Sustainability of port activities within the framework of the fisheries sector: Port of Vigo (NW Spain)

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Abstract

Sustainability of the fisheries sector is nowadays a key issue due to the significant impact that this activity may have on the environment. Besides fishing activity itself, other indirect impacts, like those originated from related activities and services also need to be addressed. For assessing the environmental burden of this sector, the indicator Ecological Footprint (EF) can be used. The application of EF to the fisheries sector is still uncommon and studies of associated activities (like ports) even more. In this work, classical EF methodology was applied in order to evaluate the environmental impact of the fisheries sector, taking as a representative sample the global activity (fishing and transportation) of the Port of Vigo (Spain), one of the biggest fishing ports in the world. A high value of total EF for both port and fishing activities was obtained. However, relative EF is much higher in the case of fishing, due to the low natural productivity associated to fish resources. Most of footprint land-components pressure was on energy-land and sea area, being resources consumption the principal category contributing to EF values in all the evaluated scenarios.

Keywords Fisheries sector; port activity; sustainability; resources consumption; ecological footprint.

1. Introduction

It is well known that marine ecosystems supply an extensive variety of goods, facilities and also food resources for humanity [1]. For this reason it is essential to protect this ecosystem, considering that the current practices within the fisheries sector are depleting marine resources and endangering biodiversity [2]. The reduction of fisheries catch can be both related with the exploitation of fishing resources as well as with pollution episodes. An evaluation of fishing sustainability is needed to know which are the main aspects influencing the depletion of marine resources. Therefore, recovery of marine ecosystems is essential to achieve oceans sustainability [2-5]. A study developed by Swartz et al. [6] showed that the worldwide development of marine fisheries through the past years was conducted by a continuous exploitation of new fishing sites. The fast decreasing of marine fisheries catches indicates a global limit to growth and highlights the crucial need for a change to sustainable fishing. Nowadays, fisheries cover a wide deep-sea area of the world, with sites of low productivity and distant waters, which implies an important consumption of fossil fuel, compromising the sustainability of fishing activity.

On the other hand, associated services necessary to facilitate fisheries trade are also a source of important environmental impacts. Within these services, port infrastructures play a critical role. Hence, the environmental impacts caused by port activities (fishing, transportation of goods and services) should be evaluated and, if it is the case, reduced. For that purpose, the first step is to correctly manage environmental issues, which requires environmental monitoring [7]. In that context, the Ecological Footprint (EF), introduced by Rees [8] and further developed by Wackernagel and Rees [9], is an important tool for quantifying the impacts generated and the sustainability of several activities and/or products. One of the main advantages of EF is its ability to inform general public about the impact that an activity and/or product has on the world's biocapacity, being also scientifically robust. The EF is an indicator that considers the energy and raw materials fluxes to and from any particular system, converting them into spaces of land or water necessary by nature for producing and/or assimilating these fluxes. Although EF was firstly developed to account for the consumption of natural resources depending on the lifestyle of nations and regions [10-18], improved methodologies allow the application of the EF to a wide variety of sectors and activities [19-30]. Pressure of nations on marine ecosystems has also been assessed by modified EF methodologies [6, 31-33]. In fact, there are only a few works related with the application of EF to the fisheries sector, although the concept of marine footprint was previously used [34], or to port activities, this latter mainly regarding administrative issues [35-37].

The fishing sector in Galicia represents an important contribution to the total volume of captures in Spain and is considered as one of the largest in the European Union. In this region, there are many companies related to fishing activities, from small-scale (inshore and coastal) fisheries catches to fish canned-industries, including some of the largest fishing companies in the world (e.g. Jealsa, Calvo, Pescanova). Lately, the Galician fishing sector has suffered a significant reorganization, allowing for less but more competitive companies. The relevance of this sector is however, essentially connected to the size and value of captures [38]. The Port of Vigo (SW Galicia) is the biggest fishing port of the world. Thus, a representative part of the fishing extractive sector relies on port activities. On the other hand, there are other important activities within the port (such as goods transportation, fish processing, administrative, etc.) which also require resources consumption and thus, need to be evaluated.

The objective of this work is to quantify the environmental impact of the total activity (fishing, transportation of goods and services) of the Port of Vigo through the application of a classical sustainability indicator, Ecological Footprint [39]. The results obtained will provide information to the Port Authority on the principal impact categories, in order to take the necessary measures to improve its environmental management strategy, and specially to optimize the traffic of fishing vessels.

