**Supporting material**

Reviews in aquaculture submission 2019-10: Availability and usefulness of economic data on the effects of aquaculture: A North Atlantic comparative assessment

**Revised version, July 2020**

Content:

1. Statistics on aquaculture production volume and value in the North Atlantic Ocean area.
2. Detailed description of the availability of economic data on the effects of aquaculture at the EU and individual country level, with reference to publications and data sources.
3. Tables with data availability with number codes and calculations to assign colour coding to cells for individual countries in table 6 in the paper.
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# Statistics on aquaculture production volume and value in the North Atlantic Ocean area.

Table 1 Production quantity in marine and brackish water aquaculture in the North Atlantic Ocean area 1976-2016, tonnes. Source: FAO statistics.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **1976** | **1986** | **1996** | **2006** | **2016** |
| **Norway** | 3476 | 49392 | 321516 | 712290 | 1326139 |
| **Spain** | 179900 | 251393 | 201711 | 244378 | 225383 |
| **UK** | 215 | 12390 | 93090 | 160877 | 183851 |
| **France** | 122251 | 194787 | 193688 | 166250 | 114340 |
| **Canada** | 631 | 5044 | 30252 | 77225 | 88693 |
| **Faroe Islands** | 51 | 2520 | 17584 | 18574 | 83300 |
| **Netherlands** | 73310 | 85896 | 95621 | 34753 | 57370 |
| **USA** | 900 | 7894 | 21683 | 40161 | 43248 |
| **Ireland** | 4869 | 12271 | 33765 | 52116 | 39520 |
| **Germany** | 22852 | 30652 | 38237 | 3851 | 22264 |
| **Denmark** | 0 | 3733 | 7802 | 9184 | 13975 |
| **Iceland** | 5 | 123 | 3373 | 7786 | 12991 |
| **Portugal** | 0 | 8576 | 4035 | 6947 | 9111 |
| **Total** | 408460 | 664671 | 1062357 | 1534392 | 2220185 |

*Source: FAO statistics on aquaculture production, from http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en, last visited 28 February 2019.*

Table 2 Production value in marine and brackish water aquaculture in the North Atlantic Ocean area 1986-2016 (Mill USD), by country. Source: FAO statistics.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **1986** | **1996** | **2006** | **2016** |
| **Norway** | 230 | 997 | 2749 | 7623 |
| **UK** | 70 | 206 | 727 | 1081 |
| **France** | 311 | 341 | 444 | 491 |
| **Faroe Islands** | 12 | 66 | 93 | 454 |
| **Canada** | 9 | 87 | 347 | 383 |
| **Spain** | 184 | 149 | 164 | 248 |
| **Ireland** | 12 | 79 | 145 | 168 |
| **USA** | 6 | 81 | 118 | 159 |
| **Netherlands** | 56 | 57 | 67 | 79 |
| **Iceland** | 1 | 13 | 36 | 72 |
| **Portugal** | 49 | 27 | 52 | 65 |
| **Denmark** | 12 | 25 | 36 | 48 |
| **Germany** | 22 | 13 | 10 | 28 |
| **Total** | 972 | 2140 | 4987 | 10901 |

*Source: FAO statistics on aquaculture production, from http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en, last visited 26 February 2019.*

Table 3 Production value in marine and brackish water aquaculture in the North Atlantic Ocean area 1986-2016 (Mill USD), by species group. Source: FAO statistics.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **1986** | **1996** | **2006** | **2016** |
| **Aquatic plants** | 0 | 0 | 1 | 2 |
| **Crustaceans** | 0 | 1 | 3 | 3 |
| **Diadromous fishes** | 341 | 1493 | 3928 | 9735 |
| **Marine fishes** | 3 | 38 | 178 | 185 |
| **Molluscs** | 629 | 609 | 878 | 977 |
| **Total** | 972 | 2140 | 4987 | 10901 |

*Source: FAO statistics on aquaculture production, from http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en, last visited 26 February 2019.*

Table 4 Production quantity 2016 in marine and brackish water aquaculture in the North Atlantic Ocean area, by product group and country (tonnes). Source: FAO statistics.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Aquatic  plants** | **Crustaceans** | **Diadromous  fishes** | **Marine  fishes** | **Molluscs** | **Total** | **Share  total** |
| **Norway** | 59 | 14 | 1321727 | 2140 | 2199 | 1326139 | 59,7 % |
| **Spain** | 2 | 163 | 5 | 11776 | 213437 | 225383 | 10,2 % |
| **UK** |  | 0 | 166896 | 67 | 16888 | 183851 | 8,3 % |
| **France** | 500 | 60 | 300 | 2490 | 110990 | 114340 | 5,2 % |
| **Canada** |  |  | 58599 |  | 30094 | 88693 | 4,0 % |
| **Faroe Islands** |  |  | 83300 |  |  | 83300 | 3,8 % |
| **Netherlands** |  |  |  | 120 | 57250 | 57370 | 2,6 % |
| **USA** |  | 0 | 16185 |  | 27063 | 43248 | 1,9 % |
| **Ireland** | 50 |  | 16300 | 0 | 23170 | 39520 | 1,8 % |
| **Germany** |  |  | 0 | 0 | 22264 | 22264 | 1,0 % |
| **Denmark** | 100 |  | 11654 | 0 | 2221 | 13975 | 0,6 % |
| **Iceland** |  |  | 12504 | 419 | 68 | 12991 | 0,6 % |
| **Portugal** | 2 | 18 | 1 | 4174 | 4916 | 9111 | 0,4 % |
| **Total** | 713 | 255 | 1687471 | 21186 | 510561 | 2220185 | 100,0 % |
| **Share total** | 0,0 % | 0,0 % | 76,0 % | 1,0 % | 23,0 % | 100,0 % |  |

*Source: FAO statistics on aquaculture production, from http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en, last visited 28 February 2019.*

Figure 1 Relative production quantity and share of molluscs and fish+ 2016

*“Fish+” is crustaceans, diadromous fishes + marine fishes. Source: FAO statistics on aquaculture production, from http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en, last visited 28 February 2019.*

Table 5 Aquaculture production value 2016 in marine and brackish water in the North Atlantic Ocean area, by product group and country (1000 USD). Source: FAO statistics.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Aquatic plants** | **Crustaceans** | **Diadromous fishes** | **Marine fishes** | **Molluscs** | **Total** | **Share total** |
| **Norway** | 109 | 521 | 7597229 | 22764 | 2400 | 7623023 | 69,9 % |
| **UK** |  | 0 | 1048952 | 1158 | 31316 | 1081426 | 9,9 % |
| **France** | 277 | 1327 | 1626 | 23218 | 464405 | 490853 | 4,5 % |
| **Faroe Islands** |  |  | 454383 |  |  | 454383 | 4,2 % |
| **Canada** |  |  | 334968 |  | 48051 | 383019 | 3,5 % |
| **Spain** | 1166 | 857 | 50 | 99868 | 145875 | 247815 | 2,3 % |
| **Ireland** | 55 |  | 115574 | 0 | 52866 | 168495 | 1,5 % |
| **USA** |  | 0 | 67653 |  | 91786 | 159439 | 1,5 % |
| **Netherlands** |  |  |  | 1029 | 78291 | 79319 | 0,7 % |
| **Iceland** |  |  | 67829 | 3862 | 68 | 71759 | 0,7 % |
| **Portugal** | 103 | 68 | 10 | 33064 | 31677 | 64922 | 0,6 % |
| **Denmark** | 53 |  | 46598 | 0 | 1564 | 48216 | 0,4 % |
| **Germany** |  |  | 0 | 0 | 28321 | 28321 | 0,3 % |
| **Total** | 1763 | 2772 | 9734872 | 184963 | 976619 | 10900990 | 100,0 % |
| **Share total** | 0,0 % | 0,0 % | 89,3 % | 1,7 % | 9,0 % | 100,0 % |  |

*Source: FAO statistics on aquaculture production, from http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en, last visited 28 February 2019.*

Table 6 2016 Aquaculture production in the North Atlantic Ocean area. Data by product group. Source: FAO statistics.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Quantity, tonnes** | **Value, 1000 USD** | **Average price, USD/kg** |
| **Aquatic plants** | 713 | 1763 | 2,47 |
| **Crustaceans** | 255 | 2772 | 10,89 |
| **Diadromous fishes** | 1687471 | 9734872 | 5,77 |
| **Marine fishes** | 21186 | 184963 | 8,73 |
| **Molluscs** | 510561 | 976619 | 1,91 |

*Source: FAO statistics on aquaculture production, from http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en, last visited 28 February 2019.*

# Details on data availability for each country/region

## Data on direct and multiplier effects

**The EU:** The legal basis for the Data Collection Framework under the Common Fisheries Policy is Council Regulation (EC) No 199/2008, together with the Commission Regulation (EC) No 665/2008. The details are laid down in Commission Decision (2008/949/EC), appendix X and in Commission Decisino (2010/93/EU), Appendix XI. Two Commission Implementing Decisions (C(2013) 5243 from 13.8.2013 and C(2013) 5568 from 30.8.2013) have prolonged the duration of the above mentioned regulations. CFP countries are EU member states that are not landlocked: Belgium, Bulgaria, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Malta, Netherlands, Poland, Portugal, Romania, Slovenia, Spain, Sweden, United Kingdom. Countries that only have freshwater aquaculture do not collect data under the DCF framework. Further details on gaps in the DCF data collection are in STECF (2016). Data on Production Volume, Production Value/Sales, Employment, Value added, Detailed cost items, Detailed company income figures, Wage costs all segmented by the most important species group are collected annually at national level and can be accessed at <https://stecf.jrc.ec.europa.eu/dd/aqua>, <https://stecf.jrc.ec.europa.eu/reports/economic>.

