Original Paper

Understanding interdisciplinarity through Adriatic maricultures and climate change adaptation

Cécil J.W. Meulenberg, Shé Mackenzie Hawke, Irina Cavaion, Peter Kumer, Blaž Lenarčič

Received: 25 July 2022 | **Accepted**: 30 August 2022 | **Published**: 21 September 2022

Citation: Meulenberg, C.J.W. Hawke, S.M., Cavaion, I., Kumer, P., Lenarčič, B. (2022). Understanding interdisciplinarity through Adriatic maricultures and climate change adaptation. *Visions for Sustainability*, 18, 1-26. http://dx.doi.org/10.13135/2384-8677/6945

Correspondence: Cécil J.W. Meulenberg, e-mail: cecil.meulenberg@zrs-kp.si
Extended author information available on the last page of the article

Keywords: Interdisciplinarity; Maricultures; Eco-linguistics; Climate change; Citizen science; Ecosystem services.

Abstract. *The consequences of accelerating climate change for land and sea biodiversity require innovative approaches to research. Interdisciplinary research serves to connect natural science, social sciences and humanities, technology, and engineering, as well as welcoming citizen scientists into the research environment. Interdisciplinarity is part of a developing innovative approach to research that emphasizes co-evolution of traditional sciences, with citizen science and participatory engagement in the realisation of research goals and the promotion of climate change mitigation strategies. In this article, through the example of shellfish maricultures we illustrate interdisciplinarity, particularly demonstrating how marine biology, health and well-being, social science and cultural geography come together at the interface between nature, culture, and climate change mitigation strategies.*

1. Introduction

The acceleration of climate change arising from the Anthropocene Epoch (Steffen, Crutzen and McNeil 2007; Hawke and Pálsson 2017) and the associated effects on land and sea biodiversity necessitate innovative ways of doing research. This paper's aim is to illustrate the importance of interdisciplinary research through the example of marine aquacultures, also known as maricultures, that produce shellfish (as opposed to freshwater aquacultures and fish maricultures). We seek to investigate the impact of maricultures on society and vice versa by describing different intersecting scientific sectors that can identify stakeholders who through citizen science can make a contribution to climate change mitigation, especially at the coastal land-water interface. For our purposes we apply the definition of interdisciplinarity from earlier research work (See Paulsen, Jagodzinski and Hawke 2022), but in specific reference to this paper, we refer to the work of Edwards (1998), who presented a framework comprised of diverse aspects of marine aquacultures, covering: production technology, socio-economic characteristics, and the environment as an ecosystem. Recently, this socio-

ecological system framework was elaborated on by Johnson *et al.* (2019), to which we add cultural heritage and participatory engagement (Kumer and Urbanc 2020) from citizen science.

In this example, we emphasize the confluence between different fields of science that include, but are not limited to, engineering and technology, marine biology, kinesiology (the study of human movement embracing health sciences), social science, cultural geography and heritage studies, together with citizen science. These all play a pivotal part in understanding the interface between nature and culture. They are not the only possible intersections, but are chosen as those most relevant to this article on maricultures and coastal climate change issues. We will also refer to the climate change innovation project Smart Control of the Climate Resilience in European Coastal Cities (SCORE)[1] as a living example of how to develop coastal resilience, in association with the ecosystem services partially provided by maricultures. Figure 1 presents a sample of intersecting areas of interdisciplinarity in relation to our field of inquiry.

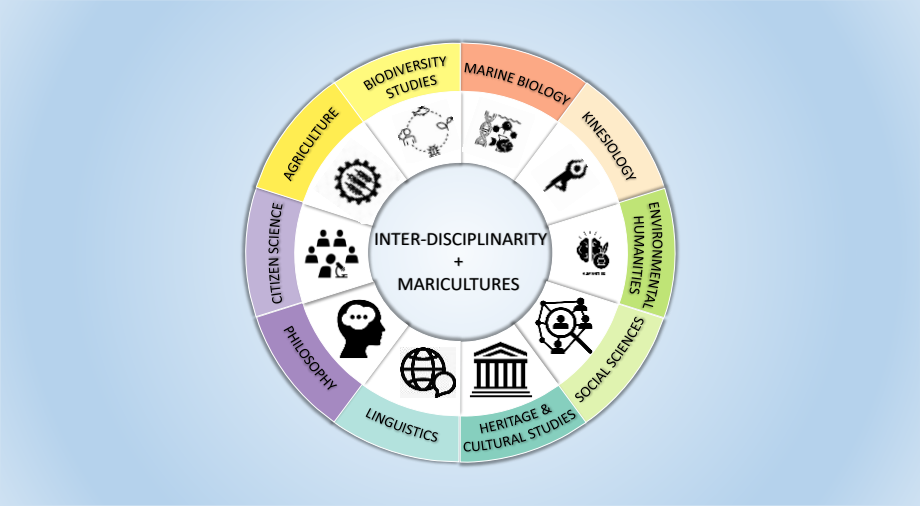

Figure 1. An example of Interdisciplinary Research Intersections through Maricultures

[1] The authors of this paper are or were partners in the SCORE Consortium. We are in the process of analyzing the data sets gleaned from the first twelve months of this project. More empirical evidence will be available in work forthcoming.

At times innovative and emergent research dialogue takes places between two fields and at other times involves many fields of scientific inquiry. Imbricated in this method of interdisciplinary research is the way in which connections evolve between theory and practice. How that interface is understood across different sectors (including business) influences rigorous and diverse research possibilities that lean towards climate change mitigation. Before we explore the world of maricultures, we present some key definitions and concepts that set the background for developments in the field of interdisciplinary studies as they relate to climate change mitigation research and practice.

2. Shellfish maricultures as an interdisciplinary case study

The probable effects of maricultures on health, environment and ecosystems, their products at the nature-culture interface, and the ecosystem services they provide, has attracted widescale research interest beyond marine biology (Johnson *et al.* 2019; Mascorda Cabre *et al.* 2021), as we will discuss below. Studying maricultures during the current period of climate change provides the opportunity for unique cross-disciplinary data about human impact and pollutants to be gathered and analysed.

The type of research necessary to discover the benefits and general effects of maricultures requires both biological and social science data, because each of these fields gathers and analyses data differently. Social science has a greater emphasis on both quantitative and qualitative data, as well as narrativization, while biological sciences approach nature more quantitatively. By merging the full spectrum of research results from each of these fields we can build a more comprehensive picture of what is happening within and through maricultures. Here the role of fishing community observances of changes in maricultures are vital and are also detected differently. Ethnography and auto-ethnography also come into play, in that they relate as much to heritage practices and lived experience as to specific biological science applied to aquaculture – marine biology. Mapping the cultural geography, habits, and practices of fishing communities, and partnering with them, thus forms a pivotal part of a broader and more robust research picture that is inherently interdisciplinary, rather than constrained by the specificity of one scientific approach.

The European Commission is embracing interdisciplinarity through its funding calls that expressly invite biological, social and citizen sciences to collaborate innovatively towards richer and more diverse research practice and outcomes. For

example, it has implemented a strategy to ensure that safe human food products enter the markets of its member states (SFEP, 2015), mandating the implementation of the Directive on Maritime Spatial Planning by 2021. In addition, there are other intiatives such as The Marine Strategy Framework Directive; The Water Framework Directive; The Flood Directive, The Natura and Habitats Directives and the 2030 Biodiversity Strategy.

