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6. The anatomy of complex marine problems: a case study of decision-making on archipelagic aquaculture

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INTRODUCTION

Analysing, understanding, and finding solutions to the increasingly complex problems facing our societies, and seas, are commonly acknowledged to need interdisciplinary approaches. It is, however, less clear what those approaches are and how they should be identified and accommodated. More scientific disciplines necessarily entail more perspectives and, often, less certainty about a given problem's optimal solution(s). How does one arrive at a conclusion when different scientific perspectives point to different solutions? How should various factors be considered or weighed against each other and how can we tell if and when we know enough to make decisions? Such questions typically arise in the context of any 'wicked' problem, which represent a particular focus for The Sea, an interdisciplinary profiling area established at Åbo Akademi University (https://www.abo.fi/en/the-sea-about/).[2]

The increasing role of scientific knowledge is well recognized in environmental governance, but it has no self-evident social authority. Many problems related to its usage stem from the features of scientific knowledge itself; it is often controversial and uncertain, thus giving room for different interpretations about the 'facts' (Yearley, 1991). Without holistic approaches, multidisciplinarity can create disagreements between scientific disciplines (Kinzig, 2001). Moreover, the value-laden character of societal problems, including environmental ones, implies that they cannot be captured by a scientific set of facts alone, but are usually challenged by other, often competing, views and/or local knowledge. The merits and means of interdisciplinarity are widely

discussed (and generally endorsed) in literature, but the significance of the issue transcends academic discussions of kinds and degrees of multidisciplinarity. It involves a very practical dimension too, concerning the normative needs decision-makers face daily. Earlier literature has extensively discussed the practices of sustainable decision-making revolving around the responses of institutional interplay, co-management, and bridging organizations (Cash et al., 2006). More recently, others have, for example, suggested specific strategies for managing conflicts among thought collectives related to sustainability transformations (Soininen et al., 2022). Our aim here is to highlight the inherent complexity in such decisions, related not only to different institutional levels or actors but also to their temporal and spatial dynamics.

This chapter seeks to illustrate and concretize challenges linked to interdisciplinarity in environmental decision-making through a targeted case study, focusing on the thorny question of aquaculture, or fish farming, in the Åland Islands, Finland, and its link to Baltic Sea eutrophication. Aquaculture currently represents by far the largest regional source of aquatic emissions, exceeding agriculture and other industries. From 2012 through 2018, aquaculture represented some 68% of the total emissions of phosphorus and 34% of nitrogen emissions (Ålands Landskapsregering, 2020).

The topic aptly illustrates the vast range of issues involved in a wicked problem, including the significance of the chosen perspective and scale of assessment for identifying the optimal solution. Yet, such complexities do not eliminate the need for authorities to continuously decide on whether or not to permit fish farms and establish the relevant conditions for their operation, even when faced with incomplete or conflicting knowledge. Following this introduction, the chapter briefly addresses the three main perspectives of sustainable development (economy, society, and environment; see United Nations World Commission on Environment and Development, 1987) and some of the key concerns raised by those perspectives for decision-making on aquaculture in Åland. Next, the chapter addresses the theme of balancing these concerns and interests against each other, followed by a discussion on the role of spatial and temporal dimensions in the search for sustainable decisions on the matter. Finally, the implications of the findings regarding regulation and governance processes more generally are considered.

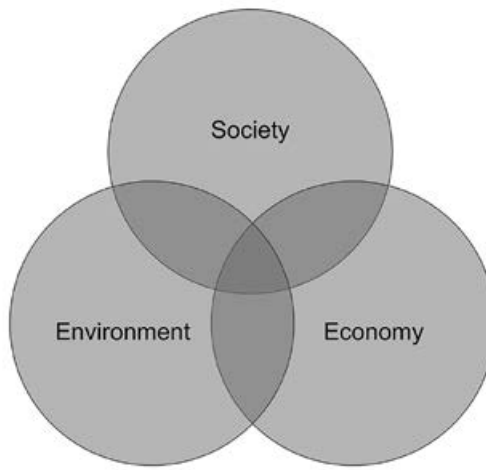
In the spirit of interdisciplinarity this chapter is co-authored by scientists from four different disciplines (marine biology/ecology, industrial management, environmental social science, and law). It is not an empirical study, but a case study illustrating a complex phenomenon from different perspectives, to inspire and motivate further research (cf. Siggelkow, 2007). The method is ongoing deliberation and co-creation among the authors. Discussions were based on literature searches and analysis of documents produced by various

stakeholders; experts and key stakeholders, mainly within academia and government, were consulted throughout the process.

DIFFERENT PERSPECTIVES ON AQUACULTURE IN THE ÅLAND ISLANDS

General – The Starting Point

Aquaculture in the Finnish archipelago, including Åland, can be studied from a multitude of perspectives. This chapter's focus is shown in Figure 6.1, drawing on the 'triple helix' of sustainability: environmental, economic, and social perspectives (Scalia et al., 2018). Aquaculture in the Åland Islands was chosen as the case study as it is an isolated problem, easy to observe, permit-based and well documented. It also has significant economic importance for the local communities, being linked to the livelihood of archipelagic communities, and this has given rise to a broad public debate. In brief, the topic aptly and concretely highlights the multitude of interests and concerns involved.



Source: the model is adapted from Scalia et al., 2018.

Figure 6.1 Governance for sustainability: a triple-helix model

Globally speaking, the main drivers for increasing aquaculture are the rising global demand for fish, declining capture fisheries, food security, and 'blue growth' policies (Food and Agriculture Organization of the United Nations,

2022). Capture fisheries (i.e., all kinds of harvesting of naturally occurring living resources) and aquaculture are important parts of the world's food supply systems, especially considering the need to reduce the footprint of land used for food production. Fish represents high-protein, low-fat food that provides a range of health benefits; consequently, demand is increasing. As stocks of fish grow scarce through overfishing, much hope is put into aquaculture, which currently is among the fastest-growing food-producing sectors in the world (Food and Agriculture Organization of the United Nations, 2022). Moreover, the European Union (EU) (and Finland) is far from self-sufficient in terms of fish, and imports make up around 60% of the total supply (Scientific, Technical and Economic Committee for Fisheries, 2021). In terms of global food supply, aquaculture provided more fish than capture fisheries for the first time in 2014 (Food and Agriculture Organization of the United Nations, 2016). Capture fisheries, however, still dominate in the EU, where aquaculture accounts for only some 20% overall of the total food supply from fish (Scientific, Technical and Economic Committee for Fisheries, 2021). Yet, aquaculture is a key part of the EU's blue economy strategy, which entails a further emphasis on aquaculture, and national Finnish bioeconomy strategies. Roughly half of the Finnish production of fish for food (not breeding) comes from the Åland Islands.[3]

The three aspects of sustainability – economy, environment and societal perspectives – will be distinguished in the remainder of this section. These perspectives are then weighed against each other.

Economic Interests and Technological Innovations

Fish farming is an entrepreneurial activity, offering people an opportunity for wealth creation locally, usually in areas where such opportunities are scarce. It is also an industrial activity, where economies of scale impact the profitability of investments. The aquaculture economy depends heavily on the fluctuating market price (driven by, for example, competition), which individual fish farmers have minor impact on, but also on production cost and a range of productivity factors, such as growth, survival and feed efficiency, and quality factors, such as body shape and flesh colour (Kankainen et al., 2012; 2016), where the entrepreneurial influence can be much greater. Feed is by far the biggest production cost item (up to 50% of total costs), followed by the cost of smolt, miscellaneous costs, harvest- and packing-related costs, labour costs, and depreciation (clearly the smallest cost item; Iversen et al., 2020). Production facilities require significant investment in technology, leading to productivity improvements. Productivity growth, especially in salmon farming, can also, at least indirectly, be attributed to increasing farm and company size (Asche et al., 2013). The trend in Åland, as globally, has been

aquaculture installations being concentrated into fewer, but larger, companies. Following a series of takeovers, six companies operate most of the business in Åland (Ålands statistik och utredningsbyrå, 2019). Fish prices also depend on global developments. Notably, the price of fish has been increasing since the war in Ukraine started in February 2022, which correspondingly has strengthened the call to secure domestic supply.

Thanks to technological development and due to stricter environmental standards, pollution from fish farming has decreased significantly over the past two decades, notably from reduced nitrogen (N) and phosphorous (P) emissions. The choice of the fish species has environmental (and economic) implications (Randau, 2012), but the high demand for salmon seems to remain. In the Åland Islands, the majority of cultivated fish are salmon and rainbow trout. Choice of feed also holds considerable potential for emission reduction. Further lowering aquaculture's environmental impact, and already used by fish farms, are optimized and automated feeding systems, although the latter typically require larger farm sizes. Another way to reduce the environmental impact of aquaculture is location management, that is, locating submersible flow-through systems (FTS) in open and deep(er) water.[4] Location management may also bring other benefits, such as improved water condition. However, locating the farms in open water increases both capital and operational expenditure for the fish farmers.