There are two regular data collections on aquaculture production. One is the DCF (Data collection framework) under the legislation adopted by the Common Fishery Policy (CFP). This is only mandatory for EU member states part of the CFP. The other regular data collection is under the Aquaculture Statistic Regulation, and covers all member states. Reporting on marine aquaculture species as well as trout, salmon and eel is mandatory. Data are normally reported annually (STECF 2016) and are also available online for national level. For regions within individual EU-countries, data availability varies, as marine socio-economic data are not collected regularly under EU regulation. The annual reports from STECF include direct effect of aquaculture on other industries, but not complete multiplier studies with indirect and induced effects (Bostock et al. 2016, referring to STECF 2014).

The data collection under the Aquaculture Statistic Regulation is based on Regulation (EC) No 762/2008 of the European Parliament and the Council. According to this all Member States shall report on all aquaculture activities conducted in freshwater and saltwater on their territory. The data shall cover annual production (volume and value), annual input (volume and value) to capture-based aquaculture, the annual production of hatcheries and nurseries and the structure of the aquaculture sector. The data shall cover at least 90% of the production and be collected by species, unless production is below defined thresholds. Data have been collected since 2009, with the last countries started reporting with data from 2011 onwards. Segmentation of the data is aimed to be harmonized between the two data collection programmes.

Trade data, segmented by species groups, but not techniques and on an annual basis can be accessed at the European Market Observatory for Fisheries and Aquaculture Sector: <http://www.eumofa.eu/de/sources-of-data>

**Norway**: Data on production and employment are collected annually from all aquaculture companies by the Fisheries Directorate and by Statistics Norway: <https://ssb.no/en/jord-skog-jakt-og-fiskeri/statistikker/fiskeoppdrett>. Data is available both national and regional level. Production volumes, feed use, export volumes and export prices are reported monthly or weekly. Profitability and cost studies for salmon and trout farming (grow-out and smolt production) have been done annually since 1986, are sample based, and provide profit data and detailed cost items at national and county levels, and also for “small”, “medium” and “large” companies: <http://www.fiskeridir.no/Akvakultur/Statistikk-akvakultur/Loennsomhetsundersoekelse-for-laks-og-regnbueoerret>. Data on the number of licences are available, making it possible to calculate direct employment and production value per license at county level. More detailed cost studies have been done in the latter years, including the costs of salmon lice for the farmers (Iversen et al. 2017, Abofiola 2015). These are only retrospective though, and public forecast or scenario studies are only done ad-hoc (e.g. Winther et al. 2013, Olafsen et al. 2012). Multiplier studies are done every second year for the national level (e.g. Richardsen and Bull-Berg 2016) and have been done on an ad-hoc basis for smaller regions (e.g. Olafsen et al. 2014).

**Scotland:** National level data is covered by EU-wide data collections. Marine Scotland publishes annual data on production volume, value, gross value added, employment by finfish and shellfish aquaculture sectors (<https://www2.gov.scot/Topics/marine/Publications/TopicSheets/tslist/economy>). Reports from annual surveys on production and employment by aquaculture sectors are available from 1979 (<https://www2.gov.scot/Topics/marine/Publications/stats/FishFarmProductionSurveys>). An assessment of the benefits to Scotland of aquaculture was done in 2015 (Alexander et al. 2015). In 2018 Marine Scotland published «Scotland's marine economic statistics», which includes aquaculture as one of the marine sectors. The publication of data seems to be planned as a regular issue, including a report, data files and a summary «Topic sheet» (<https://www2.gov.scot/Topics/marine/Publications/TopicSheets/tslist/economy>). A separate topic sheet on «The value of aquaculture in Scotland» (Marine Scotland 2017) sums up the economic impact and structure of Scotland’s aquaculture industry by region and species group (salmon, rainbow trout, other finfish, and shellfish), including the wider economic and social impacts through multiplier effect. The latter includes direct, indirect and induced effects. The topic sheet drew on “research commissioned by Marine Scotland and Highlands and Islands Enterprise (HIE) to update evidence on the baseline economic impact of Scotland’s aquaculture supply chain”. National level output multipliers for indirect effects and multiplier values for both indirect and induced effects are published by the Scotland Government on an annual basis (<http://www.gov.scot/Topics/Statistics/Browse/Economy/Input-Output/Downloads>). In the (local) planning process for finfish farming, economic assessments are required as part of the mandatory impact assessment. This includes direct and multiplier effects on a local scale (site level). The data is available for all regulatory agencies, but only to the public for a fee and for a short amount of time.

The Scottish Salmon Producers Organisation produces an economic report on the sector on a biennial basis, aggregating data for all companies across the nation but also including a breakdown for the five regions that host production operations. The report covers capital investment, services and suppliers, expenditure on wages, exports, and grants for local communities (Scottish Salmon Producers Organisation, 2017). In this paper, this has not contributed to the colouring of the data availability tables, as we have kept data from producer organisations outside.

**France:** National level data is covered by EU-wide data collections. There is no information about the indirect employment associated with aquaculture. Two national censuses of the shellfish-farming sector have been carried out, with detailed structural data and revenues of companies (Girard et al. 2005, Agreste Chiffres et Données Agriculture 2015), but not accounting information. There were national censuses on marine fish farming and salmon farming in 2011[[1]](#footnote-1). For the regional level, there are two main sources of data. The first is the national census managed by the statistic services of the Ministry of Food and Agriculture, which are carried out regularly. They collect information on the characteristics of companies, including administrative status, VAT regime, choice of accounting system, productive and commercial specialisation, surface area for aquaculture production rights, capital, labour use, commercial sales, and revenues, but not any detailed accounting data. The second source are the annual surveys conducted by the Ministry in charge of Fisheries and Aquaculture. Data collection concerns information about the number of companies by region, the total production, commercial sales and employment. For the local level, there are some ad-hoc studies mainly conducted by regional administrations. These documents describe the sector quantitatively and qualitatively at regional and local scales. Data mainly concerns structural indicators about the companies, production rights, production and employment.

**Canada:** Data are generated annually at both national and regional level. A survey program also collects financial and operating data to make national and regional national accounts (Fisheries and Oceans Canada 2018). Multiplier studies have been made on an ad-hoc basis, with the latest being from 2013 (Fisheries and Oceans Canada 2013), but based on a 2008 input-output regional economic model. Ridler et al (2007) analysed the economic viability and risks associated with integrated multi-trophic aquaculture combining salmon and mussel or seaweed farming in eastern Canada. Ad-hoc summary data on direct, indirect and induced benefits of aquaculture nationally and for the Province of Newfoundland and Labrador have been made (Manning and Hubley, 2016a, 2016b). At the local level, data is scarce other than direct employment data. Data regarding production volume and by species and production technique may be possible to extract from applications for licences and renewals.

Data on production, value, exports and value added is made annually, for nation and provinces; <http://www5.statcan.gc.ca/olc-cel/olc.action?objId=23-222-X&ObjType=2&lang=en&limit=0>. A survey program collects financial and operating data to make national and regional national accounts; <http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=4701>. More detailed data is available for selected provinces, including on costs of inputs, inventory changes, salaries and wages; <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/prim56a-eng.htm>. Fisheries and Oceans Canada have made socio-economic impact studies of aquaculture in Canada; 2013 Edition: <http://www.dfo-mpo.gc.ca/aquaculture/sector-secteur/socio/index-eng.htm>.

**USA:** National marine aquaculture production and value data is compiled annually by the National Marine Fisheries Service from contacts at state agencies and industry associations. Aquaculture data is published along with wild capture commercial fishery landings and recreational data in Fisheries of the US: <https://www.fisheries.noaa.gov/national/commercial-fishing/fisheries-united-states>. There is a two-year lag, so that Fisheries of the US 2018 is published in 2019, and provides aquaculture production data for 2017. At the state level, the most comprehensive and systematic data collection is Virginia Shellfish Aquaculture Situation and Outlook Report: <https://www.vims.edu/research/units/centerspartners/map/aquaculture/docs_aqua/vims_mrr_2018-9.pdf>. This annual report includes oyster and clam production, prices, hatchery data and employment. Some reports have been published with multiplier studies for regional (Cole et al. 2017) and local level (Murray 2014), and there has also been a recent publication demonstrating an approach to determine the economic impacts of aquaculture at the national level (Lipton et al. 2019).