2. Materials and Methods

2.1. Port activity

The Port of Vigo is dedicated to two main activities: fishing and transportation of goods. It is considered as the first port in the world in fishing for human consumption (unloaded fish in 2010 reached a record value of 788,901 tonnes), and one of the biggest in goods transportation (around 3.5 million tonnes in 2010), which includes ro-ro traffic, containers, liquid and solid bulks, etc. The Port Authority (PA) is the leading entity of all port actions, being responsible for management, administration and operation of the port. Part of the port activity is directly managed by the PA, while other sectors are controlled by private organizations which act as licensed enterprises. In this case study, therefore, only operations directly managed by the PA were assessed. A flow chart of port operations is shown in Fig. 1. The port covers several activities such as controlling of sea and land traffic, storage, loading and unloading of different products, fishing activity, administrative services, building and repair of vessels, sanitation services, emergency and maintenance operations, dredging, and MARPOL waste treatment, together with other less important activities [40]. The PA is responsible of guarantying that the licensed companies, vessels, clients and other suppliers comply with the law. The certified companies (in most cases, small fish processing companies) are obliged to deliver the PA with environmental information in accordance with their activity, as required by the legal regulations (resources consumed and waste produced). However, the activity of the private companies operating within the port limits is not incorporated in the current inventory data due to availability problems, although their resources consumption is expected to be low, based on their production.

The inventory data for performing EF analysis was provided by PA, which only includes the two main activities of the port of Vigo, i.e., fishing activity and the transportation of goods.

2.2. Data collection and methodology

The different flows of materials and energy were compiled for the year 2010, and can be seen in Table 1, grouped according to the different categories (energy consumption, resources consumption, and waste generation). The fishing activity causes different impacts on the environment, as the space used for fishing activities, the consumption of fuel by vessels, the consumption of different materials (nets, boxes, hooks, etc.) and other resources (paper, water, etc.), and by producing emissions, discharges and wastes [36]. Although in the current study the space used both for fishing and port infrastructure represents an extensive area, this was not considered in the analysis, since the aim of the present work was only focused on the activity itself. Besides, the ports have the particularity that much of their land is built on water (as in the case under study), including fishing activity, which is much less productive than terrestrial soil. For this reason, the “equivalents hectares” (real hectares by the equivalence factor) are, in fact, much lower than the real available land. This criterion underestimates the structure constructed at sea neglecting other impacts directly affecting coastal degradation [36]. The Port of Vigo is partially constructed on a Galician Ría. The Rías are known worldwide to have a unique ecosystem, very rich in nutrients and thus, highly productive [41-43]. Therefore, productivity in this case could be comparable to terrestrial soil, and the impact of building on sea area would be much less efficient than thought at first glance. Nonetheless, only the consumption of resources and the waste generation were considered for evaluating the sustainability of the activity (fishing and transportation of goods). Consequently, it has to be taken into account that the calculated value of the EF will be slightly underestimated.

Flows were converted into bioproductive area by specific equivalence factors for the land use types available from the National Footprint Account [44]. The different types of area considered in the present study were: fossil energy, arable land, pasture, forest area and sea area. Built-up land type was not considered for the reasons above mentioned.

The calculation of EF implies the conversion of units for each input and output considered in the inventory data to space units, usually hectares (ha). For that purpose, values of energy intensity and natural and/or energy productivity, depending on the case, are required. These values are specific for each subcategory, and are compiled from several studies reported in the Table 2 [10, 45-47]. The use of energy intensity values is necessary to express the units in terms of energy, reflecting the embodied energy required for the generation of a specific product. On the other hand, natural productivity is considered when the resources can be obtained directly from the land, while energy productivity reflects the possible energy produced or assimilated for a specific land [39]. The values of these factors are shown in Table 2 for the most relevant categories in terms of quantity, which are: fish, fuel, ice, cars, containers and packaging, auto parts, metal and manufacture of metal, machinery and wood, staves and sleepers. The factors used were obtained from other works and were specified for each category (Table 2). However, when the same category was not found, the most similar one was used.

3. Results

Four different scenarios were considered in this work. The aim was to identify which port activity presents a higher impact in terms of EF. Scenario 1 considers the total activity of the Port of Vigo, including fishing, transportation of goods and PA. Scenario 2 includes only goods transportation and PA (excluding fishing). The other scenarios represent the total fishing activity of the port (scenario 3) and the different fisheries included in this activity (scenario 4), which is divided in trawlers (Great Sole Bank), long-liners, inshore, and hatcheries.