One more recent technological advance in the sector is recirculating aquaculture systems (RAS), which, as opposed to flow-through filter (FTF) systems, contribute less to eutrophication due to reduced waste release (d'Orbcastel et al., 2009). However, RAS consume large amounts of energy (due to pumping and filtering), which alters the economy (although potentially reducing the risk of diseases and runaways). Hence, this may cause additional CO_2 emissions, which may be overcome by scaling up production (Randau, 2012) and improving technological designs (d'Orbcastel et al., 2009). For example, the stock exchange-listed FIFAX company recently decided to scale up their land-based RAS production facilities in the Åland Islands.[5] According to Liu et al. (2016), a land-based RAS facility can be almost as profitable as an open net-pen farm if it can sell with a 30% price premium.

Covering the extra expenditure that sustainable farming may require also drives companies to reflect these efforts in marketing their products. Certification is one way to signal sustainability to concerned or green consumers. For example, the first Aquaculture Stewardship Council (ASC) certificate for environmentally and socially responsible seafood was recently awarded to a fish farm on Åland.[6]

In conclusion, it is possible, but commercially very challenging, to cultivate fish without releasing nutrients into the marine environment. The different

methods to mitigate releases are not yet technically ripe or economically viable.

Environmental Perspective

Aquaculture in the Baltic Sea region, in the form of FTS, i.e., open net bag farming, causes eutrophication, arguably representing the main threat to 'a healthy Baltic Sea environment with diverse biological components functioning in balance, resulting in a good ecological status and supporting a wide range of sustainable economic and social activities', as highlighted by the Baltic Marine Environment Protection Commission – also known as the Helsinki Commission (HELCOM) (2021). Yet, eutrophication in the Baltic Sea and in Finnish waters is caused by excessive inputs of nutrients (P (phosphorus) and N (nitrogen)) from natural and human-mediated sources such as rivers (main source) and airborne (about one-third of the main input). The remaining input comes from overall minor point sources such as wastewater treatment plants and industry, including aquaculture (Baltic Marine Environment Protection Commission, 2021; Carballeira Braña et al., 2021; Räike et al., 2020). Fish farms are considered harmful point sources of P and N, especially in the shallow coastal waters of the Baltic Sea.

Nutrient-rich emissions from aquaculture consist of uneaten feed particles, faeces, and metabolic waste products (Helminen & Honkanen, 2002; Varjopuro et al., 2000). The extent of the environmental impact is linked to (a) the marine ecosystem in focus, i.e., pelagic (open water) or benthic (seafloor) habitats, and (b) the geological, hydrological, and ecological characteristics of the aquaculture facility's location. Feed loss and larger faeces particles, for example, will sink, affecting sediments and benthic communities, whereas dissolved inorganic and organic nutrients and small faeces particles affect the pelagic communities and the state and quality of surrounding waters). This causes potentially major changes in structure and function (decreased diversity) of benthic ecosystems locally, and a shift in the decomposition of organic matter from fauna-mediated to microbial processes (Nordström & Bonsdorff, 2017).

To exemplify the complexity of the nutrient problem, shallow-water areas with restricted water movements, such as those found in the inner Åland Islands, will be significantly more impacted than deeper and more open sea areas (e.g., the outer archipelago), as the nutrients from the aquaculture facility will be retained locally, rather than dispersed over a larger area. Yet, the overall amount of nutrient input into the Baltic Sea remains the same. The complexity of the problem is further increased by the multiple pressures that aquaculture brings to the environment, both locally and regionally, such as chemical pollutants (anaesthetics, antibiotics, antifouling chemicals, disinfectants, and

parasiticides), biological disturbance (fish aggregation, escapes, diseases, and parasites), and competition for coastal space (Carballeira Braña et al., 2021). Other problems may relate to emissions of underwater noise and artificial light at night, and emissions from the traffic between the shore and the cages. Here, the complexity of environmental impacts may represent a wicked problem of its own, because it remains difficult to determine the carrying capacities for particular areas and ecosystems.

Finally, the outlook regarding eutrophication in the region is that it is going to happen along with ocean warming, further promoting algal blooms; these consequently reduce bottom-water oxygen and thereby expand the area of hypoxic to anoxic waters in the Baltic Sea. Thus, eutrophication, in combination with an array of additional local, regional, and global stresses, has a lasting impact on coastal and open-water Baltic Sea ecosystems.

Technical solutions include improved feeding techniques and feed composition (see above). The use of fish raw material in rainbow trout feed has been significantly reduced by increasing the use of vegetable raw material such as broad beans and rapeseed oil. The so-called Baltic Sea feed (BSf) has been developed to improve the circulation of nutrients (harvesting nutrients from the sea) within the sea and is manufactured with herring and sprat caught in the Baltic Sea itself (Setälä et al., 2016). However, this still includes some vegetable material. The ecological impacts of the BSf, including that from the fishery itself (e.g., the herring fishery in the Baltic Sea has recently lost its sustainability value[7]) and the amount of fish needed to be caught and processed per kilogram of farmed fish, are aspects that need to be considered when calculating the effectiveness of the BSf for mitigating eutrophication effects from aquaculture, as well as considerations of the measure's relevant spatial scale.

To reduce aquaculture's environmental impact, compensatory measures have also been discussed. They include integrated aquaculture, for example, mussel farming (which improves water quality), and establishing wetlands to stop nutrient run-off from land, possibly combined with compensatory fishing (Ålands Landskapsregering, 2011). Mussel farming in the northern Baltic Sea is, however, not as efficient as in warmer seas with higher salinity. Compensatory fishing can be used for feed production (mussels or other species) to create a closed loop.

Taken together, there will always be an environmental impact of aquaculture affecting the status of the water and sediment (locally and regionally) in terms of the eutrophication and ecosystem status, but its environmental impact depends, inter alia, on the location of the fish farm, the feed, and inevitably, the intensity (size) of the facility. Thus, the question is what impacts the society is willing to allow.

Societal Perspective

Slater (2017) argues that comparisons of economic and environmental impacts neglect the social impact of aquaculture. In Finland, aquaculture forms a natural part of primary food production, often regarded as necessary for maintaining 'a living archipelago' (Peuhkuri, 2002). A living archipelago requires jobs, housing, schools, ferries, and other infrastructure. Fish farming compensates for the declined importance of fishing and other traditional livelihoods and could become an important employer in many rural regions, such as coastal and archipelago areas, where new forms of livelihood are rare (Mäkinen et al., 2013). In addition, traditional fishing cannot meet the growing demand for fish as awareness rises of dietary alternatives to meat and their positive health effects, and in the Åland Sea, many species already suffer from overfishing (e.g., Aps & Lassen, 2010).

In 2018, the aquaculture sector in Finland had a turnover of €78.9 million from 157 aquaculture companies employing 453 persons (320 full time; Scientific, Technical and Economic Committee for Fisheries, 2021). The production of fish for food from the Åland Islands accounts for €37 million in turnover, a little over 1% of the gross domestic product (GDP), and around 100 employees.[8] About one-third of the total fish production for human food consumption in Finland was from Åland, suggesting that most of the fish produced in Åland are consumed in Finland, not exported. Although Finnish fish farms are not economically important on a national level (e.g., Scientific, Technical and Economic Committee for Fisheries, 2021), locally their economic impact may be significant, especially in archipelago communities. Furthermore, fish production is only one part of the value chain that covers considerable processing and distribution as well as food supply industries.

The opposition to (increased) aquaculture often focuses on environmental concerns, intertwined with fears that activities will harm recreational activities and simply do not belong in the marine environment (Ålands Landskapsregering, 2011). Further concerns can relate to, for example, negative physical impacts of infrastructure, animal welfare and species preservation; inappropriate locations; lack of clear and participatory decision-making; absence of transparent information; negative influences on local culture, social cohesion and tradition; and equitable access to natural resources and livelihoods (Ertör & Ortega-Cerdà, 2015). Fish farming may also negatively affect other businesses, such as tourism.

In some instances, industrial-type fish farming is juxtaposed to small-scale fisheries, which are generally considered to be of higher cultural value and with greater environmental know-how (Salmi & Mellanoura, 2020). Yet, as noted, aquaculture can also serve as an enabler for the living archipelago, so rejecting installations may also diminish archipelagic life.