**Spain:** National level data are covered by the EU-wide data collections. National and regional data are also available on more detailed level for industry structure, use of various inputs, production use (household or industrial), on economic performance, and type of commercialization channels. Additional ad-hoc regional data also exists (MAGRAMA, 2016).

The Spanish Ministry of Agriculture, Fisheries, Food and Environment (MAPAM) provides public annual data of production (in volume and value) of marine and continental aquaculture since 1985. The information also includes the number of aquaculture installations, number and type of species. To collect this data, the MAPAM develops two surveys: one about economics of aquaculture and one about aquaculture installations.

For the first survey, the MAPAM offers public data for the 2009-2016 period including such as type of species, production at basic prizes, added value, revenues, intermediate inputs (feed inputs, maintenance, public subsidies and other taxes), direct employment by gender, salaries, type (on land or at sea), and size of aquaculture farms. This survey also provides information of socioeconomic indicators (e.g., annual rate of employment, profitability per worker, unit cost per worker, productivity, etc.) to monitor the aquaculture development over time[[2]](#footnote-2).

The survey on aquaculture installations[[3]](#footnote-3) provides information for the 2002-2017 period by including data on the number of farms with authorizations (with and without production), production (in volume and value) by species, by Autonomous Community (AC), production uses (human consumption or industrial uses), type of employment (full and part-time and type of aquaculture farms), destination for products (same AC, other AC, other countries of the EU or third countries), and type of commercialization channels (at fishing guilds, central points of commercialization channels, wholesalers, retail traders).

The Spanish Government annually collect information on export data of aquaculture products. The ICEX database (https://www.icex.es/icex/es/index.html) also provides detailed information of the origin and destination by countries and Autonomous Communities, type of species -fishes, molluscs and crustaceans- and type of presentations -fresh, frozen, etc.-) of aquaculture products.

**Ireland:** National level data is covered by the EU-wide data collections. Annual Aquaculture Survey Reports are published by the national agency responsible for aquaculture within 5 months of the surveyed year and provides national and regional data for production volume and value and direct employment, like BIM (2018). Aquaculture trade data at national level, though mixed in with data of the other seafood sectors, is published annually and within three months of the surveyed year, like in BIM (2017). An early study of the socio-economic impacts of aquaculture in regions in Ireland were White and Costello (1999).

**Germany:** National level data is covered by EU-wide data collections. Marine aquaculture (mussels production) is practiced in two federal German states: Lower Saxony and Schleswig-Holstein. Statistic offices in these states publish data and reports for the number of farms and their production, whereas volume separated by municipalities is only segmented for the most prominent species, not including marine molluscs. For Schleswig-Holstein, data on production value for “fish products and seafood“ overall is published. Statistics on trade are published, summerized as „Fish, Shellfish, molluscs“, or „Fishmeal, Meatmeal and others“ which allows no distinction between fisheries and aquaculture products, species or production technique: E.g. Schleswig-Holstein: <https://www.statistik-nord.de>; Lower Saxony: <http://www.statistik.niedersachsen.de>. For lower Saxony, data on employees within regional fish production, not specified per species and techniques, is only available on an annual basis until 2002 for regional data: <http://www1.nls.niedersachsen.de/statistik/html/default.asp>. Quaterly data per Federal State for the total fisheries sector is available from: <https://statistik.arbeitsagentur.de/>. No data is available on multiplier effects, not on the national nor the regional level.

In addition, the German federal statistic offices publish data and reports for the number of marine farms and production volume separated by federal state on an annual basis. Quarterly data on employment within the aquaculture sector is only available on a national level and without distinction between marine and freshwater production or on a federal state level for the total fish sector (fishery and aquaculture employees), both from the federal labour office statistics. Statistics on trade are published, but do not allow a distinction between fisheries and aquaculture products, species or production technique. No data is available on multiplier effects (direct and indirect) on the national or regional level.

## Data on effects on non-aquaculture markets

**EU-market overall:** The importance of salmon product type and origin in the overall European salmon market was analysed by Asche et al. (1998). For the impact of aquaculture on seafood markets, Asche et al. (2015) investigated how the introduction of aquaculture production reduces the price volatility of the species’ total supply, but found that these effects vary between species.

**Norway:** Gaasland (2008) used a general equilibrium model for Norwegian food sectors to analyse growth in Norwegian aquaculture under two regimes for international trade, and how it also impacted other sectors in Norway, as well as labour, capital and foreign exchange rate. Tveteras (2002) found agglomeration gains in Norwegian aquaculture, indicating that companies located in aquaculture clusters had cost savings compared to those outside of clusters. The cost saving could be due to lower prices of inputs, a market externality, but it could also be due to knowledge externalities giving a more efficient operation.

**Scotland:** No data or studies found.

**France**: Regnier and Bayramoglu (2016) suggests that French markets for wild and farmed sea bream are integrated, but not the markets for wild and farmed sea bass.

**Canada**: No data or studies found.

**USA:** Anderson (1985) considered market Interactions between salmon aquaculture and the common-property commercial wild salmon fishery analytically, but not empirically. Norman-López (2009) studied the competition between farmed and wild tilapia.

There is no standardised data collection of market externalities by public authorities in Spain. Price interactions between farmed salmon and wild fish species have been investigated by Jaffry et al. (2000) and Rodriguéz and Ramundo (2015), Fernández Polaco and Luna (2010) studied the public perceptions of quality of wild and cultured seabream, Villasante et al. (2013) analysed the prices in origin and destination to better understand the dynamics of the seafood markets in traditional, supermarkets and large shopping areas, Villasante et al. (2013a) investigated the degree of economic concentration EU markets, while Rodríguez et al. (2014) studied the market interactions between cultured and captured Gilthead sea bream.

**Spain**:Price interactions between farmed salmon and wild fish species have been investigated by Jaffry et al. (2000). Fernández Polaco and Luna (2010) studied the public perceptions of quality of wild and cultured seabream. Rodriguez et al. (2013) found no market integration between cultured and wild gilthead sea bream in the Spanish seafood market. Rodriguéz and Ramundo (2015) found that farmed and wild gilthead sea bream, sea bass, turbot and farmed salmon are not substitutes in the Spanish seafood market. Villasante et al. (2013) analysed the prices in origin and destination to better understand the dynamics of the seafood markets in traditional, supermarkets and large shopping areas. Villasante et al. (2013a) investigated the degree of economic concentration in EU wild fish and aquaculture markets, while Rodríguez et al. (2014) studied the market interactions between cultured and captured Gilthead sea bream.

**Ireland**: No data or studies found.

**Germany**: Bronnmann (2016) analysed the whitefish market, while the market integration of farmed trout was studied by Nielsen et al. (2007).

**Elsewhere/Global:** Some analyses relevant for the aquaculture sector in the region focused on here have been made where the market is global or outside of the region. Asche et al. (1999) considered the global market for five species of salmon. Asche et al. 2001 studied market interactions for aquaculture products for salmon, catfish and sea bass/sea bream on the global market. Asche et al. (2005) analysed the market for salmon in Japan, including both farmed and wild salmon, as well as different salmon types from different countries. Asche et al. (2018) studied how the Chilean aquaculture disease crisis affected global salmon aquaculture markets. Villasante et al. (2013) also carried out a global analysis to investigate the level of concentration of aquaculture and wild fish species production by using the four-firm concentration ratio (CR4) and the Herfindahl Index, both indicators commonly used in economics. Asche and Tveteras (2004) studied the global market for fish meal and soy meal.

## Data on economic externalities

**Several countries:** Whelan et al. (2006) estimated costs of sea lice treatment in salmon farming in Norway, Ireland and Scotland, and explored its potential benefits as greater income and employment in the commercial and recreational salmon fishing sectors. However, they did not collect data on the actual empirical link between these variables.

**Norway:** How escaped farmed salmon from fish farms affect the willingness-to-pay for recreational fishing of Atlantic salmon in Norwegian rivers has been investigated by Olaussen & Liu (2011). The parasitic Salmon lice that occur in Salmon farms (as well as naturally in nature) can give higher production costs for other farms due to elevated infestations, and reduced catches of wild salmon due to increased mortality of wild salmon being infested (Asche et al. [1999](http://onlinelibrary.wiley.com/doi/10.1111/jfd.12061/full#jfd12061-bib-0010)). Abolofia et al (2017) estimated the private cost of salmon lice for the salmon farmers, which could be viewed both as a direct effect and an externality. Olaussen et al. (2015) estimated the cost of sea lice induced mortality on wild Atlantic salmon in Norway. Liu et al. (2014) developed a model to study escaped farmed fish as an invasive species and used a case study of farmed salmon in Norwegian salmon rivers, but did not present actual numbers. Asche et al. (2016) studied the benefits of industrial agglomeration for individual aquaculture companies. Aanesen et al. (2018) studied the willingness of people in northern Norway to pay for environmental regulations that affected the future number of fish farms on the coast, and marine fishing tourism facilities, the number of new jobs, the amount of garbage on the beaches, and the typical catch in marine recreational fishing. Aanesen and Mikkelsen (forthcoming) did a cost-benefit analysis of aquaculture expansion in a Norwegian region, including direct and indirect economic effects and people’s willingness to pay to get/avoid aquaculture. The Norwegian Institute of Marine Research annually publishes a risk assessment of Norwegian fish farming (Grefsrud et al. 2018), including the impacts on wild salmon stocks, marine fishes, and on the environment, but so far it has not included economic assessments. As part of (municipal) coastal zone planning, proposed aquaculture localities must normally be impact assessed, but it is not usual to include economic assessments, except sometimes on direct employment.