Other instruments that engage in research practice and knowledge sharing across fields include the Sustainable Development Goals (SDGs) adopted by the United Nations (UN, 2015). These goals identify areas in which it is argued that development can be promoted while ensuring protection of the planet by adopting interwoven socio-cultural, environmental and geographical approaches. In relation to maricultures, goals no.3 – *Good Health and Well Being*, no.12 – *Responsible Consumption and Production* and no.14 – *Life Below Water* are particularly relevant. The motivation behind the adoption of the SDGs was to educate and to enact mitigation pathways in the face of climate change, and also explain how these effect people and species in different parts of the world, thereby combining cross-cultural and geo-political concerns with ecological concerns. By merging directives and instruments with the practices of daily life – in this instance citizen scientists in the mariculture communities of the Mediterranean area (in particular the Adriatic Sea) – further knowledge can be built by expert researchers and commissions that have already reported about mariculture products, its benefits and pitfalls (EUMOFA, 2017).

Continual building of research across fields, and indeed going beyond borders, towards the achievement of sustainable goals for maricultures and biodiversity, is crucial. Human cultures that do this as part of their cultural heritage while also being citizen scientists, demonstrate both the need for interdisciplinary research conversation and a better understanding of how interdisciplinarity can be applied to modern research (Johnson *et al.* 2019) and climate change challenges (Jones *et al.* 2022; Mascorda Cabre *et al.* 2021). Part of that research is developing methodological frameworks that attend to both ecosystem services and the socio-economic assessment of the sustainability of those services for local as well as market communities. By consolidating transboundary and interdisciplinary links, a more comprehensive research picture will emerge for maricultures, while still respecting the specificity of marine biology and its rich tradition.

3. A methodology involving Citizen Science

The Green Paper on Citizen Science (2013, p. 21) defines the participation and co-creation of lived experience science and research in terms of how "citizen science refers to the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort, or surrounding knowledge, or with their tools and resources."

The term "citizen science" encompasses a wide range of activities and practices related to renewed collaborations between research and society (Haklay *et al.* 2021, p. 4). It includes the generation of scientific data, engages volunteers over a large area, and addresses a politically, economically, socially, or environmentally relevant issue. Without a precise definition and adoption by all fields of inquiry, citizen science and its associated participatory engagement gives rise to discussion about what type of activities and practices should be included (Haklay *et al.* 2021) in its scope. But fundamentally it includes "public participation and knowledge production" in science and research activities (p. 2). Later in our article we look at fishing communities and their everyday science lived experience through the lens of citizen science, considering it as inherited knowledge enacted daily.

The growing need for solving complex research and environmental challenges demonstrates the inherently interdisciplinary aspect of citizen science research and approaches. Tipaldo and Allamano (2017) argue that interdisciplinary approaches focus on citizen science as well as on social mechanisms that push non-experts (i.e. citizens) to invest time and personal knowledge in collaborative initiatives for science. This is not to be confused with crowdsourcing, which is more of a funding drive that engages citizens to contribute to research costs.

As Heiss and Matthes (2017) observe, activities and projects following social sciences and humanities topics and approaches are less easily discernible in citizen science practice, although they may be fueled by genuine and challenging questions. This is supported by the data available from the EU open science monitor (European Commission, 2020) which shows that among the citizen science projects financed by the EC the great majority of projects in 2019 were in the field of ecology and environment (623), followed by nature and outdoors (618), biology (518) and animals (396). Hence, it is possible to justify the use of citizen science as a research method in climate change phenomena and research, as citizens are faced with elemental challenges emphasized by funding bodies. Conversely, according to Tauginienė et al. (2020), social sciences may apparently recruit fewer citizen scientists because of the stable, long-lasting relationships social

science has developed with communities in general, through surveys and focus groups, but not necessarily defined as citizen science.

In relation to coastal cities, mapping hazards such as tidal surge, coastal flooding and the concomitant effects on infrastructure and tourism, as well as everyday life, a participatory approach with citizen scientists who live in the local area is both logical and desirable. Many citizens also have multi-generational links with an area, such as fishing communities, and know about more or different aspects of a geographical area and its weather changes through their lived experience than what is available through technological data collection. Fishing communities also take us into the field of history, heritage studies, eco-linguistics, ethnography, and cross-cultural engagement, as we show in this article.

In the Smart Control of the Climate Resilience in European Coastal Cities-project (SCORE), for example, nine European Union coastal cities and one from Turkey have been chosen to monitor, research and contribute to research data and output about climate change mitigation, and protection of resources such as fresh water and biodiversity. In this project, the concept of 'living labs' is applied as defined by the European Network of Living Labs (2022):

Living Labs are open (urban) innovation ecosystems in real-life environments based on a systematic user (stakeholders and citizen scientists) co-creation approach that integrates research and innovation activities in communities, actively involving stakeholders (including citizens) to co-create, implement, test, and evaluate innovations in real-life situations (Anton *et al.* 2022)[2].

This extends to coastal cities, creating the Coastal City Living Labs (CCLL) as a new and innovative approach that uses the people of the coastal city as a fundamental part of the research base, rather than confining research to a science laboratory. Through this method, stakeholders (citizens, businesses, academia, and governance) co-identify the primary coastal hazards of each of the ten coastal

[2] Some of the early results and definitions of the SCORE project were reported by Anton et al at the EGU General Assembly 2022, Vienna, Austria and Online, 23–27 May 2022, EGU22 5469 and at the 2nd Consortium Meeting in Sligo, June 2022, and at the conference on Pedagogy and Climate Change in August 2022. https://www.itsligo.ie/education-with-sustainability. As the projects CCLL's mitigation strategies develop until 2024, more data will become available. Local projects such as Dobro za Morje (Rural development program of the Republic of Slovenia through the Ministry of Agriculture Forestry, and Food combined with the European Fishery Fund 2014-2020, https://dobrozamorje.si), have also yielded early information particularly in relation to Aquacultures. The definition of Living Labs applies to the projects methodology and is drawn from the Living Labs concepts.
https://score-eu-project.eu/wp-content/uploads/2022/03/Introduction-to-the-SCORE-CCLL-framework-and-methodology_compressed.pdf

cities, along with their impacts, and co-address climate change adaptation and resilience issues. Already the CCLL of Piran has demonstrated extreme climate change hazards and impacts (Kumer et al. 2022), such as drinking water scarcity and coastal flooding. Furthermore, through advanced mapping information provided together with local environmental and civil protection agencies, it is possible to view both superficial and deep changes on the coastline that effect marine habitats and species such as maricultures. For example, the Slovenian Environmental Ministry (ARSO) and the Civil Protection and Disaster Relief Agency have collected data to represent the increase in intensity and timing of extreme events such as storm surges, landslides, sea floods and tidal erosion. The research team is currently developing and analysing the data gathered so far, but even at this early stage the project shows how the intensity and frequency of extreme weather events are on the rise. We have been graphing data sets from 2005 to the current time, and coastal flooding is the most predominant risk factor, along with the coastal erosion it creates. This makes the coastal city of Piran and its maricultures very vulnerable. Recently Mascorda Cabre *et al.* (2021) mapped the influence of the presence of offshore maricultures on coastal and seabed erosion, as well as various weather events. The results suggest that not only do maricultures provide relevant ecosystem services, valorized food and well-being sources, they could provide shoreline protection and seabed stabilisation in the face of future extreme coastal weather events.

