Is lack of space a limiting factor for the development of aquaculture in EU coastal areas?

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1. Introduction

While in the last three decades (1980–2010) world food fish production from aquaculture expanded at least tenfold, at an average annual growth rate of 9.5% (FAO, 2014), in the EU production is stagnating in the freshwater and molluscs segments and growing at a much lower rate of 4% in the case of marine aquaculture (own elaboration on the basis of FAO data). Following this low growth rate, the EU share on world aquaculture production fell from 2.3% in 2009 to 1.5% in 2011. Presently the EU only supplies 35% of its seafood demand and the remaining 65% is imported (STECF, 2014).

As regards the potential of growth in the EU, in its report of 2013 on the economic performance of the EU aquaculture sector, the
Scientific, Technical and Economic Committee for Fisheries (STECF) stated: “Marine fish aquaculture is characterised by being generally capital intensive, with high input and high labour productivity. This segment has potential to compete on the increasingly globalised market but it faces constrains which hinder further expansion” (STECF, 2013).

Marine aquaculture developed in EU member states in the mid-1980s and 1990s, although with large differences between countries in the rate of growth and development (FAO, 2012). It was essentially an economic development within small and medium sized enterprises in remote areas where alternative employment was scarce. This has been particularly evident for Atlantic salmon in Scotland, Norway and Ireland, sea bass and sea bream in the Mediterranean and mussel farming by line or raft in Ireland, Spain and France (Fernandes et al., 2000).

Information from competent authorities and aquaculture associations in the main fish farming member states revealed that no or only very few (1 or 2) new farming licences were issued in the past 10–15 years for marine fish farm in cages (Hofherr et al., 2012).

The very few new licences are indicative of problems of governance of the sector in addressing some common constrains. One reason for not expanding could be the economic performance of fish farming; especially in the Mediterranean Sea, the segment of sea bass and sea bream production had a low profitability and a process of restructuring and consolidation can be observed (STECF, 2014). Despite favourable market conditions, also in the salmon production no licences for new sites have been issued (STECF, 2014). Analyses of the governance and regulatory systems for the EU aquaculture commissioned by the European Parliament (Hedley and Huntington, 2009) and evaluations of the sector’s performance (OECD, 2010; Hofherr et al., 2012; STECF, 2013; European Commission, 2013; OECD, 2014; STECF, 2014) indicate that EU aquaculture development is hindered by i) competition for space in coastal areas, ii) lack of clear priorities for the development of the sector, iii) fragmentation of competences for the authorization of aquaculture sites, and iv) diverging interpretations and applications of environmental legislations which is causing uncertainty for potential investors. Also for Turkey comparable constrains are described by Yucel-Gier et al. (2009). A recent in-depth analysis of conflicts in relation to the environmental justice theory confirms the complex set of claims of the various actors over fish farm in aquaculture in Europe, often aligning opposition from the tourist sector, small scale fisheries, local population and NGOs (Ertör and Ortega-Cerdà, 2015).

Similar problems for the development of aquaculture are observed in coastal regions in the United States, eastern Australia and northern New Zealand (Gibbs, 2009). In these countries the recreational and amenity services provided by coastal regions, have become highly prioritized values, and aquaculture is often perceived to be a threat to these values. These values often are confused or mingled with other arguments regarding the overall sustainability of aquaculture activities. Where Gibbs sees a risk that prospective operators and administrative regulators are confronted with the need to demonstrate ‘indefinite sustainability’, other authors describe ways and criteria to assess ecological, economic and social aspects of aquaculture activities for a wide range of applications, e.g. Trujillo (2008) to have an objective tool to demonstrate long-term sustainability.

Differently to the isolated view on marine aquaculture, Coll et al. (2012) studied in a fine-scale analysis the spatial accumulation of human activities for the Mediterranean Sea. The findings show that the interaction between cumulative threats and areas of high marine biodiversity is mainly concentrated along certain coastal areas. Most of these areas are also used for aquaculture. Putting greater emphasis on the ecosystem approach, these findings could stimulate the tendency of moving aquaculture further offshore or in closed systems on land (recirculating aquaculture systems - RAS).