Moreover, there is a more fundamental critique against aquaculture (and the idea of blue growth more generally) as a viable strategy for securing sustainable development and nutrition (Hadjimichael, 2018). This critique is sometimes dismissed as expressive of the 'not in my backyard' (NIMBY) syndrome, carrying a connotation of selfish concern for one's own property or other local interests, or reduced to being merely a dispute over differing values. Yet, research shows that the concerns are more complex than that. Often, they boil down to the socioeconomic and cultural contexts (reality) of the opponents, as well as to various institutional constraints that inhibit public engagement and open and constructive dialogue about the issue (Burningham et al., 2015). This is an important aspect from the societal and cultural points of view because it also relates to social justice: who has the power to define what directions development should take, and what is the acceptable level of harm a socially important activity can cause?

Local pro-aquaculture inhabitants, entrepreneurs, and policymakers often argue that they have the priority and moral right to utilize natural resources in their area. Differing ideas, cultures, interests, and values are clearly at stake when trying to solve the challenges of aquaculture and eutrophication. Values are problematic as a focal point of research because the same environmental values are often used to support opposing viewpoints, potentially harming effective communication and collaboration (see Reser & Bentrupperbäumer, 2005). Moreover, misalignment of values and attitudes with actual behaviour is a well-known gap (Carrigan & Attalla, 2001). Interests do not fully explain how people behave, either; human beings do not always act rationally.

Legal Framework

As always in maritime governance, the applicable rules derive from many levels, including international, EU and national rules. The key rules with respect to aquaculture are indicated in Table 6.1 below.

Åland has regional self-governance over its marine areas, environment, and business policy, which means that the key rules for aquaculture in Åland are laid down at the regional level. As in Finland, the key laws are the Environmental Protection Act and the Water Act, but the Åland rules are not identical to the Finnish ones and there are important differences between them.

Aquaculture above a certain quantitative threshold is a permit-based activity in Finland. In the case of Åland, the permit authority is the local environment and health protection authority (Ålands miljö-och hälsoskyddsmyndighet, ÅMHM, see www.amhm.ax). The (temporally limited) permits and associated conditions ensure that authorities have knowledge and control over regional aquaculture activities.

Table 6.1 Overview of the main legal framework related to the case study of aquaculture in the Åland Islands

Scale	Rules	Authority	Applicable sea area
European Union (EU)	WFD Dir. 2000/60 (fresh and sea water) MSFD Dir. 2008/56 (sea water) MSPD Dir. 2014/89 (spatial planning)	EU Commission	EU Member state (MS) coastal waters (internal waters + 1 nm from baseline) Marine waters (Terr. Sea, EEZ) Coastal and marine waters
Baltic Sea region	Helsinki Convention-framework	HELCOM	Baltic Sea, including internal waters of Baltic Sea Region (BSR) states
National (Finland)	EPA (527/2014), WA (587/2011), LUBA Ch 8a (MSP)	AVI	Internal waters, territorial sea, EEZ
Regional (Åland)	EPA (2008:124) WA (1996:61), Förordning 2007:57 om fiskodling (Enactment on Aquaculture)	ÅMHM	Internal + territorial sea

Notes: Abbreviations included in the table: Water Framework Directive (WFD), Marine Strategy Framework Directive (MSFD), Marine Spatial Planning Directive (MSPD), Exclusive Economic Zone (EEZ), Regional State Administrative Agency ('Aluehallintovirasto' – AVI), Åland Environmental and Health Protection Authority ('Ålands Miljö- och hälsoskyddsmyndighet' – ÅMHM); Environmental Protection Act (EPA), Water Act (WA), Finnish Land Use and Building Act (LUBA).

In Åland, new aquaculture businesses have not been permitted since the Åland Water Act entered into force in the late 1990s. Under Åland laws, the permits are required for installations producing more than 20 tonnes of fish per year.[9] The main rule guiding whether a permit should be issued is that any new or modified activity not subject to specific quality norms (which aquaculture is not) shall not contribute to eutrophication of the 'saltwater area' in question (Water Act, Ch. 5, section 9(2)).[10] The geographical extent of this rule is not entirely clear,[11] but in practice, the area concerned appears to have been interpreted as the four main sea area divisions made through section 30 and Annex 9 of the Water Regulation 2010: 93. This divides the marine areas of Åland into four main geographical segments, North, East, South, and West, from land to the baseline from which the territorial sea is measured. Hence, operators as a starting point should be free to move or conglomerate their aquaculture installations within these areas, because a mere shift of location does not contribute to eutrophication. Whether the rule applies beyond the baseline, within the territorial sea, is unclear, but to date there does not seem to have been much demand for installations that far out. Section 12 of the Water Act also includes

a local compensation rule, permitting increased emissions in case an 'improvement surplus' can be utilized.[12] This mechanism, however, has not been of much use in practice. A new Water Act, which will be decisive for the future development of the aquaculture industry in Åland, is currently being prepared.

More detailed rules for aquaculture installations are laid down in the Aquaculture Regulation (2007: 57), which only applies to salmon farming. The regulation provides minimum criteria for the location of installations (based on minimum depth, openness and water circulation).[13] Section 4 of the regulation further includes a formula under which the maximum environmental load of the aquaculture is to be calculated based on the weight of the fish and the feedstock.[14]

Two EU rules are particularly relevant in this regard, and their applicability is determined by geographical location: within one nautical mile of the baseline, the Water Framework Directive (Directive 2000/60, WFD) applies, and further out (covering the entire Baltic Sea except Russian waters), the Marine Strategy Framework Directive (MSFD). Both Directives adopt a goal-based and ecosystem-oriented approach. They set out generic goals to achieve good environmental/ecological status within a certain time period and establish a process to be carried out in Member States to define the environmental situation and the need for further measures and monitoring in a continuous process based on coordinated six-year cycles.[15] In view of the location of the Åland fish farms, the main EU rule of relevance is the WFD, which is considerably more specific than the MSFD. In addition, the Directives must be interpreted in light of the CJEU ruling in the *Weser* Case (C-461/13), implying that a permit should be denied if the proposed project risks deteriorating ecological quality elements in the coastal waters (see also Finnish Supreme Administrative Court 14.2.2018 t. 608). Rules aimed at protecting marine sites and habitats may impose further limitations on permits for aquaculture installations in the proximity of such areas.[16]

Apart from this, the general environmental law principles included in many regulatory layers may have an impact on permit decisions and conditions for particular aquaculture installations. For example, both the relevant Åland Acts and the Helsinki Convention provide for the application of the best available technology and best environmental practices.[17]

Apart from the legally binding rules and principles, 'soft law' (non-binding policy) instruments may play a role in the overall assessment. The Nutrient Reduction Scheme linked to HELCOM's Baltic Sea Action Plan, has as its objective a Baltic Sea 'unaffected by eutrophication', and consequently includes certain reduction targets. Yet, those actions do not cover aquaculture, and the scheme, in any event, sets national targets, not targets for subnational regions, such as Åland.[18] By contrast, the governance plans and programme of measures emanating from the EU Marine Directives discussed above will

guide policymakers.[19] Aquaculture in the Archipelago Sea/Åland was on HELCOM's list of environmental hotspots earlier but was removed in 2002.

As to marine spatial planning, Åland produced its own (non-binding) plan in 2021 under Directive 2014/89.[20] However, despite a more ambitious approach in earlier proposals, all private waters (owned by individuals or collective entities, which amounts to most waters inside the baseline) have been excluded from the plan. Since the remaining public waters (coastal and marine areas belonging to the local Åland government, outside the baseline) have not been properly assessed for the purpose, aquaculture installations do not feature in the plan at all.[21] Åland does not have an Exclusive Economic Zone (EEZ) of its own.[22]

SEARCHING FOR AN OPTIMUM BALANCE

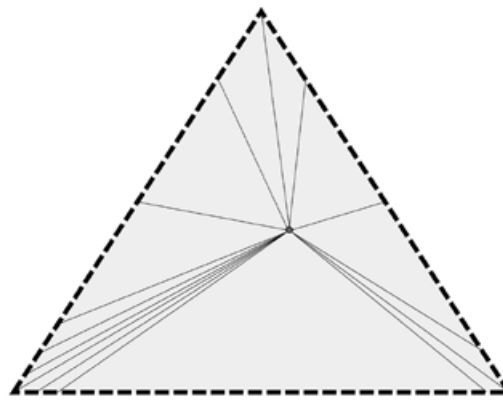
General

It follows from the above that different perspectives may, and will, give different outcomes as to whether and how new applications for aquaculture in the Åland archipelago should be approached and decided. Economic interests favour one solution, environmental considerations another, and societal concerns a third, which leads to the question of how to balance the different perspectives to achieve a (socially, economically and environmentally) sustainable level of activity.

