Chapter 17
Socio-economic Aspects of Marine Bivalve Production

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Abstract This paper provides an overview of a number of socio-economic aspects related to bivalve aquaculture focussing on cultural services these activities provide to the culturing communities. Some direct socio-economic benefits of aquaculture in general exist through its supply of highly nutritious foods and other commercially valuable products. Additionally, it provides a variety of jobs and creates a set of income options. Yet, the question arises how to capture these in a coherent manner - what data is available and applicable to assess sustainable aquaculture in an inclusive way?

Starting with some general information on marine bivalve aquaculture development and the local contexts of the producing (usually coastal) communities, the paper discusses what it takes to generate meaningful information needed for decision-making and governance of the sector. To date, such decisions about marine aquaculture development are still (too) often based on incomplete and short-termed information, particularly in relation to socio-economic dimensions. Consequently, inadequate accounts of how trade-offs are associated with different development options are made. Aquaculture expansion may come at the expense of increased and possibly unsustainable pressure on ecosystem goods and services, ultimately jeopardizing people's food security, health and livelihoods. Its development may therefore generate negative impacts on other industries and people's livelihoods, e.g. fisheries, agriculture, shipping, and tourism. Additionally, in some cases, benefits derived from aquaculture systems are moving away from the local communities directly affected by aquaculture to stakeholders operating at a global market level. These considerations are discussed in this paper. Central focus is placed here on the question of how a more direct way of cultural inclusion of the local (mostly coastal) communities directly involved and dependent on marine bivalve aquaculture could occur.

Exemplified by case-studies, the paper will look at the culturing communities themselves, their everyday challenges, socio-economic controversies and benefits

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but also conflicts related to e.g. management and certification schemes. Our focus hereby is exclusively on *cultured bivalves*, not on the many and complex systems around the world where wild bivalves are harvested. Marine bivalves can represent important opportunities for economic activity and social cohesion in coastal rural areas, providing many jobs in those areas that are often otherwise economically depressed. Provided for a good governance set-up, the culturing community thereby contributes to the wellbeing of all its members – which in turn is defined as the willingness of members of a society to cooperate with each other in order to survive and prosper.

Due to its ocean-bound nature, marine bivalve aquaculture could also provide an occupational alternative for displaced fishermen. Its development can preserve the character and ambience of seaside fishing communities, utilize the local acquired knowledge and skills of the coastal folk, and allow the local denizens to remain economically and culturally tied to the marine environment. The consideration on the socio-economics of culturing communities should, however, neither stop at the local level, nor at the border of each country. On a national level, main considerations must stress small-scale units which, due to their size, pose fewer management problems and function with more flexibility. These projects must have a privileged status on domestic markets particularly in developing countries. From then onwards, they hold the potential, via well-developed and sustainable markets and trade pathways, also to extrapolate internationally.

Abstract in Chinese 本文概述了与双壳贝类水产养殖有关的一些社会经济活动，重点是这些活动为进行养殖的社区所提供的文化服务。 一般来说，水产养殖直接的社会经济效益是通过提供高营养食品和其他有商业价值的产品来实现的。 此外，它提供了不同工作岗位，为人们创造了一系列的创收选择。然而，问题在于如何以一种连贯的方式捕捉这些数据——哪些数据是可用的，并且适用于以一种包容的方式评估可持续的水产养殖?

根据一些海洋双壳贝类养殖发展的基本资料信息和养殖（通常是沿海）区域的实际情况出发，本文讨论了如何为有关部门的决策和监管提供有用的信息。迄今为止，关于海水养殖发展的一些决策仍然是基于不完整和短时间内的信息，特别是涉及到社会经济方面。因此，如何权衡决定不同的养殖发展选项时需要足够的支持信息。水产养殖的无序扩张不但对生态系统可持续发展及其产品和服务方面造成压力，威胁到人们的粮食安全，健康和生计，还可能对其他行业和民生例如渔业，农业，航运和旅游业造成负面影响。此外，在某些情况下，水产养殖带来的利好正在从直接从事养殖的当地养殖户惠及到全球市场上的利益相关者。本文讨论了这些考虑因素，重点在于如何寻找一种更加包容的方式将海水双壳贝类养殖与沿海社区发展有机融合在一起。

以个案研究为例，本文将着眼于从事贝类养殖的社区它们每天所面临的问题，社会经济争议和利益以及涉及到管理和认证等方面的冲突。 我们的关注点仅限于养殖的双壳贝类，而不涉及野生双壳贝类的采捕。海水双壳贝类养殖可以提升沿海和农村地区经济活力，为一些经济萧条的地区提供诸多就业机会。 同时，也有助于促使社区建立一个互利合作，共同致富，发展繁荣的良好发展管理体系。

由于海洋区域的特性差异，海洋双壳类养殖也可为流离失所的渔民提供就业岗位。 它的发展可以保护海滨渔业社区的特点和文化氛围，有效利用当地

民众掌握的知识和技能, 使当地居民无论是在经济上, 还是在文化上都与海洋保护密切关系。.