Kociper *et al.* (2019) outline an index of agricultural climate change vulnerability in terms of three factors: exposure, sensitivity, and adaptive capacity. Applying such an indexing approach to general information and vulnerabilities, coupled with specific data from Piran, the SCORE project and the mariculture communities, will enable more effective data generation and sharing for disaster planning and biodiversity and infrastructure protection.

Despite generous funding from organizations such as the European Commission, citizen science remains under-utilized and often misunderstood in many European settings. In Slovenia for example, the most notable citizen science input is with ecologically centered projects that relate to *Natura 2000* and the national monitoring of jellyfish, the four-lined snake[3] and invasive species[4]. In the context of the SCORE project Slovenia is represented through the CCLL of Piran in Slovenian Istria near the Croatian border because it is the most vulnerable to climate change impacts such as coastal flooding and storm surges (together

[3] (http://www.natura2000.si/novica/goz/)

[4] (https://www.tujerodne-vrste.info/)

with water scarcity) affecting everyday life, infrastructure, tourism, and fishing, including maricultures. Slovenia has only 42 kilometers of coastline and Piran is one of four main cities, the others being Koper, Izola, and Ankaran near the border of Italy. In studies of mariculture, citizen science has already been utilized, especially with regards to gathering and delivering data and identifying precise aquaculture species (see Tiralongo *et al.* 2020), for broader scientific audiences and environmental agencies alike.

4. An ecolinguistic, intercultural and ethnographic view of maricultures

Maricultures, like all human actions on the environment, perform a function related to survival, but do so in compliance with human laws and capital, in other words, economic and social needs. Maricultures are based on direct, physical, and immersive relationships between humans and nature. These relationships are established through actions, gestures, and words that come from the sea. The words arise from ancient actions and efforts aimed at caring for, preserving, indicating, explaining, and warning about natural phenomena and elements that are important to a more modern study of the nature-culture interface, and ongoing respect for "all planetary life" (Hawke and Spannring, 2022). This lexicon is often poetic as well as scientific and cultural. It could also be described as ethnographic, or auto-ethnographic (Spannring and Hawke 2022), whereby the researcher also becomes the object of study. This makes maricultures a fitting case study, as fishing communities are constantly analyzing and adapting their practices, making meaning of their own life and work.

The fishing communities in the northern Adriatic Italian-Slovenian Sea region are characterized by a common language that dates to the ancient Republic of Venice at the beginning of the XV century (Dudine, 2014; Rogelja and Janko Spreizer, 2017; Saracino, 2021). Despite the fall of the Venetian Serenissima Republic at the end of the eighteenth century, common, and arguably nature-based, language was developed and continues to be maintained to this day in the fishing communities, which all speak an Istrian-Venetian dialect (Dudine, 2014; Rogelja and Janko Spreizer, 2017; Saracino, 2021).

The craft of the sea was passed down among families, predominantly from parent to child and through the Istrian-Venetian language, which gave a name to tools, boats, fishing techniques, recipes, and weather conditions. In Istrian-Venetian fishing communities, knowledge was shared with all areas of life that included food preparation, usually the domain of the women, although women were also involved in the fishing. Recognizing the importance of this specific linguistic and

semantic universe enriches the skills and the understanding of any researcher in the field of scientific, social, or humanistic studies who wishes to tackle the study of mariculture in the northern Adriatic Sea, and create genuine cross-cultural participatory engagement built on the way fishermen speak about their lifeworld to themselves, cultural neighbors, and researchers.

The Istrian-Venetian terms that refer to this ecolinguistic world include *musoli*, *musolere*, *musoler* (mussels); *trabacoli*, *bragozzi*, *batei* (typical local boats); *mandracchio*, *squero* (spaces for the repairs and maintenance of boats, places of encounters, of specialized professionals and sea lovers). These words cannot (do-not-need-to) be translated. They exist as referents to experiences difficult to tell and describe yet known because lived. They are words that transcend geographies and times, that survive republics, empires, nations, communities (both mainstream and marginalized) and perhaps even globalization. These are words that identify people, their actions, and choices, define communities and economies, words as semantics of place, of natural balances between human-territory intervention-tradition and which represent a body of information, to be listened to rather than merely assumed.

To study the biodiversity of a territory without immersing oneself through all the senses, and in the sound of languages that describe and interpret ancient wisdom natural phenomena and their nuances, including, warnings, advice, relationships, and traditions, is a sectoral scientific approach that can bring new insights, collaborative possibilities, and dialogue with other disciplines. However, in a truly interdisciplinary approach, maintaining a wholeness and solidity of perspective that avoids being overly influenced by specific fields of study and their methodologies is crucial. Studying the biodiversity of places without including and engaging minority autochthonous communities (often left aside from scientific research) is a missed opportunity. To act through an approach based on cultural empathy, understood as "the attempt to organize experience through a set of constructs that are more characteristic of another culture than of one's own" or "the imaginative, intellectual and emotional participation in another's person experience" (Bennett, 1993, p. 156), is necessary.

The study of communities, their history and their traditions tells us a lot about this territory, indirectly indicating the extent of the phenomena, the presence, absence or replacement of certain fishing varieties and mariculture practices. And while it may be challenging to merge modern science with ancient practices, interdisciplinarity opens some space for such possibilities.

Since the Middle Ages, fishermen on the Adriatic coast have been organized into brotherhoods which became over centuries until the twentieth century, cooperatives that developed canneries and fish processing factories. Before World War II, the cooperative united more than 300 fishermen in Piran alone, and after the war and the emigration of most of the population from the coastal towns, the first established post-war cooperative had about 90 members. In Piran, the first fishermen's cooperative was founded in the early years of the twentieth century under the Austro-Hungarian Empire and was dissolved in 1911. The second cooperative, *Cooperativa fra pescatori di Pirano*, was founded in 1925. Particularly important was and still is the annual catch of mullet in the Bay of Piran in late autumn (Juri, 2019).

Acknowledging these fishermen and their linguistic environment is an important reference for interdisciplinary scientific investigation. This is because linguistics, according to Stibbe (2015):

> "[…] provides tools for analyzing the texts that surround us in everyday life and shape the kind of society we belong to. These tools can help reveal the hidden stories that exist between the lines of the texts. Once revealed, the stories can be questioned from an ecological perspective: do they encourage people to destroy or protect the ecosystems that life depends on? If they are destructive then they need to be resisted, and if beneficial they need to be promoted" (p. 2).

Furthermore, historic knowledge and hidden stories may indeed re-surface and contribute to understanding coastal climate change issues and knowledge through fishing communities invited to take part in research as citizens scientists. We will now look more specifically at the biological, health sciences and natural science component of interdisciplinarity through a case study of Mediterranean maricultures.