To address competing interests, it is possible, even common, to undertake cost–benefit analyses, emphasizing the optimal economic justification for the decision. Similarly, it is common (for certain bigger installations, it is even required) to prepare advance studies on the environmental impact to gain an overview of the environmental consequences of various decisions. It is also feasible to undertake, for example, spatial prioritization (i.e., to figure out where the impact on the environment and competing interests is least (e.g., Virtanen et al., 2022). Yet, *merging* or balancing this – and other – information about the optimal decision, and weighing them against each other, produces severe methodological challenges, with few existing models. Indeed, different disciplines tend to have their own methods, concepts, and traditions for problem-solving, but such unidisciplinary tools are by definition inadequate for resolving conflicts between different perspectives, such as the ones we are confronted with here (Vikström, 2011).

In the absence of commonly accepted scientific principles to deal with the question, and in keeping with the three perspectives on sustainability, a triangle is used in Figure 6.2 to illustrate the matter. In the triangle, the relationships and tensions between the three perspectives are linked to each other through the three legs. Somewhere inside this triangle lies a fictive optimal solution

for a given decision, as illustrated by the small circle, the position of which is determined by a number of strings pulling it in different directions at variable intensity (the 'strings' in the picture). The optimum position (the small circle) depends on the strength and direction of the various interests (strings), which are not only pulled towards the corners of the triangle but may also be situated somewhere on the leg between them, if a particular interest serves two concerns (e.g., economic benefits for the enterprise will also benefit the community in several ways, or an environmentally sustainable solution raising aquaculture's output). Strong concerns will have stronger pulling forces and vice versa.



Note: The triangle illustrates the relationships between three perspectives, i.e., environmental, economic, and social perspectives, and the different 'strings' pulling the optimal solution in different directions.

Figure 6.2 Conceptual figure of balancing sustainability perspectives to solve a wicked problem

In reality, of course, countless such imaginary strings exist, and it may not be feasible to identify them all or to assess their strengths and hence find an optimal solution, even in theory. However, they serve our purpose of focusing on the interaction between the three interests and, hence, on the 'starting point' of the string on the larger triangle, through a few examples. At this stage, the relevant geographic scale is the municipal/sub-regional level.

Economy–Environment Relationship

Economic considerations at the entrepreneurial level represent the main drivers behind aquaculture in the archipelago. In a local setting, the nutrition perspective is less dominant; most of the fish cultivated in archipelago-based fish farms tends to be bought and consumed outside the community, often exported beyond the borders of the region. The relationship between economic and environmental concerns is probably the key clash of interests when it comes to archipelagic aquaculture. The issues raised are illustrated by means of four different examples.

First, there is the question of the optimal location of the installations. From a business perspective, many considerations favour a sheltered close-to-shore location, including proximity to transport and service work and less harsh weather conditions (notably waves) that otherwise would require investments in stronger structures to withstand the increased stress. On the other hand, the local negative environmental impact will be most dramatic in sheltered areas with limited exchange of seawater. As discussed above, moving the aquaculture installations to more open and deeper waters also comes with some benefits, mainly thanks to improved exchange of water. Hence, a sheltered location with vast exchange of water would seem ideal.

Another question that raises similar considerations relates to the optimal size of the installation. Merging several installations close to each other and increasing their size (which has been the tendency over the past decade or so) would clearly provide economic benefits, but at the same time concentrate the nutrient emissions and hence intensify negative local environmental impacts. However, larger production units also improve the economy of the installation, which tends to improve the business's ability to invest in more efficient feed systems and other more sustainable technologies.

A third basic choice that is decisive for the intensity of environmental and business considerations relates to the technology used. At the high end of the environmental side, we find installations which permit the operation of aquaculture with reduced nutrient emissions. Semi-closed or closed net pens have proven to be a solution for producing healthier fish, entailing less direct pollution, but increase the need for maintenance (cleaning operations).[23] These systems are the most realistic technologies for mitigating nutrient pollution at this level (Badiola et al., 2018, Soininen et al., 2019). Taking the matter one step further, recirculation aquaculture systems are currently permitted only in closed inland water systems (lakes) or onshore, hence allowing them to benefit from available shore-based infrastructure. These technologies, however, come at a price. As of now, the main restraint on a shift towards sustainable aquaculture practices is the cost gap in relation to existing technologies (and perhaps

their other sustainability dimensions), while land-based technologies are not economically viable at all (Martins et al., 2010, Zou et al., 2018).

The balance between environmental and economic considerations is also affected by operational decisions. Emissions may, for example, be reduced by natural mitigation measures such as multi-trophic aquaculture (e.g., the simultaneous farming of filter-feeding molluscs, such as mussels and oysters, and seaweed, that act as extractors of inorganic and organic nutrients (Chopin et al., 2013). The effectiveness of such approaches at the Baltic Sea region (BSR) level is acknowledged, but its effect in the Finnish archipelago's cold and low-salinity water conditions remains uncertain (Kotta et al., 2020).

Economy–Social Relationship

The sociocultural effects of aquaculture are multifaceted. On the one hand, aquaculture brings several (collective) benefits to the community (mainly economic, but also entailing much broader gains such as employment opportunities enabling conditions for a living archipelagic community, a local population required to maintain schools, local services, etc.). On the other hand, the impact of aquaculture on the local community is not only positive. Apart from the concerns directly associated with the environmental impact, aquaculture may impact the community's reputation and hence reduce its 'liveability' status. Such issues may directly impact the local economy in various fields, including recreation and tourism, independent of concrete environmental damage. Cottage tourists or sports fishermen, for example, may be among those who shun communities that are known for their positive stance on aquaculture.

The societal benefits at the local level are also evaluated in terms of where the cultivated fish is sold. Endorsing aquaculture as part of the 'local community project' can be presumed to be significantly weaker if all fish is exported to distant regions or not even used for human consumption. At the same time, the global drivers linked to efficient production of proteins and human nutrition are likely to play a more limited role at the local level, where such concerns may not be perceived as crucial ones.

Aquaculture is neither an old traditional industry in the Finnish archipelago (the first installations were introduced in the early 1960s) nor does it enjoy the same ethno-cultural recognition and justification as, for example, smaller-scale coastal fisheries. Yet, in a relatively short time, this industry has established a broad network of supporters in the communities, not least by persons and policy interests emphasizing the need for jobs in remote areas (Ålands Landskapsregering, 2011).

Aquaculture also raises issues of justice at the local level: is it fair that a few corporations and individuals enrich themselves at the expense of the shared

environment and community values? Such concerns are exacerbated if the individuals and corporations concerned are not locally based, further decreasing the share of economic gains that stay in the local economy, through taxes, spending, and otherwise.

Social–Environment Relationship

A community's dependency on acceptable environmental conditions is rarely more evident than in the case of archipelagic communities' dependency on a healthy marine environment. Reliance on earlier industries such as coastal fisheries has shifted to new industries, including recreation, tourism, and indeed aquaculture itself, all of which depend as much – if not more – on a functioning marine ecosystem.

Clearly, direct environmental harm caused by aquaculture installations will have a very negative impact on many aspects of the community, including all the indirect concerns discussed above in relation to the economy. Local entrepreneurs operating tourism facilities, for example, will be directly affected by reduced environmental quality and will normally oppose such establishments being installed in their vicinity. Similarly, interest in the location by both potential new residents (permanent or residential) will be significantly affected, given that peacefulness and a sense of 'back to (unspoilt) nature' can attract people to settle in a location (e.g., Van Den Berg et al., 2007).

Societal attitudes to novel aquaculture installations are hence often coloured by the NIMBY syndrome, according to which locals may very well be positive towards such installations – as long as they do not impact their own interests and areas of significance, i.e., their immediate neighbourhoods.

Other tensions between environmental and community interests are readily appreciable in the field of technology choices in aquaculture. This is particularly noticeable in the field of land-based installations, which could offer significant reductions to marine pollution but at the same time involve significant sacrifices by the municipality as a whole – for example, in the form of increased capacity demands on the sewage treatment facility or electricity supply.

Towards an Interdisciplinary Optimum?

In view of the various interests involved and their interrelationships, the question arises as to whether it is feasible at all to identify an optimal balance of interests that could guide decision-making in the field (which authorities are expected to do continuously, despite limited guidance from the legal and scientific framework). Hence, the remainder of this section seeks to identify

some pathways, or even solutions, which might be defendable based on the observations made thus far.

A closer reading of the tensions between various interests above suggests that some conclusions may be drawn. An environmentally defendable installation does not currently appear to be feasible in terms of cost and/or state of technological development. In the meantime, it seems that the main (environmental and social) drawbacks of the installations are quite local in nature, depending on the (perceived or real) harm caused by the installations to their closest neighbours. At the same time, most environmental concerns appear to be reducible at the local level by placing the installations in carefully selected locations where (natural) water circulation ensures sufficient dilution of emissions. Relocating the facilities further offshore will also limit the direct environmental impacts that occur in shallower waters and allows more flexibility in selecting the installation location.