但是对从事双壳贝类养殖社区社会经济方面的考虑, 既不能局限于养殖区当地, 也不能停留在每个国家的边界层面。在国家层面上, 主要考虑的是小型的养殖企业, 因为小型的养殖企业规模较小, 管理问题较少, 运作灵活。 这些项目必须在国内市场, 特别是在发展中国家中享有特殊地位。在这种局面下, 这些养殖企业有潜力通过良好的可持续的市场和贸易途径拓展国际市场。

Keywords Marine bivalves · Aquaculture · Socio-economic dimensions · Social indicators · Cultural services · Decision support

关键词 海水双壳贝类 • 水产养殖 • 社会经济规模 • 社会指标 • 文化服务 • 决策支持

17.1 Background

> Scotland will have a sustainable, diverse, competitive and economically viable aquaculture industry, of which its people can be justifiably proud. It will deliver high quality, healthy food to consumers at home and abroad, and social and economic benefits to communities, particularly in rural and remote areas. It will operate responsibly, working within the carrying capacity of the environment, both locally and nationally, and throughout its supply chain (Shared Vision, Scottish Government on Scottish Aquaculture[1])

This vision of the Scottish Government towards aquaculture generally sums up nicely the great potential of sustainable culturing; it reflects the definition of sustainable aquaculture, which will be used in this paper. However, to date, aquaculture has not yet fully realized its potential as a source of food, nutrition, and income generation, among other (e.g. technological) reasons often due to the unavailability of the metrics or tools for understanding and assessing the social and economic impacts. This is in stark contrast to the fact that the interest and investment into marine aquaculture to provide humankind's increasing demand for (sea)food is spreading and growing rapidly globally (Anderson 2002; FAO 2016; SAPEA 2017). Thereby, a 'people-policy' gap remains for many aquaculture endeavours (Krause et al. 2015), i.e., the gap in available knowledge and available policies taking up this knowledge in an integrated way, a gap in knowledge exchange between the aquaculture industry, policy makers trying to support aquaculture development and people who depend on aquaculture for a job and/or food source.

Among various institutions around the globe, this gap has seen increasing attention over the past years, leading to more research attention at the human-nature interface. In the following, we consider marine bivalve culture as part of a social-ecological system (SES) in which humans are considered an intrinsic part of the

[1] Strategic Framework for Scottish Aquaculture (www.scotland.gov.uk/library5/environment/sfsa-00.asp).

natural system. SES can be defined as bio-geo-physical territories with their associated social agents and institutions (following Glaser et al. 2012), where the individual parts of the system mutually interact, shape and reshape the resource itself, its goods and benefits, and its governance. While this paper does not intend to apply the SES concept to all these individual parts in the context of bivalve aquaculture – considering aquaculture as part of a SES involves envisioning a paradigm shift from the persisting strong focus on biological, technical, and economic considerations of aquaculture. This shift was the main driver behind developing this paper. As a case in point, the International Council for the Exploration of the Sea (ICES) has increased their activities at this interface for the north Atlantic, leading to the establishment of the Strategic Initiative on the Human Dimension in Integrated Ecosystem Assessments, whose task is to develop strategies to support the integration of social and economic sciences into ICES work. More specifically for aquaculture, the Working Group on Social and Economic Dimensions of Aquaculture (WGSEDA) addresses this gap, with the question of how to balance the negative and positive socio-economic consequences of aquaculture development. Motivation behind its founding was the observation that while in many instances the introduction of aquaculture was technically a success, socio-economic and cultural factors of the technology were not well-adopted by local communities and municipalities. Oftentimes, some of these activities are more visible, such as farm construction, and some to a lesser extent, such as the manufacturing of processing equipment, or hatcheries (Krause et al. 2015).