An extensive review of the literature on determinants for aquaculture siting listed approximately 20 bio-physical and 10 socio-cultural variables affecting the positioning of marine farms (Rennie, 2002). Among the bio-physical variables, water quality and sheltered conditions are considered key requirement for most farming systems. Over time there was lower relevance assigned to sheltered conditions which may be explained by the availability and adoption of technological solutions (i.e. submersible cages, mooring technologies) which allow farming in more open waters avoiding competition in areas close to shore. In many cases the difficulties encountered by aquaculture can be traced back to social conflicts arising from the incompatibility of the aquaculture activities with the social context, rather than with issues related to the biophysical environment. In an attempt to avoid conflicts, aquaculture enterprises, increasingly consider remoteness and distance from urban areas as key criteria for site selection (Rennie et al., 2009).

The kind of social conflicts and opposition faced by aquaculture development in coastal area is variegated and determined by local socio-political conditions. In some cases aquaculture enterprises are seen as outsiders to the local community and their allocation of licences for the establishment of aquaculture farms is seen as a form of expropriation of the common sea space used for traditional fishing activities by local groups (Pinkerton and Silver, 2011; Marshall, 2001; Suryanata and Umemoto, 2003). In other cases it is the external touristic use of the coastline which is seen more hindering the aquaculture development. Communities are in general less motivated to embrace aquaculture if they see opportunities to generate local employment elsewhere and conflicts increase closer to urbanised areas and areas popular for recreation (Gibbs, 2009).

Science may play a manifold role in the debates around the siting of aquaculture activities. These debates are characterised by divergent sets of values favouring or contrasting aquaculture development using sustainability concerns as the main argument. The interplay between science and these values are seen at the opposite ends in the influences of “client-science” supporting the industry and “civic-science” supporting the preservation of local tradition from the establishment of new aquaculture activities (McGinnis and Collins, 2013).

The European Commission in the context of the new EU Common Fisheries Policy issued guidelines for the sustainable development of aquaculture to boost the growth of the sector (European Commission, 2013). The guidelines contain recommendations to improve governance systems and reducing bureaucracy. According to these guidelines, EU member states are expected to establish marine spatial plans in which the needs for the development of the sector are balanced against other uses of the marine space in coastal areas.

Despite the relevance of the issue of lack of space in coastal areas often indicated by the aquaculture industry and the high priority assigned to spatial planning for a better governance of the sector, information on the spatial characteristics and needs of marine aquaculture is limited, especially when zooming out from a very local geographical scale of specific coastal regions. On one side there is statistical and economic data collected through the EU Data Collection Framework which is highly aggregated at national level (European Commission, 2008) and on the other side there is spatial information on specific sites (European Commission, 2008a) which is used for spatial planning and environmental impact assessment at a local geographical scale. Both levels of spatial aggregation don’t allow appreciating the socio-economic factors which favoured the establishment of aquaculture in specific coastal regions in a country
or form an EU wider perspective.

In a wide range of fields, Geographic Information Systems (GIS) and remote sensing techniques are employed for spatial planning, modelling and monitoring activities, as e.g. in the water resource management in agriculture (Rahimi et al., 2015), in the restoration of wetlands (Newcomer et al., 2014), in crop-monitoring (Wu et al., 2014), in pesticide exposure modelling for large areas (Wan, 2015) or in urban planning by automated sensing of ecological indicators (Behling et al., 2015).

Since 2008, EUROSTAT started to collect, along the production volume and value statistics, also data on surfaces occupied by aquaculture according to the Regulation (EC) 762/2008 (European Parliament and the Council, 2008). This information is still partial and collected as aggregated country statistics without geographical references. Geographical information on aquaculture sites is available in several national registers and maps but this information is dispersed and does not generally provide information on surfaces and production volumes.

At the supra-national level there have been recently three main initiatives to map marine aquaculture sites.

The Global Mariculture Database (GMD) in the context of the ‘Sea Around Us’ project represents the first global time-series compilation of production data of its kind. For each coastal country, historical mariculture production data were collected, and when necessary estimated. The datasets were then taxonomically and geographically disaggregated into distinct species and attributed to more than 600 different provinces/states in 112 coastal countries between 1950 and 2004. Nonetheless, GMD production figures are not assigned to specific geographical coordinates or the farm level. Instead they are generally spread across the Exclusive Economic Zone of the country in question. FAO (Meaden et al., 2013; Aguilar-Manjarrez and Crespi, 2013) set up exhaustive technical guidelines on GIS and remote sensing for fisheries and aquaculture to address the need for better marine spatial planning and ecosystem approaches through these techniques. The National Aquaculture Sector Overview – NASO maps which are a GIS tool published by FAO, should illustrate geographically where aquaculture is taking place. Key information features that could accompany the geographical locations are either by administrative units or individual farms and they include: cultured species, technology used, culture systems, environments, farm characteristics and respective production quantities, and main issues (credit, diseases, environmental impact, etc.). It is not clear until when all FAO member countries who are reporting aquaculture statistics to FAO and who also wish to inventory and monitor aquaculture in their respective countries will have fed the necessary information into the system.