5. Cultured shellfish as Mediterranean human food

Shellfish maricultures traditionally developed as a food source well before modern concerns over climate change and aquaculture food security. Compared to land-based agriculture, maricultures use less land, but more importantly, produce less greenhouse gases and their products contain more micronutrients per protein quantity (Parodi *et al.* 2018; Barange, 2020). We will now examine their contribution to both food sustainability and climate change mitigation.

In recent decades much attention has been given to the health benefits of the consumption of marine fish, especially in regard to providing bulk protein and high concentrations of essential fatty acids. The literature clearly demonstrates that health benefits are associated with consumption of omega-3 long-chain polyunsaturated fatty acids (PUFAs) abundantly present in mariculture food products (Parodi *et al.* 2018), including Adriatic shellfish (Bongiorno *et al.* 2015; Prato *et al.* 2019). A FAO/WHO report mentions that these associations are demonstrated in numerous studies across a wide range of populations and in differing but complementary fields of inquiry which go beyond health sciences, and reflect the sum of benefits and risks from all of the constituents (FAO/WHO, 2011). However, fish was defined as finfish and shellfish, whether of marine or freshwater origin, farmed or wild. Thus, for the consideration of total omega-3 PUFAs intake, the majority of studies examined finfish consumption, rather than considering also shellfish. In other words, the health benefits induced by consumption of fish as opposed to shellfish (or even farmed versus wild), have not generally been investigated. This presents the fields of broader kinesiology (human movement, physical health and wellbeing) and social sciences with opportunities to further explore partnerships with citizens who are co-producing the products of the Mediterranean diet and to carry out research that might further valorize their food, cultural heritage and lifestyle, in the face of changing climatic conditions.

Shellfish have traditionally been cultured as food within the Mediterranean basin, as part of the *Mediterranen diet* that has been recognized as an 'intangible cultural heritage' (UNESCO, 2013). Hence, the Mediterranean diet can be interpreted as a *lifestyle* (Meulenberg, 2019a). Noting the lived experience of a group of people adds greater possibilities for heritage studies and social sciences to map the many features of the Mediterranean diet, as adherence to the lifestyle can provide sustainable wellbeing and longevity (Meulenberg, 2019b). Using narrative and oral history accounts and focus groups as a participatory method can yield a more personal understanding of the industry that further adds to the interdisciplinary nature of research into maricultures constituted also by heritage studies, ethnography and auto-ethnography as a practice of observing communities that takes us beyong ourselves to include fisherman within their own communities.

However, recent wild fish stock depletion (largely due to unsustainable over-fishing practices) makes it necessary to investigate separately the potential health benefits of farmed shellfish consumption, in relation to supply. Such research could provide kinesiologic evidence to support the valorization of this type of food, as a proven ingredient for physical well-being, as well as demonstrating the

ongoing relationship between people and the sea, through mariculture production and acquatic cultural heritage (Figure 2). The association of such benefits as resulting from the interdisciplinary mariculture sector would also support blue growth and provide sustainable food choices (Jones et al. 2022; Mascorda Cabre et al. 2021, Meulenberg, 2019b; Naylor et al. 2021).

Figure 2. Views from the vineyards of the Debeli Rtič landscape park: the lined-up floaters of the maricultures in the Slovenian waters with the Italian city of Trieste on the opposite coast (second picture). Photos by Cécil Meulenberg.

6. The contribution of shellfish maricultures to biodiversity

In this section we look at shellfish maricultures from the perspective of biodiveristy and marine studies. In the Adriatic sea, which includes coastlines of

Slovenia, Croatia and Italy, farms traditionally consist of vertical lines to which shellfish adhere directly and attach in socks.

The organisms do not need human-introduced biotic elements to feed on. The cultured shellfish species are filter-feeders, meaning they consume the microscopic plankton and floating sediment already in the sea waters. By filter feeding they diminish eutrophication, the natural process of water enrichment with nutrients and minerals especially nitrogen and phosphorus, and thus improve water clarity and the quality of coastal-interface waters (e.g., Petersen *et al.* 2016). Hence, the circularity of this ecosystem – its circular economy – is guaranteed and is also free of introduced antibiotics and growth promoters (as compared to common agriculture activities).

The most common farmed species are endemic, such as the Mediterranean blue mussel (*klapavica* – *Mytilus galloprovincialis*) and oysters (*ostriga* – *Ostrea edulis*) that need a susbstrate to attach to. Others like clams (*ladinke* – *Venus verrucosa*) do not require a substrate, but can be reared in cages. Spillover of de-attached/de-caged individual specimens into the sea waters is not regarded as a problem precisely because farmed species are endemic, although the fall-off shells can cause alterations in sediment biogeochemistry and can attract predatory species (Callier *et al.* 2018). The floaters and the vertical lines, with cages deeper down the line (close to the sea floor) will combine the farming of two or more species (known as integrated multi-trophic aquacultures), and as a whole might contribute to attracting both mobile and immobile species, like algae, crustaceans, and fish, provide shelter and act as nurseries similar to the diverse communities of natural reefs, as Callier *et al.* (2018), have noted. However, the water column and the husbandry activities might also repel certain species. In the Eastern Adriatic waters of Croatia, there have been reports of predation on farmed shellfish by sea bream (Tičina *et al.* 2020). Despite this predation, the introduced farms contribute to a novel foodweb structure, although it will be important for future research to also consider the effects of climate change events such as storm surges and coastal erosion to this unique foodweb structure. In the North Adriatic Sea, research regarding the effects of shellfish aquacultures on local marine biodiversity is still relatively new. Moreover, through inclusive partnerships with fishing communities, using applicable smart sensor technologies (for monitoring the growth in the mariculture or sea water properties) with inter-generational marine expertise (about species and the marine environment), the mariculture sector can be upgraded as a modern food supply system while incorporating essential local and historical knowledge.

Such an interdisciplinary approach provides opportunities for both the maricultures and the people involved in the production of this food.

7. Shellfish as environmental/ecosystem biomarkers

Throughout the Adriatic waters, mussels in particular have been investigated as biomarkers for various environmental aspects, as outlined by Bajt *et al.* (2019). Shellfish occupy a basic position in the marine food chain, and due to their filter-feeding tend to accumulate chemicals introduced through pollution (either natural or human). Contaminants of a human nature identified in shellfish range from heavy metals, polychlorinated biphenyls (PCBs) and organochlorine pesticides, to polycyclic aromatic hydrocarbons (see also Prato *et al.* 2019). From 2014 to 2017 a decline in visible collected macro litter, mainly consisting of plastics, was observed for Slovenian beaches (Schmid *et al.* 2021). On the other hand, human laundry activities that create microplastic fibres also enter marine ecosystems and damage the DNA, gill, and digestive gland tissues of *Mytilus galloprovincialis* (Alnajar *et al.* 2021). The consequences of such pollution are not completely understood, but emerging research suggests more marine species and their environments will be adversely affected. Furthermore, appropriate research can help to direct practical interventions, as well as support public and business education on the benefits of the industry.