**Scotland:** Willingness to pay for environmentally sustainable salmon aquaculture practices were assessed by (Whitmarsh & Wattage, 2006).

**France**: No available economic data or studies of externalities.

**Canada:** For the east coast of Canada, which is focus here, we have not been able to find specific data or studies. Martinez-Espiñeira et al. (2016) estimate the non-use benefits by Canadians from adopting integrated multitrophic aquaculture to mitigate external effects on the marine environment from Atlantic salmon aquaculture. Liu et al (2011) considers the effect of sea lice from farmed salmon impacting wild salmon fisheries using bioeconomic modelling but the geographic focus of the study was the west coast of Canada. Knott and Neis (2017) explored the privatization and marketization (in herring fleet ITQs and salmon aquaculture lease systems), (re)regulation, financialization and globalization have interacted to support the reshaping of regional fisheries from mixed small-scale, family-based, petty commodity fisheries towards vertically-integrated, corporate, financialized fisheries characterized by ocean grabbing in New Brunswick.

**USA:** Hicks et al. (2004) did an empirical analysis of improved recreational fishing benefits due to fishing over planted oyster bottom. Lipton (2008) included an Empirical analysis of direct industry benefits from oyster aquaculture and a theoretical discussion of impacts of oyster production on water quality, recreational fishing and commercial capture of other species, as well as waterfront property values. Higgins et al. (2011) measures economic value of cost savings to meeting water quality goals due to different methods of oyster aquaculture, while DePiper et al. (2017) does the same, but covers both oyster restoration and aquaculture.

**Spain:** Villasante (2009) analysed the social-ecological effects of the Galician mussel farming on shellfisheries and small-scale fisheries in Galicia (NW Spain), Gozlan (2010) analysed the cost of non-native aquatic species introductions, of which aquaculture is an important source.

**Germany:** Schernewski et al. (2012) analysed the economic costs and benefits of intentionally using Zebra mussel farming to reduce eutrophication due to agricultural run-off in the Oder Lagoon in Germany.

**Ireland:** van Osch et al. (2017) estimate the Irish public's willingness to pay a premium for salmon farmed in an Integrated Multi-Trophic Aquaculture (IMTA) production system with a decrease in environmental pressures compared to ordinary farming.

**Elsewhere:** There have been some studies of external effects of aquaculture in the region on actors or areas outside of the region. Asche and Tveteras (2004) consider if the demand for fish meal for aquaculture feed could lead to overfishing in reduction fisheries, where Chile and Peru are the dominating actors.

# Overview of availability of economic data on the effects of aquaculture

Data availability summed up and average score calculated across different statistics for each country and geographic level is given by Table 8 - Table 10 below. Green is given the value 3, orange 2 and red 1. Average scores are then calculated across all variables for each country and geographic level (bottom of Table 8 - Table 10). This is used for colour-coding in Table 6 in the paper. Hence, the variables in each of the tables are given equal weight for the colour coding for that type of economic data/effect in Table 6 in the paper. Where data for several geographic levels are in the “Data need level” in Table 6 in the paper, the average across those levels are used to colour code.

Table 7 Data availability on direct and multiplier effects.



Table 8 Data availability of effects on non-aquaculture markets.



Table 9 Data availability on external effects.



# Management system for aquaculture

This section describes how the management systems for aquaculture are in the EU and our case countries, and thus implicitly explains Table 4 in the paper.

Before that we present the data behind the triangle plots (Warnsloh, 2015) in Figure 1 and Figure 2 in the paper, based on Table 4 in the paper. These illustrate how the responsibility for aquaculture management in the case countries is distributed between national, regional and local level administrations, and how the responsibility for the different types of aquaculture management is distributed between levels across our case countries. The numbers behind the plots are given in Table 11 and Table 12, respectively. For both, each cell in Table 4 in the paper is given equal weight. The plots should only be seen as rough illustrations, as the actual share of responsibility in countries could be different from the mathematical rule (presented in the footnotes to the tables below) we have used to calculate the data for the triangle plot.

Table 10 Data for triangle plot illustration on how aquaculture-related management is distributed between national, regional and local management levels in our case countries\*.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Country** | **L** | **N** | **R** | **SUM** |
| NOR | 0.80 | 3.1 | 1.1 | 5.00 |
| SCO | 1.00 | 2 | 2 | 5.00 |
| FRA | 4.60 | 0 | 0.2 | 4.80 |
| CAN | 0.33 | 1.33 | 3.33 | 4.99 |
| US | 0.00 | 1.9 | 3.3 | 5.20 |
| ESP | 0.00 | 4 | 1 | 5.00 |
| IRE | 1.60 | 3.4 | 0 | 5.00 |
| GER | 1.00 | 1 | 2 | 4.00 |
|  |  |  |  |  |
| **Relative shares of SUM:** | **L** | **N** | **R** | **Sum** |
| NOR | 0.16 | 0.62 | 0.22 | 1.00 |
| SCO | 0.20 | 0.40 | 0.40 | 1.00 |
| FRA | 0.96 | 0.00 | 0.04 | 1.00 |
| CAN | 0.07 | 0.27 | 0.67 | 1.00 |
| US | 0.00 | 0.37 | 0.63 | 1.00 |
| ESP | 0.00 | 0.80 | 0.20 | 1.00 |
| IRE | 0.32 | 0.68 | 0.00 | 1.00 |
| GER | 0.25 | 0.25 | 0.50 | 1.00 |

*\*) Each cell in each country’s row in Table 5 in the paper is assigned a value of 1, which is divided between L, R and N according to which hierarchical levels are involved in that type of aquaculture management. If it is only one hierarchal level involved, that level gets a score of 1. If it is shared equally between levels (denoted with a “/”), they get equal shares of 1. If one or two hierarchal level has some influence (denoted with bracket “(.)”), the ones in the brackets share 0.2, and the main hierarchal level gets 0.8. Then it is summed up across L, R and N for the five types of aquaculture management.*

Table 11 Data for triangle plot illustration on how different types of aquaculture-related management is distributed between national, regional and local management levels in our case countries\*.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Type of aquaculture-related management** | **L** | **N** | **R** | **SUM** |
| Production license | 0.90 | 3.80 | 3.30 | 8.00 |
| Area planning inshore/CZ | 1.50 | 1.90 | 4.60 | 8.00 |
| Area planning offshore | 0.50 | 5.60 | 1.90 | 8.00 |
| Location permit | 0.40 | 1.80 | 4.80 | 7.00 |
| Other permits\* | 1.83 | 3.63 | 2.53 | 8.00 |
|  |  |  |  |  |
| **Relative shares of SUM:** | **L** | **N** | **R** | **sum** |
| Production license | 0.11 | 0.48 | 0.41 | 1.00 |
| Area planning inshore/CZ | 0.19 | 0.24 | 0.58 | 1.00 |
| Area planning offshore | 0.06 | 0.70 | 0.24 | 1.00 |
| Location permit | 0.06 | 0.26 | 0.69 | 1.00 |
| Other permits\* | 0.23 | 0.45 | 0.32 | 1.00 |

*\*) Each cell in each country’s row in Table 4 in the paper is assigned a value of 1, which is divided between L, R and N according to which hierarchical levels are involved in that type of aquaculture management. If it is only one hierarchal level involved, that level gets a score of 1. If it is shared equally between levels (denoted with a “/”), they get equal shares of 1. If one or two hierarchal level has some influence (denoted with bracket “(.)”), the ones in the brackets share 0.2, and the main hierarchal level gets 0.8. Then it is summed up across L, R and N for the five types of aquaculture management.*

## The EU

The EU use non-binding strategic guidelines to promote an integrated approach to aquaculture by the Member States. Thus, the licensing of aquaculture and the regulation of fish farms is a matter for the Member States. However, compliance with EU environmental legislation, particularly in relation to environmental impact assessment and the protection of biodiversity under the Habitats and Birds Directive, as well as EU measures to control disease and to ensure food safety law must be ensured (Long, 2016).

## Norway

**Overview:** The Ministry of Trade, Industry and Fisheries controls production licences. This is done to regulate growth and production volume both with commercial market and environmental considerations (Meld. St. 16. 2014-15). A license for using a particular locality is granted by regional aquaculture authorities (county level), but requires permits or acceptance also from national authorities (regional branch offices) for environment, food safety, watercourses and coastal administration (Sandersen and Kvalvik 2014). The locality must also be in an area that is designated for aquaculture in the area’s coastal zone plan. In Norway, the municipalities are responsible for area planning for activities up to 1 nm from the base line, and they can also grant exemptions from their area plan.[[4]](#footnote-4) For sea areas beyond 1 nm from the base line, the state (national level) is the planning authority. From 2017, a system of 13 Production Areas for aquaculture was established (Regulation 2017). There, production capacity regulation will be based on assessments of the impact on wild salmon stocks from salmon lice originating from salmon farming.