Trujillo et al. (2012) mapped marine aquaculture sites in the Mediterranean Sea to estimate fish production. The Google Earth method intuitively makes use of freely available satellite images to locate finfish farms. Along with providing geographical coordinates to the fish farms, the images offer the possibility of estimating fish farm production volume via surface area of pens and cages at a certain point in time. These estimates can be used to verify the reliability of official statistics on aquaculture production by FAO and to disaggregate production data at lower geographical level than in national statistics. Yet the quality and resolution of the images will determine how accurate the proxy can be for calculating production by surface occupancy. Some difficulties that have to be considered in estimating production levels from cage surfaces detected from satellite images are related to the conversion of a production factor or density by volume into a production factor by surface, to the lack of information on the effective occupation of the cages and to the lack of information on the species and phase of production.

Although using a very similar approach of remote imaging, the present study puts its focus on the space occupancy of marine finfish aquaculture and its spatial relations with respect to coastline length and to touristic use. This spatial analysis is mostly concerned on social and policy aspects and considers the broader national and supra-national scale in respect of classical GIS studies on aquaculture considering bio-physical and environmental impacts at the very local level of specific sites or coastal areas (Rennie, 2002; Meaden et al., 2013; Perez et al., 2005; Perez et al., 2003; IUCN—The World Conservation Union et al., 2009; ECASA project – Ecosystem Approach for Sustainable Aquaculture http://www.ecasa.org.uk/).

The mapping of aquaculture sites in this study has three main objectives. The first is to assess the issue of lack of space in coastal waters. Given the fact that lack of space is often invoked as the cause for the lack of growth of the sector in the EU it is important to understand if this is true in absolute terms or if this has to be rather considered in the context of conflicts with the other possible uses of space or other actors.

The second objective is to identify geographical clusters where aquaculture was able to establish and to develop. Theoretical explanations of the spatial clustering of economic activities in the economic literature can be grouped in five main approaches: the reduction for transportation and transaction costs, institutional thickness, agglomeration economies, innovative milieus and market conditions (Giuliani, 2010). In the case of marine aquaculture the fact that activities are taking place in a common resource space for which licencing and concessions have to be allocated poses specific challenges compared to other farming or industrial activities on land. The establishment of new aquaculture farms requires establishing property rights at sea and this aspect gives particular significance to local governance and social acceptance by coastal communities as determinants for the clustering of activities. Ideally, the clustering of aquaculture activities would also take account of socio-economic parameters. However, socio-economic data for the EU aquaculture are available on national levels only in aggregated form (STECF, 2013) and the remote imagery does not allow allocating cage aquaculture sites to specific enterprises. The identification of spatial clusters therefor can only represent a first step towards understanding which were these enabling conditions and identifying examples of best practices in governance.

The third objective is to provide evidence of the negative interactions between aquaculture and the touristic use of the coastline which has been often indicated in literature as a major problem for the expansion of the sector in developed countries, e.g. Ertör and Ortega-Cerda (2015), Gibbs (2009).

2. Methods

The study covered marine finfish aquaculture in sea cages in ten EU member states (Cyprus, Spain, France, Greece, Croatia, Ireland, Italy, Malta, Slovenia and United Kingdom) and Turkey. It did not include inland structures for marine finfish production, or space occupied for the production of bivalves and algae. The position of the aquaculture sites was identified starting from coordinates available in national registers on aquaculture production established according to the EU veterinary legislation (European Commission, 2008a). This information was combined with a mapping exercise of aquaculture in the Mediterranean by Trujillo et al. (2012). In respect of the paper by Trujillo et al. the coverage was extended to other EU member states in terms of production and a temporal reference was added to each site considering all layers of historical images available in Google Earth.

The images in Google Earth of the years 2000–2012 were analysed by drawing at each site the boundary of the polygons.
surrounding interconnected groups of cages.

Several spatial analysis methods were applied on these polygons to define geographical cluster, calculate the sea surface occupation, the length of coastline affected and the interaction with other uses of the coastline. The analyses were performed using a combination of packages in the statistical software R (rges, sp, maptools, spatstat) and in ARCGIS.

