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# Visualizing the social in aquaculture: How social dimension components illustrate the effects of aquaculture across geographic scales

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ABSTRACT

Until very recently, governments of many countries, as well as their supporting organizations, have primarily addressed the biological, technical and economic aspects of aquaculture. In contrast, social and cultural aspects of aquaculture production have taken a backseat. Drawing on the observation that aquaculture development in Western Societies has largely failed to address these social effects across different scales and contexts, this paper offers a new way of capturing and visualising the diverse social dimensions of aquaculture. It does so by testing the ability to operationalise a set of social dimensions based on categories and indicators put forward by the United Nations, using several case studies across the North Atlantic. Local/regional stakeholder knowledge realms are combined with scientific expert knowledge to assess aquaculture operations against these indicators. The approach indicates that one needs to have a minimum farm size in order to have an impact of a visible scale for the different social dimension categories. While finfish aquaculture seems to be more social impactful than rope mussel farming, the latter can hold important cultural values and contribute to place-based understanding, connecting people with place and identity, thus playing a vital role in maintaining the working waterfront identity. It could be shown that aquaculture boosts a potential significant pull-factor to incentivise people to remain in the area, keeping coastal communities viable. By visualising the social effects of aquaculture, a door may be opened for new narratives on the sustainability of aquaculture that render social license and social acceptability more positive.

## 1. Introduction

The United Nations Sustainable Development Goals (SDGs) can be viewed as a bold commitment to produce a set of universal goals that meet the urgent environmental, political and economic challenges of our time [1]. However, whether current measurement and reporting models adequately capture contemporary conditions and challenges remains to be seen. One such challenge that has been gaining global attention is protecting marine biodiversity (linking to SDG 14) while utilizing marine areas, such as through aquaculture to ensure marine food security,

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creating income options and viable working waterfront communities, among others (linking especially to SDG 1, 2, 3, 8, 9, 11, 12).

Under this umbrella, governments of many countries, as well as their supporting organizations, have primarily addressed the biological and technical aspects of aquaculture. In contrast, social and cultural aspects of aquaculture production have taken a backseat compared with trade, technology and biological implications [2]. The SDGs however explicitly include social and economic goals that need to be recognized side by side if aquaculture is to fulfil its potential of feeding a hungry world [3,4]. Hence, we need to appropriately capture the complexity of the linkages between aquaculture practices and their economic, social, institutional and natural environments in order to be able to operationalise the three pillars of sustainability on a level playing field. Hereby identifying and visualising the relevant social dimensions must be seen as a first step, since the operationalisation of truly inclusive sustainability assessments of aquaculture are still in very nascent stages. The observable rise of the "social licence to operate" (SLO) and the "social acceptability" (SA) discourses in contemporary aquaculture research is a case in point for the failure to capture these linkages (see theoretical framing and review in Ref. [5]).

In this context, it is important to note the difference between SLO and SA, viewed here not only as epistemological categories [6–8] but are part of the social infrastructure that makes a given type of societal discourse possible. In both cases, focus is placed on the analysis of factors influencing public perceptions [9]. However, SLO is more focussed on the private sector and is communication oriented, fostering best practices for the private sector to be better accepted by not only local but regional, national and international communities [5,10–13]. Achieving SLO in this context is, therefore, the outcome of a successful exchange between the company and its public, at multiple geographical levels. Thus, SLO does not require a formal institutional process to guide the exchange between the company and the public [14].

In contrast, SA refers to a collective community-based evaluation [15] that reinforces participatory democracy, aiming at implementing governance processes based on deliberation and public involvement [16]. In this way, SA is a social construction [17] based on a trade-off between pros and cons. In this paper, we are utilizing these concepts in order to guide companies and the public alike to capture key social components that warrant greater attention in sustainable aquaculture development. We argue that knowledge on these components support management being context-specific and reflective of social conditions thus more likely to foster support on multiple levels.

Drawing on the observation that aquaculture development in Western Societies has largely failed to capture and evaluate these social effects across different geographic scales and contexts (see for example [2,5,18], the purpose here is to test the ability to operationalise a set of social dimensions using indicators which are based on the social dimension categories put forward by the United Nations (UN) [19–21]. [18] argues, countries should prioritise developing broader aquaculture policy that demonstrates measurable social benefits of aquaculture. These could include improved well-being from better access to farmed nutritious protein and wider participation in education. The latter made possible from income generation associated with sustainable aquaculture sector growth. Social components of aquaculture, as is the case with many natural resource sectors, remain poorly considered - if at all - in policy development.

The recommendations support the ongoing discourse on how to capture and evaluate the social effects of aquaculture on multiple levels and how these relate to meeting the SDG targets in the near future. That said, there is a need for inclusive systems thinking as a way to measure growth performance of natural resource sectors, such as aquaculture, to provide assurance about risk to investors and governments [22].

Our working hypothesis is that aquaculture is highly site-specific and contextual with sustainability outcomes depending strongly on the set-up and effects of the social dimensions on multiple levels. In this regard, operationalisation of the social dimensions of aquaculture are "wicked problems" in that all parameters cannot be specified, there is no single optimum to be attained and "… there is no criterion system nor rule which would tell you what is correct or false" [23]. However, we argue that, if key social components on multiple geographic scales are not met, it renders aquaculture production unsustainable in view of the UN-SDGs. This paper demonstrates the importance of integrating social dimensions of aquaculture to inform sustainable sector growth.

### 1.1. Research approach

Many countries in the North-Atlantic with potential to increase aquaculture development have large and deeply indented coastlines, diverse coastal ecosystems, and broad demographic segmentation. Aquaculture production set-up ranges from small-scale inshore to large-scale (industrial) offshore and from being family-run (small-holders) systems up to multi-national aquaculture enterprises. The siting of farms is highly contextual and all of these have different social implications on various spatial and temporal levels. In this wide geographical setting, we seleceted several case study examples, in focussing on two types of aquaculture production systems, rope mussel (Blue mussels, *Mytilus edulis*) and net-pen finfish (Atlantic salmon, *Salmo salar*) that represented typical aquaculture set-ups within the respective country for these types of production systems. Furthermore, to reduce variability in different geographical characteristics and to enhance social-ecological comparability, marine aquaculture from the North-Atlantic region was applied. This enabled us to employ experimental questions which addressed important social dimensions relevant to aquaculture across locations and social variables with a greater degree of commonality in geo-spatial scales.

The following section describes the case study areas used in this study and include Canadian Provinces and US States as well as European States. Of these, three located in the North West Atlantic (Nova Scotia, and Prince Edward Island (Canada) and Maine (USA)) and two in the North East Atlantic (Scotland (UK) and Ireland). For eastern Canada, Nova Scotia (NS) was selected for the finfish case study while Prince Edward Island (PEI) was selected for the mussel case study, given the low production of mussels in NS (less than 1000 tonnes) and the complete absence of detectable finfish aquaculture in PEI [24]. In Table 1, an overview of the central features of each case study area and a more detailed description of the central social features for finfish (Atlantic salmon) and mussel (Blue mussel) cultivation are provided.

All five case studies share a long maritime tradition and are characterized by spatially isolated and small coastal communities (<10.000 inhabitants) that are typically economically challenged in regard to i.e. low diversity in jobs and employment levels. In all cases, desirable waterfront and coastal property has led to an influx of wealthy property owners, although Maine's proximity to the eastern US megalopolis has accentuated this change by the strong development of waterfront properties.