**Details:** The management and planning related to aquaculture in Norway takes place at different political, administrative and geographical levels. To do aquaculture, a license to produce a specific volume of specific species at specific localities is required. For grow-out of salmon and trout in seawater, the number of licenses is limited, and they have been issued following license calls in application rounds. The government (as a whole) or the relevant ministry set Regulations under the Aquaculture Act to decide details on how aquaculture is regulated, and under what conditions new licenses can be issued. To get a production license, also demands following the Acts on Food Safety, Animal Welfare, Harbours and Shipping, Biodiversity, Pollution, Outdoor Recreation, Water Resources, and Planning and Building must be fulfilled. Through this, several Regional State Offices are involved, as well as the county municipality and the municipality for where the localities are. Norway has 18 county municipalities and 422 municipalities as of February 2018. Following a regional reform, the numbers in 2020 will be 11 and 354, respectively.

The county municipalities are coordinating the location application processes. A locality must be placed in a zone where aquaculture is allowed in the local coastal zone plan (or an excemption from it must be granted). The municipalities are the authorities for coastal zone planning to 1 nautical mile beyond the base line (The base line is a line connecting the outer parts of the mainland, islands and skerries). If a zone in the proposed coastal zone plan is to include aquaculture, this should normally be impact assessed. While the municipal council is the one making the formal decision on their coastal zone plan, several authorities can make formal objections to proposed zoning. These authorities include several state agencies, neighbouring municipalities, the county municipality. Unless such objections are resolved, the plan is not valid for those zones. If negotiations between the planning municipality and the authority with the formal objection does not resolve it, the Ministry in charge of the Planning and Building Act will decide.

In the Aquaculture Acts through the years, and in the documents preparing the Acts, important concerns for regulating the number of licenses have been for the environment, the markets for products and input factors, rural development, and the development of the aquaculture industry. Detailed concerns and priority factors, beyond what the Aquaculture Acts directly have set, have been defined in Regulations with call for licences (Hersoug et al. 2019). These include characteristics of those to be granted a license (e.g. smaller actors, in specific geographic regions, with measures to achieve “extra” local and regional economic integration and effects, and/or reduce environmental risks, and achieve innovations (op. cit.)). When the number of licenses to be issued in different regions is set in the Regulations, the Fisheries Directorate’s regional offices decide among the applicants in their region. For licenses without a regional designation, the priority is done at national level. The national level is also appeal authority.

For the making of laws and regulations, as well as coastal zone plans, public participation is required. As a minimum, this must be through public hearings, but consultations through different types of public meetings are common.

From 2002, the state could demand payment for a license. The cost has steadily gone up. In the latest license round (announced in 2013), some of the licenses were auctioned off, and the highest price was 66 Mill. NOK. A license allows for a Maximum Allowed Biomass (MAB) at any given time of 780 or 945 tonnes (depending on region, with the largest MAB in the north).

Since October 2017, the Norwegian coast has been divided into 13 “Production Areas”. In each of these, the plan is to regulate production volume depending on environmental conditions. As of 2018, the indicator to be used is the number of salmon lice per fish on different farms, and a “traffic licht” assessment of the salmon lice-induced mortality on wild salmon stocks in the area (REF Ot Prop). Following an evalution of this in 2017, 2 areas with “red light” may have to reduce capacity (to be decided in 2019). In 8 areas, with “green light”, production capacity as MAB can be increased by up to 6 %. 2 % of this is offered to existing farmers there, at a fixed price corresponding to a license price of 93.6 – 113.4 Mill NOK. Existing farmers who can document that they have not contributed to the salmon lice problem can apply for a full 6 % increase in MAB, regardless of the evalution verdict for their Production Area. Remaining production capacity increase up to 6 % overall will likely be auctioned off (St. meld. 16 2014-15).

The system for management of aquaculture can be described to have transformed, since the temporary Aquaculture Act of 1973 and up to today, from announcing and awarding new grow out licenses for salmon and trout based on pre-determined geographic allocation and discretionary consideration of a number of factors announced in Regulations, to an overall environmental indicator-based production regulation, where allocation among farmers is mainly based on willingness to pay for the license.

Through the years, the municipalities’ willingness to prioritise area for aquaculture in their coastal zone plans have varied. The Norwegian aquaculture industry has developed much from the 1970s, when it was mainly locally owned and locally operated. Now, large companies dominate, the production at the pens is capital intensive with relatively small need for labour, and the slaughter and processing is in relatively big facilities, typically centralised to one municipality in a wider region. Fish from pens also in other municipalities are transported there by well-boats. Overall, this means that some municipalities get relatively much jobs and other benefits from aquaculture activities, while others get relatively little. The municipalities that have lost out in this process, have pressed on for an area-fee or similar arrangement to get more of the benefits. An Aquaculture fund (“Havbruksfondet”) was established in 2016. 80 % of the payment for new licenses or increased Maximum Allowed Biomass goes into the Fund, and is then distributed among all the municipalities and county municipalities with aquaculture localities.

In addition to the ordinary commercial grow out licenses, there are several other types of licenses. They include for research, education, exhibition, parent fish (producing roe), hatcheries for fingerlings/juveniles, and for development. The government opened for a round of development licenses in 2015, to stimulate innovation. These licenses are time-limited, but those that fulfil their goals with the development license may, depending on approval, convert it to an ordinary grow out license against a set fee. A total of 64 applications came in, asking for a total of 605 licenses. For comparison, as of 2017, the total number of existing grow out licenses for salmon and trout was around 980, so the total production volume applied for is very large.

## Scotland

**Overview**: Area planning and infrastructure policies are made at a regional level. However, the development of these policies and the areas for focus are reviewed and renewed every five years, under a national level Scottish Planning Policy, and the National Planning Framework. These reviews involve the most local statutory tier of governance, community councils, as well as public hearings. Community councils and public hearings influence the priority areas for development in their local areas. As such, regional area planning and infrastructure policies are made up of local-scale priorities, matched with national level strategies, and are signed off by national level government officials before being enforced by regional authorities.

**Details:** An independent report of consenting and planning processes provided an overview of the regimes and time-frames which are involved in gaining the correct licences for operating aquaculture sites, both finfish and shellfish (Scottish Government, 2016). Without amendments, hold-ups, or resubmissions of evidence, the consenting process takes two and a half years for finfish, one year for shellfish and is variable for seaweed. The report highlighted the high costs and lengthy consenting process as a barrier to shellfish aquaculture development and a risk to finfish aquaculture expansion. Table 13 provides an overview of the consenting authorities and licences needed to develop and aquaculture operation in Scotland.

Table 12 Regulations and authorities involved in consenting for Scottish aquaculture activities (based on Scottish Government 2016)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Application** | **Legislation** | **Level** | **Authorising regulator** | **Aquaculture type** | | |
| **Fin-fish** | **Shell-fish** | **Sea-weed** |
| **Planning Permission** | Town and Country Planning (Scotland) Act 1997 | Regional/ Local | Local Authority | 🗸 | 🗸 |  |
| **Environmental Impact Assessment (mainly finfish, but can be for shellfish)** | Town and Country Planning (Environmental Impact Assessment) (Scotland) Act 2011 | Regional | Local Authority | 🗸 | 🗸 |  |
| **Marine Licence** | Marine Scotland Act 2010 | National | Marine Scotland Licencing Operations Team | 🗸 | 🗸 | 🗸 |
| **Seabed Lease** | Scottish Crown Estate Bill 2018 | National | Crown Estate Scotland | 🗸 | 🗸 | 🗸 |
| **Aquaculture Production Operation Authorisation** | Aquatic Animals Health (Scotland) Regulations 2009 | National | Marine Scotland Fish Health Inspectorate | 🗸 | 🗸 |  |
| **Controlled Activity Regulation Licence** | The Water Environment (Controlled Activities) (Scotland) Regulations 2011 | National | Scottish Environment Protection Agency | 🗸 |  |  |
| **Habitats Regulations Appraisal** | The Conservation Regulations 1994 as amended | National/ Regional | All of the above and Scottish Natural Heritage | 🗸 | 🗸 | 🗸 |
| **Work Licence** | Zetland County Council Act 1974 | Regional/ Local | Shetland Islands Council |  |  | 🗸 |

Plans for the economic development of Scotland (of which aquaculture is one) are identified at a national level. However, these plans are enforced at a regional level in consultation with local level community consultees and national level statutory consultees/ government agencies (Scottish Natural Heritage, Marine Scotland, Historic Scotland, the Maritime and Coastguard Agency and other infrastructure agencies). The permitting agencies are siloed, with only the Local Authority considering the economic dimensions of any aquaculture development, within the Local Development Plans under Scottish Planning Policy, and considering Scotland’s national level Economic Strategy. This data is often limited in scope and not easily available to the general public. Site specific local direct effects economic data is available to decision-makers through the Town and Country Planning process. Economic data is not considered in other permits. However, given the relative scale of the industry in Scotland, especially on the West Coast and Islands, more granular and detailed economic data could be useful within other areas of the licensing and consenting regime for assessing the overarching efficacy of the industry.