The question arises how to identify and capture the direct socio-economic benefits of aquaculture in general through its supply of highly nutritious foods and other commercially valuable products whilst providing a variety of jobs and creating a network of income options. What data is available and applicable to assess sustainable aquaculture in an inclusive way? More often than not, available socio-economical relevant data is not regarded as being of relevance to aquaculture, and/or is not being collected at the appropriate scale or level to generate meaningful information needed for decision-making and governance of the sector. Consequently, inadequate accounts are made of how trade-offs relate to different development options. Hence, aquaculture expansion may come at the expense of increased and possibly unsustainable pressure on ecosystem goods and services, ultimately jeopardizing people's food security (and health) and livelihoods (e.g., in events of bivalve diseases, parasite infestation). Its development may therefore generate negative impacts on other industries and respectively related livelihoods, e.g., fisheries, agriculture, and tourism. Additionally, benefits derived from aquaculture systems are in some cases shifting from the local communities directly affected by aquaculture, to stakeholders operating at a global market level.

These considerations form the point-of-departure of this paper, which will focus in a more direct way on the local (mostly coastal) communities directly involved and dependent on marine bivalve aquaculture. In many countries in e.g., Asia, North America, and the Mediterranean, bivalve culture has been the oldest sector of the aquaculture industry. For example, the commercial culture of the Pacific oyster in British Columbia began soon after it was first introduced from the Far East in 1912, and in the Gulf of Taranto in Italy, it was an important large commercial commodity since the Middle Ages (Cataudella and Spagnolo 2013). As such, these examples provide an excellent basis for the focus on cultural services of marine bivalve aquaculture in this book section in general, and the socio-economics of the respective coastal communities in particular. Our focus will be exclusively on *cultured bivalve*, not on the many and complex systems around the world where wild bivalve is harvested.

17.2 What Defines Bivalve Culturing Communities?

For this paper, we define a 'culturing or producing community' as a coastal community anywhere in the world, where most of its local residents are directly (e.g., farm operator) or indirectly (e.g., manufacturer of clam mesh bags or further processing of the harvested crop) dependent on marine bivalve aquaculture, and who receive goods and services from this culture. These can be a Norwegian coastal community directly running "semi-intensive" marine bivalve farms, or a local community in Panama of which most members work in a foreign-owned farms, or an extensive relayed mussel on-bottom farming for a local community in China. The individual ownership settings, responsibilities, time, and finances invested vary depending on the position in the entire process (if existing) – who is doing the culturing, running the businesses, taking care of health standards, doing the marketing, etc.

The overarching question here is the (variable) degree of dependency on marine bivalve aquaculture. Dependency also develops and 'materialises' differently as to whether the producer is purely oriented towards economic gain, or whether his/her motivation is rather a combination of tradition and socio-cultural factors. The level of dependency therefore varies for these communities and for their members, and so does whatever is at stake for them, whether it is the main source of income, or the clean coastal waters for paying tourists to enjoy. Often, the higher the dependency, the higher is the potential of being vulnerable to shocks, and the higher is the responsibility people are willing to take on.

Thus, depending on the contextual setting of bivalve cultivation, the goods and services to these communities vary across scale and time – hence, the identification and value of the cultural service of this activity also surface differently, which pinpoints to the dilemma of capturing the cultural services of bivalve cultivation across different global settings. One point of entry to tackle this is to look into more detail on the socio-economic typology of bivalve cultivation.

17.3 Cultural Services

The broad range of important aspects mentioned in the previous sections has already provided some vital insights into the wide range of cultural services the coastal communities involved in bivalve aquaculture are receiving at present, and could be receiving in the future (Daniel et al. 2012). The Millennium Ecosystem Assessment (2005) defined cultural services as "the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values". Understood in this context, cultural services of bivalve aquaculture move way beyond the cultural aspects of shells as money for traditional ceremonies (Duncan and Ghys 2019). Cultural services have "value in their own right, and they can play an important role in motivating public support for the protection of ecosystems" (Daniel et al. 2012, p. 8817). In the context of sustainable bivalve aquaculture, one rather tangible cultural service is that it enables coastal rural communities to stay in their familiar environment and not having to move away to urban areas for employment. Thus, bivalve culture may act as important keystone activity for local meaning-making, shaping the cultural identities of a place and ownership. This again can be linked to some less visible cultural services such as job satisfaction, freedom, way of life, lifelong learning, providing a sense of home, relation to nature, spiritual value of 'being out there', the knowledge of doing something *with* and *for* the marine environment, and for sustaining a healthy food production and a healthy coastal ecosystem. Other examples for cultural services extend even to the visitors of the region and the tourism industry, in that bivalve aquaculture can offer opportunities for tourists to experience aquaculture as an occupation one may not come across very often, and in addition profit from the produced healthy food. This may even lead to promoting local food culture that again shapes cultural identities and place-based meaning making (SAPEA 2017), as well as to external benefits if the bivalve products are used outside the SES where they were produced.