Tourism is a vital industry in Nova Scotia (NS) and even larger in Maine. Since tourism also relies heavily on the aesthetic attractiveness, tourism operators express concerns about coastal aquaculture, posing risks to degrading the economic value of the seascapes [35]. Based on expert knowledge, it can be stated that in NS, a relatively wider area of the province contains finfish farms compared to Maine where this activity is almost exclusively restricted to the northernmost Washington County. Farms in Maine and New Brunswick (NB) in the contiguous Cobscook-Passamaquoddy Bays are operated by the same multi-national company. In contrast, farming of mussels (*Mytilus edulis*) and oysters (*Crassostrea virginica*) is more widespread through all areas of eastern Canada and the US New England. At present, mussel farming and salmon farming do not geographically overlap in Maine, although there is interest in developing mussel culture in Washington County where there is already oyster culture. In Prince Edward Island (PEI), the estuaries and ice/temperature conditions are not suitable for fish farming. However, PEI is the largest producer of mussels in North America, and there is a

**Table 1**
Contextual profile of aquaculture in the five case study areas across geographic scales (local, regional, national).

| Case study | Total population | Landmass ($km^b$) | Finfish production - Atlantic Salmon (T) | Mussel production -Blue Mussel (T) |
|---|---|---|---|---|
| Scotland | 5,295,403[a] | 78,789[b] | 189,707[c] | 8,232[d] |
| Ireland (R.O. I.) | 4,857,000[e] | 70,282[f] | 12,000[g] | 9,000 (Rope mussel only)[g] |
| Nova Scotia (Canada) | 923,598[h] | 52,942[h] | 11,078[i] | – |
| Prince Edward Island (Canada) | 142,907[h] | 5,686[h] | – | 20,004[i] |
| Maine (USA) | 1,338,404[j] | 91,646[j] | 11,127[k] | 964 [k] |

[a] [25] Population and Households. https://www.scotlandscensus.gov.uk/population-households.
[b] [26] Rural Scotland: key facts 2018. https://www.gov.scot/publications/rural-scotland-key-facts-2018/pages/2/.
[c] [27] Scottish Fish Farm Production Survey 2016, Marine Scotland Science. Available at: http://www.gov.scot/Publications/2017/09/5208.
[d] [28] Scottish Shellfish Farm Production Survey 2017, Marine Scotland Science. Available at: http://www.gov.scot/Resource/0048/00484806.pdf.
[e] [29]. https://www.cso.ie/en/statistics/population/.
[f] [30] (www.Gov.ie) http://www.gov.ie/en/essays/geography.html.
[g] [31]; BIM, The Irish Sea Fisheries Board. http://www.bim.ie/our-publications/aquaculture/.
[h] [32] Census Program. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E.
[i] [24] Canadian Aquaculture Production Statistics (tonnes). https://www.dfo-mpo.gc.ca/stats/aqua/aqua17-eng.htm.
[j] [33]. https://www.census.gov/quickfacts/ME.
[k] [34]. https://www.maine.gov/dmr/aquaculture/harvestdata/index.html.

longstanding tradition of mussel culture.

In Ireland and Scotland, tourism is also a mainstay of the economy which poses similar concerns in regard to aquaculture operations competing for the same space. Irish fish farming is located predominantly along the west coast of the country and is relatively small-scale in comparison to Scotland, where farms can be found spanning the entire west coast and the islands. In Ireland, the finfish industry is comprised of a combination of small-scale operators and one large multi-national company, all of which are organically certified. In contrast, the Scottish industry is dominated by five multi-national companies, of which the vast majority of are not organically certified. However, many are certified through the Aquaculture Stewardship Council standard and the Royal Society for Protection of Animals welfare standards. Rope mussel farms in Ireland are concentrated in the deep-water bays of the Southwest and in several deep-water bays farther north. The effects, as for Scotland, are mainly localized, though less so. Rope mussel and salmon farms occur in proximity to each other, within deep-water bays, as for Scotland. In Scotland, mussel farming and fish farms overlap regionally, so there is geographic coherency in their economic focus.

In all cases, aquaculture operations are reliant on employee populations which are local to their sites or can realistically commute at short notice. Nonetheless, there is a strong rural/urban dichotomy with finfish farms displaced from urban population centres. Production occurs in rural settings, and aquaculture is a targeted sector for enhancing the regional economies, often conflicting (or perceived as conflicting) with other coastal users, i.e. coastal tourism.

## 2. Materials and Methods

We selected the UN social dimension categories (Population (P), Health (H), Education (E), Work (W), Housing (HO)) as a point-of-departure, under which each of these umbrella categories a number of sub-categories were defined, i.e. social equity, working conditions, ownership of housing, access to food, etc (see details in Table 2). These were used to combine the knowledge of a group of experts (n = 18) during a series of meetings of the International Council for the Exploration of the Sea (ICES) Working Group Social and Economic Dimensions of Aquaculture (WGSEDA) between 2015 and 2018. A first set of context-specific variables for each of the UN social dimension categories was developed that considered the sustainability of aquaculture operations on multiple levels and were relevant for the case studies. The multi-disciplinary background from these experts ranged from media and communication science, social science, geography, aquaculture, fisheries, marine biology, oceanography as well as economics, governance, policy and engineering. The trends identified from the experts were verified by desktop studies and literature reviews. To operationalise the context-specific variables, we created interview questions that addressed various aspects of each social category, complemented by a set of potential quantitative and qualitative indicators (Table 2). This set of questions was then pre-tested and outcomes were further refined within the WGSEDA group.

This approach was then applied to the case studies to determine the prospective visibility of the social dimensions of aquaculture by utilizing a standardised procedure. Hereby the specific properties of each case study site were assessed for each of the social UN categories for each geographical spatial level (local, regional, national). Hereby local is defined as the direct aquaculture production site and its direct neighbouring communities, regional is geographically defined as combining several adjacent municipalities and the national geographical scale as the State level. In the case of Canada and USA, the latter level encompasses the East coast of Canada and the State of Maine, respectively. This is due to the large spatial and geographical diversity of these States.

In a second step, WGSEDA members provide the scores for the different indicators by reviewing peer-reviewed and grey literature, as well as using their expertise on the topic for each level and for each social variable. Where possible these scores were then validated with local experts from the case study sites. This validation was done in most cases in the form of semi-structured interviews with an operator working directly on an aquaculture site and opposing groups in order to obtain a full picture of the case study discourse, i.e. one salmon farmer, one mussel farmer, and one anti-fish farming NGO representative.

The scoring range for each spatial level (local, regional, national) was defined as follows: 0 = not relevant/does not apply; 1 = almost not relevant (1–20% relevant at this level); 2 = rather relevant (21–40% relevant at this level); 3 = more relevant (41–60% relevant at this level); 4 = relevant (61–80% relevant at this level); 5 = fully relevant/fully applied (81–100% relevant at this level).

In a final step, the outcomes were analysed among the WGSEDA members and a summary of the results is collated below.

## 3. Findings

### 3.1. The relative influence of aquaculture on the social dimesions at multiple scale levels

This section provides the results of the study according to the overarching variables defined in Table 2 (population, health, education, work, and housing) and the type of aquaculture being assessed; net-pen salmon finfish (Fig. 1 a-e) and rope mussels (Fig. 2 a-e), respectively. The central focus here is on the predominant differences and similarities between indicators, case studies and scales, as in the interests of space and readability it is not within the scope of this paper to describe every detail. The following figures provide the average score of the key components per each UN social dimension category.