The principal drawbacks of this solution consist of increased costs and more difficult operating conditions, but recent developments suggest that these might still be manageable.[24] It should be borne in mind that problem avoidance in the format of mitigating local pollution (and related legal disputes), and in improving the prospect of social endorsement of the activity, also has a monetary value for the entrepreneurs in terms of direct savings, but also corporate image, social acceptability, etc. It also appears likely that, from an economic point of view, a shift of the installations further out to sea permits the establishment of larger entities and hence enables savings in economies of scale.

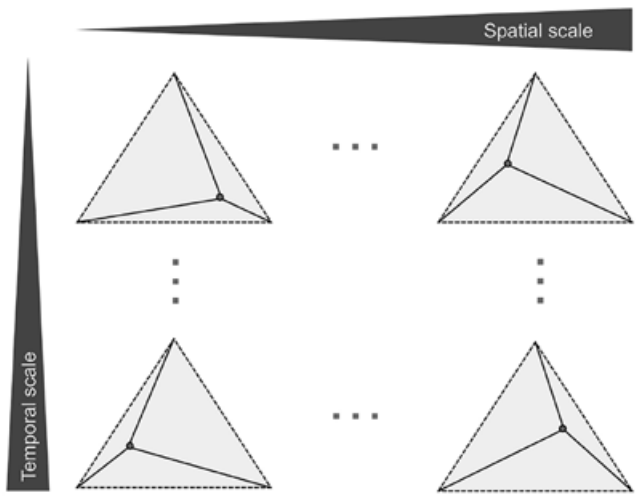
In addition, moving the installations out to sea is – perhaps inadvertently – also encouraged by the existing legal framework, originating in EU law. As was noted earlier, the EU Marine Directives provide few restrictions and limitations beyond the one nautical mile line from the baseline, which separates the MSFD from the WFD, and the scope of the *Weser* judgment. The restraints imposed by the *Weser* judgment do not apply beyond that limit.

ADDING DIMENSIONS

General

The broad-brush overview of considerations above has indicated that there may indeed be an optimal place for the small circle in Figure 6.2, or at least a certain limited area in which such a circle can be placed in view of the various pulling forces and direction of the considerations at play. However, solving wicked problems plays out in multilevel and multiscale contexts: actors and processes operating on different scales and levels are involved, depending on how the spatial, temporal, administrative, and other relevant scales of the problem are defined. Shifting the scale frame can redefine the problem, foregrounding new

solutions and political structures while foreclosing others (Buizer et al., 2011; Tynkkynen, 2015). The definition of the spatial and temporal scale of environmental problems is an inseparable part of their understanding and solution (van Lieshout et al., 2011). The definition of local problems includes a discussion on the nature and boundaries of the locality in question, and on the relationship between the local community and trans-local powers (Peuhkuri, 2002). The knowledge base that the actors represent affects their way of framing the spatial and temporal scale of the problems. Emphasizing scientific interpretation often supports trans-local framing and may thus transfer powers from local communities (Cash et al., 2006; Folke & Berkes, 1995).



Note: The figure seeks to illustrate that the optimal balance of interests (for permitting an aquaculture installation) may differ widely depending on the spatial or temporal scale that underlies decision-making, i.e., depending on the geographical area concerned and the time perspective.

Figure 6.3 *The triangle from Figure 6.2 across differing temporal and spatial (administrative) scales*

The Spatial Scale, or Administrative Levels

The arguments against and in favour of certain solutions introduced earlier in this chapter were premised on a limited geographical perspective. The consequences of interests and impacts beyond the municipality concerned were not considered. However, it is not necessarily more correct to assess the

matter at a municipal level than at some other level(s). In the following, five spatial scales are referred to as: local (municipality), (sub)regional (Åland/ Archipelago Sea), national (Finland), BSR, and EU. Even the global scale could be added as overall global nutrition demand, combined with the depletion of captured fish, represent the main drivers for aquaculture in general. This concern may be expected to diminish as a factor in decision-making as the governance level is scaled down. At the local level, nutrition demand is not a main consideration for aquaculture. Similarly, regarding environmental concerns, eutrophication does not feature prominently as a marine environmental threat at global, or even at the EU, level. It is a source of concern mainly for the BSR, due to its specific geographical and ecological characteristics (Joas et al., 2022). But even at the BSR scale, as noted above, aquaculture does not represent a very big contribution to the overall nutrient input to the Baltic Sea.[25] By contrast, at a subregional level, such as Åland, this may even represent the most serious source of pollution, both in physical and ideational terms.

Societal interests, too, differ according to perspective. While considerations of the exact location of the installation represent the main concern at the local level, higher levels of governance make other societal issues, such as a 'living archipelago' and food self-sufficiency, more relevant. Yet, the subregional level, between the national and municipality levels, will normally not have the means to benefit directly from economic gains associated with the installations.

The tools available at different governance levels vary, too. Higher ones, such as the subregional government or national level, have better opportunities to promote a change towards more technologically advanced installations through regulation and other governance mechanisms, including funding and fiscal and other support measures, while research and development funding to stimulate such technology development is mainly available at national and EU levels.

Some of the proposed solutions build upon – and even assume – a certain scale of framing to make sense. A good example is the idea of promoting the use of feedstock based on fish caught in the Baltic Sea. The argument underlying this project is that if the feedstock consists of fish only caught in the BSR, its release into the aquatic environment will not increase the overall load of nutrients in this region. While the ecological justifiability of using this solution for allowing more emissions locally may be debated, it is clear that its underlying spatial logic extends beyond the area for which the decision-maker is responsible. Traditionally, Finnish legislation does not accept *ex situ* offsetting in other regions as a containment measure for environmental harm, and the shift towards this type of feedstock has, accordingly, not been accepted in the decision-making by (subregional) permit authorities to date (Kostamo et al. 2020; Leino & Belinskij, 2018; Setälä et al., 2018; Soininen et al., 2019).

All this suggests that both the concerns and what may be regarded as the optimal balance of interests vary significantly with the chosen spatial (and administrative) scale.

The Temporal Dimension: The Relevant Time Frame

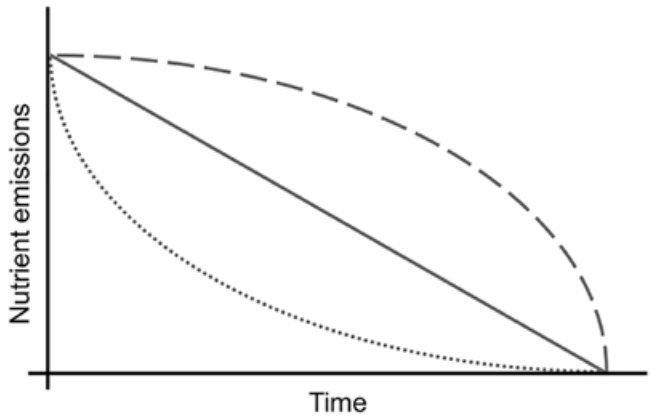
Widening the temporal scope of the assessment necessarily affects the number of issues to be considered and adds significant uncertainty (e.g., climate change predictions and developments, food needs, capture fish stocks, and technological development). For example, in the longer run, we can expect innovation and economies of scale to reduce the cost gap between closed fish production systems and fish farmed in open net pens. On the revenue side, we should also be able to anticipate that some sort of sustainability labelling may be rewarded with a price premium by consumers, although too much hope should not be put on green consumerism in the short term (Wang et al., 2021). Financiers may also exert pressure on polluting fish farmers through stricter environmental, social, and governance (ESG) reporting criteria. The question is what emission levels we can accept during the transition period.

Climate-smart solutions call for consideration of additional factors (e.g., amount and type of energy and fuel required to maintain and service the installations), which may provide an additional consideration in the search for an optimal balance (e.g., as the long-term shore-based solution requires energy for heating, cooling, and circulation).

In the bigger picture, all measures indicated as solutions here represent temporal (interim) steps towards the fully sustainable technology solution, which allows aquaculture to be performed with minimal amounts of energy and water, producing no nutrient discharge. However, whether and when such a solution is available is far from certain. The legal principle promoting 'best available technology' only refers to existing technologies, which does not encourage taking into account future developments at the permit stage.

Yet, as Figure 6.4 illustrates, different paths for arriving at an optimal result of zero emissions entail very different environmental impacts in the interim. The overall emissions are significantly higher under the scenario pictured by the dashed line than under the dotted one, which illustrates the significance of early action with respect to emission reduction requirements, and hence the importance of choices in the early phases of the temporal scale, rather than only focusing on the eventual outcome.