The bounding polygons around the cages represent a minimum measure of surface occupation. A geographical cluster analysis was performed to identify larger areas which may more realistically represent allocated zones for aquaculture. The geographical clustering was carried out by applying a buffer around the polygons and grouping the sites which were subsequently intersecting. Several buffer sizes from 500 to 8500 m were tested to determine the most appropriate criteria for clustering. The selection of the best buffer size was done analysing silhouette widths of the generated clusters (Rousseeuw, 1987). The optimal buffer size was chosen on the basis of the highest average silhouette width of the generated cluster which is indicative of a clustering approach that minimises the average distances between observations in each cluster and maximises their average distances from observation in other clusters.

In addition to the geographical clustering each site was linked to the closest municipality on land (local administrative units at NUTS3 level from EUROSTAT) to compute a series of descriptive statistics by administrative units.

To calculate the length of coastline affected by aquaculture activities the centroids of the aquaculture sites were snapped on the closest point on the coastline, a buffer of 1500 m was created around each of these points, the resulting intersecting polygons were dissolved and the length of the section of coastline falling in the dissolved polygon was computed. Finally the length occupied by aquaculture was related to the total length of coastlines for each local administrative unit to assess the relevance of aquaculture activities on the coastline.

The interaction with other uses of the coastline was analysed considering the geographical distribution of hotels around the aquaculture sites. The position of the touristic structures was obtained using a web service provided by the Google Places API, which gives the possibility to extract programmatically the coordinates of points of interest a certain radius from a given location. A specific program was created in the R statistical software to interrogate the Google API and extracting the coordinates of business of the type “lodging” along the EU coastline (these category includes in addition to hotels other touristic infrastructures such as bed & breakfast and camping sites, but will be summarized further in the text under ‘hotels’). From the individual coordinates it was possible to derive a density map of hotels and more specifically to calculate their frequencies at different distances from the aquaculture sites.

As a term of comparison a similar exercise was carried out in respect of the position of bathing water sampling sites. Information on bathing water quality is collected at EU level by the European Environmental Agency and is made available through the geo data portal ‘Water Information System for Europe’ – WISE. More than 22,000 bathing areas are monitored annually according to the provision of the bathing water directive (Directive 2006/7/EC). The monitoring takes place where most bathers or the greatest risk of pollution are expected. Based on these requirements the sites cover all main beaches along the coastline of the EU member states and their position can be considered as a proxy to represent centres of gravitation of touristic activities along the coastline. To account of different distributions of hotels in EU regions, frequencies of hotels were calculated in respect of bathing water sampling sites randomly selected in the same areas of the aquaculture sites and the results compared at an aggregate level.

3. Results

In total 4257 polygons of aquaculture cages were identified from the analysis of the satellite images. These polygons represent sites at different temporal layers ranging from the year 2000–2012. The images of different years of the same coastlines indicated in some areas substantial changes in cage position, especially in Turkey, Spain and Italy. However, for the same site, images were not always available for all years or in some cases the quality was not sufficient to identify properly the aquaculture cages; therefore an analysis of the evolution of occupied surfaces and affected length of coastline by time was not possible. Instead of analysing data by year the results on area occupation and length of coastline were considered as maximum size over the entire period 2000–2012.

Table 1 shows the area occupation and the percentage of length of coastline affected by country. In all cases the surface and the portion of coastline affected by aquaculture are extremely limited. The interaction of aquaculture with other uses of the coastline was assessed by calculating length of coastline affected by aquaculture with symbols proportional to their surface. The 10 largest clusters are related to countries where aquaculture is the most important economic activity in recent years. In the case of Greece for example, which has an aquaculture production accounting for more than 28% of the entire EU marine finfish aquaculture is occupying a surface of 230 ha and the portion of coastline affected by finfish aquaculture is 3% of the total coastline. The large differences between individual countries regarding the percentage of coastline affected by aquaculture are related to their differences in aquaculture activities and to the length of available coastline. Although France and Spain have a comparable length of coastline, France contributed 1.6% to the total EU marine finfish production in 2010, while Spain had a share of 11.1%. On the example of smaller countries, such as Malta and Slovenia it can be seen that a relatively small aquaculture sector can affect a high percentage of coastline.