**Table 2**
UN social dimension categories, their key components and context-specific variables related to aquaculture. For each of these, specific questions were developed which captured the impacts of aquaculture relative to other relevant sectors of the working waterfront. Potential quantitative/qualitative indicators were identified that illustrate the various potential social dimensions of the key components.

| UN Social Dimension Category | Key Components | Context-specific Variables | Impacts Relative to Other Relevant Sectors | Potential Quantitative/Qualitative Indicators |
|---|---|---|---|---|
| POPULATION | | | | |
| | Demographic change | Potential scale of development | *To what extent does aquaculture farm (AQF) affect demographic change?* | Age distribution; life expectancy; emigration and immigration |
| | Community structure | Role/importance/scale of aquaculture (AQ) | *How relevant is AQF to community structure?* | No. communities having AQ; no. AQFs per municipality; no. residents vs. transients (cross-municipal migration); no. people employed from total population (direct, secondary) |
| HEALTH | | | | |
| | Nutrition/Food | Food quality/security | *How relevant is AQF product as direct food source?* | Food access potential |
| | Mental well-being/ Satisfaction | Improvement of living conditions, generation of social order | *To what extent does AQF improve living conditions?* | Social trust and respect within local communities; relationship between companies and communities on management of impact of production |
| | Public health | Health coverage | *To what extent does AQF improve health coverage?* | No. of medical service/doctors per inhabitant; life expectancy |
| EDUCATION | | | | |
| | Informed decision-making | Access to relevant information; Awareness of options | *To what extent is AQF endorsed in decision making?* | No. of public hearings; no. of attendance at public hearings/public discourses |
| | Formal education (training/skills) | Level of schooling/training | *How relevant is AQF to formal education?* | Years of schooling; % of high school graduates; farm part of university courses |
| | Informal education (experience) | Learning from your parents and peers | *How relevant is AQF to informal education?* | % of children taking over same profession as parents; farm part of public days |
| WORK | | | | |
| | Income levels | Generation of income and employment | *To what extent does AQF improve income levels?* | No. homes below average minimum wage; salary levels compared to national average |
| | Justice | Labor interests | *To what extent does AQF support formation of unions/employment rights?* | No. of labor unions; transparency; due process |
| | Equality | Hierarchy and structure | *How relevant is AQF to improving equality?* | Gender balance; nationality and ethnicity; pay equality; % flexible work hours; age composition |
| | Livelihood protection | Source of income | *How relevant is AQF to improving livelihood protection?* | Degree income diversification; no. households that declare AQ as main source of income; no. of permanent and seasonal employment linked to harvest season |
| | Quality of Employment | Job satisfaction; occupational health | *How relevant is AQF to improving job satisfaction?* | No. sick-days; employee retention; degree inter-sector movement; reported stress; salary range; full vs. part-time |
| HOUSING | | | | |
| | Type | Quality of housing | *To what extent does AQF affect quality of housing?* | Size of house; no. rooms per house/person; maintenance quality |
| | Proximity | Access to transportation | *To what extent does AQF affect availability of transportation?* | Availability and quality of public transport; no. cars/home; company cars provided |
| | Social mobility | Potential for socio-economic improvement | *How relevant is AQF to improving social mobility?* | Spatial segregation by income; degree interaction across social strata |
| | Ownership | Housing tenure distribution | *To what extent does AQF affect homeownership?* | Ratio renting/owning housing; property prices; distribution of housing (apartment, house, etc.); no. houses owned by staff; no. secondary homes |

### *3.2. The social dimensions of finfish aquaculture across different spatial scales*

#### *3.2.1. Effects of finfish aquaculture on the UN social category population*

The relevance of the finfish farming industry to population (Fig. 1a) is higher on a regional than a local scale in all cases due to job opportunities and associated increased social and economic activity. The exception is Nova Scotia, where the regional and national level relevance is the same. In Scotland, there are processing and head offices located in the region. Processing plants often employ EU workers and such head offices can attract highly skilled individuals from urban areas. This results in a larger number of full-time year-round jobs on a regional rather than a local scale in comparison to other sectors and the other case studies. Conversely, in Nova Scotia and Ireland the population influence is recognized on a local scale, as there are more significant drivers for population and demographic change on regional and national scales. In Ireland, these drivers, including industries such as agriculture, tourism and light manufacture take precedence.

#### *3.2.2. Effects of finfish aquaculture on the UN social category health*

In all cases, the aquaculture companies invest in community initiatives which promote positive health outcomes (Fig. 1b). Rural areas are challenged by the availability of health care professionals, but aquaculture contributes to making these communities more desirable through improved services. In Canada, Scotland, and Ireland there is universal health care, so that rural poverty has less impact on local health compared to Maine where there are direct payment obligations by the individual. In terms of nutrition, across all case studies, salmon for local consumption is available to buy on occasion, mitigating the lack of supply due to the decline of wild stocks; although in Maine, the price is often prohibitive for many at the local and regional level. Interestingly, in Ireland, the price of imported salmon is usually cheaper than the local one, which is organically certified. In all case studies, industry invests in the local communities by sponsoring sport teams, play parks and/or other initiatives. At the regional scale, salmon farming plays an important role in Scotland, where it can contribute to the viability of health centres by making villages and towns more desirable places to live and work, also by increasing the working-age populations in rural

