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Article

Fishprint of Coastal Fisheries in Jalisco, Mexico

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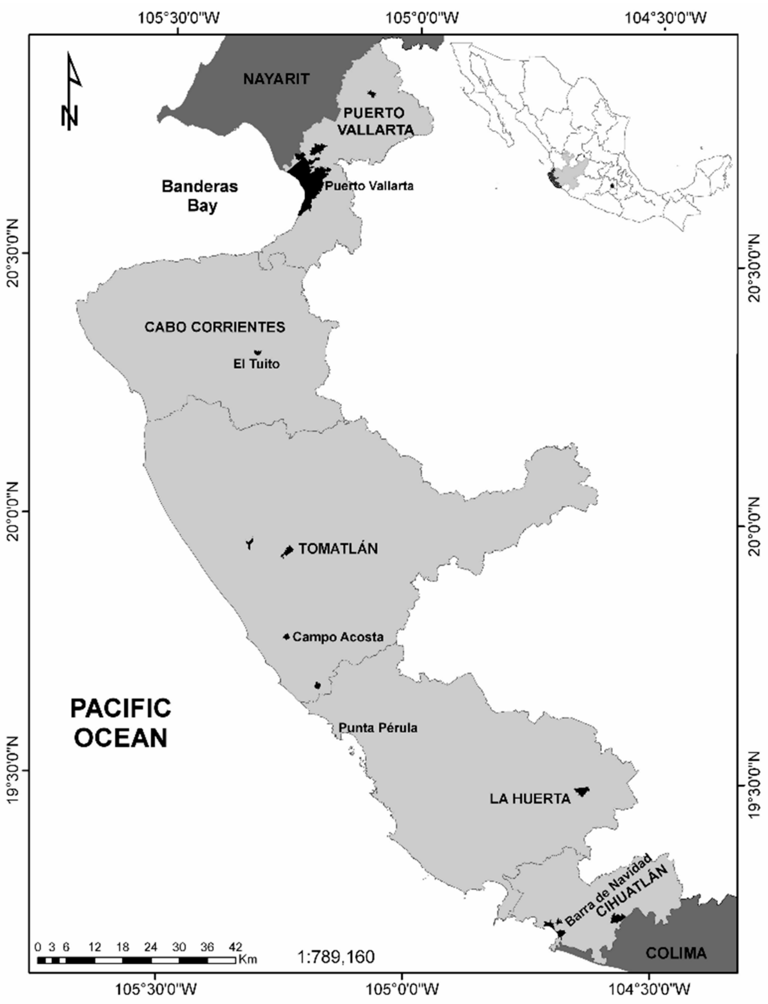
Abstract: Coastal fisheries contribute to global food security, since fish are an important source of protein for many coastal communities in the world. However, they are constrained by problems, such as weak management of fisheries and overfishing. Local communities perceive that they are fishing less, as in other fisheries in the world. The aim of this study was to evaluate the fisheries sustainability in the Jalisco coast through the fishing footprint, or fishprint (FP), based on the primary productivity required (PPR) and the appropriated surface by the activity (biocapacity). The total catch was 20,448.2 metric tons from 2002–2012, and the average footprint was calculated to be 65,458 gha/year, a figure that quadrupled in a period of 10 years; the biocapacity decreased, and the average trophic level of catches was 3.1, which implies that it has remained at average levels, resulting in a positive balance between biocapacity and ecological footprint. Therefore, under this approach, the fishing activity is sustainable along the coast of Jalisco.

Keywords: trophic level; primary productivity; biocapacity

1. Introduction

The coast of Jalisco is located on Mexico's Pacific coast, bordered to the north by the state of Nayarit and to the south by the state of Colima, with a length of 351 km, including five municipalities: Puerto Vallarta, Cabo Corrientes, Tomatlán, La Huerta and Cihuatlán [1] (Figure 1). It is an occasional upwelling area [2] with the presence of an immediate current to the coast of Cabo Corrientes, which intensifies on the surface [3]. Fishing activity is only artisanal, but it maintains a good level of labor employment and generates a significant demand for technical and commercial services [4].

Figure 1. The coast of Jalisco, México, located in the Pacific Central-American Coast Large Marine Ecosystem (www.seaaroundus.org/lme) and in the Pacific, East Central Food and Agriculture Organization (FAO) fishing area [5].



It is estimated that about 14,274 people live on fishing directly [6]. Most of the people depend on fishing in this region not only to feed themselves, but for cultural reasons. If fishing is an important activity here, how sustainable is it?

Fishing is important worldwide: more than a billion people, mostly in poor countries, depend on fish products to meet their need for animal protein in their diet.

The consumption of fishery resources in the world has increased to 130.8 million tons intended for human consumption due to aquaculture, increased fishing and improvement of distribution channels.