Fig. 1 shows boxplots for the distances of the aquaculture sites from the closest point on the coastline by country. Cages are in general positioned very close to the coastline with median values of less than 1000 m in all countries. While there was no apparent trend by time, clear differences emerged among countries. Low average values are indicating that cages are placed very close to the coastline in the case of Greece (68 m), France (164 m), Turkey (184 m), while they are more distant in the case of Malta (592 m), Cyprus (628 m), Slovenia (766 m), Croatia (839 m), Italy (991 m) and Spain (1106 m). Intermediate values are present in UK (374 m) and Ireland (379 m).

A high variability in the distribution of values and several examples of aquaculture at more than 2000 m from the coastline are present in Croatia, Ireland, Spain, Turkey and UK.

In the case of Croatia, Italy and Spain the high distance of the aquaculture sites from the coastline may be attributed to cages for the farming of tuna, while in the case of Ireland and UK there are cases of salmon farming in more exposed waters developing in particular in recent years.

In the clustering exercise the best approach was obtained by using a buffer of 4500 m. This buffer size resulted in the highest value of a silhouette width of 0.80 and allowed to identify a total of 217 clusters. The map in Fig. 2 shows the location of these clusters with symbols proportional to their surface. The 10 largest clusters in terms of surfaces were in Ireland (Donegal), Spain (Murcia), Greece (Dytiiki Ellada, Stere Ellada, Peloponnisos) and Turkey (Izmir and Muğla).

Another approach for grouping the aquaculture sites was to relate them to the closest local administrative unit on land. In total 257 local administrative units in the ten EU member states have aquaculture sites along their coastline. Fig. 3 shows for each of them the percentage of affected coastline by length of the coastline, while the size of the symbols is proportional to the maximum cage surface across all years. The three largest clusters have a surface of 47 ha (in Spain), 44 ha and 30 ha (in Greece) and occupy
respectively 33%, 7% and 45% of the coastline of the local administrative units. The local administrative units which have a medium to high percentage of their coastline occupied by aquaculture, considerable surfaces of aquaculture and at the same time a total length of the coastline of around 20–80 km stand out for the relevance the aquaculture activities may have for the respective local coastal communities. In these local administrative units aquaculture must have found local enabling conditions and social acceptance which allowed its establishments and development up to the point of representing a relevant portion of the available coastline.

Further in the analysis the interactions between aquaculture sites and tourism was evaluated. Fig. 4 shows how the density of hotels within 5 km to the nearest point of the coast along the EU coastlines varies between member states, with the lowest density in the Northeast of the Baltic Sea (around 0.04 hotels/km²) and highest along the French, Spanish and Italian coasts (around 0.1 hotels/km²). Based on these densities the problem of conflicting use between aquaculture and tourism may be considered less relevant in countries like Sweden, Denmark and Finland which have a very low density of hotels. Aquaculture expansion could be expected to incur in fewer conflicts with tourism in Scotland, western Ireland and Greece in respect of France, Spain and Italy.

The analysis also considered how the density of hotels varies in respect of the presence of aquaculture sites and as term of comparison in respect of bathing water sampling sites. Fig. 5 plots the frequencies and cumulative frequencies of hotels by increasing distance from the aquaculture and bathing water sampling sites. A total of 4550 hotels were identified within 5 km of the aquaculture sites while 5905 were identified at the same distance from the bathing water sampling sites. For lower distances, the frequency of hotels in respect of the aquaculture sites has an opposite distribution pattern in respect of the bathing water sampling sites. Very few hotels can be found in the close proximity of the aquaculture sites while they tend to be concentrated at few hundred meters in respect of bathing water sampling sites. The two frequency distributions start to become parallel at around 3 km.

4. Discussion

This study used GIS methods to examine the characteristics of marine aquaculture sites in the EU. In particular it provided the first map of marine aquaculture at EU level for some ten member states, it quantified the used surface and affected coastline and it

<table>
<thead>
<tr>
<th>Country</th>
<th>Area occupied by aquaculture (ha)</th>
<th>Length of coastline (km)</th>
<th>Length of coastline affected by aquaculture (km)</th>
<th>Percentage of coastline affected by aquaculture (%)</th>
<th>Percentage of the volume of production in respect of the EU total in 2010 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Croatia</td>
<td>69.98</td>
<td>5664</td>
<td>99</td>
<td>1.7</td>
<td>1.9</td>
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<td>3.0</td>
<td>1.1</td>
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<td>38</td>
<td>0.5</td>
<td>1.6</td>
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<tr>
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<td>15,147</td>
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<td>28.1</td>
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</table>
identified a series of geographical and administrative clusters where aquaculture development was particularly significant. Finally the study considered the interaction between aquaculture sites and the touristic uses of the coastline looking at densities of hotels around the aquaculture sites and, as a term of comparison, around water quality sampling sites. This study differs from previous GIS analyses applied to the aquaculture sector since it considers a larger, supra-national scale and other factors than bio-physical and environmental for site selection.