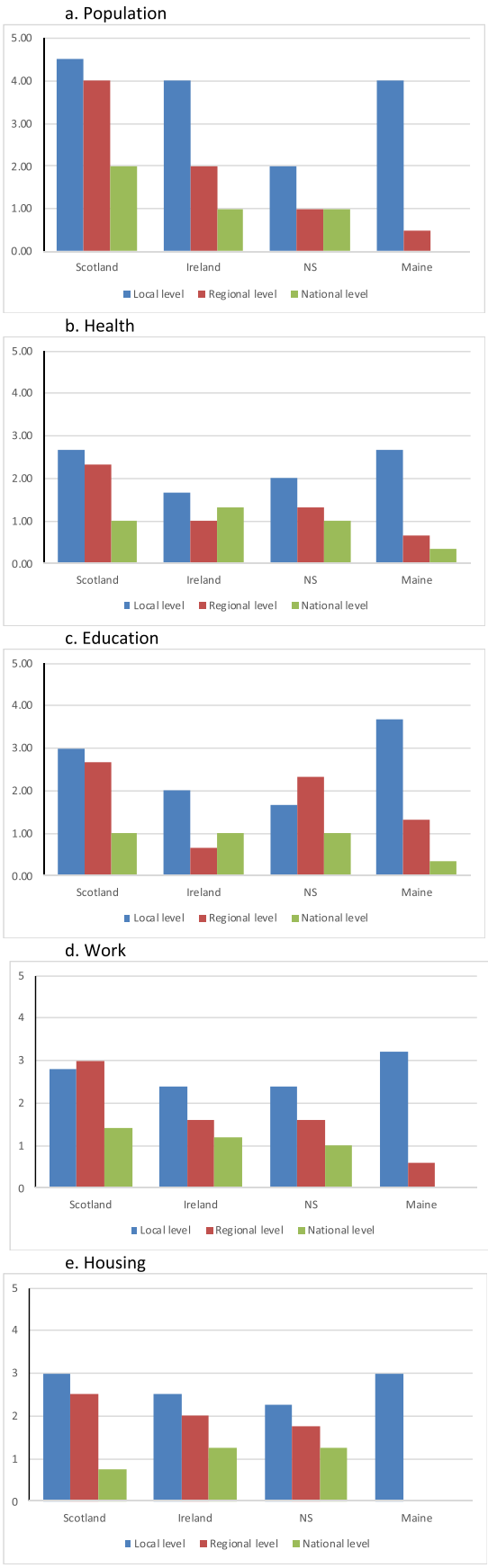


**Fig. 1.** Relative influence of salmon farm on UN social dimension variables at multiple scale levels by countries.

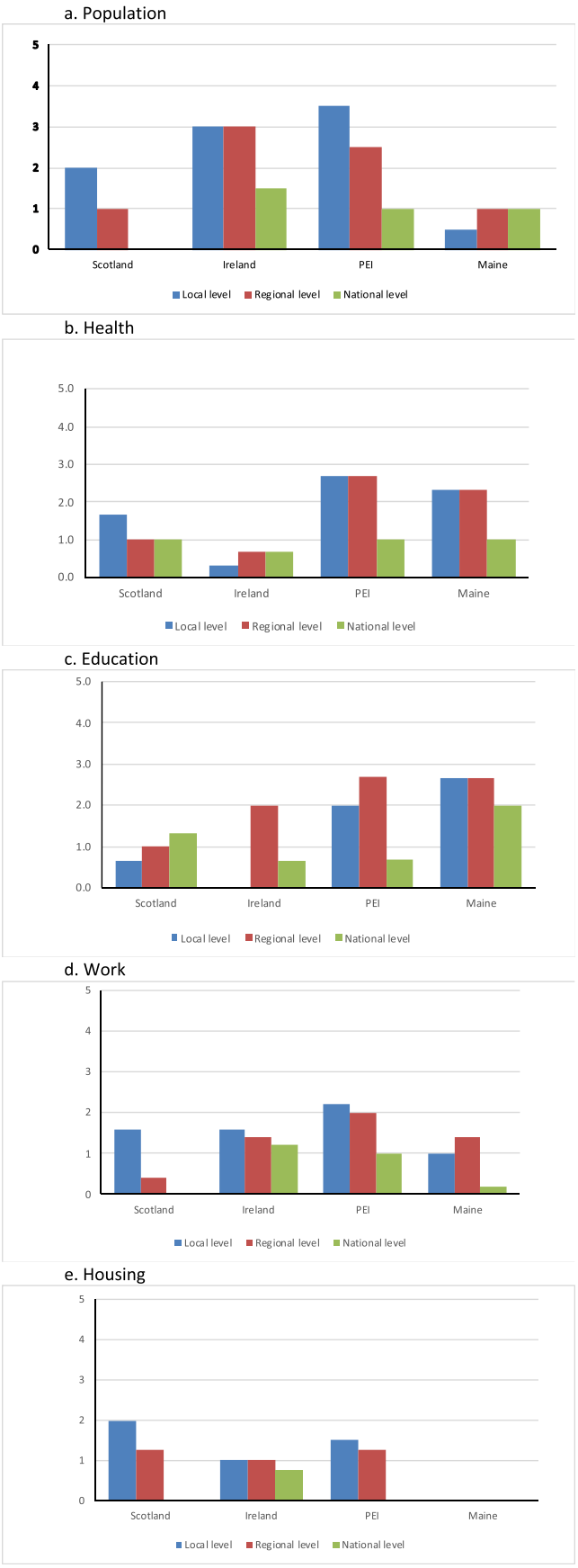


**Fig. 2.** Relative influence of rope mussel farm on UN ssocial sdimension variables at multiple scale levels by countries.

areas. In contrast some residents view aquaculture as aesthetically unpleasing. Despite these objections, in the remaining case studies, salmon farming plays a positive role at the regional level in terms of access to food and bringing additional capital. At the national level, salmon is a limited regular purchasing option due to premium price marketing in all case studies. In the case of Ireland, the national relevance is higher than the regional as the regional level is strongly influenced by agricultural heritage, where seafood plays a minor role compared to the more urbanized national level. In general, other health-related aspects of the industry do not affect populations on a national scale in all case studies.

#### 3.2.3. Effects of finfish aquaculture on the UN social category education

In Canada, Maine and Scotland, the local impact on education (Fig. 1c) is relatively high. A lot of information regarding aquaculture production passes at local level through informal networks (e.g. sale and purchase of land for land-based operations, employment of new staff, deliveries of feed, wellboat activities, site harvesting schedules, fish escapes, etc.). Formal educational networks are limited and regular contact exists with local community councils and industry-community committees. If untrained personnel are hired, training is provided by the company. In Ireland, there are usually good opportunities for youth to follow their parents into work on the farm. Despite these similarities in average scores, there are some specific differences across case studies. In the case of Nova Scotia, farms are new in the communities and consequently it is not possible to confirm their impact in informal education as successions have not yet occurred. In Ireland, there are also local ad-hoc arrangements for visits with the local schools and contacts are being made with regional technical colleges. Short summer work experience opportunities arise. At regional level, the impact on education is heterogeneous. Universities or research institutes in NS and Scotland offer a formal aquaculture qualification. In the four sites, industry itself does not provide any formal training, but it can organize partnerships with academic institutions at different levels upon request for educational purposes. However, PEI has significant aquaculture training as a service to the industry, and one of the premier research centres in farmed fish health (Atlantic Veterinary College) despite having no fish farming. Companies also facilitate visits from local schools and students in Scotland. At national level, impacts are low in all case studies. Similar to NS, the University of Maine, and several universities in Scotland have formal aquaculture qualifications and researchers are involved in aspects of salmon aquaculture and partnerships between the company and academic institutions exist. In Ireland, there is one national college offering formal training in aquaculture, with several specialised courses on offer, created from partnerships between regional colleges and the Seafood Development Agency.

#### 3.2.4. Effects of finfish aquaculture on the UN social category work

The localized nature of finfish farms provides a limited impact on employment numbers in the surrounding communities in the Maine, Nova Scotia, and Ireland case studies (Fig. 1d). However, there is a regional effect of finfish farming (Washington County, Maine; southwest Nova Scotia), which make it relatively important to these economies. In contrast, the scale of the industry on the West coast of Scotland in comparison to local populations is such that it is one of the most significant industries in these areas (Fig. 3).

Indeed, for Scotland, the increase in effect of finfish production on employment from local to regional level reflects the population distribution concentrated along the west coast and the effects change from that of one production unit locally to the effects of production, processing and other vertically integrated units at regional level. At national level, the competing effects of urban-based industries reduce but do not eclipse the effects. The distribution shape for Nova Scotia and Ireland are similar, indicating a steady fall-off of effects on employment, from significant local effects, dropping sharply at regional but still registering an effect at national level. Regionally, the populations of Nova Scotia and Ireland are distributed evenly away from the coast, unlike Scotland with significant agriculture employment and the aquaculture effects therefore are much reduced on regional scale. The profile for Maine is that of a small-scale industry, concentrated in one area of the country, significantly affecting the employment of that locality.

#### 3.2.5. Effects of finfish aquaculture on the UN social category housing

There is shared characteristics across all of the case studies in terms of the interactions of how the activity of finfish farming interacts with the category of housing (Fig. 1e). At a local scale, the industry is of relevance as it increases the opportunity for generating income and ability for people to purchase property due to full-time employment opportunities. Private ownership of vehicles is generally necessary to live and work in these areas and as such there is limited influence on public transportation. In Scotland, Ireland, and PEI availability of housing and prices on a local level are impacted by wealthy buyers from other areas purchasing properties for second homes. At a national scale, the distance from aquaculture operations in relation to the population centres is too large for there to be any interactions in all cases. In both Scotland and Ireland, there are general housing stock issues related to their national political and economic climates. These impact all industries and employers.

### 3.3. The social dimensions of rope mussel aquaculture across different spatial scales

#### 3.3.1. Effects of rope mussel aquaculture on the UN social category population

Due to the small scale of mussel farming as a whole and the small scale of the sites in all case studies, there are no national level population dimensions associated with this activity (Fig. 2a). Conversely, the localized nature of the sites in all case studies concentrated the impacts on population at local and to a slightly lesser extent, regional scales. In Scotland, the relevance of even one part-time job in a remote location can have an impact on community structure. In Maine, sites can offer up to 10 jobs, however when compared to other industries located in this particular area, this is still small scale. As the population centres in Maine are in the south, so the benefits of aquaculture are localized. This is similar to both Scotland and Ireland, were the mussel industry is small and not located close enough to the population centres to have a significant impact on a national scale. In Ireland, full-time staff are recruited locally, whereas there is a trend to employ non-EEA nationals for seasonal work. Mussel farming in PEI provides year-round employment in an area that had traditionally relied on seasonal fishing and agriculture. As such, it contributes to reducing the level of emigration, and plays a major role in maintaining local community resilience. On a regional scale, however, the service and agricultural sectors have more influence on population. The effects at the national scale are negligible in all case studies.