For example, the growth cycles of shellfish are dependent on the availability of nutritious plankton, in combination with the properties of the sea water like temperature, salinity and acidification. When the marine environment changes – due to pollution or climate change effects such as ocean temperature rise – the plankton properties change. Subsequently the growth of shellfish adapts and their biochemical compositions and nutritional values change. The functionality of shellfish physiology, the biochemical composition of both the soft tissues and the shell, can indicate particular aspects of environmental and ecosystem health. Sea acidification, in combination with low oxygen levels (hypoxia), in warm waters might have a particularly negative impact on the shell size of crustaceans and molluscs and corresponding mechanical strength (Gazeau *et al.* 2013) and their nutritional values (Anecleto *et al.* 2014). This climate change phenomenon causes developmental harm and can give rise to smaller specimens more susceptible to disease and predation. Moreover, in recent years the Adriatic Sea has seen a partial decrease in nutrient (phosphate and nitrate) concentrations, very likely as a direct result of stricter waste water policies that have cleaned up rivers. On the other hand, it has been observed in the Mediterranean Sea that the

irregular combination of low salinity, increased sea water temperatures and eutrophication driven by climate change lead to a greater occurrence of toxic tides (Zingone *et al.* 2021), and more frequent harmful algal blooms (HABs). Consequently, aquaculture production has at times been halted in the Adriatic Sea. Mapping trends specifically related to toxic algal species is a developing area of longitudinal research.

It has been speculated that maricultures control erosion along shorelines by stabilizing local sediments through increase of the sedimentation, and might moderate the effects of extreme (weather) events (Alleway *et al.* 2019; Gentry *et al.* 2020). The SCORE project is currently investigating such impacts in coastal cities in Europe through various methodologies that focus on the sustainable protection of sea life broadly understood, as well as general erosion impacts[5]. Furthermore, the SCORE project and associated local environmental agencies provide coastal mapping data of off-shore environments (e.g., Espinosa and Portela, 2022; Toledo, *et al.* 2022), also using sensor technology. This new data will certainly enhance coastal resilience strategies and assist in the reliability of predictive data to protect people and aquatic life alike.

It could therefore be affirmed that shellfish organisms as a whole, both wild and farmed, are important marine biomonitors concerning both pollution and climate change. Hence, seasonally monitoring the properties of shellfish both in and around the vicinity of the farms, as well as in the wider marine-land interfaces, will provide relevant information on the health of the marine ecosystems. Fishing communities, businesses and citizen scientists together form an integral and mutually constituted part of this research that simultaneously sheds light on the ecosystem services provided by the shellfish themselves.

8. Ecosystem Services of Shellfish Farming: Understanding Shared Values for the Future

Ecosystem services (ESSs) consist of many and varied benefits provided by the natural environment and healthy ecosystems for primarily human purposes. Often the catogories of such ecosystem services are divided into categories

[5] For example, at the recent »Education with Sustainability" Conference in Ireland August 15-17, (https://www.itsligo.ie/education-with-sustainability/), representatives from SCORE presented climate change issues through innovative methods and practices in pedagogy. Teaching climate change studies is a new area from which and through which future participatory resources will be developed. See for example Lucy and Freeney (2022).

(Haines-Young and Potschin, 2018), such as 1) *provisional services* in the form of provison of food, drinking water and raw materials; 2) *regulating and maintenance services* that provide support to habitat and ecosystems by moderating natural phenomena and processes; and 3) *cultural services* that cover non-material benefits, generally providing wellbeing to communities and contributing to the development and cultural advancement of people. Here again maricultures and shellfish farming prove to be a productive example of the relationships between nature and humans and the shared understanding of what contains value for life in terms of the here and now, together with visions for the future (Figure 3).

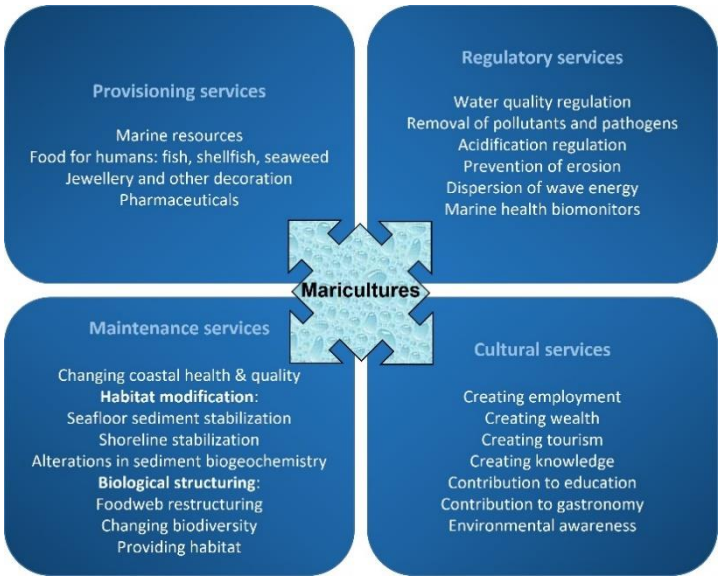

Figure 3. Ecosystem services of maricultures

Maricultures enable *provisional services* in the form of farmed food, and thus enable food security (Bush and Osterveer, 2019; Jones *et al.* 2022; Naylor *et al.* 2021), as well as contributing raw materials in the form of decorations (such as shells) and pharmaceuticals. The high quality and healthy foods provided by aquacultures are part of the rich Mediterranean gastronomy in the Adriatic. Additionally, the aquacultures contribute culinary aspects in the form of *cultural ecosystem services* that also cover the provision of wellbeing of rural and coastal communities of the Adriatic by generating wealth and employment, livelihood, tourism and education (Spanou *et al.* 2020; Weatherdon *et al.* 2016). Maricultures also maintain

cultural heritage through natural and culinary lifestyle, and raise environmental awareness that can enhance broader marine conservation.

Marine aquacultures as an introduced technical 'farm' within the marine-land interface ecosystems, also provide *regulating - habitat and supporting - maintenance services* (Smaal *et al.* 2019; Rullens *et al.* 2019), and may positively affect marine biodiversity. Shellfish maricultures in particular have a potential to contribute to *regulating services* such as habitat modification, water quality regulation, removal of nutrients, pollutants and pathogens, and stabilization of both sea floor sediment and shoreline (Alleway *et al.* 2019; Jones *et al.* 2022; Rullens *et al.* 2019). Ecosystem services provided by marine aquacultures can also include climate change mitigation strategies (Reid *et al.* 2019a,b; Rosa *et al.* 2014). The sector is certainly influenced by climate change drivers but might also provide potential solutions to these global threats, most importantly with possibilities and actual roles as ecosystem service providers. As part of the SCORE project, we have been mapping the alignment between ecosystem services and nature-based solutions as a means of augmenting resilience in vulnerable coastal cities. Weather sensing technology, for example, can enhance predictions of disruption to certain ecosystem services and communities in general, thereby enabling mitigation strategies for protection of coastal biodiversity to be planned for in advance. Preliminary evidence from SCORE suggests that smart technology to measure (the lack of) rainfall and predict droughts and its effects (Espinosa and Portela 2022), will become an essential feature of climate change mitigation practice from which future data can be analysed.