This situation allowed the growth of the world's supply of fish per capita from 9.9 kg (live weight) in 1960 to 18.8 kg per capita in 2011 [7].

Although world fisheries production has remained stable over the last ten years and reached a peak of 86.4 million tons in 1996, concerns about the sustainability of fisheries have been expressed related to overfishing, depletion of some stocks, ecosystem changes induced by humans and its potential impact on supplies and equity at the local level [8].

In 2011, the Food and Agriculture Organization (FAO) [9] reported that 28.8% of the stocks were overexploited, 9.9% were exploited moderately or underexploited and the rest were fully exploited. Therefore, catches are considered close to their maximum sustainable limits, without the possibility of increasing [10].

Given the need to understand the impacts of fisheries and their status, some indicators have been developed. The ecological footprint (EF) is an indicator that measures human needs in terms of area required for the generation of products and waste absorption during the course of the production process [11] and can be used for many purposes. The EF of fishing, a tool to measure the spatial extent of human appropriation of marine ecosystems based on primary productivity required relative to the catch, can be used to establish the ecological impacts and sustainability of fish production and consumption at different levels.

Pauly and Christensen [12] developed a method to improve the estimation of the primary production required to sustain global fisheries catches and proposed an equation that takes into account the catch efficiency of the energy transfer between the trophic level and trophic level of the species or group of species caught. Results showed in general that 8% of primary productivity was necessary to sustain catch levels, almost four-times more than previously estimated [13]. The requirements were only 2% for the open ocean, but fluctuated between 24% and 35% in fresh water upwelling systems and the continental shelf, which justifies the current concerns about sustainability and biodiversity.

In collaboration with *The Sea around Us* project, the Redefining Progress organization published The Fishprint of Nations [14], which extends the analysis of EF to aquatic resources. The fishprint (FP) provides a method to quantify the pressure that the human population has on marine ecosystems at different scales and allows one to distinguish between levels of sustainable or unsustainable fisheries. They established the worldwide FP between 1950 and 2003, including 149 countries, and their results were interpreted as "unsustainable levels of fishing" probably since mid-1970, where 60.4% of countries had a negative ecological balance in 2003. The highest deficit scores were obtained by Japan, Indonesia, China, Philippines, Thailand and Norway. Mexico resulted also in a negative ecological balance in terms of its biocapacity, occupying the 23rd place.

Tyedmers *et al.* [15] quantified fuel consumption due to sea fishing, using statistical data from more than 250 fisheries around the world, and found that about 50 million liters of fuel were consumed during the capture of about 80 million tons of marine resources. This represents 1.2% of world oil consumption and directly emits more than 130 million tons of carbon dioxide into the atmosphere. From an efficiency perspective, the energy content of the fuel consumed by the world's fisheries is 12.5-times greater than the energy content of protein in the catch [15].

The State of World Fisheries and Aquaculture report 2008, stated that these activities had a small, but significant contribution to the emission of greenhouse gases during fishing operations, transportation, processing and storage of the product captured [10].

Regarding the impact of fishing on marine ecosystem, Galván-Piña [16] constructed a trophic model based on Ecopath (a program used to characterize the trophic structure and function of an ecosystem based on the mass balance [17]) to describe the structure and biomass flows of the ecosystem at the continental shelf along the south coast of the state of Jalisco and the north coast of Colima state. The model includes 38 functional groups, where 22 are fishes; nine are invertebrates and a group of marine mammals, seabirds, zooplankton, phytoplankton, dead fish and detritus. He found that most of the significant negative impacts were on the groups of higher trophic levels, confirming the hypothesis about the negative effect of fishing on the ecosystem. Therefore, he proposed as a strategy for the area to increase the fishing effort by 10% for gillnet fleet, to increase the commercial diving fleet three times and to reduce the shrimp fleet by 10%.

Most fisheries scientists agree that fisheries have declined in the world in the past 20 years. Fishermen along the coast of Jalisco perceive an outflow of resources related to poor catches. This situation is not reflected by the official catch data in the last 20 years in the region, but the fishing effort is greater, as perceived by fishermen.

In this global and regional context, the aim of this study was to determine the sustainability of coastal fisheries along the coast of Jalisco, under the approach of the FP, based on primary productivity required (PPR) to catch resources in the period from 2002 to 2012.

2. Results

The catch totaled 20,448.2 tons between 2002 and 2012. Marked variations are observed; there was a steady increase, reaching the highest records in 2008, and a sharp decline in 2009 (Figure 2). The best represented group in the total catch were fishes (about 84.9% of the biomass); the second were mollusks (12.8%), and the rest were crustaceans. In official catch records, there were 73 groups identified, where 67 corresponded to fish. The most frequent species in catches were snapper (Lutjanidae family), grouper (Serranidae family), octopus (*Octopus hubbsorum*) and Pacific sierra (*Scomberomorus sierra*), which together account for 47.5% of the total catch during the period analyzed (Figure 3).