#### 3.3.2. Effects of rope mussel aquaculture on the UN social category health

Considered as healthy (Fig. 2b) and affordable seafood, mussels are available to local communities and restaurants in all case studies. The activity, usually family-run business and carried out in rural areas, is often part of the local landscape/seascape. In the case of PEI and Ireland, the traditional family-run operations are being merged into larger companies, regardless of which, farming is still seen as a strong component of traditional heritage. In PEI, due to the strong branding and associated tourism, the impact at the local scale in health indicators is higher than in the other case studies, and this is also applicable to the regional level. Similarly, the 'locally grown' movement plays a strong role in Maine, boosting the impact on health indicators at local and regional levels. Mussels are usually accessible in markets and restaurants at the regional and national scale in all case studies, although in the case of Canada, accessibility in the inland provinces may be limited at times. Due to the low value of the product, the impact on other indicators of health is limited at local, and very low at regional and national levels,

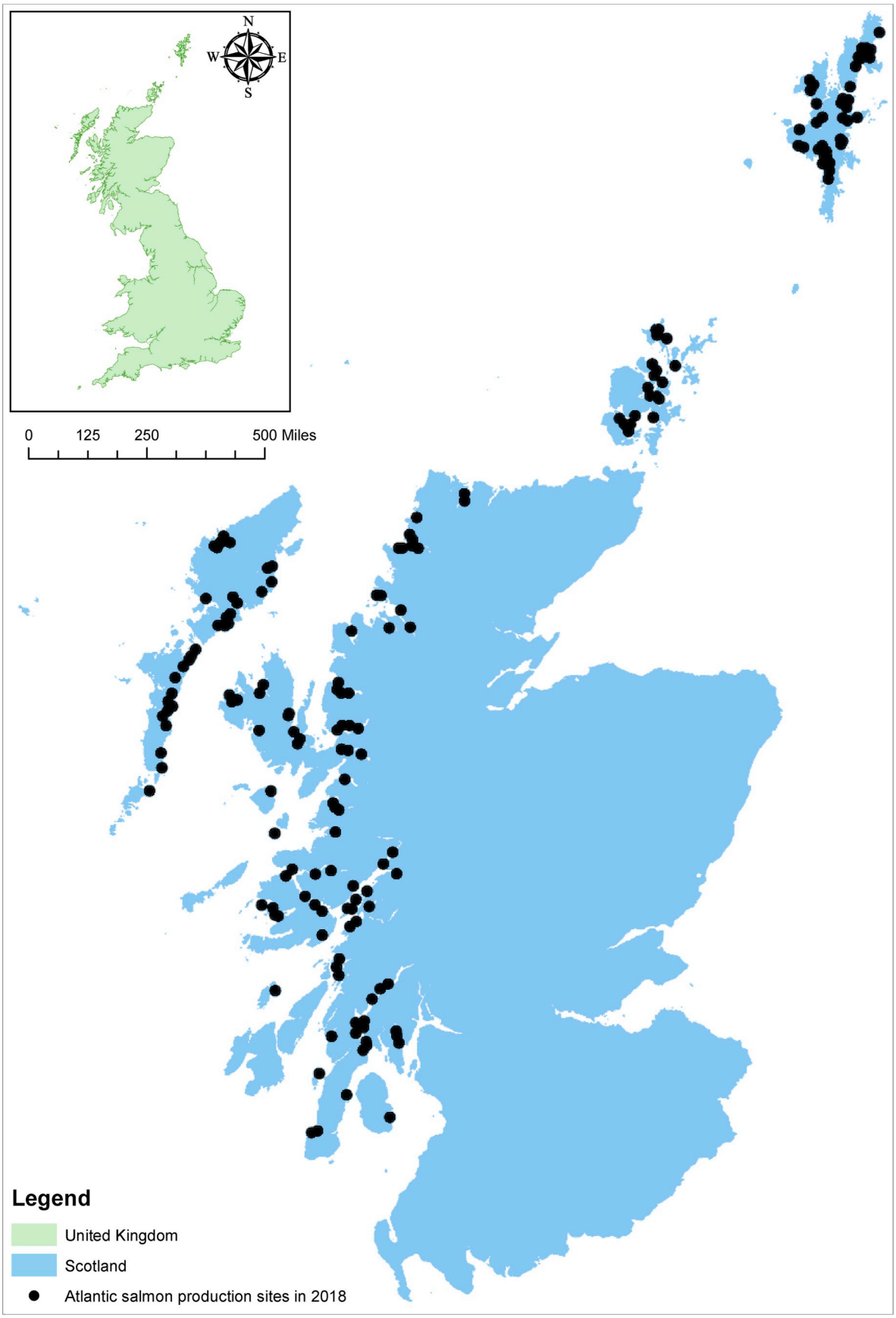


**Fig. 3.** Active salmon aquaculture sites, Scotland (Source: [36]).

with the exception of the local and regional levels of PEI, as was stated above.

#### 3.3.3. Effects of rope mussel aquaculture on the UN social category education

At a local scale, the highest impact on education occurs in Maine through partnerships between farms, and different education institutions (Fig. 2c). There is also a high education impact in PEI, but through informal education where training for positions in the industry are provided on the job. As in PEI, informal education in Scotland, is the only education indicator of relevance at a local scale, where training for positions in the industry are provided on the job and research expertise in mussel farming is often sought from outside of the province. Ireland is a particular case with no local impacts on education at local level, even if there is good communication and exchange between company and public. At regional scale, there are significant impacts on education in all case studies, excluding Scotland, though substantial support in terms of research in PEI (as well as from NS) and Maine or collaboration with regional technological colleges in Ireland. Informal education provided through learning on the job in Ireland and Scotland also contribute to education at a regional level. At a national scale, the impact on education is low in all case studies, excluding Maine. In this case study, there are partnerships between aquaculture farms and organizations involved in aquaculture around the state that conduct research and provide educational visits to the farm. Scotland also makes an impact at national level to promoting knowledge exchange by promoting the Scottish seafood through the Seafood Trail. In Ireland, the 'Wild Atlantic Way' branded partnership between tourism and shellfish farming is beginning to impact public education at a national level. However, there is only one formal aquaculture college and ad-hoc relationships between researchers (both university and government) and industry are the norm.

#### 3.3.4. Effects of rope mussel aquaculture on the UN social category work

The effects of the rope mussel industry across the four countries appeared to be only rather relevant for any level, indicating that the main effect of the industry on employment (Fig. 2d), is at local level and modest in effect. However, mussel farming in PEI is significant economically on a provincial scale and is so pervasive in coastal estuaries that it likely touches all areas of the province. The Irish and Scottish production levels are comparable with a more pronounced decrease effect, seen across all levels for Scotland. The effect at local level is highest for PEI, remaining relatively relevant also regionally and nationally, reflecting the rural population of the province where employment has traditionally been dominated by agriculture and more recently also by tourism and shellfish. The profile for Maine indicates the modest role of rope mussel within overall shellfish production dominated by the oyster industry (Mussels are under 1000 tonnes (964) and oysters are just over 5000 tonnes (5,393) [34] and aquaculture production in general which is a significant employer at national level. In Maine, aquaculture overall is growing in significance as an employer, compared to other relevant sectors, but most of this is oyster aquaculture and it still does not come close to employing the same numbers as the lobster industry at the state level. However, despite this, it is significant since it is one of the top few options for working on the water.