The ecosystem approach to aquaculture (Brugère *et al.* 2018) is a global strategy for the integration of aquaculture activities within the wider ecosystem such that it promotes a truly sustainable form of development, equity, and resilience of interlinked social-ecological systems. While the approach demonstrates mainstrain integration into global and regional 'blue growth' programmes, recently, the Aquaculture Advisory Council (AAC, 2021) reported that:

> "[…] well-managed finfish in ponds, lagoons and estuaries and bivalve aquaculture contribute significantly to the preservation and improvement of environment, maintain the biodiversity associated with aquatic ecosystems and generate ecosystem services to society that are not always recognized. The specifics of these aquacultures in terms of both ecosystem services and needs, should be better understood and acknowledged by policy makers and the public" (p.35).

It is possible to assess general environmental impacts associated with all the stages of a commercial product through the Life Cycle Assessment (LCA), where every step of a production cycle is evaluated in carbon-footprint and monetary terms. Hence, such LCAs show that the lowest greenhouse gases production per unit of protein is from molluscs and salmon aquaculture, as well as small pelagic, large pelagic and demersal fish fisheries. Catfish, invertebrate and shrimp aquaculture production are the largest emitting sectors, with greenhouse gases production per unit of protein comparable to land-based beef production (Barange, 2020). This LCA knowledge can affect consumers' willingness to pay, enable sustainable food choices and support the marine aquaculture sector. In short, this can contribute to the ecosystem awareness that the ACC is promoting. Both an ecosystem services analysis and an LCA analysis of the mariculture sector will contribute to understanding its sustainability for all stakeholders. The involved economic costs, carbon footprints, and emittances do also depend on geography, and for Slovenia and the Adriatic region, no assessments of this kind have yet been performed. Thus, while better mapping of ecosystem services linked to maricultures be of interest to (local) authorities and producers, knowledge about such services and how climate change affects marine ecosystems and marine aquacultures may help further empower citizens in their contribution to science and enhance environmental awareness.

9. Conclusions

What we have tried to present in this paper through both interdisicplinarity and cross-cultural engagement is how the mariculture sector can profit both ecologically and economically from well-planned interdisciplinary research involving both academia and knowleageable citizen science. Maricultures provide an alternative to our dependence on land-based farming and on wild-caught fish stocks for food and fishmeal (Barange *et al.* 2014). Combined with technological developments in production design, and weather forecasting and sensing, maricultures could significantly contribute to global food security with climate change, while limiting greenhouse gas production. The mariculture interdisciplinary approach is a unique example of how people, governments and researchers can come together to develop, sustain and share best care and sustainability practices in the face of climate change for vulnerable coastal land-marine interfaces.

Acknowledgments

The authors wish to thank the peer reviewers and editors for their astute comments on this paper. We also wish to thank our colleagues in the SCORE project and the Slovenian Civil Protection and Disaster Relief Agency for sharing natural hazard reporting data.

References

Anton I., Paranunzio, R., Gharbia, S., Baldin, L., Ahmed, T., Giannetti, F., Carlo Brandini, Ortolani, A., Meulenberg, C., Adirosi, E., Hawke, S., Pilla, F. and Jose Gregorio Iglesias Rodriguez, J.G.I. (2022) Challenges in retrieving and using climate services' data for local-scale impact studies: insights from the SCORE project. EGU General Assembly 2022, Vienna, Austria and Online, 23–27 May 2022, EGU22 5469. https://score-eu-project.eu/project-concept/

Aquaculture Advisory Council 2021. The provision of ecosystem services by European Aquaculture. 2021-08. Available from: https://aac-europe.org/images/jdownloads/Recommendations/EN/AAC_Recommendation_-_Ecosystem_Services_2021_08_revised2.pdf

Alleway, H.K., Gillies, C.L., Bishop, M.J., Gentry, R.R., Theuerkauf, S.J. and Jones R. (2019). The ecosystem services of marine aquaculture: Valuing benefits to people and nature. *BioScience*, 69(1), 59-68.

Alnajar, N., Jha, A.N. and Turner, A. (2021). Impacts of micriplastic fibres on the marine mussel, *Mytilus galloprovincialis*. *Chemosphere*, 262, 128290.

Anacleto, P., Maulvault, A.L., Bandarra, N.M., Repolho, T., Nunes, M.L., Rosa, R. and Marques, A. (2014). Effects of warming on protein, glycogen, and fatty acid content on native and invasive clams. *Food Research International*, 64, 439-445.

Bajt, O., Ramšak, A., Milun, V., Andral, B., Romanelli, G., Scarpato, A., Mitrić, M., Kupusović, T., Kljajić, Z., Angelidis, M., Çullaj, A. and Galgani, F. (2019). Assessing chemical contamination in the coastal waters of the Adriatic Sea using active mussel biomonitoring with *Mytilus galloprovincialis*. *Marine Pollution Bulletin*, 141, 283-298.

Barange, M., Merino, G., Blanchard, J.L., Scholtens, J., Harle, J., Allison, E.H., Allen, J.I., Holt, J. and Jennings, S. (2014). Impacts of climate change on marine ecosystem production in societies dependent on fisheries. *Nature Climate Change*, 4, 211-216.

Barange, M. (2020). Climate change impacts on aquatic ecosystems are modulated by other forcing factors. reducing overall stress boots resilience to climate change. *EuroFish Magazine*, 2, 62-64.

Bennett, M.J. (1993). Towards Ethnorelativism: A Developmental Model of Intercultural Sensitivity. In Paige, M. (ed.), *Education for the Intercultural Experience* (pp. 21-71). Yarmouth, ME: Intercultural Press.

Bongiorno, T., Iacumin, L., Tubaro, F., Marcuzzo, E., Sensidoni, A. and Tulli, F. (2015). Seasonal changes in technological and nutritional quality of *Mytilus galloprovincialis* from suspended culture in the Gulf of Trieste (North Adriatic Sea). *Food Chemistry*, 173, 355-362.

Brugère, C., Aguilar-Manjarrez, J., Beveridge, M.C.M. and Soto, D. (2019). The ecosystem approach to aquaculture 10 years on – A critical review and consideration of its future role in blue gowth. *Reviews in Aquaculture*, 11(3), 493-514.

Bush, S.R. and Oosterveer, P. (2019). *Governing Sustainable Seafood*. Routledge.

Callier, M.D., Byron, C.J., Bengston, D.A., Cranford, P.J., Cross, S.F., Focken, U., Jansen, H.M., Kamermans, P., Kiessling, A., Landry, T., O'Beirn, F., Petersson, E., Rheault, R.B., Strand, Ø., Sundell, K., Svåsand, T., Wikfors, G.H. and McKindsey, C.W. (2017). Attraction and repulsion of mobile wild organisms to finfish and shellfish aquaculture: A review. *Reviews in Aquaculture*. 10(4), 924-949.

Dudine, G. (2014). La pesca a Isola d'Istria. Quando i contratti si stipulavano con una stretta di mano. [Fishing in Isola d'Istria. When contracts were made with a handshake]. Comunità degli italiani "Dante Alighieri" di Isola.