17.4 Socio-economic Controversies: Benefits, Dependencies, Complementarities

Despite some clear and much needed socio-economic benefits from marine bivalve aquaculture, it also competes for economic, social, physical, and ecological resources, can limit the perceived beauty of a seascape, and can result in environmental degradation (Bacher et al. 2014).

The economic effects of marine bivalve culture on the culturing communities can be immense (e.g., in terms of investments, market influence, risks and hazards, benefits) and its repercussions to society vast. Municipalities may oppose establishment of marine bivalve aquaculture unless the benefits to the municipalities are made clear, transparent, and actually stay in the communities.

Bivalve culture has been a vital part of global coastal communities' livelihoods for centuries, and has contributed a vital, sometimes the main, part to local incomes. This can be substantial and means a substantial vulnerability to crises driven by environmental changes (Guillotreau et al. 2018a). In the following, insights from various recent case studies help to shed some light on the broad complexities of the socio-economic effects of bivalve aquaculture, as well as how environmental changes/disasters to such socio-economic important systems can affect the dependent communities (incl. producers, wholesalers and consumers; e.g., Héral and Deslous-Paoli 1991). One important example is the Bonamia outbreak in European oyster cultures, which also led to the introduction of the Pacific oyster (Buestel et al. 2009; Bromley et al. 2016).

During the last decades, harvested and cultured bivalves around the world have been repeatedly struck by mass mortality events/episodes, leading to socio-economic vulnerabilities and the development of adaptation strategies by the culturing communities (Guillotreau et al. 2018a). The various mitigation or adaptation responses of farmers and farming communities have rarely been assessed for their social and ecological aspects (Bundy et al. 2016; Guillotreau et al. 2018b). In France in summer 2008, for example, the consequences of young oyster mass mortality events related to environmental change affected an entire bivalve culturing profession and its related SES. Short-term effective responses came mainly from the industry itself: against all scientific recommendations, the oyster farmers decided to over-invest in hatcheries and spat (oyster seed) collection to compensate for the high mortality rates striking the cultured stocks. This resulted in significant market price increases after the decline of output levels, resulting in better profitability levels for the surviving firms (Guillotreau et al. 2018b).

In Matsushima Bay, north-eastern Japan, oyster farming also constitutes a major activity (Seki 2018). The Great East Japan earthquake and tsunami in March 2011 destroyed fishing boats and oyster farms, as well as sewage treatment facilities. This resulted in coastal pollution and ultimately the spread of Norovirus, resulting in widespread food poisoning caused by consumption of contaminated oysters. Again, the oyster industry was the driver of first responses by adopting a virus inactivation (heat) treatment of shucked oysters (Seki 2018). In this case, however, this treatment substantially modified the oysters, vastly reducing the price at which they could be sold, hence resulting in an income decline for the over 160 farmers in the area. However, alternative and more innovative methods to stop pathogenic pollution are difficult to find, especially with dysfunctional sewage treating facilities.

In another case from the US Pacific Northwest (Washington and Oregon) in summer 2007, substantial production failures of Pacific oyster (*Crassostrea gigas*) larvae in the three main bivalve hatcheries jeopardized an industry worth US $270 million and 3200 jobs in Washington State alone (Cooley et al. 2018). Scientists and industry cooperated and identified ocean acidification to be the major cause, exacerbated by nutrient runoff and sluggish exchange with ocean water in the region. As an immediate response, the hatcheries began ocean acidification monitoring and building hatcheries outside of the region. A state-level panel consisting of scientists, industry representatives, elected officials, and natural resource managers reviewed knowledge around ocean acidification and recommended appropriate responses, e.g. to advance research and monitoring in cooperation with Washington State University. A Marine Resources Advisory Committee was established to contribute to multi-stakeholder consultative policymaking for the aquaculture-dependent industry, and to prioritize ocean acidification in regional-level management efforts. These state-level responses originated primarily from informal governance networks, led by charismatic industry representatives who used their social capital also to exert influence on science and policymaking.