## France

**Overview**: Aquaculture licenses are authorized by the Marine Culture Commission. There is one Commission per “department” (the sub-regional administrative level in France). The Commissions have members from public administration, aquaculture industry, and other stakeholder groups, and are chaired by the Prefet, the representative of the State on the regional level. Area-allocation to aquaculture are decided on the local level and also include conditions for production in terms of species, stage of rearing, and cultural techniques.

**Details:** In France, production rights are granted by decentralized administrations. The application for a concession is registered at the Administration but its allocation is previously discussed in local Marine Culture Commissions (Mongruel and Pérez Agúndez 2012). These local institutions in charge of the management of the marine public domain reserved to aquaculture are composed by representatives of the administration, of professionals and other stakeholders. In this co-management systems professionals constitute a proposal force but the prefect, as the representative of the State takes the final decision of any decision concerted by the MCC. Areas allocated to aquaculture activities are fixed and described in local management plans called "schema des structures" (SDS). These plans describe precisely the extent of the marine space allocated to aquaculture and the conditions of production in terms of species, stage of rearing, cultural technique (Girard and Pérez Agúndez 2014). A new request of concession (existing or created) must respect the requirements described it the national decree N° 83-228 modified by the decree N° 1349-2009 of 29 October 2009 and the effects on the environment must also be assessed (Directive 2011/92/EU) before being approved.

## Canada

**Overview**: The regulation of aquaculture involves federal and provincial authorities, in some cases also territorial governments, and must regard the constitutionally protected rights of Aboriginal peoples (Doelle and Saunders 2016). Three of the provinces on the East coast have themselves primary responsibility for regulating marine-based aquaculture in their territory, through their own acts regulating aquaculture, and Memorandums of Understanding with the federal government. This regards New Brunswick, Newfoundland and Labrador, and Nova Scotia. Federal agencies are responsible for issues regarding wild fisheries, endangered aquatic species, transportation, health and food safety (op cit.). In the fourth province, Prince Edward Island, a joint federal-provincial committee oversees the approval of marine aquaculture. Licenses can be granted for up to 20 years. While an aquaculture site plan must be approved for an aquaculture license to be granted, overall marine zoning plans with areas for aquaculture are not common in Canada.

**Details:** Aquaculture regulation and development in Canada involves both federal and provincial authorities, and in some cases also territorial governments. No agency has plenary authority over “aquaculture as aquaculture”, but some nine federal departments have some level of authority over approving and regulating aquaculture (Doelle and Saunders 2016). The federal Department of Fisheries and Oceans (DFO) is given a coordinating role, in addition to its own regulatory mandate. Others include Environment and Climate Change Canada (Canadian Shellfish Sanitation Program), Transport Canada, the Canadian Food Inspection Agency and the Canadian Environmental Assessment Agency. DFO also has responsibility for setting overarching national policies regarding aquaculture development. In collaboration with provincial governments and the Yukon Territory, the principal current policy level document governing the sector, “National Aquaculture Strategic Action Plan Initiative (NASAPI) – Overarching Document” was developed in 2011. This document under the auspices of the Canadian Council of Fisheries and Aquaculture Ministers (CCFAM, 2011), was developed following broad sectoral input from governments at multiple levels, First Nations and other indigenous groups, industry, community and academia at some 30 workshops across the country. Recognizing the contextual differences inherent in a country as large as Canada, the document identified five separate strategic action plans focusing on Pacific finfish and shellfish, Atlantic finfish and shellfish and fresh water aquaculture. Specifically focusing on the complexities associated with both the federal and provincial/territorial (Yukon) levels having some degree of shared authority over the sector, one of three strategic objectives over the lifespan of the plan is to strengthen the current regulatory framework. While the jointly developed East Coast marine finfish and shellfish action plans (CCFAM, 2011) are applicable to all four Atlantic provinces (New Brunswick, Newfoundland and Labrador, Nova Scotia and Prince Edward Island), the individual provinces do have authority on issues relating to land tenure. They also have responsibilities as specified in memoranda of understanding with the federal government as it relates to aquaculture development (Doelle and Saunders 2016). This includes the setting of provincial strategies, policies and making regulations, determining conditions affecting site selection and the issuing of licences (DFO 2015; Doelle and Lahey, 2014). In Prince Edward Island, however, the approval of marine-based aquaculture is under a joint federal-provincial committee (Doelle and Saunders 2016). Prince Edward Island do not have specific provincial aquaculture regulation in place, and the federal aquaculture process operates under the Fisheries Act. The constitutional rights of Canada’s Aboriginal peoples relate to title over defined areas (possibly including marine space), rights to certain activities (like fishing), and the right to be consulted if interference with their rights may be authorised (Doelle and Saunders 2016). All these can be relevant for granting and regulating aquaculture.

## USA

Responsibility for siting and managing marine aquaculture operations is either with the individual states or the federal level, depending on where the operations will take place (Powers and Carroll 2016). Generally, mariculture activities within three miles of the shore are managed by the individual states, and those further out by the federal level. The exception is “water bodies of the United States”, which are water bodies that can be less than three miles from the shore, but which can facilitate interstate commerce. There, the federal level also is responsible for siting and regulating mariculture operations. Which water bodies that are suitable for interstate commerce have however been disputed at times. Federal authorities are also responsible for regulations according to the Magnuson-Stevens Fishery Conservation and Management Act, the Endangered Species Act, the Marine Mammal Protection Act and the National Environmental Policy Act of 1969, and applications for mariculture permits and licences are often challenged on the basis of these (op cit.).

The US has a National Coastal Zone Management Program[[5]](#footnote-5), where all coastal states except Alaska participate. The states plan the use of their coastal areas according to standards set in the National Program, and receive federal funding in return. This included planning for aquaculture facilities in the coastal zone. The US also has a National Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes[[6]](#footnote-6), under which Regional bodies for marine spatial planning are established. These Regional Planning Bodies have representatives both from the coastal states and federal agencies. For the North Atlantic area studied in this paper, the Northeast, Mid-Atlantic and the Southeast regions are established.

## Spain

**Overview**: The State, through the Ministry of Agriculture, Food and Environment (MAFE), authorize aquaculture permits and concession for occupation of public spaces of maritime-terrestrial domain. A production permit is also required from the institution with marine competences in the Autonomous Community in which operations will take place. The Autonomous communities are Spain’s highest-level regions. A permit to discharge materials to the sea is also required at regional level when the aquaculture farm will be in a public maritime-terrestrial domain. A permission can be for 75 years, extensible for another 75 years.

**Details:** In Spain, the General Administration of the State, through the Ministry of Agriculture, Food and Environment, intervenes in the procedure for the concession for occupation of public spaces of maritime-terrestrial domain.

The responsible institution who starts the process for the authorization of an aquaculture permit in each Autonomous Community (AC) is the one with competences in fisheries and aquaculture. A company interested to ask for an aquaculture permit send a form to the Council of Fisheries (in a given AC) and the Ministry of Agriculture, Food and Environment including: a) justify of being a physical or legal entity, b) civil project technically viable indicating the detailed site and extension, and justification of the need for the occupation of public maritime-terrestrial space, c) an exploitation plan for the aquaculture development, d) the payment of a royalty (Law 42/2007) depending on the type of aquaculture installation (0,0133 €/m2/year if the concession is authorized within the estuaries, 0,0325 €/m2/year if is localised in territorial and internal waters, and 0,4005 €/m2/year in private property spaces).

After a period of official information without claims to the project, the AC will ask for a perceptive report from the Coast Department of the Ministry of Agriculture, Food and Environment, informing about the viability of the occupation. In case the interested company accept the conditions, the AC will publish the resolution in the Official Journal. The authorization is generally for 75 years, extensible for another 75 years. If the aquaculture installation is localised in a public space, the company needs for a “concession for occupation” of the public maritime-terrestrial space to be given by the Ministry of Agriculture, Food and Environment. The transmission of the concession is not allowed between companies or physical persons.

All installations with > 500 tn/year have to obtain the authorization to discharge in public and maritime-terrestrial space and an environmental permit are also both required in all AC. In addition, aquaculture exploitation should also be registered to be monitored by AC for diseases from aquatic animals (Real Decree Nº 1614/2008). The average time for the concession of an aquaculture permission has been 24.5 months in the 2006-2012 period (JACUMAR, 2013).

## Ireland

**Overview**: The final determination of all aquaculture licence applications is made at the ministerial level, after inputs from local government, private, and public stakeholder and relevant state agency and state department levels. For local level area management related to aquaculture siting and operation, the so-called Co-ordinated Local Aquaculture Management System (CLAMS) incorporates [Single Bay Management](https://www.marine.ie/Home/site-area/areas-activity/aquaculture/sea-lice/single-bay-management) with Coastal Zone Management policy and County Development Plans.