A second example relates to climate change, which is expected to significantly impact the ecology in the Baltic Sea and to accentuate the impacts of its eutrophication over time.[26] Yet, this aspect features nowhere among the considerations on which to base decisions for aquaculture installations. In the Åland example, this may be covered under the general prohibition on increas-



Note: The trajectory towards a potential future solution might drive the priority and order of actions taken. In the example figure (e.g., representing the overall emissions of nutrients to a particular region), a reduction in nutrient inputs can be negative exponential (decreases at a decreasing rate) over time (dotted line), steady (straight line), or decreases at an increasing rate (dashed line).

Figure 6.4 Conceptual figure of temporal trajectories to finding a solution

ing eutrophication under section 9(2) of the Water Act, but in practice the impact of climate change on the marine environment and eutrophication does not appear to have been part of decision-making to date.

Public opinion may change over time, too. The perception and tolerability of aquaculture installations correlate closely with the presence of algal blooms, for example. Conversely, the growing demand for efficient nutrition production and the declining state of capture fisheries may also significantly alter the readiness of people, at least on a larger geographical scale, to adopt a more favourable stance to aquaculture.

In view of such future variations of the premises affecting the optimal decision, the question is what the 'right' time perspective is or should be for deciding on the matter. Ideally, a science-based approach might be expected to cover the foreseeable future. As has been shown, however, the future may not be foreseeable at all, and we may neither know nor even understand the level and nature of the challenges that future developments bring about. The uncertainties are not necessarily of a kind that would invoke the guidance offered by the precautionary principle. From a legal point, these risks have been mitigated

(but far from eliminated) by the temporary limitations of the permit to five to ten years.

CONCLUSIONS

The discussion above has sought to illustrate the multitude of dimensions and issues that surround the decision-making process on aquaculture installations in Åland and beyond. Apart from the factual circumstances, which have not been the focal point of this chapter, the variety and complexity of perspectives involved cast doubts on whether a scientifically justifiable decision can be expected in view of the 'wickedness' of the problem.

The competing interests of the different aspects of sustainability (economic, social and environmental interests) promote different solutions to the basic question of whether such installations should be permitted or not, and on what conditions. But even if it were possible to identify a particular solution, in the form of an optimal balance of the interests at stake in a particular setting, that solution would necessarily be affected by the temporal and spatial dimensions considered and hence be relative to a particular time or geographic perspective. What may seem like the right decision from a local perspective looks very different if the scale is shifted to the national or Baltic Sea level, or if future developments are to be included in the equation. In view of this, there may not even be an optimal balance that could be defended on scientific grounds, particularly if the broader geographical and temporal scales are brought into the picture.

In searching for an optimum in an interdisciplinary context, the question will inevitably also be raised as to whether the matter is indeed confined to balancing competing perspectives and interests of various stakeholders, or whether it also involves prioritizing between competing advice offered by different scientific disciplines. Where science does not offer tools for prioritization, which it rarely does, the issue is left to decision-makers' and policy-makers' own judgement.

Making more informed decisions, on aquaculture installations or otherwise, is also linked to the amount of knowledge available. While knowledge on this matter is by no means complete, it is probably fair to assume that today we have enough knowledge about aquaculture's environmental impact and other effects to make informed decisions. On this basis, placing environmental concerns in the foreground would favour a very restrictive policy with respect to salmon and trout farming installations in the Åland waters. However, even the most informed decision-maker will not be able to prioritize between the competing interests that underlie each application. Moreover, if only permit authorities are left to defend the environmental interest, while other institutions and stakeholders promote the social and economic interests involved, an insti-

tutional imbalance may be inherent in the process, which in itself may serve to strengthen, rather than weaken, antagonism between various stakeholders and perspectives.

The permit authorities in charge of decision-making are supposed to be neutral, but they are offered rather limited regulatory guidance on this matter, which contributes to uncertainty in the field for all stakeholders (Galland & McDaniels, 2008). More specific regulatory guidance, e.g., on the geographical and temporal scope, or on the relevance of compensatory measures, would reduce such uncertainties, but would not do away with the fundamental problem of prioritizing between interests and scientific advice.

This chapter has sought to contribute to the debate on transdisciplinary decision-making with an illustrative case study pinpointing the challenges linked to making informed, real-world decisions about permits to exploit the sea. Decisions involving sustainability considerations often constitute wicked problems. This case study highlights that even in a comparatively straightforward case of decision-making, where information is available, governance is clear and the end objective (i.e., the core elements of sustainable aquaculture) is by and large agreed on by all involved, there are serious challenges in finding an optimum balance, even for a given temporal and spatial/administrative scale. The absence of a 'right' spatial and temporal scale for the analysis further adds to the wickedness of the matter.

Further research on this topic might, for example, add more cases helping us to contextualize the decision-making process and understand other dimensions involved in it. The perspective of additional scientific disciplines, such as those representing humanism and cultural studies, would also be important, but would no doubt add to the complexity of the matter. Scientific ways of dealing with scientific disagreement in policy decisions appears to be a very under-studied field. As to processes, a closer linkage between science and stakeholder involvement, well ahead of the formal decision-making process, appears to be an important element of reducing conflicting interests to begin with, but the management of such a process deserves closer academic scrutiny.

NOTES

1. The writing of this chapter has been enabled by funding from the Academy of Finland. We are also grateful to a number of scientists and other experts, in particular FD Sonja Salovius-Laurén and FM Tony Cederberg, for their input and comments on earlier versions of this manuscript. Nevertheless, all the remaining mistakes are our own.
2. As to terminology, the text uses the term 'multidisciplinary' as referring to the involvement and relevance of two or more scientific disciplines or perspectives, 'inter-disciplinary' involves weighing different scientific perspectives against each other, and 'trans-disciplinary' refers to a full integration of different scien-

tific perspectives in the analysis of a particular question (see Introduction in this volume).

3. https://www.kalankasvatus.fi/kalanviljely/kalanviljely-elinkeinona/
4. See https://www.luke.fi/uutinen/itameri-tekoja-osa-3-vesiviljelyn-innovaatio-ohjelmassa-kehitetaan-ymparisto-ja-elinkeinotavoitteita-yhteen-sovittavaa-uudenlaista-kalankasvatusta/, accessed 27 August 2020.
5. See https://fifax.ax/en/investors/fifax-as-an-investment.
6. https://www.kalankasvatus.fi/brando-laxin-kirjolohelle-vastuullisen-kalankasvatuksen-asc-sertifiointi/
7. See https://ec.europa.eu/commission/presscorner/detail/en/IP_21_4202.
8. See www.fiskodlarna.ax; https://freshfish.ax/.
9. Åland Water Act (1996: 61), Chapter 6, section 16, and Environmental Protection Act section 10(1)(a). This is more than the corresponding Finnish requirements, under which the permit obligation applies to all fish farms using at least two tonnes of fish fodder or equivalent annually and operations with an annual weight of reared fish greater than two tonnes (EPAF Annex I, Table 2, point. 11(c)) and Chapter 3, section 2 of the Water Act of Finland (WAF, 587/2011).
10. In Swedish: 'Om inte kvalitetsnormer gäller för vattenområde i saltsjön syftande till att begränsa övergödning, såsom kvalitetsnormer avseende ekologiska förhållanden eller kvalitetsnormer i enlighet med 4 § 1 mom., får ny eller ändrad markanvändningsåtgärd eller verksamhet komma till stånd i vattenområdet eller dess tillrinningsområde endast om det visas att åtgärden eller verksamheten inte kan bidra till ökad övergödning i området eller att förbättringsöverskott utnyttjas enligt bestämmelserna i 12 §.' In broad terms, this means that in the absence of specific quality norms, new or altered land-use measures or activities may only take place in the water area or its catchment area if it is shown that the measure or activity cannot contribute to increased eutrophication in the area, or that surpluses are utilized in accordance with section 12 of the same Act.
11. Sea area in this regard is defined in Ch. 1 section 3(1)(3) only as 'area that is not only temporarily covered by surface water and whose border with land is assessed according to the mean water level' (original Swedish: 'Område som inte endast tillfälligt är täckt av ytvatten och vars gräns mot land bedöms enligt medelvattenståndet').
12. Compensation measures are not available in Finland generally (YM 2020: 22, p. 50).
13. Regulation Ch 3. In the Appendix a map is given for six sea areas that are considered 'internal waters' for the purpose of the regulation, where stricter location requirements apply.
14. Under the formula, the annual load may not exceed 6 g phosphorus and 50 g nitrogen per kilogram of produced fish, assuming that the weight ratio of the farmed fish in question is 0.4% phosphorus and 2.75% nitrogen.
15. Åtgärdsprogram 2022–2027, förvaltningsplan 2022–2027, derived from https://www.regeringen.ax/styrdokument-rapporter-publikationer/ramdirektivet-vatten-0.
16. Notably the Natura 2000 network of protected sites established under the EU's Birds and Habitats Directives, but may also include other forms of nature reserves, bird protection areas, sites protected under the RAMSAR Convention on Wetlands, or Baltic Sea Protected Areas. Such protected areas are governed at regional level by the Åland Nature Conservation Act (Landskapslag 1998:82 om naturvård), but also by the Water Act (1996: 61) and the Environmental

Protection Act (2008: 124). Currently 2.8% of the Åland waters are protected by such measures, well below the targets of 10% adopted in the Convention on the Protection of Biological Diversity and included in the Åland sustainability agenda, and the 30% target set by the EU. See also Rinne et al. (2019).