3.1. EF of the different port activities

Pressure on the different footprint land-components can be seen in Fig. 2 for the analysed scenarios. Total EF of the Port of Vigo (scenario 1) has a value of 4,984,650.4 ha, which corresponds to 1.4 ha·ton^{-1}, while the value obtained in the scenario 2 was 2,733,905.2 ha, corresponding to 0.8 ha·ton^{-1}. Regarding fishing activity, the total EF (scenario 3) presented a value equal to 2,250,745.3 ha, which corresponds to 13.5 ha·ton^{-1} of unloaded fish. Analysing the EF according to each fishery (scenario 4) resulted in the values: 885,002.1 ha (37.3 ha·ton^{-1}) for trawlers; 341,258.2 ha (41.2 ha·ton^{-1}) for long-liners; 289,910.1 ha (19.8 ha·ton^{-1}) for inshore; and 397,586.3 ha (10.1 ha·ton^{-1}) for hatcheries. Results show that EF of transportation and PA activity is similar to EF of total fishing activity. However, relative EF is much higher in the case of fishing, due to the slow natural productivity of this resource. In fact, trawlers and long-liners present the highest EF per tonne of product (fish), due to the combination of high extractive capacity of natural resources and high consumption of fossil fuel (long distance travelled for catching).

In general, energy land was the most affected in all scenarios (except for the scenario 3 and hatcheries in scenario 4), followed by sea area. The category which more contribute to the pressure on sea area was fish, considering that is extracted from this area type. Fossil energy area was affected by the consumption of direct fuel consumption (fishing and transportation of goods) and the energy used in the transformation of the materials, considering that cannot be obtained directly from the nature. Finally, forest area also represented an important footprint contribution, mainly in scenario 2, due to the consumption of wood, staves and sleepers. This land-analysis reflects the importance of fossil fuel consumption in the global port activity, even in the case of considering only fishing activity.

3.2. Resources contribution to EF

The resources category was the main one (more than 95%) contributing to EF in all the assessed scenarios, followed by energy and wastes (Fig. 3). When analysing the resources category alone in the scenario 1 (total port activity), fish (25.86%), cars (20.21%) and fuel (17.70%) were identified as the main contributors to the high value of EF (Fig. 3). In the case of fish, its important contribution is mainly due to the low value of natural productivity associated with EF calculation. Cars (ro-ro traffic) pose an important percentage of transportation activity, and besides, the raw materials employed in cars production has associated a high value of energy intensity, this being traduced in an important impact on the EF value. Finally, contribution of fuel was due to the high traffic of vessels for goods transportation and fishing. When assessing transportation of goods and PA activity (scenario 2), cars (36.62%), containers and packaging (10.85%), auto parts (8.44%), metal and manufactures of metal (8.02%), machinery (7.92%) and wood, staves and sleepers (7.20%) were identified as the principal resources contributing to EF. These results showed the negligible contribution of PA activity, which is mainly associated with administration. In scenario 3 (fishing activity), fish resources (57.71%) and fuel consumption (39.49%) were identified as the major contributors to EF, although ice consumption (2.77%) is also significant. Scenario 4 analysed in detail the fishing activity and therefore, fish, fuel and ice were again the main subcategories contributing to EF in the resources category. However, their influence was different depending on the fishery. In the case of trawlers, the contribution is: fuel (71.30%), fish (21.44%) and ice (7.19%). For long-liners, fuel presents a contribution of 59.39%, followed by fish (20.59%) and ice (19.81%), while for inshore (less travelled distance), the following order was observed: fish (43.57%), fuel (32.43%) and ice (23.75%). Finally, hatcheries contribute within resources with fish (83.06%) and ice (16.76%), since there is no fuel consumption associated with this activity.

3.3. Energy and residues contribution to EF

In the energy category, coal and fossil fuel consumption were the most influencing factors to energy EF, followed by fossil gas and liquid fuel, all of them non-renewable resources. This contribution pattern was the same for all the evaluated scenarios. Regarding residues category, organic wastes were identified in scenarios 1, 3 and 4 as the principal contributors to the EF (around 98%), due to the high quantity of fish residues, such as livers, skins, etc., resulting from fishing and further processing, mainly at auction activity and in-port fish processors. For the scenario 2, the contributing profile was paper and cardboard (59.29%), hazardous wastes (20.19%) and electronic wastes (19.87%).