#### 3.3.5. Effects of rope mussel aquaculture on the UN social category housing

Mussel aquaculture in Maine has no impact on any housing indicators due to the small scale of the industry compared to other activities (Fig. 2e). In the remaining case studies, it is difficult to separate the impact of farming on housing in the case of family-operated farms, which is a common feature between Scotland and Ireland, and at a smaller scale in PEI. Disentangling the impact on housing becomes even more problematic when families have several sources of income, which applies to both owners and employees. In general, farm owners and employees are homeowners. Given that farm location is driven by environmental conditions, most of the sites are located in rural/remote areas, often requiring the use of private transportation given the lack of public transport. At the regional scale, proximity is the only relevant indicator as commuting to the farm on private vehicles is a common feature across the case studies. Given the small scale of the industry at a national scale, the scoring is small in Ireland and negligible in Scotland and PEI.

### 3.4. Summative visualization of the social impacts of the context-specific variables of the UN social dimensions relative to other relevant sectors

The simultaneous summative visualization of the five social dimension indicators provides a holistic analysis of the impact of both forms of aquaculture production at the local, regional and national scales (Figs. 4 and 5, for salmon and mussels, respectively). Given that impacts at the regional and national level strongly depend on the contribution of the aquaculture activity compared to other sectors, influenced by total population and size of the country, among others, this section will focus on the effects at the local scale. Among all social dimensions, population results in the highest rankings of the indicator for both production types, health and housing scoring the lowest for finfish and rope mussel, respectively (Table 3). Despite this common pattern in the scoring of population for both species, the absolute values differed across species. Across the case study examples, salmon aquaculture resulted in higher social indicators than mussels for all social indicators considered (Table 3).

It is also important to highlight that the standard deviation for each indicator was always larger for mussels than for salmon (Table 3) suggesting that the effects on social indicators by salmon aquaculture are more homogeneous than those by mussel farming across the different case-studies.

The dominance of salmon aquaculture on the social dimensions at the local scale is also true when comparing within each case study, with the exception of Canada (Table 4). This exception is related to the nature of the Canadian case studies, in which PEI, the most productive area for mussels in North America, and where aquaculture plays a major role in local culture, is compared to Nova Scotia, a province in which salmon aquaculture is less widespread. Salmon farming in Maine, with an average score of $3.31 \pm 0.53$, is the case study in which aquaculture plays the largest role at the local scale in terms of positive effects on the social dimensions, and mussel farming in Ireland is the smallest one, with an average score of $1.19 \pm 1.19$ (Table 4). Figs. 4 and 5 provide a general visualization of these metrics using radar charts [37], where the specific relevance of population can be observed for salmon in the case of Scotland, Ireland and Maine (Fig. 4a, c, and 4d, respectively), and mussels in the case of Ireland and PEI (Fig. 5b and c). The simultaneous representation of all indicators per country allows for a quick identification of extreme values, such as the negligible contribution of mussel aquaculture to education and housing in Ireland and Maine, respectively (Fig. 5b and d, respectively).

## 4. Discussion

This paper offers a new framework - through use of the UN social dimension indicators - to demonstrate benefits around applying social acceptance and social licence concepts to help visualization of integrating the social dimension of aquaculture. The results herein highlight how having a greater understanding of the social drivers underpinning and shaping aquaculture development can improve the overall sustainability of aquaculture. This can be useful for governments wanting to assess likely impacts on people beyond solely traditional environmental and economic drivers.

### 4.1. Employing qualitative mix-methods for aquaculture assessment

In the case of aquaculture, there are multiple relationships, effects and trade-offs that warrant consideration if sustainable aquaculture in

