have so far received little attention although they are important for driving appreciation of non-monetary values, conservation, stewardship and inclusivity [129]. Examples include biomimetics or morphology, physiology, and behavior of marine organisms (ibid.), slow, responsible and sustainable tourism [130], creating circular solutions from waste materials (Vázquez et al., 2023; Rudovica et al., 2021) [131,132] as well as restoration of mangroves, seagrass beds and dune vegetation [133]. Researchers of ocean sustainability science can and should engage with these. Science plays a strong role in the transitions from high-risk, low-mobility jobs to those in sustainable blue economy [134].

Other examples of overlooked jobs at the intersections of ocean sustainability and marine research relate to community engagement (including building ocean literacy, [135]); nurturing rituals and traditions; manufacturing and mending of traditional and artisanal products; educational services of spreading knowledge about seas; developing new products based on ocean biotechnology; planting edible coastal plants; conserving and restoring marine resources, and others. Promising opportunities can be actively explored through pilots, policy labs and entrepreneurial businesses, among other things. The exact mechanisms, however, will need to be tailored towards the specific context in which it is embedded for maximum success, and thus we encourage further research in this regard (i.e. to match strategy to context).

7. Conclusion

There is a broad consensus on the urgency to rapidly transform towards ocean sustainability and the pivotal role of science in that process. This article has mapped the competences needed for individuals' working at the intersection of marine science and ocean sustainability to fulfil that consensual vision. The starting point was future-oriented and linked to normative objectives as well as ongoing challenges and opportunities. We offer a list of competences that outline the functional literacy or proficiency of ocean scientists and researchers. Our mapping of competences builds on the transformative ambitions and visions, which are captured in key policy documents and scholarly literature, including the Ocean Decade, but missing – in an explicit format – in the programmes for how the desired transformation can operate at the level of individuals, and how they can contribute to it. We present a list of knowledge, skills, and attitudes that individuals should aim at, and scientific teams possess to enable and foster the transformation from the current ocean economy to a sustainable and equitable one. Many of the competences listed go beyond the narrow understanding of research and science and link the researchers' profiles more closely to other segments of society, areas of work and shared tasks. While researchers are not the only nor the privileged ingredient of the transformation, they are instrumental change makers through evidence-based societal engagement.

We propose to integrate the competences into the educational and training activities of existing and new generations of ocean scientists and popularise the opportunities for jobs inspired by the competence framework. But advancing the knowledge model cuts to the core of the existing power relations, which underlie any transformation at seas [136]. An important next step is thus to identify facilitators for the implementation of the holistic and emancipating competence framework, including long-term strategic interventions at the institutional, cultural, and policy levels.

CRediT authorship contribution statement

Andrea Barbanti: Funding acquisition, Investigation, Validation, Writing – review & editing. **Amel Hamza-Chaffai:** Funding acquisition, Investigation, Validation, Writing – review & editing. **Christopher Cvitanovic:** Formal analysis, Funding acquisition, Investigation, Methodology, Validation, Visualization, Writing – review & editing. **Jean Baptiste Jouffray:** Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – review & editing, Funding acquisition. **Ahmed Elshazly:** Funding acquisition, Investigation, Validation, Writing – review & editing. **Melita Mokos:** Funding acquisition, Investigation, Validation, Writing – review & editing. **Nezha Mejjad:** Funding acquisition, Investigation, Validation, Writing – review & editing. **Jerneja Penca:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing.

Data Availability

Data will be made available on request.

Acknowledgments

We thank Lene Topp from Joint Research Centre of the European Commission, Ulrike Pitsiotis from the Directorate-General for Education, Youth, Sport and Culture of the European Commission, Andy Kontoudakis from the DG MARE, European Commission and Olena Bekh from the European Training Foundation for providing expert insight into the development of competence frameworks they were involved with; Lucía Fraga from Centro Tecnológico del Mar - Fundación CETMAR, Celia Murcia Lorenzo from the Blue Jobs portal, Daniel Depellegrin, Manal Nader and Ant Türkmen for taking part in the expert survey as part of data collection. JP acknowledges support from the Slovenian Research Agency, project number J5–2562. AB acknowledges support from the project CROSSGOV, funded by the European Union's Horizon Europe research and innovation programme under grant agreement No. 101060958. JBJ was funded by the Knut and Alice Wallenberg Foundation (2021.0343). The brainstorming workshop was hosted in June 2022 by the Jean Monnet Centre of Excellence for Sustainable Blue Economy at the Euro-Mediterranean University, where JP served as the Director.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2024.106132

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