4. Discussion

As concluded from the results, there are no significant differences within the total EF of fishing and port activities, since for both a high footprint value was obtained. The main contributor in port activities was the fuel consumption related with goods vessel transportation while for fishing activity, EF was associated with the consumption of fish resources, although fuel consumption was also important (Fig. 3). A high value was obtained in this work (2,733,905.2 ha for scenario 2) when compared to previous EF studies of Port Authorities [35-37], in which values between of 3,279.84 ha and 6,483 ha were obtained. Nevertheless, in these cases only administrative services of PA were evaluated, while in this study, besides PA activities, the transportation of goods was also considered, causing a substantial increase in the value of EF. Since there are only few studies related to the application of EF in the fisheries sector (including administrative services like PA), it is necessary to emphasize the need for a implementation of sustainability indicators in the different integrative parts of this sector, in order to achieve more and better comparisons between them. In fact, considering that the fisheries sector is currently characterized by a globalisation and an increase number of fishing captures, it is the extremely important to assess the impact of fisheries, being EF an adequate methodology to be used. Parker and Tyedmers [34] evaluated the EF of fisheries in terms of the marine portion of EF of products derived from various fisheries such as, Peruvian anchovy (*Engraulis ringens*), Atlantic herring (*Clupeaharengus*), Gulf menhaden (*Brevoortia patronus*), blue whiting (*Micromesistius poutassou*) and Antarctic krill (*Euphausia superba*). Other studies revealed the stress on the marine ecosystems by the application of modified EF methodologies [6, 31-33]. In these studies, the state of fisheries stock over the years were evaluated, being identified a progressively decrease of marine ecosystems productivity. Other works assessed the impact on fuel used related with fishing activity, since in the last years there is an increase movement through distant waters [6]. High fuel consumptions have been identified as a serious problem for fishing sector for many reasons, including economical factor [48], but the most important is linked with environmental problems related with greenhouse gas emissions [49, 50]. In fact, high fuel consumptions associated with fishing activity and transportation of goods vessels were identified in the present study. This knowledge allows the different stakeholders (e.g. managers, policy makers) a better comprehension of the actual state of fisheries, emphasizing for the need of restructuring of this sector. However, it would be necessary to increase the number of EF studies of port activities in order to achieve more and most accurate comparison data.

During an environmental assessment, contemplating all the data involved in the activity is most of times very difficult, being the establishment of the system boundaries a critical step. Therefore, the uncertainty of the results should be always considered. In the present study the results obtained are probably underestimating the real footprint value, since the built-land component (corresponding to port infrastructures) was not considered. Besides, in this particular case, the part built on sea is of particular concern due to the richness of the Galician coastal area, which could be comparable to arable land. In fact, future assessments should incorporate a productivity value specific for the Galician Rías. Also, land area (corresponding to infrastructures related with production processes) required to provide all materials related with port and fishing activity (plastic, cars, machinery, vessel, packaging, etc.) was not considered. Besides, although fuel consumption was thoroughly compiled, this data was probably not totally complete, considering that vessels usually supply fuel at other ports, apart the consumption in the port of Vigo. Finally, conversion factors for the different materials were not the most appropriate in some cases.

The different EF methodologies (National Footprint Accounts, land disturbance, emergy, EF-net primary production, dynamic EF and further extensions) were reviewed and analysed in a recent study developed by Wiedmann and Barrett [51]. It was verified that EF methodology is a powerful tool for identifying the sustainability of diverse activities, although it cannot provide the information necessary to conduct a deep policy assessment. Beyond the need for better methods for the application of EF, it is important to create a system of environmentally representative safe areas. These areas are essential to protect marine ecosystems, giving depleted fish species the opportunity to recuperate, and also to remove critical fishing practices, with the goal of achieving sustainable fisheries and for reduce the overexploitation of resources [52].

5. Conclusions

The present study showed that the total activity of the Port of Vigo presents a high value of EF. However, it has to be considered that this is the biggest fishing port (for human consumption) in the world and one of the most important in goods transportation. Among the different categories evaluated, resources consumption (fish and fuel) were identified as the main influencing factors to EF. Besides, relative EF of total fish production presents a very high value (13.5 $ha \cdot ton^{-1}$). Therefore, in terms of sustainability, measures should be taken in order to improve not only fishing practices but also to reduce fuel consumption, investing on estimation/prediction tools (abundance fishing maps, for example) that allows vessels to find optimal activity areas, minimising fuel use.

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Figure captions:

Fig. 1. Flow chart of port operations in the Port of Vigo.

Fig. 2. Pressure on the different footprint land-components.

Fig. 3. Categories contribution to EF and resources contribution to EF (scenario 1).