The final example from British Columbia's aquaculture industry (Canada), which dates back to 1912, focuses not on the challenges of adaptation to shocks but is included here to show-case the strong dependency and socio-economic impact bivalve aquaculture systems can have (Vancouver Island University, Centre for Shellfish Research[2]). In this region, the most commonly farmed species since 1912 are the Pacific oysters (*Crassostrea gigas*) and Manila clams (*Venerupis philippinarum*). In 2003, the aquacultural production was equivalent to that of the wild industry. Currently, there are 460 licensed shellfish tenures occupying 2114 ha in British Columbia (BC Agriculture & Lands). Much of the economic benefit and impact associated with the industry remains in the coastal communities and local economies of Vancouver Island and British Columbia's mainland. The great majority of bivalve operators are still small companies, many of which are family-owned, thus providing permanent, year-round employment in areas where jobs are scarce and the percentage of displaced workers is high. On a percentage basis, the bivalve aquaculture industry spends more on wages than other sectors such as conventional agriculture and fishing. Currently, 700–1000 direct jobs can be attributed to this industry, with workers under the age of 30 holding approximately 50% of those jobs. In addition to direct jobs, there are >500 jobs associated with industries that supply and service bivalve aquaculture. This 'spin off' employment is itself also located in rural coastal communities, rather than in the larger urban centres.

17.5 Discussion

The examples outlined above clearly show some of the socio-economic challenges and potential risks affecting the various levels and scales of marine bivalve aquaculture. The strong involvement of local communities and the related institutional arrangements, for example related to property rights, are shaped and reshaped as part of the interactions between users/stakeholders and 'their' marine resources. To highlight some of the more visible challenges, the following two sections will discuss relevant aspects of such 'shaping processes' taking place in the everyday activities of culturing communities (17.5.1) and the involved multidisciplinary research and governance environment (17.5.2).

[2] https://www2.viu.ca/csr

17.5.1 Critical Processes

Aquaculture activities can be at the centre of a number of diverse **conflicts** – as seen in many contemporary public discourses as well as in the examples above. Marine bivalve aquaculture can indeed be both a source as well as a victim of factors leading to conflict.

Pollution, as exemplified above, can be one main source of conflict for the bivalve culturing communities. Especially, in regard to its direct linkage to health risks and biosafety aspects as the more obvious risks, but also financial, legal, and insurance risks for every stakeholder involved in the culturing of bivalves, and the marketing and distribution of the bivalve products. As such, they also indicate some of the obstacles towards the implementation of sustainable aquaculture, but also pathways to some of the potential solutions.

Bivalve cultivation can also be faced with increased social conflicts between the stakeholders involved - farmers, nature conservationists, recreation/tourism, fisheries, shipping (commercial/private) and people aesthetically impacted by installations. These conflicts (e.g., with fisheries, wind farms) are often based on competition for space (and hence substractability, where one user's use directly affects the potential of resource use by another). Most EU countries employ a complex aquaculture planning consultation process to minimize the environmental impact of their culturing developments, and to ensure that the deposit and cultivation of aquaculture animals does not conflict with rights of others (e.g., moorings/boats, farm effluent, sites of scientific interest, tourism). These processes follow, for example the Best Management Practice of the UN Food and Agriculture Organisation, as well as the Best Environmental Practice (BET) and Best Available Technique (BAT) guidelines (FAO Code of Conduct for Responsible Fisheries[3]). In addition, industry codes of practice are designed to encourage sustainability with minimum impact (e.g., see the *Association of Scottish Shellfish Growers Code of Best Practice for shellfish aquaculture*[4]).

A new emerging and promising avenue towards sustainability and the acknowledgement of the positive effects of bivalve cultivation are the **certification schemes** of cultured bivalves. Some of the aspects commonly considered for bivalve certification include land and water use, water pollution, benthic effects, effects on biodiversity, use of antibiotics and other chemicals, and relationships with workers and local communities (Boyd et al. 2005). Further discussions include water use conflicts (see above), public health risks associated with bivalve consumption, and the introduction of non-native species and related genetic alterations, e.g. of oysters (Boyd et al. 2005; Cranford et al. 2012). To date, certification schemes face the challenges of most aquaculture products on what to certify and how to certify aquaculture production itself. Despite these difficulties, it is something many culturists are keen to achieve, and are, more often than not, actively driving this process forward.

[3] http://www.fao.org/docrep/005/v9878e/v9878e00.htm

[4] www.assg.co.uk

This is especially valid, as they already have to work with very high environmental and human health standards (at least in Western societies).