**Details:** The final determination of all aquaculture licence applications is made at ministerial level, after inputs from local government, private, and public stakeholder and relevant state agency and state department levels. Additional requirements of other government departments may need to be met in certain areas, for example of the Department of Arts Culture and the Gaeltacht regarding underwater archaeology issues. Aquaculture licensing is administered by the Aquaculture Foreshore Management Division of the Department of Agriculture, Food and the Marine on behalf of the Minister. The main piece of aquaculture licensing legislation is the Fisheries (Amendment) Act of 1997 and sections 2,3 and 4 of the Fisheries and Foreshore (Amendment) Act 1998. Minimum requirements are to get; An aquaculture production licence, a foreshore licence (for the intertidal zone, up to the spring high water line, which is state owned). Licences are typically granted for a period of 10 years. Businesses applying to renew a licence, are permitted to continue operating on the site during the renewal process, though are barred from grant aid access until fully licenced again.

The Co-ordinated Local Aquaculture Management System (CLAMS) incorporates [Single Bay Management](https://www.marine.ie/Home/site-area/areas-activity/aquaculture/sea-lice/single-bay-management) with Coastal Zone Management policy and County Development Plans. It is a non-statutory management system, separate to the licensing process but is an effective way of informing it, providing a concise description of the bay in terms of aquaculture operations, future potential, problems, etc. It also allows various Codes of Practice to be integrated into the local aquaculture management, providing the framework from which a management and development plan can be drawn. An information channel from local to national level and vice versa is thus created providing a framework for addressing issues affected by aquaculture activities and streamlining the resolution of these.

The ‘ Review Of The Aquaculture Licencing Process’ (May 2017) ([www.fishingnet.ie/independentaquaculturelicensingreview2017](http://www.fishingnet.ie/independentaquaculturelicensingreview2017/)) outlines definitively, via a series of flowcharts in appendices 6 to 10, the process and timeframe for making determinations on aquaculture licence applications separately for coastal finfish, shellfish culture sites and landbased facilities. The process is summarised more generally in ‘The National Strategic Plan For Sustainable Aquaculture Development’ (June 2015), pages 94-96, https://www.agriculture.gov.ie/.../aquaculturepolicy/nationalstrategicplanforsustainable..

The majority of Irish aquaculture operations lie adjacent to or within Natura 2000 sites, meaning that most licence renewals as well as new licence applications are subject to the Appropriate Assessment (AA) process. The system is addressing a backlog of applications that had added years to the process, in many cases. The backlog developed in part, due to failure to comply with the Water Framework Directive regarding AAs and the resultant Judgement against Ireland in December 2007 by the EU Court of Justice.

## Germany

There is no separate marine aquaculture location permit. The impact on nature and environment together with the authorisation for aquaculture production are decided in a Piggyback method (“Huckepackverfahren”). R/L indicates that permits are generally regulated by competent authorities on regional and local level, but for unincorporated regions, the management takes place at a regional level only.

# Index for data needs and data availability

Table 6 in the paper gives a colour code overview of the availability of different types of economic data for different geographical levels up against the needs. The colour coding there is based on the calculations in Table 7, Table 8 and Table 9 here in the supplementary material. The colour coding can however mask relatively large differences in the data availability. With also many types of policies/considerations and varying perceived usefulness of economic data for different policies and countries, we have tried to make a numerical index for the different countries that considers all these aspects.

The index builds on several elements. The first is the *Usefulness of economic data*, as indicated in Table 5 in the paper, and also in Table 6 in the paper: “X”=information can be useful; “**XX**”=Information is important to make a knowledge-based decision. This is used to assign “weight” to the data availability scores from Table 7, Table 8 and Table 9 corresponding to the geographic data need levels in Table 6 in the paper for that country, type of policy and type of economic data. The product of the usefulness weight and the data availability score from Table 7, Table 8 or Table 9 gives a *Data usefulness and availability score*. The table below calculates the index for each country based on this. The sum *Data usefulness and availability score* is divided by the sum *Usefulness of economic data* score to give the *Index* for that country.

The maximum index score is 3.0. It is achieved if all economic information perceived useful is available with a score of 3.0 in Table 7, Table 8 and Table 9. The minimum index score is 1.0. The weight for information important to make a knowledge-based decision is set to 1.0, and for information that “can be useful” to 0.3. Hence, poor data availability for “important” economic information impacts the index more than similarly poor data availability for information that only “can be useful”.

In the index, each type of policy/consideration weighs as much as the sum “usefulness” of the economic data. This may not reflect the relative importance of different aquaculture policies in the different countries correctly. The index should be interpreted with caution.

The weight assigned to X relative to the weight assigned to XX will impact the relative index scores of different countries. We have therefore done a sensitivity analysis, calculating the index values for varying relative weights for X from 0.1 to 0.5. This is given in Table 14, and illustrated in Figure 1.

The index scores are rather low for all countries, but there is variation among them.

Countries with index scores that increase with increasing weight for X ("information can be useful") have relatively better economic data availability for «information that can be useful» than for information «that is important», and vice versa.

We see that particularly Scotland’s index score increases with increased weight for X, but all the countries with a relatively low index score has this pattern. The index scores for the countries with relatively high index scores are less affected by the weight for X, indicating that their availability of economic data is more equal across «useful» and «important» information.

Table 13 - Index for data usefulness and availability

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | **Usefulness of  economic data** | | | **Data usefulness and availability score** | | |  |  |  |
| **Country and Type of policy/ consideration** | **Data need level** | **Direct and multiplier effects** | **Non-aquaculture markets** | **External effects** | **Direct and multiplier effects** | **Non-aquaculture markets** | **External effects** | **INDEX** | **Data usefulness and availability sum score** | **Usefulness sum score** |
| **NORWAY** |  |  |  |  |  |  |  |  |  |  |
| Production license | N | 1 | 1 | 1 | 2.91 | 2.00 | 1.30 |  |  |  |
| Area planning | L, R | 0.3 | 0.3 | 1 | 0.52 | 0.30 | 1.20 |  |  |  |
| Location permit | L, R | 0.3 | 0.3 | 1 | 0.52 | 0.30 | 1.20 |  |  |  |
| \*Impact assessment | L, R | 1 |  | 1 | 1.73 |  | 1.20 |  |  |  |
| \*Food safety, veterinary | L, R |  |  | 1 |  |  | 1.20 |  |  |  |
| \*Pollution | L, R |  |  | 1 |  |  | 1.20 |  |  |  |
| **Norway sum scores & index** |  |  |  |  | **5.67** | **2.60** | **7.30** | **1.53** | **15.57** | **10.2** |
| **SCOTLAND** |  |  |  |  |  |  |  |  |  |  |
| Production license | R | 0,3 | 1 | 1 | 0,79 | 1,00 | 1,10 |  |  |  |
| Area planning | L, R | 0,3 | 0,3 | 1 | 0,76 | 0,30 | 1,10 |  |  |  |
| Location permit | R | 0,3 | 0,3 | 1 | 0,79 | 0,30 | 1,10 |  |  |  |
| Other permits | N,R,L | 1 | 1 | 1 | 2,64 | 1,00 | 1,13 |  |  |  |
| **Scotland sum scores & index** |  |  |  |  | **4,98** | **2,60** | **4,43** | **1,41** | **12.02** | **8.5** |
| **FRANCE** |  |  |  |  |  |  |  |  |  |  |
| Production license | R, L | 0.3 | 0.3 | 1 | 0.48 | 0.33 | 1.00 |  |  |  |
| Area planning | L, R | 0.3 | 0.3 | 1 | 0.48 | 0.33 | 1.00 |  |  |  |
| Location permit | L, R | 0.3 | 0.3 | 1 | 0.48 | 0.33 | 1.00 |  |  |  |
| \*Impact assessment | L | 1 |  | 1 | 1.36 |  | 1.00 |  |  |  |
| Other permits | L |  |  | 1 |  |  | 1.00 |  |  |  |
| \*Food safety etc | R, L |  |  | 1 |  |  | 1.00 |  |  |  |
| \*Pollution | R, L |  |  | 1 |  |  | 1.00 |  |  |  |
| **France sum scores & index** |  |  |  |  | **2.80** | **0.99** | **7.00** | **1.10** | **10.79** | **9.8** |
| **CANADA** |  |  |  |  |  |  |  |  |  |  |
| Production license | R | 1 | 1 | 1 | 2.82 | 1.40 | 1.10 |  |  |  |
| Area planning | R, L | 1 | 0.3 | 1 | 1.91 | 0.36 | 1.05 |  |  |  |
| Location permit | R, L | 0.3 | 0.3 | 1 | 0.57 | 0.36 | 1.05 |  |  |  |
| \*Impact assessment | R, L | 1 |  | 1 | 1.91 |  | 1.05 |  |  |  |
| Other permits | R, L |  |  | 1 |  |  | 1.05 |  |  |  |
| \*Veterinary | R, L |  |  | 1 |  |  | 1.05 |  |  |  |
| \*Pollution | R, L |  |  | 1 |  |  | 1.05 |  |  |  |
| **Canada sum scores & index** |  |  |  |  | **7.21** | **2.12** | **7.40** | **1.41** | **16.73** | **11.9** |
| **USA** |  |  |  |  |  |  |  |  |  |  |
| Production license | **R** | 1 | 1 | 1 | 1.91 | 1.20 | 1.30 |  |  |  |
| Area planning | R | 0.3 | 0.3 | 1 | 0.57 | 0.36 | 1.30 |  |  |  |
| Location permit | R | 0.3 | 0.3 | 1 | 0.57 | 0.36 | 1.30 |  |  |  |
| \*Impact assessment | R | 1 | 0.3 | 1 | 1.91 | 0.36 | 1.30 |  |  |  |
| Other permits | N/R/L | 0.3 |  | 1 | 0.47 |  | 1.30 |  |  |  |
| **USA sum scores & index** |  |  |  |  | **5.44** | **2.28** | **6.50** | **1.45** | **14.22** | **9.8** |
| **SPAIN** |  |  |  |  |  |  |  |  |  |  |
| Production license | R, L | 1 | 1 | 1 | 2.64 | 1.20 | 1.20 |  |  |  |
| Area planning | R, L | 0.3 | 0.3 | 1 | 0.40 | 0.36 | 1.20 |  |  |  |
| Location permit | R, L | 0.3 | 0.3 | 1 | 0.40 | 0.36 | 1.20 |  |  |  |
| Other permits | R, L |  |  | 1 |  |  | 1.20 |  |  |  |
| **Spain sum scores & index** |  |  |  |  | **3.43** | **1.92** | **4.80** | **1.41** | **10.15** | **7.2** |
| **IRELAND** |  |  |  |  |  |  |  |  |  |  |
| Production license | N, L | 1 | 1 | 1 | 1.95 | 1.00 | 1.25 |  |  |  |
| Area planning | N, L | 0.3 | 0.3 | 1 | 0.59 | 0.30 | 1.25 |  |  |  |
| Location permit | N, L | 0.3 | 0.3 | 1 | 0.59 | 0.30 | 1.25 |  |  |  |
| Other permits | L | 0.3 |  | 1 | 0.44 |  | 1.30 |  |  |  |
| **Ireland sum scores & index** |  |  |  |  | **3.56** | **1.60** | **5.05** | **1.33** | **9.96** | **7.5** |
| **GERMANY** |  |  |  |  |  |  |  |  |  |  |
| Production license | R, L | 1 | 1 | 1 | 1.55 | 1.00 | 1.00 |  |  |  |
| Area planning | N | 0.3 | 0.3 | 1 | 0.76 | 0.30 | 1.00 |  |  |  |
| Location permit | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |  |  |  |
| Other permits | R, L | 0.3 | 0.3 | 1 | 0.46 | 0.30 | 1.00 |  |  |  |
| **Germany sum scores & index** |  |  |  |  | **2.77** | **1.60** | **3.00** | **1.19** | **7.37** | **6.2** |