17. Åland Environmental Act sections 1, 4 and 4a, and Water Act Chapter 4, sections 6 and 7(2). Helsinki Convention Article 3(3) and Annex II. (See also in Finland: EPA section 6 (operator has a duty to be aware of environmental risks); section 8 (best available technology to be used); and section 20 (precautionary principle).)
18. Åland program of measures 2022–2027, p. 16: 'The reduction targets for 2021 in HELCOM's Baltic Sea Action Plan play a role to the extent that *landskaps-regeringen* chooses to take these into its national plans' (original Swedish: 'HELCOM:s Baltic Sea Action Plans reduktionsmål till 2021 spelar en roll i den utsträckning landskapsregeringen väljer att beakta dessa i sina nationella planer').
19. Ibid., FIN: merenhoitosuunnitelma: Location (2014); Strategy (2022).
20. Based on Chapter 5, sections 24a and 24b in the Åland Water Act (1996: 61). See also https://www.regeringen.ax/sites/www.regeringen.ax/files/attachments/page/karakteristik_for_planeringsomradet_aland.pdf.
21. See https://www.regeringen.ax/sites/default/files/attachments/page/havsplan.pdf; https://www.regeringen.ax/sites/www.regeringen.ax/files/attachments/page/forklaring-till-markeringar-i-havsplanen.pdf.
22. This sea area belongs to Finland and hence is covered by the Finnish Environmental Protection Act and Water Act.
23. See, e.g., https://nasf.is/en/open-and-closed-containments/.
24. See, e.g., the application (by an Åland-based aquaculture company) for large offshore aquaculture installations outside Kaskö in the Bothnian Sea, Decision by the Centre for Economic Development, Transport and the Environment EPOELY/418/2020.
25. According to the Finnish Environment institute (SYKE), aquaculture only accounts for 1.4% of the total emissions of phosphorus and 0.7% of nitrogen emissions on a national level in Finland. See https://www.ymparisto.fi/sv-FI/Kartor_och_statistik/Belastning_pa_vattendrag_och_naturlig_urlakning.
26. See, e.g., the HELCOM Factsheets available at https://helcom.fi/wp-content/uploads/2021/09/Baltic-Sea-Climate-Change-Fact-Sheet-2021.pdf, with further references.

REFERENCES

Ålands Landskapsregering (2011). *Fiskodling på Åland ur ett helhetsperspektiv*. https://www.regeringen.ax/sites/default/files/attachments/page/samradsrapport-fiskodlingar.pdf

Ålands Landskapsregering (2020). *Förvaltningsplan för de åländska vattnen 2022–2027* https://www.regeringen.ax/sites/default/files/attachments/guidedocument/forvaltningsplaner_for_de_alandska_vattnen_2022-2027.pdf

Ålands statistik och utredningsbyrå (2019). *Fiskenäringens betydelse för samhällsekonomin på Åland.* Rapport 2019:8. https://www.asub.ax/sites/default/files/reports/rapport_2019_8_fiskerinaringens_betydelse_for_samhallsekonomin_pa_aland.pdf

Aps, R., & Lassen, H. (2010). Recovery of depleted Baltic Sea fish stocks: a review. *ICES Journal of Marine Science*, *67*(9), 1856–1860.

Asche, F., Roll, K. H., Sandvold, H. N., Sørvig, A., & Zhang, D. (2013). Salmon aquaculture: larger companies and increased production. *Aquaculture Economics & Management*, *17*(3), 322–339. https://doi.org/10.1080/13657305.2013.812156

Badiola, M., Basurko, O., Piedrahita, R., Hundley, P., & Mendiola, D. (2018). Energy use in recirculating aquaculture systems (RAS): a review. *Aquacultural Engineering*, *81*, 57–70. https://doi.org/10.1016/j.aquaeng.2018.03.003

Baltic Marine Environment Protection Commission (2021), HELCOM Baltic Sea Action Plan – 2021 update. https://helcom.fi/wp-content/uploads/2021/10/Baltic-Sea-Action-Plan-2021-update.pdf

Buizer, M., Arts, B., & Kok, K. (2011). Governance, scale and the environment: the importance of recognizing knowledge claims in transdisciplinary arenas. *Ecology & Society*, *16*(1), 21. http://www.ecologyandsociety.org/vol16/iss1/art21/

Burningham, K., Barnett, J., & Walker, G. (2015). An array of deficits: unpacking NIMBY discourses in wind energy developers' conceptualizations of their local opponents. *Society & Natural Resources*, *28*(3), 246–260. https://doi.org/10.1080/08941920.2014.933923

Carballeira Braña, C. B., Cerbule, K., Senff, P., & Stolz, I. K. (2021). Towards environmental sustainability in marine finfish aquaculture. *Frontiers in Marine Science*, *8*. https://doi.org/10.3389/fmars.2021.666662

Carrigan, M., & Attalla, A. (2001). The myth of the ethical consumer: do ethics matter in purchase behavior? *Journal of Consumer Marketing*, *18*(7), 560–577. https://doi.org/10.1108/07363760110410263

Cash, D. W., Adger, W. N., Berkes, F., Garden, P., Lebel, L., Olsson, P., Pritchard, L., & Young, O. (2006). Scale and cross-scale dynamics: governance and information in a multilevel world. *Ecology & Society*, *11*(8). http://www.ecologyandsociety.org/vol11/iss2/art8/214

Chopin, T., Cooper, J. A., Reid, G., Cross, S, & Moore, C. (2013). Open-water integrated multi-trophic aquaculture: environmental biomitigation and economic diversification of fed aquaculture by extractive aquaculture. *Reviews in Aquaculture*, *4*, 209–220. https://doi.org/10.1111/j.1753-5131.2012.01074.x

D'Orbcastel, E. R., Blancheton, J. P., & Aubin, J. (2009). Towards environmentally sustainable aquaculture: comparison between two trout farming systems using life cycle assessment. *Aquacultural Engineering*, *40*(3), 113–119.

Ertör, I., & Ortega-Cerdà, M. (2015). Political lessons from early warnings: marine finfish aquaculture conflicts in Europe. *Marine Policy*, *51*, 202–210. https://doi.org/10.1016/j.marpol.2014.07.018

Folke, C., & Berkes, F. (1995). Mechanisms that link property rights to ecological systems. In S. Hanna & M. Munasinghe (Eds.), *Property Rights and the Environment, Social and Ecological Issues* (pp. 121–137). The World Bank.

Food and Agriculture Organization of the United Nations (2016). *The State of World Fisheries and Aquaculture, Contributing to Food Security and Nutrition for All.* FAO.

Food and Agriculture Organization of the United Nations (2022). *The State of World Fisheries and Aquaculture 2022*. *Towards Blue Transformation*. FAO. https://doi.org/10.4060/cc0461en

Galland, D., & McDaniels, T., (2008). Are new industry policies precautionary? The case of salmon aquaculture siting policy in British Columbia. *Environmental Science & Policy*, *11*(6), 517–532.

Hadjimichael, M. (2018). A call for a blue degrowth: unravelling the European Union's fisheries and maritime policies. *Marine Policy*, *94*, 158–164. https://doi.org/10.1016/j.marpol.2018.05.007

Helminen, H., & Honkanen, T. (2002). The role of aquaculture in the eutrophication process of the Archipelago Sea, SW Finland. *SIL Proceedings 1922–2010*, 28(3), 1176–1179, https://doi.org/10.1080/03680770.2001.11902639

Iversen, A., Asche, F., Hermansen, Ø., & Nystøyl, R. (2020). Production cost and competitiveness in major salmon farming countries 2003–2018. *Aquaculture*, *522*, article 735089. https://doi.org/10.1016/j.aquaculture.2020.735089

Joas, M., Ringbom, H., & Tynkkynen, N. (2022). The Baltic Sea and global environmental change: best in class in governance? In P. G. Harris (Ed.), *Routledge Handbook of Marine Governance and Global Environmental Change* (pp. 195–205). Routledge/Informa.