While organic certification is a promising tool towards sustainability, organizations currently use different standards for organic certification, which have to be evaluated. Certification schemes relevant in some way to aquaculture have been reviewed by Corsin et al. (2007) and the World Wildlife Fund (WWF). The latter also co-founded the Aquaculture Stewardship Council in 2010, which targets 'responsible aquaculture' and includes social standards.[5] Other organisations active in this field include the UN Food and Agriculture Organisation, Friend of the Sea,[6] Naturland (the only organic certification scheme at present[7]), Global G.A.P. (mainly focussing on farm assurance with only some sustainability components[8]), and the Aquaculture Certification Council, which, in addition to environmental and safety standards, also includes social standards (recently changed to Best Aquaculture Practices Certification[9]). The Marine Stewardship Council[10] is only interested in ecologically sustainable fisheries, with only capture-based bivalve aquaculture operations certified. The majority of certification schemes have in common that they consider (or at least strive for) ecological sustainability as key requirement for securing long-term socio-economic benefits (and hence cultural services). Some include social standards (closely linked to cultural services), most do not (yet). There remains much scope of improvement of certifications schemes for bivalve aquaculture to cover all the aspects related to the culturing activities, including considerations of the social, economic, and environmental impact of bivalve culture and management (Cranford et al. 2012). This also requires a critical reflection on other (often unintended) consequences of certification schemes, for example, bivalves that used to be available for local consumption, trade or cultural services may be exported to a global market through preferred (high retailer demand) markets for certified aquaculture products. The phenomenon of marine bivalve aquaculture products being shipped around the world may have repercussions on the availability of and access to these bivalves by local communities (Brenner et al. 2014; Muehlbauer et al. 2014). Particularly, where small-scale aquaculture producers are in the employ of companies or depending on middlemen, the economic benefits from harvesting a certified resource may not reach them in full extend.

Sustainability issues related to responsible consumption of cultured bivalves received increasing attention over the course of the last decades. In response to consumer requests for organic products, organic certification of cultured bivalves is therefore gaining speed. The afore-mentioned aspect to local production for global markets, however, does question sustainability and has to be integrated in the evolution of aquaculture certification schemes. In addition, bivalve cultivation activities

[5] www.asc-aqua.org

[6] www.friendofthesea.org

[7] https://naturland.de

[8] www.globalgap.org

[9] https://bapcertification.org

[10] www.msc.org

can have adverse effects on the ecosystem, such as bottom disturbance when dredging for seed, enhanced deposition of organic material in local areas, and reduction of the carrying capacity for other filter feeders, as well as effetcs on the entire ecosystem (e.g., Byron et al. 2011; Filgueira et al. 2015; Smaal and van Duren 2019). Together with potential changes in biodiversity as induced by the introduction of culture facilities and the bivalves themselves, these aspects could again impact the outcome of certification processes.

Directly relevant to the certification schemes for marine bivalve aquaculture, there is a discussion on the reliability of tools and methods for genetic confirmation of **species identification** of cultured bivalves, as the correct species' names are not always available. A review of current methods and recommendations for species identification are needed. Correct names are important for commercial purposes and certification, as well as for disease control and management, thus inherently affecting the culturing activities of the local communities. For example, the introductions of closely related species that can produce infertile hybrids should be avoided.

The introduction and translocation of live bivalve from hatcheries and field sites around the world, can involve the introduction of **non-indigenous species, diseases, parasites, and harmful algae**. Potential implications to wild and cultured stocks include impacts on recruitment, reduced fitness, increased competition, and predation, as well as change in genetic composition, diversity, and polymorphism. Information is gathered and needed on guidelines for, and records of, the transfer of cultured bivalve in ICES countries (ICES 2009). Potential implications and effects of the introduction and transfer of alien species need to be considered to help minimize impacts and guide farmers, aquaculture-dependent communities and policy makers in support of the development of policy decisions on cultured bivalve transfers.

Finally, there are also some positive **practical considerations** that need to be highlighted briefly. Despite these daunting conflicts and challenges, bivalves nevertheless make an excellent candidate for an organic product, as it does not need additional foreign-source input of feed other that naturally occurring phytoplankton. Furthermore, their protein content makes them an interesting option from the point of providing and maintaining food security for the growing world population (SAPEA 2017). In addition, during their life in the coastal zone, they also have a role in ecosystem services such as reducing nutrients in the water column and acting as a carbon sink (see other papers in this book). An oyster farm of about 1 ha can compensate for the nitrogenous waste of 40–50 coastal inhabitants (Shumway et al. 2003; Petersen et al. 2019). In this way, bivalve feeding can also avoid harmful algal blooms. These health and safety aspects are clearly not to be underestimated in their importance to the communities. Bivalve aquacultures operate under public health standards, e.g., waters that are certified under national sanitation programmes, and are thus regularly and strictly monitored. For example, in the USA, the *National Shellfish Sanitation Program* (NSSP) standards exceed those required for swimming; and failure has immediate consequences such as the closing of waters to harvest. The presence of bivalve aquaculture therefore often results in increased awareness and monitoring of environmental marine conditions. No untreated sewage can be tolerated, a different marine stewardship develops, and other harmful inputs into the local waters are regularly monitored alongside. This correlation has often provided political impetus for improvement of sewage and wastewater treatment, not rarely placing bivalve farmers first in the line of defence towards enacting laws on water quality, implementing technological advances, etc.. Many bivalve producing companies have or are developing ‘environmental codes of practice’, including, for example, best management practices, to ensure that as the industry develops, it maintains a responsible environmental record (e.g., in Scotland), which again can facilitate the development of certification schemes. Cultured bivalves therefore do not only represent a valuable food product, their cultivation can also enhance alternative livelihoods in rural areas, provide social welfare, as well as ecological, economic, social and cultural services (e.g., improving social capital related to certification standards).