For Table 7 in the main paper, the sum scores for each type of economic data in the “Data usefulness and availability score” column have each been divided by the sum weight from the corresponding column under “Usefulness of economic data”.

Table 14 Index score sensitivity analysis for weight of X («information can be useful»).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **X weight** | **0.1** | **0.2** | **0.3** | **0.4** | **0.5** |
| **NO** | 1.54 | 1.53 | 1.53 | 1.52 | 1.51 |
| **SCO** | 1.40 | 1.40 | 1.41 | 1.42 | 1.43 |
| **FR** | 1.07 | 1.08 | 1.10 | 1.11 | 1.13 |
| **CA** | 1.40 | 1.41 | 1.41 | 1.41 | 1.41 |
| **USA** | 1.44 | 1.45 | 1.45 | 1.45 | 1.46 |
| **ES** | 1.45 | 1.46 | 1.46 | 1.47 | 1.48 |
| **IRL** | 1.34 | 1.35 | 1.36 | 1.37 | 1.37 |
| **GER** | 1.14 | 1.17 | 1.19 | 1.21 | 1.23 |

Figure 2 Index score sensitivity for weight of X ("information can be useful").

# Correlation between aquaculture sector characteristics and data availability and usefulness?

In Figure 3, the countries’ index score is plotted against their total (Atlantic) aquaculture production in tonnes in 2016. This uses the index scores based on weight for X (“information can be useful”) of 0.3. The variation in production accounts for 30 % of the variation in index scores (R2=0.30).

In Table 15, the R2-values are reported for linear correlation between the overall index scores and aquaculture production volume (tonnes) in total, for molluscs only and for “fish+” (diadromous fish, marine fish and crustaceans), and similar for production value.

France stands out as a relatively large aquaculture producer, yet have low data availability. We therefore tested the linear regression without the data for France. Then, the linear correlation fit was 0.42 with total production volume as independent variable and 0.38 with total production value as independent variable, in other words markedly higher R2-values than with France.

In Table 16 the R2 values from a power regression between the overall index scores and total aquaculture production volume (tonnes) is presented, and similar for total production value. A power regression may be more plausible than a linear one. As an industry becomes of a “significant” size a certain level of information is needed for good governance, but the need for extra information as an industry grows will be limited, and at some point it will not be possible to get much more information. The table presents results both when all countries’ data are included, and when France’s are excluded.

A linear regression of countries’ overall index score against production value as share of countries’ total GDP was also done. This was to see if the relative size of the aquaculture sector in the total economy could explain the variation in data availability. GDP was used as a proxy for gross output. For Canada and the US only GDP for the North-Atlantic provinces/states were used. The regression gave a R2-value of 0.29.

Table 17 has central statistics for a multiple linear regression between the index scores and fish+ and molluscs production in volume or value as explanatory variables.

Figure 3 Country overall index score vs. Country total (Atlantic) aquaculture production (tonnes)

Table 15 Linear correlation (R2-values) between countries’ overall index scores and aquaculture production in volume or value (2016).

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Total production** | **Fish+ production** | **Molluscs production** |
| Aquaculture production volume | 0.30 | 0.30 | 0.03 |
| Aquaculture production value | 0.27 | 0.30 | 0.43 |

Table 16 Power regression results for countries’ overall index score and their volume or value for aquaculture production (2016).

|  |  |  |
| --- | --- | --- |
|  | Production volume | Production value |
| With all countries | 0.24 | 0.22 |
| Without France | 0.54 | 0.60 |

Table 17 Multiple regression results for countries’ overall index score and their volume or value for fish+ and molluscs production (2016).

|  |  |  |
| --- | --- | --- |
| Model  Statistic | Production volume | Production value |
| Adjusted R2 | 0.026 | 0.381 |
| Significant F | 0.403 | 0.130 |
| Fish+ coefficient p-value | 0.221 | 0.285 |
| Molluscs coefficient p-value | 0.980 | 0.151 |

# Keywords for literature searches

As described in section 3.1 of the main paper, the searches for relevant literature and databases have been done by Google and Google Scholar searches, in global databases of economic studies, and by searching within publications that were already identified as relevant. Below is a list of major keywords used for the searches, in English. As literature and databases are in many different languages, also the keywords have been in many different languages, and the set of keywords evolved and increased during the search. The list below is not exhaustive for all keywords in all languages, but contains major keywords used.

Keywords signifying aquaculture

* Aquaculture, mariculture, fish farming, mussel/salmon/(specie) farming

Keywords identifying data/literature of different types of effects

1. For direct and multiplier effects of aquaculture

* Production, sales, slaughter, production value, revenues, employment, man-years, value added, profits, wages, costs, trade, exports, ripple effects, multiplier, input-output model

1. For effects on non-aquaculture markets

* Wild fish, Market impacts, demand, supply, prices, inputs, input costs, meat, chicken, feed, soy

1. For externalities proper

* Externalities, fisheries, tourism, marine fishing tourism, pollution, disease spread, parasites, recreational fishing, angling, wild salmon, salmon rivers, property prices, house prices, water quality, landscape, view, visual pollution

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1. Online data is available in <http://agreste.agriculture.gouv.fr/enquetes/aquaculture/> [↑](#footnote-ref-1)
2. <http://www.mapama.gob.es/es/estadistica/temas/estadisticas-pesqueras/acuicultura/encuesta-economica-acuicultura/default.aspx> [↑](#footnote-ref-2)
3. <http://www.mapama.gob.es/es/estadistica/temas/estadisticas-pesqueras/acuicultura/encuesta-establecimientos-acuicultura/produccion/default.aspx> [↑](#footnote-ref-3)
4. The base line is the line drawn between the outermost points of fjords, headlands and islands less than 1 nm from the coast. [↑](#footnote-ref-4)
5. <https://coast.noaa.gov/czm/> , visited 20 October 2018. [↑](#footnote-ref-5)
6. <https://cmsp.noaa.gov/framework/index.html> , visited 20 October 2018. [↑](#footnote-ref-6)