Kankainen, M., Setälä, J., Berrill, I. K., Ruohonen, K., Noble, C., & Schneider, O. (2012). How to measure the economic impacts of changes in growth, feed efficiency and survival in aquaculture. *Aquaculture Economics & Management*, *16*(4), 341–364. https://doi.org/10.1080/13657305.2012.729247

Kankainen, M., Setälä, J., Kause, A., Quinton, C., Airaksinen, S., & Koskela, J. (2016). Economic values of supply chain productivity and quality traits calculated for a farmed European whitefish breeding program. *Aquaculture Economics & Management*, *20*(2), 131–164. https://doi.org/10.1080/13657305.2016.1155961

Kinzig, A. P. (2001). Bridging disciplinary divides to address environmental and intellectual challenges. *Ecosystems*, *4*, 709–715. https://doi.org/10.1007/s10021-001-0039-7

Kostamo, K., Kymenvaara, S., Pekkonen, M., & Belinskij, A. (2020). *Nutrient compensation for aquatic coastal environment – legal, ecological and economic aspects in developing an offsetting concept.* Study for the Åland/Central Baltic SEABASED project.

Kotta, J., Futter, M., Kaasik, A., Liversage, K., Rätsep, M., Barboza, F. R., … & Virtanen, E. (2020). Cleaning up seas using blue growth initiatives: mussel farming for eutrophication control in the Baltic Sea. *Science of the Total Environment*, *709*, article 136144. https://doi.org/10.1016/j.scitotenv.2019.136144

Leino, L., & Belinskij, A. (2018). Vesienhoidollinen kompensaatio hankkeiden toteuttamisen edellytyksenä. *Ympäristöpolitiikan ja -oikeuden vuosikirja*, *XI*, 117–167.

Liu, Y., Rosten, T. W., Henriksen, K., Hognes, E. S., Summerfelt, S., & Vinci, B. (2016). Comparative economic performance and carbon footprint of two farming models for producing Atlantic salmon (*Salmo salar*): land-based closed containment system in freshwater and open net pen in seawater. *Aquacultural Engineering*, *71*, 1–12. https://doi.org/10.1016/j.aquaeng.2016.01.001

Mäkinen, T., Salmi, P., & Forsman, L. (2013). Towards interactive fish farming governance? A comparison of Finland and Sweden. *Aquaculture International*, *22*, 711–721. https://doi.org/10.1007/s10499-013-9700-3

Martins, C. I. M., Eding, E. H., Verdegem, M. C. J., Heinsbroek, L. T. N., Schneider, O., Blancheton, J. P., … & Verreth, J. A. J. (2010). New developments in recirculating aquaculture systems in Europe: a perspective on environmental sustainability. *Aquaculture Engineering*, *43*(3), 83–93. http://dx.doi.org/10.1016/j.aquaeng.2010.09.002

Nordström, M. C., & Bonsdorff, E. (2017). Organic enrichment simplifies marine benthic food web structure. *Limnology and Oceanography*, *62*(5), 2179–2188.

Peuhkuri, T. (2002). Knowledge and interpretation in environmental conflict: fish farming and eutrophication in the Archipelago Sea, SW Finland. *Landscape and Urban Planning*, *61*(2–4), 157–168. https://doi.org/10.1016/S0169-2046(02)00110-X

Räike, A., Taskinen, A., & Knuuttila, S. (2020). Nutrient export from Finnish rivers into the Baltic Sea has not decreased despite water protection measures. *Ambio*, *49*, 460–474.

Randau, K. (2012). Livscykelanalys av sex olika fiskodlingssystem [Unpublished Master's thesis, Uppsala University].

Reser, J. P., & Bentrupperbäumer, J. M. (2005). What and where are environmental values? Assessing the impacts of current diversity of use of 'environmental' and 'World Heritage' values. *Journal of Environmental Psychology*, *25*(2), 125–146.

Rinne, H., Björklund, C., Hämäläinen, J., Häggblom, M., & Salovius-Laurén, S. (2019). *Mapping Marine Natura 2000 habitats in Åland, Final report*. Forskninsgsrapporter från Husö biologiska station, No 153.

Salmi, P., & Mellanoura, J. (2020). Finnish small-scale fisheries: marginalisation or revival? In J. J. Pascual-Fernández, C. Pita, & M. Bavinck (Eds.), *Small-Scale Fisheries in Europe: Status, Resilience and Governance* (pp. 537–557). Springer. https://doi.org/10.1007/978-3-030-37371-9_26

Scalia, M., Barile, S., Saviano, M., & Farioli, F. (2018). Governance for sustainability: a triple-helix model. *Sustainability Science*, *13*, 1235–1244. https://doi.org/10.1007/s11625-018-0567-0

Scientific, Technical and Economic Committee for Fisheries (2021). The EU Aquaculture Sector – Economic report 2020 (STECF-20-12). EUR 28359 EN, Publications Office of the European Union. https://data.europa.eu/doi/10.2760/441510

Setälä, J., Kankainen, M., Vielma, J., Niukko, J., Pitkämäki, A., Saario, M., … & Tommila, P. (2016). *Itämerirehua kotimaisista kalavirroista.* Luonnonvara- ja biotalouden tutkimus, Luonnonvarakeskus. http://urn.fi/URN:ISBN:978-952-326-242-3

Setälä, J., Saario, M., Lindholm, T., Ekroos, A., Juvonen, T., Kankainen, M., … & Pitkänen, A. (2018). *Meriviljelyn luvituspilotit.* Valtioneuvoston kanslia. https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/160878/38-2018-Meriviljelyn%20luvituspilotit%202552018.pdf

Siggelkow, N. (2007). Persuasion with case studies. *Academy of Management Journal*, *50*(1), 20–24. https://doi.org/10.5465/amj.2007.24160882

Slater, M. J. (2017). Societal and economic impacts of aquaculture. *Journal of the World Aquaculture Society*, *48*(4). https://www.was.org/articles/Societal-and-Economic-Impacts-of-Aquaculture.aspx#

Soininen, N., Belinskij, A., Similä, J., & Kortet, R. (2019). Too important to fail? Evaluating legal adaptive capacity for increasing coastal and marine aquaculture production in EU-Finland. *Marine Policy*, *110*, article 103498. https://doi.org/10.1016/j.marpol.2019.04.002

Soininen, N., Raymond, C. M., Tuomisto, H., Ruotsalainen, L., Thorén, H., Horcea Milcu, A. I., … & Nagatsu, M. (2022). Bridge over troubled water: managing compatibility and conflict among thought collectives in sustainability science. *Sustainability Science*, *17*(2), 27–44.

Tynkkynen, N. (2015). Baltic Sea environment, knowledge and the politics of scale. *Journal of Environmental Policy & Planning*, *17*(2), 201–216. https://doi.org/10.1080/1523908X.2014.936582

United Nations World Commission on Environment and Development (1987). *Report of the World Commission on Environment and Development: Our Common Future*. Oxford University Press. https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

Van Den Berg, A. E., Hartig, T., & Staats, H. (2007). Preference for nature in urbanized societies: stress, restoration, and the pursuit of sustainability. *Journal of Social Issues*, *63*(1), 79–96.

Van Lieshout, M., Dewulf, A., Aarts, N., & Termeer, C. (2011). Do scale frames matter? Scale frame mismatches in the decision-making process of a 'mega farm' in a small Dutch village. *Ecology and Society*, *16*(1). http://www.jstor.org/stable/26268852

Varjopuro, R., Sahivirta, E., Mäkinen, T., & Helminen, H. (2000). Regulation and monitoring of marine aquaculture in Finland. *Journal of Applied Ichthyology*, *16*, 148–156. https://doi.org/10.1046/j.1439-0426.2000.00255

Vikström, B. (2011). Vem kan vi lita på – när är kunskapen tillräcklig? In E. Bonsdorff, P. Hagman, M. Joas, T. Kurtén, & B. Vikström (Eds.), *Konflikter i skärgårdshavsmiljön* (pp. 137–158). Åbo Akademis förlag.

Virtanen, E. A., Lappalainen, J., Nurmi, M., Viitasalo, M., Tikanmäki, M., Heinonen, J., … & Moilanen, A. (2022). Balancing profitability of energy production, societal impacts and biodiversity in offshore wind farm design. *Renewable and Sustainable Energy Reviews*, *158*, article 112087.

Wang, J., Shen, M., & Chu, M. (2021). Why is green consumption easier said than done? Exploring the green consumption attitude–intention gap in China with behavioral reasoning theory. *Cleaner and Responsible Consumption*, *2*, article 100015. https://doi.org/10.1016/j.clrc.2021.100015

Yearley, S. (1991). *The Green Case. A Sociology of Environmental Issues, Arguments and Politics.* Harper Collins Academic.

Zou, S., Guan, L., Taylor, D. P., Kuhn, D., & He, Z. (2018). Nitrogen removal from water of recirculating aquaculture system by a microbial fuel cell. *Aquaculture*, *497*, 74–81. https://orbit.dtu.dk/en/publications/nitrogen-removal-from-water-of-recirculating-aquaculture-system-b