17.5.2 Working with Socio-economic Indicators?

To support the marine bivalve aquaculture activities of the involved communities, our perceived **role as scientists** in the development of a management approach for bivalve aquaculture impacts is to provide science-based advice (e.g., Kluger et al. 2017) on:

- Effective performance-based approaches and indicators for characterizing ecosystem status and impacts of a highly diverse bivalve aquaculture industry;
- Identifying the potential consequences to coastal marine ecosystems from changes in ecosystem status and impacts, and identifying related thresholds of potential public concern;
- Identifying effective measures for preventing or mitigating any impacts from bivalve aquaculture;
- Reviewing and assessing available management frameworks that facilitate ecological sustainability by considering their capacity to incorporate an ecosystem perspective, societal values, and the economic viability for industry (ICES 2009).

Socio-economic science considerations are paramount in setting critical decision criteria, e.g., what constitutes an unacceptable impact? Deliberations on many components of a pragmatic bivalve aquaculture management framework require the discussion of costs to the diverse industry involved (e.g., for monitoring) and “potential” public concerns (e.g., impact mitigation measures). To help define what level of impacts are ‘acceptable’, ecology and socioeconomics can help in clarifying the values and expectations of different groups, and contribute to the economic evaluation of environmental services. Furthermore, environmental conservation and protection, and other legislations pertaining to the utilization of coastal areas, are clearly important considerations for the selection of indicators, and particularly for the setting of regulatory triggers/thresholds.

An integrated, ecosystem-based bivalve aquaculture management approach requires endorsing socio-economic activities, potential societal consequences, as well as the environmental dimensions of sustainability (Cranford et al. 2012). Indicators of socio-economic issues not only need to measure the operating performance of commercial bivalve cultures, which at its simplest could be summarized using financial ratios, but also the wider impacts of aquaculture on society at large. Indeed, it is precisely these impacts which can be expected to invoke an institutional response intended to alter the way in which aquaculture is regulated and managed.[11] Among the many different indicators proposed in the literature, some are of direct relevance for bivalve culture operations. They are related to four different overarching social dimensions, namely (1) the social acceptability of the bivalve culture, (2) the supply availability to the market, (3) the livelihood security for the local communities, and (4) the economic efficiency of bivalve culture operations. Possible indicators related to these four social dimensions are outlined below (cf. ICES 2009).

1. **Social acceptability** of the bivalve culture operations can be assessed with two indicators:

    - Public attitude towards aquaculture (bivalve culture). This is evaluated by means of regular enquiries, using statistical treatments (Whitmarsh and Wattage 2006).
    - Assessment of emerging and existing conflicts. Bivalve culture may be the origin of visual intrusion, which may affect tourism, or it may compete for space with other coastal activities in a spatially constrained environment. These can be evaluated by means of observations, regular interviews with local stakeholders, and institutional bodies.

2. An indicator on the **supply availability** to the market corresponds to the consumption of bivalve products per capita (in those cases where bivalves are consumed locally) and to their entailing costs for the consumer:

    - The consumption of bivalves is usually computed at national levels, indicating the quantity of food per capita and per year.
    - The consumers' price is based on the trends in wholesale prices. Large national markets publish trade journals from which these data can be obtained.

3. **Livelihood security** for the local communities corresponds to the well-being of the bivalve producer on the local level. Indicators that address this issue pertain to:

    - Income per capita. The importance of aquaculture in supporting local livelihoods is most directly measured by per capita income in this sector. A proxy measure may be derived based on the ratio gross value added (GVA) to employment.

[11] www.ecasa.org.uk

- Employment rate. Total employment is a measure of the scale (or 'importance') of the aquaculture industry in absolute terms. It is an indicator of the number of people that depend on aquaculture directly and indirectly for their livelihood. It has a political as well as an economic significance.

  However, these two indicators do not consider long-term aspects of income provision, inherent to the implications of the term 'livelihood security'. A bivalve culture classified as 'secure' through this may still be vulnerable towards external (e.g., environmental or market-driven) disturbances.