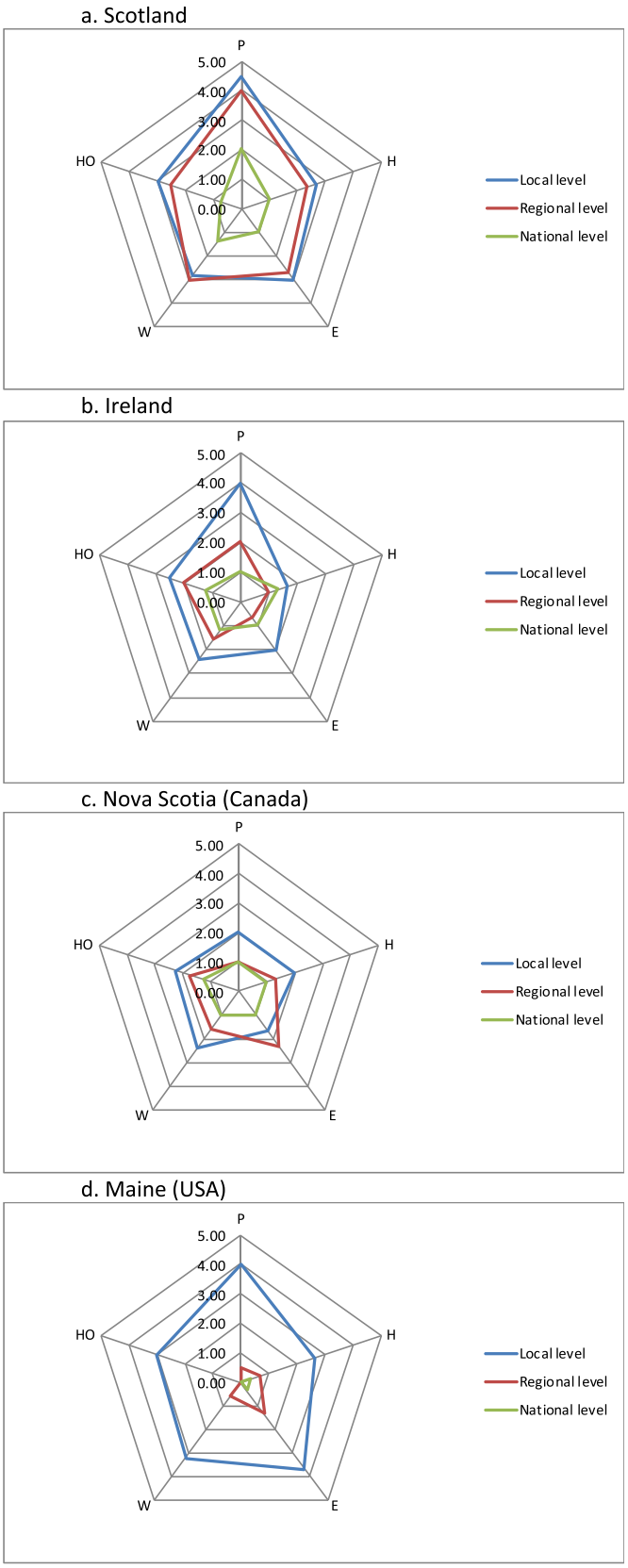


**Fig. 4.** Relative influence of salmon farm by country on UN social dimension variables.

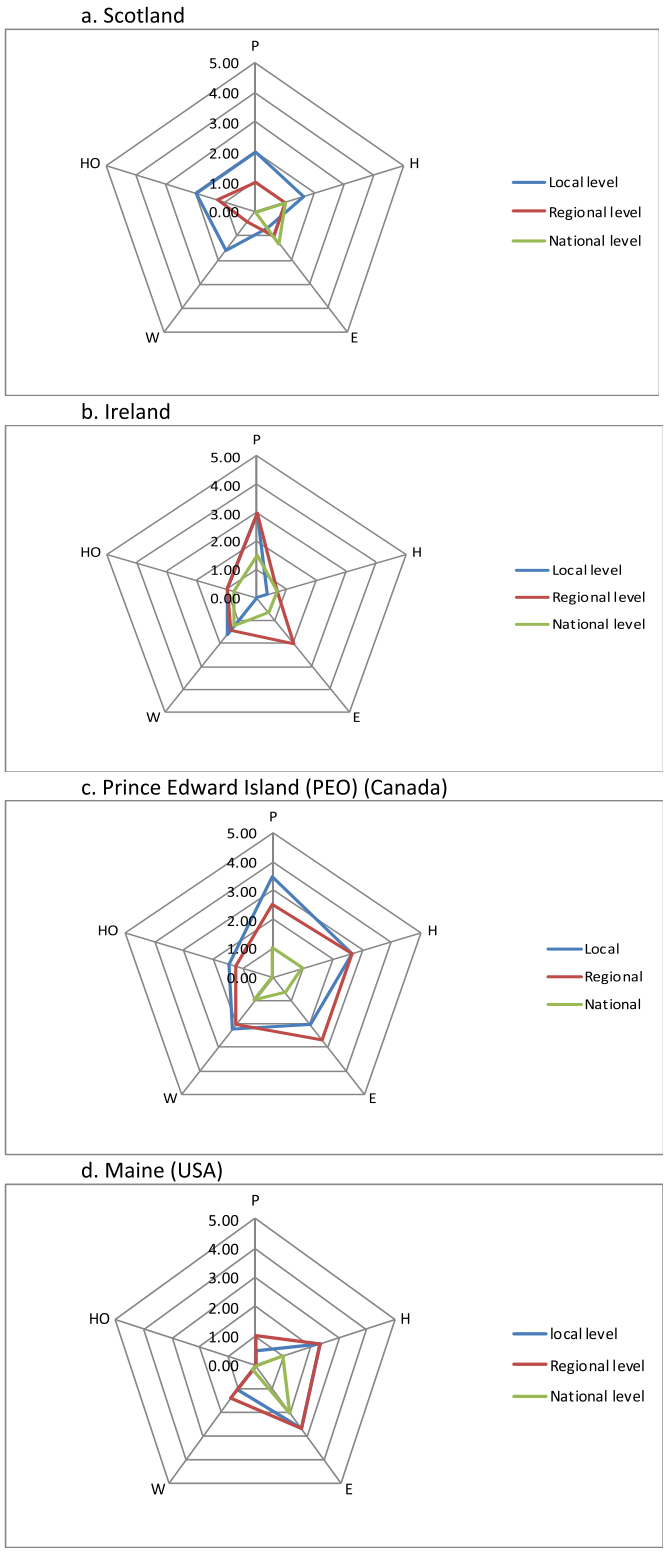


**Fig. 5.** Relative influence of rope mussel farm by country on UN social dimension variables.

relation to the United Nations SDGs is taking place. The methods employed harnessed a suite of social science mix-methods with a strong emphasis on qualitative data. This was done out of the recognition that in most cases individual perceptions shape and drive social acceptance of aquaculture and are difficult to quantify. Indeed, when it comes to decision-making, ecological, economic and distributive outcomes are

**Table 3**
Average across case-studies (±standard deviation) of social dimension indicators per type of indicator and farmed species.

| Type of indicator | Salmon | Mussel |
|---|---|---|
| Population | 3.63 ± 1.11 | 2.25 ± 1.47 |
| Health | 2.25 ± 0.50 | 1.75 ± 1.10 |
| Education | 2.58 ± 0.92 | 1.33 ± 1.17 |
| Work | 2.70 ± 0.38 | 1.60 ± 0.77 |
| Housing | 2.69 ± 0.38 | 1.13 ± 0.66 |
| *Global* | *2.77 ± 0.51* | *1.61 ± 0.43* |

**Table 4**
Average (±standard deviation) of social dimension indicators per case study and farmed species.

| Case study | Salmon | Mussel |
|---|---|---|
| Scotland | 3.19 ± 0.74 | 1.59 ± 0.55 |
| Ireland | 2.51 ± 0.59 | 1.19 ± 1.19 |
| Canada | 2.06 ± 0.28 | 2.37 ± 0.76 |
| Maine | 3.31 ± 0.53 | 1.30 ± 1.16 |
| *Global* | *2.77 ± 0.59* | *1.61 ± 0.53* |

not the only things that matter [38], but depend on the individual perception of well-being, and thus ultimately on personal and societal values [39] embedded within a social-ecological system [40].

To make these characteristics more visible, we addressed them by integrating the social variables across different scales. Since social variables can potentially lead to bias (i.e. individual perspective of "effect" vs "influence"), we provided definitions and descriptions to guide the "scorer"/interviewee whilst being able to ask the same questions in each case study in a standardised manner. Through this approach, we improve consistency and make qualitative research data rigorous (following [41] whilst ensuring generalizability and transferability to other settings [42]).

We recognize that some of the scoring of the central variables may be affected by the personal views of the interviewee. Indeed, as [42] pointed out, the processes of obtaining data within verbal interaction or observation, the interpretative nature of analysis, and the subjective nature of data itself can be perceived as threats to validity. To counteract this situation, we interviewed key informants, that is those stakeholders most likely to know the information required (i.e. the aquaculture farm site operator), in addition to collating expert knowledge and conducting an in-depth literature review.

A level of complexity was introduced by asking the interviewee to rank aquaculture in relation to other relevant sectors. This required the interviewee to hold sufficient holistic knowledge of the aquaculture farm as well as on aquaculture operations on the regional and national scale. Furthermore, the other relevant sectors may be different across case studies as well as in their degree of importance. We used the relevant sector comparison as a metric to identify the significance of aquaculture in a social perspective.

Thus, the scoring values from 0 to 5 employed must not be seen as absolute numerical values, but rather as an indicative tool to illustrate the relative importance of one indicator in contrast to the others. This ensured that the qualitative data collected included information far beyond the "numbers of participants" that are listed in demographic tables [43]. As one central finding, this approach indicates that there is a minimum farm size which produces an impact of a visible scale for the different social dimension categories.

Our approach addresses and contextualizes the social aspects of aquaculture in a detailed manner across different scales. This is timely, in view of current global efforts to meet the SDGs by 2030. So far, the interactions and trade-offs between different SDG targets (see examples provided by Refs. [44–46]) are not well captured pertaining to aquaculture.

### 4.2. The social dimensions in context

Each marine region has a long heritage of contextualized historical, cultural, and political roots and knowledge of ocean use that must be recognized if sustainable aquaculture development is to be fostered. These drive the sustainability of aquaculture production, as much as the economic, technological and ecological processes [2,40,47]. Contemporary aquaculture challenges are invariably linked to broader concerns such as ecosystem health, social justice, sustainable livelihoods and food security. Responses to such problems must consider context; specifically, the character of aquaculture systems themselves, their institutional conditions, and the internal and external interactions that affect them [48]. Missing in the current discourse on sustainable aquaculture sector development is the context-specific inclusion of social variables that are of relevance to a specific setting, to specific spatial levels and the stakeholders therein. In the following, we focus on the local level as a point-of-departure and subsequently scale up. This is done out of recognition that the social licence to operate (SLO) as well as social acceptance (SA) both emerge on the local level, since they are rooted in local realities [49]. It is at this scale that the social mobilization of the territory often has effects on the management dynamics of private projects or public decisions [9].

As shown by our results, net-pen finfish aquaculture seems to be more socially impactful than rope mussel farming. Most notably, this pertained to UN category component variables related population dynamics. This highlights the large gap between coastal rural and urban locations in certain parameters such as education opportunities, employment, income, and community facilities. They can be regarded as 'push' factors when they are insufficient in the rural place of origin, and as a 'pull' factor if they are available in the city [50,51]. People decide to migrate if a threshold is passed in a priority factor, or in combinations of several of them. The thresholds however, and the direction of migration, are not determined externally, but depend on the individual perception of well-being, and thus ultimately on personal and societal values [39]. In dual economy models [52] positive and negative push-full factors typically reflect the relative strength of the local economies. In our case studies, finfish aquaculture boosts a significant positive pull-factor which incentivises people, e.g., in the case of Scotland to remain in the area, and keeping rural communities viable. In other instances, where communities are impoverished and spatially disconnected, like in the State of Maine where coastal communities are geographically very remote, aquaculture acts as an important income opportunity to maintain local livelihoods. Additionally, scope for further opportunities for employment in rural communities through secondary activities, such as hatcheries, processing, etc. can occur, thus emphasising the importance of considering the local context.