The lack of space is often cited by the industry as one of the main hindering factors for further expansion of the marine finfish aquaculture. This study showed that only around 3% of EU coastline is affected by aquaculture and that the marine finfish sector occupies a negligible surface of marine waters. In the ten member states analysed; some 630 ha of cages correspond to the production of around 95% of the entire EU marine finfish by volume in 2010. These occupied surface values seem extremely low especially if compared with on land farming activities (for example 1335 agriculture farms in the UK have an average size of 2416 ha per farm (EUROSTAT 18/2011)). The high relevance assigned to the issue of lack of space as a hindering factor for aquaculture development seems to relate more to the common nature of the sea space and the amenity values of the sea landscape in western countries as Gibbs (2009) points out. While property rights on land are historically established and land farming activities are often even seen as contributing to the amenity value of terrestrial landscapes, marine aquaculture is a relatively new activity which has to negotiate its space demands in the not fully anthropic coastal environment against much stronger economic interests such as those represented by tourism.

Not each stretch of coastline is equally suitable and accessible for aquaculture. The observed clustering of sites in specific regions may be explained by the favourable specific physical, biological and environmental conditions of local stretch of the coastline. But obviously similar suitable locations e.g. in Scotland or in Greece show no or much less aquaculture activities. The siting of aquaculture especially when zooming out from the local perspective may be traced back to similar institutional and/or social acceptance of the sector by some coastal communities (Ertor and Ortega-Cerdà, 2015). This acceptance seems particularly significant in respect of other determinants for the clustering of economic activities normally considered in the economic geography literature such as agglomeration economies and market conditions, for which not sufficient disaggregated data are available for the aquaculture sector. One peculiarity which may explain this difference is that aquaculture has to go through complex and in most cases cumbersome authorisation procedures for the allocation of site licences (Hedley and Huntington, 2009; OECD, 2014, 2010).

One factor which emerges from the analysis of the location of existing sites is that in most of the cases aquaculture finds its space in areas hidden from the visibility range of touristic infrastructures. The analyses on the interaction with touristic use of the coastline showed that aquaculture sites are clearly located to avoid interference with hotels. A negative spatial interaction was proved by comparing densities of hotels around aquaculture sites with water quality sampling sites. Water quality sampling sites were chosen as proxy for centre of touristic attraction along the coastline being a quite comprehensive set of spatial data on beaches and bathing
places. The densities of hotels are increasing with distance in the case of aquaculture sites and decreasing in the case of water quality sampling sites. The differences in distributions which are expressions of positive and negative interactions disappear at a distance of around 3 km. This distance can be considered as the threshold at which the negative and positive effects disappear and the density of hotels is starting to assume the characteristics of a random distribution. This findings support with quantitative spatial information the observations of Gibbs (2009) regarding the conflicts affecting the establishment of marine aquaculture in coastal regions with very high recreational and amenity values in USA, Canada, Australia and New Zealand. In return, it could be assumed that in coastal regions with less touristic use the chances for establishing new aquaculture sites should be higher. The plot of hotel density on EU coasts suggests a higher potential for finding new aquaculture sites especially on the northern coasts of the Baltic Sea, the eastern North Sea, but also around Scotland, Ireland, northern Denmark and in Greek waters.

Although, as the above analysis shows, marine aquaculture affects only very limited stretches of EU coastline, sustainable coastal aquaculture requires adequate consideration of the interactions among the social, economic and ecological components (Primavera, 2006). What stands out in the spatial approaches is the heterogeneity of the coastal conditions where marine finfish aquaculture activities currently exist, raising the question on whether certain coastal systems may be better or ill-suited for finfish aquaculture developments. In the EU, to bring these loose ends together, integrated coastal zone management — ICZM and maritime spatial planning — MSP are considered suitable instruments addressing the conflict between different uses of coastal zones, increasing demand for aquaculture products and environmental conservation, taking into account the heterogeneity of the coastal conditions (Kaiser and Stead, 2002; Primavera, 2006). A spatial analysis of conflicting claims of users in the Bay of İzmir (Yucel-Gier et al., 2010) backs the view that fish farming is often a minor claimant for marine space and that aquaculture developments should therefore be planned in the broader integrated framework of ICZM and MSP to become a recognised partner.