4. One of the most important group of indicators relate to the direct **economic efficiency** of a particular bivalve aquaculture operation. These can be gauged as follows:

   - Productivity ratio. Productivity is a measure of output per unit of input. For instance, trends in labour productivity are an important indicator of technical progress in aquaculture, and productivity differences between farms may indicate which farms are most vulnerable to falling prices and profits.
   - Protection costs. Costs may be incurred in dealing with the environmental impact of aquaculture, and are likely to consist of two elements: (i) Compliance costs incurred bivalve cultures (e.g., arising from the obligation of producers to undertake Environmental Impact Assessments (EIAs)), and (ii) regulation, surveillance and enforcement costs by the respective institutions. Environmental protection costs are the counterpart of environmental damage costs. Thus, an inverse relationship between these can be expected.
   - Profit. Profitability is a basic indicator of financial viability. In the absence of published data, the profitability of a bivalve operation can be addressed and calculated from its different elements (i.e. input costs, pricing of products, etc.)

Finally, a further dimension of socio-economic indicators could be the existence and performance of **financial and social security institutions** for culturists/producers (e.g., FAO 1985), including:

- Specialized banking organisations (e.g., The Fund for Regulation and Organisation of the Market for sea and marine culture products in Spain), to improve the collective infrastructure of the sector;
- Socio-educational programmes to enable the participation and representation of culturists/producers;
- Acknowledgement of culturists' "brotherhoods" and shared reimbursement, which in the Mediterranean date back to the thirteenth century and can have the power to negotiate and ensure authority, e.g., for participation in government decisions (sometimes evolved into professional chambers with extensive management powers).

17.6 Conclusions and Outlook

The information in the section above summarizes some of the complexities surrounding marine bivalve aquaculture. This snapshot already very clearly highlights the contextual nature of the cultural and socio-economic benefits and implications for communities living with and from these cultured products. Marine bivalves can thus represent important opportunities for economic activity and for supporting social cohesion in coastal rural areas, providing potential jobs to areas that may be economically isolated otherwise. If working well, the culturing community hence contributes to the well-being of all its members, by their willingness to cooperate with each other in order to survive and prosper.

Due to its ocean-bound nature, marine bivalve aquaculture could also provide an occupational alternative for migrant or job-seeking fishers (i.e., fishers who did not lose their job due to aquaculture). This statement clearly has to be made with caution in view of evidence that fishers are not farmers and may find it difficult if not impossible to adapt and adopt to commercial bivalve culture. Nonetheless, bivalve aquaculture development can preserve the character and ambience of seaside fishing communities, utilize the local acquired knowledge and skills of the coastal residents, and allow the local denizens to remain economically and culturally tied to the marine environment.

The consideration of the socio-economic aspects of culturing communities should, however not stop at the local level, nor at the border of each country. These small-scale projects must have a privileged status on domestic markets particularly in developing countries. Nevertheless, they can also be extrapolated internationally via well-developed and sustainable markets and trade pathways.

Finally, a further dimension, which is important but goes beyond the scope and objective of this paper, is the growing potential and spread of offshore bivalve aquaculture (e.g., in concepts such as Open Ocean Aquaculture or Open Sea Shellfish Farming). This brings a very different perspective to the discourse and reality of the culturing and producing communities, with implications on their responsibilities and contribution in local and regional marine spatial (and potentially even protected area) planning efforts. This development 'far offshore and away from sensitive ecosystems' has the potential to both reduce and exacerbate user conflicts, for example in terms of employment, ownership (of both equipment and production and planning processes), or technological choices, particularly in developing countries (often more directed towards producing luxury products destined for European countries). This leads, however - from a cultural, economic or ecosystem service point of stance – to the normative questions of how we can evaluate effects of new established marine management strategies such as a marine spatial planning act. What are indicators of the status of social perception of bivalve culture that can help in avoiding conflicts? How do social values and norms as well as administrative organizations in different countries/regions affect trends in the intensity, methodology, structure, and type of aquaculture? Moreover, who decides, what type of social value will be traced in the planning and management process? These are clearly important aspects to consider in the management of shellfish resources and bivalve cultivation in particular, in such a way that they will generate cultural (and other) services in the longer term.

One of the closer objectives will be to identify specific cross-cutting and integrative methods (to also include local historical and long-term data, for example) to support the evaluation of the direct and indirect socio-economic consequences of aquaculture operations at all levels, from the local to the global. In this way, already existing socio-economic data and lessons will not be lost but their applicability used and further developed, to identify current data gaps and more narratives of successful sustainable marine bivalve aquaculture projects.

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