Depending on the scale and size of the finfish aquaculture industry, i.e. small-scale farm owners versus multi-national companies, additional infrastructure (i.e. streets, medical or fire services) arising from their social responsibilities as corporate entities [53,54] may be provided, positively affecting the UN social indicator category health. In this light, comparing finfish aquaculture outcomes for the UN social component education across different countries, multi-national companies have the ability to foster educational partnerships across all spatial levels. For example, in Ireland, there appears to be a lack of opportunity for formal education at the local and regional scales that may be related to the rather small-scale nature of the industry.

In contrast, rope mussel aquaculture exhibits a lower magnitude of social influence on multiple scale levels. This may indicate that a minimum size of aquaculture farm is needed to pose a social signal. It is important to emphasise that social impact is not directly proportional to economic impact. That said, the social value of safeguarding traditional rural communities may have low economic consequences but high cultural heritage values, which in some cases may have considerable weight in the decision-making process. Despite the value of such cultural aspects and supporting local identities, most of applied variables relate to

socio-economic outcomes, devaluing the impacts of rope mussel aquaculture on schools, services, or the salaries and number of jobs. However, this type of aquaculture, even on a small scale, can hold important cultural values and contribute to place-based understanding [40] that warrant consideration.

For example, in Scotland, many of the rope mussel aquaculture farms are family-run businesses that foster a connection with place and identity. Despite that many of the mussel farms are very rural and use private slipways and remote harbours, these mussel farms are visible though, which creates an impression of a working seascape. It thus can serve a vital impetus in maintaining the working waterfront in coastal communities. In Maine, there exists a high demand for local seafood production. As a result, much of the farmed rope mussel production remains in the State, providing healthy options to local communities thus positively affecting the UN social indicator category health while creating indirect economic revenue to the local economy. Rope mussel production in PEI has contributed to alternative livelihoods by providing year-round employment to the local community (see also examples given by Ref. [55,56]. This contrasts the fluctuating income options provided by seasonal fishing, agriculture or tourism activities.

Hence, it can be concluded that on a local scale, the UN social indicator approach selected may not capture cultural values connected to specific types of aquaculture in sufficient detail. This gap must be acknowledged when comparing the social dimensions of finfish versus rope mussel aquaculture.

### 4.3. Optimising aquaculture governance by visualising social dimensions

The main trends highlight that the proposed social indicators offer governments a type of key performance measure to evaluate the extent to which aquaculture can provide benefits to communities. Our case study results support the wider application of the methods used herein and can help governments to uncover and reflect social factors often missed in the discourse and decision-making process of aquaculture development projects.

In our case studies, the Scottish government has a specific growth agenda for finfish farming on the national level, motivated by the positive impact of the aquaculture sector on rural coastal communities [57]. In Ireland, current national government policy is in support, in principal, of growing the production of farmed finfish. In both of these cases there are social license issues. In Scotland this mainly relates to fish farm interactions with wild salmon, and visual and environmental concerns [58]. However, in Ireland this is more prominent as the consenting process for finfish farming is highly influenced by anti-salmon farm lobbies.

Hence, it can be argued that to date, most aquaculture narratives have focused on the ecological pillar of sustainability [2,59]. With varying degrees of thoroughness and misdirection, narratives in this context are oftentimes understood as accounts of local events articulating the relationships of the organizations with its “stakeholders” and/or its immediate environment [60]. By visualising the social effects of aquaculture, a door may be opened for new narratives on the sustainability of aquaculture that render SLO and SA more positive. This is timely, as being highly site-specific and contextual, aquaculture sustainability outcomes depend strongly on the set-up and effects of the social dimensions on multiple levels. Thus, if key social components on multiple scales are not met, it renders aquaculture production unsustainable. Using the UN social dimension categories, we were able to illustrate the importance of these across different countries and contexts. As a case in point, one of our interviewees opposing aquaculture from an ecological stance, scored similar to a finfish farm manager regarding the social dimensions of the operation.

However, we caution here that scaling up aquaculture can make a difference in the relative importance and weighting of the social indicators, which may collide with SLO. As [60,61] pointed out, only on those rare occasions when indicators capture the key issues – and the issues are equally key to all parties – can the range of indicators necessarily be said to provide a full narrative. Social acceptability, as well as the definition of sustainable development, are social constructs and therefore their perception also depends on the cultural structures of each society [49]. Therefore, the construction of social indicators such as those proposed in this work can provide information for trade-offs to be considered in decision-making [62].

This is yet an open issue, as more often than not, opinions of public comments present some biases reflecting only the most vocal interest groups and may not capture the more variable perspectives of a country [58,63]. Different types (nearshore vs. offshore), species, scale (small--scale family-run vs large-scale industry) and contexts (policy vs. development) of aquaculture have important implications for the understanding and management of public opinion. Thus, a broader vision is needed to consider other criteria that relate beyond the environmental impacts of the aquaculture sector. These need to include the competition for resources and space with other users, or the perception of the products it provides on the allocation of resources according to their effects on neighbouring communities. Systems thinking and open innovation offer ways to develop this vision in a broader multi-level governance context; i.e., governments need to think through the intended and unintended consequences of aquaculture interventions at local, national, regional and international scales at the same time when developing policy [18,22,64].

Despite these challenges, by including the social and economic pillars of sustainability, communities and policy-makers are better able to evaluate the trade-offs (i.e. [46] for the energy sector) that are associated with sustainable aquaculture development. Indeed, engaging and visualising the social dimensions and their degree of relevance may also help communities, NGO’s, and companies alike to focus on where improvements towards more sustainable outcomes can be made and where negative trade-offs that require societal consensus can be expected. Revealing the real versus perceived (social) impacts of aquaculture could aid in clarifying the debate on the sustainability of aquaculture, and help to navigate to future sustainable pathways for sector development.

## 5. Conclusion

This paper offers a new way of capturing and visualising the diverse social dimensions of aquaculture to address the current dearth of knowledge on how to operationalise the social and economic pillars of sustainable aquaculture in a holistic manner. It has done so by drawing on several case studies across the North Atlantic and including local/regional stakeholder knowledge realms with scientific expert knowledge. Several key issues have emerged from this exercise:

First, by providing definitions and descriptions to guide the assessment, we make qualitative research data rigorous whilst ensuring generalizability and transferability to other settings. Second, this approach indicates that one needs to have a minimum farm size in order to have an impact of a visible scale for the different social dimension categories. Third, while finfish aquaculture seems to be more impactful from a social perspective than rope mussel farming, the latter can hold important cultural values and contribute to place-based understanding. The latter connecting people with place and identity, thus playing a vital role in maintaining the working waterfront. Fourth, aquaculture boosts a potential significant pull-factor to incentivise people to remain in the area, keeping communities viable. Fifth, by visualising the social effects of aquaculture, a door may be opened for new narratives on the sustainability of aquaculture that render SLO and SA more positive.

The latter is central in the quest towards meeting the SDG targets in the near future. Indeed, social acceptability, as well as the definition of sustainable development are social constructs and therefore their perception also depends on the cultural structures of each society. Therefore, the construction of social indicators such as those proposed in this work can provide information for trade-offs to be considered in the

governance on the allocation of resources and how to evaluate the social effects of aquaculture on multiple levels.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpol.2020.103985.

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