ICZM is described as a dynamic planning and coordinating process whereby decisions are made for the sustainable use of coastal areas and resources. ICZM addresses both coastal waters and land and takes into account the interests of the various coastal
stakeholders (European Parliament and the Council, 2002). MSP is seen as a tool for improved decision-making. It provides a framework for arbitrating between competing human activities and managing their impact on the marine environment. Its objective is to balance sectorial interests and achieve sustainable use of marine resources (European Commission, 2008b).

ICZM and MSP activities are in various stages of implementation, e.g. Kelly et al. (2014), Scarff et al. (2015). A number of projects have been carried out to give guidance or to identify best practices for ICZM and MSP (e.g. http://iczm.ucc.ie/, http://www.coexistproject.eu/, http://ec.europa.eu/ourcoast/). In some regions, coastal zone planning has strong emphasis on aquaculture development, e.g. (IUCN et al., 2009; Grant, 2010). In Greece, on the basis of the spatial planning provisions, aquaculture development areas were defined in various regions, in which areas of organised development of aquaculture activities – POAY can be established (Joint Ministerial Decision, 2011). Although it will take some years to evaluate the effects the Greek spatial planning provisions will have on their national aquaculture industry, the integration of aquaculture activities in the spatial planning process and defining aquaculture development areas is seen to have multiple beneficial effects compared to the present situation: it guarantees the integration of aquaculture in the coastal zones, identifies suitable areas in socio-economic and environmental terms, minimises the conflicts for the use of space with other stakeholders, encourages investments and local production by common and simpler licencing rules, reduces and mitigates environmental impacts by an integrated monitoring system (Argyrou and Papaioannou, 2008).

Mapping of geographical clusters in relation to local administrative units show where aquaculture production is particularly significant. The example of licences for new marine aquaculture sites in some regions of Spain (Hofherr et al., 2012), albeit the generally high recreational use of coasts, indicate that there are further enabling factors. The differences in aquaculture occupation between administrative units could point to different regional/local administrative conditions or planning approaches and would merit further research for understanding the local enabling conditions which favoured the expansion of aquaculture and at the same time satisfied the participation of stakeholders in these areas. It may thus allow identifying examples of best practices for the

![Fig. 5. Frequency (columns) and cumulative frequency (lines) of hotels at increasing distances from bathing water sites (above) and aquaculture sites (below).](image-url)
governance of the sector as also the results of Ertoř and Ortega-Cerdá (2015) on conflicts with fishfarm aquaculture indicate frequent problems regarding even distribution of burdens and benefits, recognition of relevant stakeholders, effective participation process in which all actors have access to adequate and transparent information and the capacity to influence the decision-making.

Further efforts to improve our knowledge regarding coastal attributes are encouraged if EU marine aquaculture developmental goals to increase production in a sustainable way are feasible future outcomes.

It is acknowledged that there are a number of other, equally important aspects affecting the growth of marine aquaculture and sites selection which have not been addressed by this study. E.g., the findings of Coll et al. (2012) regarding anthropogenic threats to biodiversity may help to direct the industry’s future development to coastal zones with lower biodiversity accounts (such as the south-eastern Mediterranean waters) where fishfin production may be perceived less controversial. Another aspect which will determine acceptance of marine aquaculture is its long-term sustainability, where common criteria for ecological, economic and social aspects of aquaculture can be applied to show distinctive differences between countries, independent of areas and species farmed (Trujillo, 2008). Recent work highlighting the overall condition and sustainable use of the global ocean evidenced that mariculture (all species combined) in coastal zones was perceived as performing poorly in this context, and garnered widespread concern from the public, policy makers and resource managers (Halpern et al., 2012). Such concerns are not only of spatial character, as e.g. the use of pelagic fish for aqua feed, although a clear trend for a substantial reduction of fish-based ingredients in commercial fish diets can be observed (Tacon and Metian, 2008; Sarkar et al., 2013).

The growth of marine aquaculture with mainly piscivorous species will therefore also be influenced by the ability to further substitute fishmeal and fish oil in the diets and improving feed conversion ratios (Pelletier et al., 2009).

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