Edwards, P. (1998). A systems approach for the promotion of integrated aquaculture. *Aquaculture Economics and Management*, 2(1), 1-12.

Espinosa, L.A., Portela, M.M. (2022). Grid-point rainfall trends, teleconnection patterns, and regionalised droughts in Portugal (1919–2019). *Water*, 14, 1863.

European Commission. Data on open collaboration. Figures on availability of scientific APIs, open code policies, citizen science projects as well as case studies. Available from: https://ec.europa.eu/info/research-and-innovation/strategy/strategy-2020-2024/our-digital-future/open-science/open-science-monitor/data-open-collaboration_en

EUMOFA 2017. The EU Fish Market. Directorate-General for Maritime Affairs and Fisheries of the European Commission. European Market Observatory for Fisheries and Aquaculture Products. Available from: https://www.eumofa.eu/documents/20178/108446/The+EU+fish+market+2017.pdf

European Network of Living Labs (2022). https://enoll.org

FAO/WHO (2011). Report of the Joint FAO/WHO Expert consultation on the risks and benefits of fish consumption. Food and Agriculture Organization of the United Nations; Geneva World Health Organization.

Gazeau, F., Parker, L.M., Comeau, S., Gattuso, J.P., O'Connor, W.A., Martin, S., Pörtner, H.O. and Ross, P.M. (2013). Impacts of ocean acidification on marine shelled molluscs. *Marine Biology*, 160, 2207-2245.

Gentry, R.R., Alleway, H.K., Bishop, M.J., Gillies, C.L., Waters, T. and Jones R. (2020). Exploring the potential for marine aquaculture to contribute to ecosystem services. *Reviews in Aquaculture*, 12(2), 499-512.

Green Paper on Citizen Science (2013). Citizen science for Europe: Towards a better society of empowered citizens and enhanced research. SOCIENTIZE Consortium. (https://digital-strategy.ec.europa.eu/en/library/green-paper-citizen-science-europe-towards-society-empowered-citizens-and-enhanced-research.)

Haines-Young, R. and Potschin, M.B. (2018). Common International classification of ecosystem services (CICES) V5.1 and guidance on the application of the revised structure.

Haklay, M., Dörler, D., Heigl, F., Manzoni, M., Hecker, S. and Vohland, K. (2021). What Is Citizen Science? The Challenges of Definition. In Vohland, K., Land-Zandstra, Cecaroni, L., Lemmens, R., Perello, J., Ponti, M., Samson, R. and Wagenknecht, K. (eds.), *The Science of Citizen Science* (pp. 13-33). Berlin: Springer.

Hawke, S.M. and Pálsson, G. (2017). Water futures, biosociality, and other-wise agency: An exploratory assay. *Anuac*, 6(1), 233-252.

Hawke, S.M. and Spannring, R. (2022) Embodying the Earth: Environmental Pedagogy, Rewilding Waterscapes and Human Consciousness. In Paulsen, M., Jagodzinski, J. and Hawke, S.M. (eds.), *Pedagogy in the Anthropocene: Rewilding Education for a New Earth* (pp. 197-213). Springer.

Heiss, R. and Matthes, J. (2017). Citizen science in the social sciences: a call for more evidence. *GAIA-Ecological Perspectives for Science and Society*, 26 (1), 22–26.

Johnson, T.R., Beard, K., Brady, D.C., Byron, C.J., Cleaver, C., Duffy, K., Keeney, N., Kimble, M., Miller, M., Moeykens, S., Teisl, M., van Walsum, G.P., and Yuan, J. (2019). A socio-ecological system framework for marine aquaculture research. *Sustainability*, 11, 2522.

Jones, A.R., Alleway, H.K., McAfee, D., Reis-Santos, P., Theuerkauf, S.J. and Jones, R.C. (2022). Climate-friendly seafood: The potential for emissions reduction and carbon capture in marine aquaculture. *BioScience*, 72(2), 123-143.

Juri, F. (2019). Restavriran prapor ribiške zadruge Piran. [Restored flag of the fishing cooperative Piran.]. *eMorje*,5 (54). Available from: https://emorje.com/pomorska-dediscina/restavriran-je-prapor-ribiske-zadruge-piran/

Kociper, D., Vintar Mally, K., and Kajfež Bogataj, L. (2019). Climate vulnerability of agriculture in statistical regions of Slovenia. *Italian Journal of Agrometeorology*, 2, 35-48.

Kumer, P. and Urbanc M. (2020). Focus groups as a tool for conducting participatory research: A case study on small-scale forest management in Slovenia. In Nared, J. and Bole, D. (eds.), *Participatory Research and planning in Practice,* Chapter 13 (pp. 207-220). The Urban Book Series Springer.

Kumer, P., Meulenberg, C.J.W., and Hawke, S.M. (2022). Piran Coastal City Living Lab (CCLL): Challenges and opportunities. SCORE consortium meeting, 28-30 June, Sligo, Ireland. Poster 11.

Lucy, F., and Freeney, D., (2022) Sustainable futures: Collaborative education for a low carbon future. At *Education with Sustainability* Conference, 15-17th August 2022, Atlantic Technical University (ATU), Ireland.

Mascorda Cabre, L., Hosegood, P., Attrill, M.J., Bridger, D., Sheehan, E.S. (2021). Offshore longline mussel farms: A review of oceanographic and ecological interactions to inform future research needs, policy and management. *Reviews in Aquaculture*, 13, 1864-1887.

Maulu, S., Hasimuna, O.J., Haambiya, L.H., Monde, C., Musuka, C.G., Makorwa, T.H., Munganga, B.P., Phiri, K.J. and DaMascene Nsekanabo, J. (2021). Climate change effects on aquaculture production: Sustainability implications, mitigation, and adaptations. *Frontiers in Sustainable Food Systems*, 5, 609097.

Meulenberg, C.J.W. (2019a). Health benefits induced by adherence to the Mediterranean lifestyle components diet and physical activity. *Annales Kinesiologiae*, 10(1), 15-30.

Meulenberg, C.J.W. (2019b). Lifestyle components of the global oldest old assessed as effective nonpharmacological strategies to maintain lifelong cognitive and functional health. *Exercise and Quality of Life Journal*, 11(1), 37-50.

Naylor, R.L., Hardy, R.W., Buschmann, A.H., Bush, S.R., Cao, L., Klinger, D.H., Little, D.C., Lubchenco, J., Shumway, S.E. and Troell, M. (2021). A 20-year retrospective review of global aquaculture. *Nature*, 591(7851), 551-563.

Nikodic, J. (1981). Dynamique dedimentarie dans la partie occidentale de la baie du Mont Saint-Michel: Influence des installations ostreicoles. *PhD thesis*, Université de Nantes, Nantes, France.

Parodi, A., Leip, A., de Boer, I.J.M., Slegers, P.M., Ziegler, F., Temme, E.H.M., Herrero, M., Tuomisto, H., Valin H., van Middelaar, C.E., van Loon, J.J.A. and van Zanten, H.H.E. (2018). The potential of guture goods for sustainable and healthy diets. *Nature Sustainability*, 1, 782-789.

Paulsen, M., Jagodzinski, J. and Hawke, S.M. (2022) (eds.), *Pedagogy in the Anthropocene: Rewilding Education for a New Earth* (pp. 197-213). Springer.

Petersen, J.K., Saurel, C., Nielsen, P. and Timmermann, K. (2016). The use of Shellfish for eutrophication control. *Aquaculture International*, 24(3), 857-878.

Plew, D.R., Stevens, C.L., Spigel, R.H. and Hartstein, N.D. (2005) Hydrodynamic implications of large offshore mussel farms. *IEEE Journal of Oceanographic Engineering*, 30(1), 95-108.

Prato, E., Biandolino, F., Parlapiano, I., Giandomenico, S., Denti, G., Calò, M., Spada, L. and Di Leo, A., (2019). Proximate, fatty acids and metals in edible bivalves from

Italian market: Beneficial and risk for consumers health. *Science of the Total Environment*, 648, 153-163.

Reid, G. K., Gurney-Smith, H.J., Marcogliese, D.J., Knowler, D., Benfey, T., Garber, A.F., Forster, I., Chopin, T., Brewer-Dalton, K., Moccia, R.D., Flaherty, M., Smith, C.T. and De Silva, S. (2019a). Climate change and aquaculture: Considering biological response and resources. *Aquaculture Environmental Interactions*, 11, 569-602.

Reid, G.K., Gurney-Smith, H.J., Flaherty, M., Garber, A.F., Forster, I., Brewer-Dalton, K., Knowler, D., Marcogliese, D.J., Chopin, T., Moccia, R.D., Smith, C.T. and De Silva, S. (2019b). Climate change and aquaculture: Considering adaptation potential. *Aquaculture Environmental Interactions*, 11, 603-624.

Rogelja, N. and Janko Spreizer, A. (2017). *Fish on the Move: Fishing Bbetween Discourses and Borders in the Northern Adriatic*. MARE publications series, volume 11. Springer Cham.

Rosa, R., Marques, A. and Nunes, M.L. (2014). Mediterranean Aquaculture in A Changing Climate. In Goffredo, S. and Dubinsky, Z. (eds.), *The Mediterranean Sea* (pp. 605-616). The Netherlands: Springer.

Rullens, V., Lohrer, A.M., Townsend, M. and Pilditch, C.A. (2019). Ecological mechanisms underpinning ecosystem service bundles in marine environments – A case sudy for shellfish. *Frontiers in Marine Science*, 6, 409.

Saracino, Z. (2021). La Slovenia riconosce il dialetto istro-veneto como bene culturale. [Slovenia recognizes the Istrian-Venetian dialect as a cultural asset.]. *TriesteNews*, July 27, 2021. Available from: https://www.triesteallnews.it/2021/07/la-slovenia-accetta-la-tutela-del-dialetto-istro-veneto-come-bene-culturale/

Scanlon, E. and Papathoma, T. Citizen science as interdisciplinary working. (2020). In *Networked Learning Conference, 2020*, 18-20 May 2020, Kolding, Denmark.

Schmid, C., Cozzarini, L. and Zambello, E. (2021). A critical review on litter in the Adriatic Sea: Focus on plastic pollution. *Environmental Pollution*, 273, 116430.

Science for Environment Policy (2015). Sustainable aquaculture. Future Brief 11. Brief produced for the European Commission DG Environment by the Science Communication Unit, Universit of the West of England, Bristol. Available from: http://ec.europa.eu/science-environment-policy

Smaal, A.C., Ferreira, J.G., Grant, J., Petersen, J.K. and Strand, Ø. (2019). *Goods and Services of Marine Bivalves*. Springer.

Spanou, E., Kenter, J.O. and Graziano, M. (2020). The effects of aquaculture and marine conservation on cultural ecosystem services: An integrated hedonic – eudaenomic approach. *Ecological Economics*, 176, 106757.

Steffen, W., Crutzen, P.J. and McNeil, J. R. (2007). The antropocene: Are humans now overwhelming the great forces of nature? *Ambio*, 36(8), 614-621.

Stibbe, A. (2015). *Ecolinguistics. Language, Ecology and the Stories We Live By*. London and New York: Routledge.

Tauginienė, L., Butkevičienė, E., Vohland, K., Heinisch, B., Daskolia, M., Suškevičs, M., Portela, M., Balász, B. and Prüse, B. (2020). Citizen science in the social sciences and humanities: The power of interdisciplinarity. *Palgrave Communications*, 6, 89.

Tičina, V., Katavić, I. and Grubišić, L. (2020). Marine aquaculture impacts on marine biota in oligotrophic environments of the Mediterranean Sea - A review. *Frontiers in Marine Science*, 7, 217

Tipaldo, G. and Allamano, P. (2017). Citizen science and community-based rain monitoring initiatives: an interdisciplinary approach across sociology and water science. *Wiley Interdisciplinary Reviews: Water*, 4(2), e1200.

Tiralongo, F., Crocetta, F., Riginella, E., Lillo, A.O., Tondo, E., Macali, A., Mancini, E., Russo, F., Coco, S., Paolillo, G. and Azzuro, E. (2020). Snapshot of rare, exotic and overlooked fish species in the Italian seas: A citizen science survey. *Journal of Sea Research*, 164, 101930.

Toledo, I., Pagán, J.I., López, I. and Aragonés, L. (2022) Causes of the different behaviour against erosion: Study case of the Benidorm Beaches (1956–2021). *Marine Georesources and Geotechnology*, doi: 10.1080/1064119X.2022.2084003

UNESO (2013). Mediterranean Diet. Mediterranean diet - intangible heritage - Culture Sector - UNESCO. Available from: https://ich.unesco.org/en/RL/mediterranean-diet-00884

United Nations (2015). Sustainable Development Goals. Available from: Why should you care about the sustainable development goals? (un.org)

Weatherdon, L.V., Magnan, A.K., Rogers, A.D., Rashid Sumaila, U. and Cheung, W.W.L. (2016). Observed and projected impacts of climate change on marine fisheries, aquaculture, coastal tourism, and human health: An update. *Frontiers in Marine Science*, 3, 48.

Zingone, A., Escalera, L., Aligizaki, K., Fernández-Tejedor, M., Ismael, A., Montresor, M., Mozetič, P., Taş, S. and Totti, C. (2021). Toxic marine microalgae and noxious blooms in the Mediterranean Sea: A contribution to the global HAB status report. *Harmful Algae*, 102, 101843.

Authors

Cécil J.W. Meulenberg, Institute for Kinesiology Research and Mediterranean Institute for Environmental Studies, Science and Research Centre, Koper (ZRS). cecil.meulenberg@zrs-kp.si (Corresponding author)

Shé Mackenzie Hawke, Mediterranean Institute for Environmental Studies, ZRS.

Irina Cavaion, Institute for Linguistic Studies Science, ZRS.

Peter Kumer, Mediterranean Institute for Environmental Studies, ZRS.

Blaž Lenarčič, Institute for Social Sciences, ZRS.

Funds

This paper is funded by the European Commission, SCORE Project, GA No. 101003534.

Competing Interests

The authors declare no conflict of interest.