Figure 2. Annual catch trends off the coast of Jalisco in the period 2002–2012. Data obtained from SAGARPA (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food)).

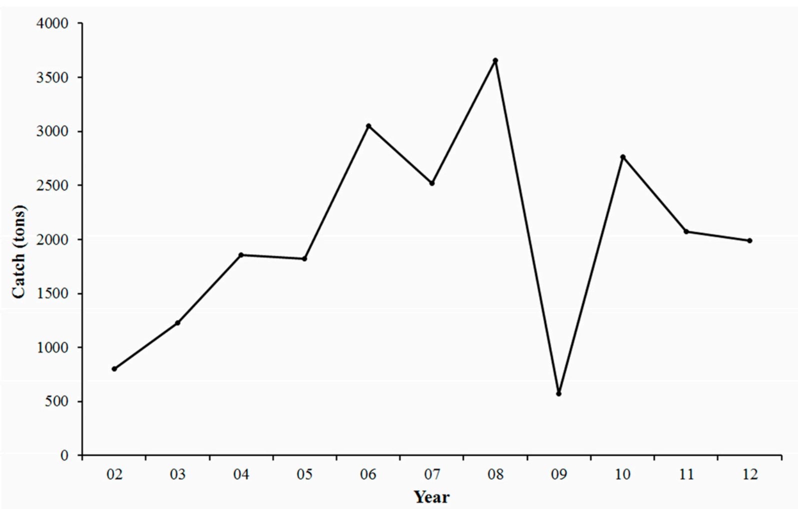
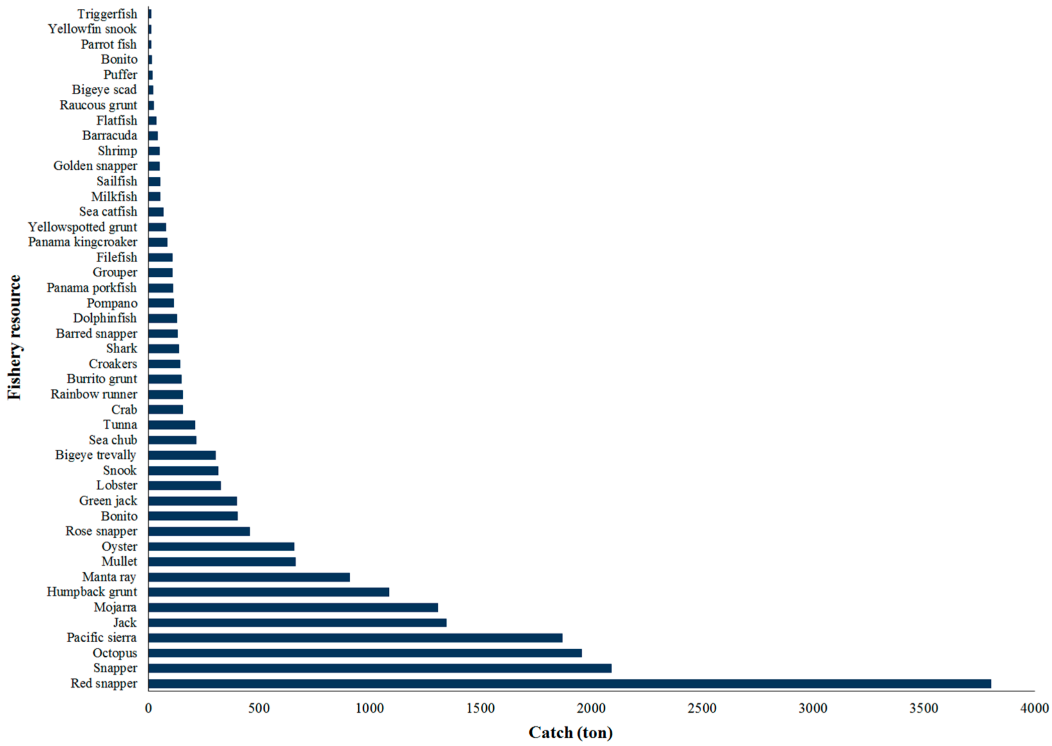


Figure 3. Catches off the coast of Jalisco in the period 2002–2012. Resources with catches higher than 10 tons are shown.



The fish caught by artisanal fishermen were classified into 39 groups, with trophic levels ranging between two (parrot fish, *Scarus compressus*) and 4.5 (roosterfish, *Nematistius pectoralis*) (Table 1).

PPR to support the catch was calculated to be 598,642 tons; the groups that require greater primary productivity were carangids, the Pacific sierra and scombrids (Table 1, Figure 4).

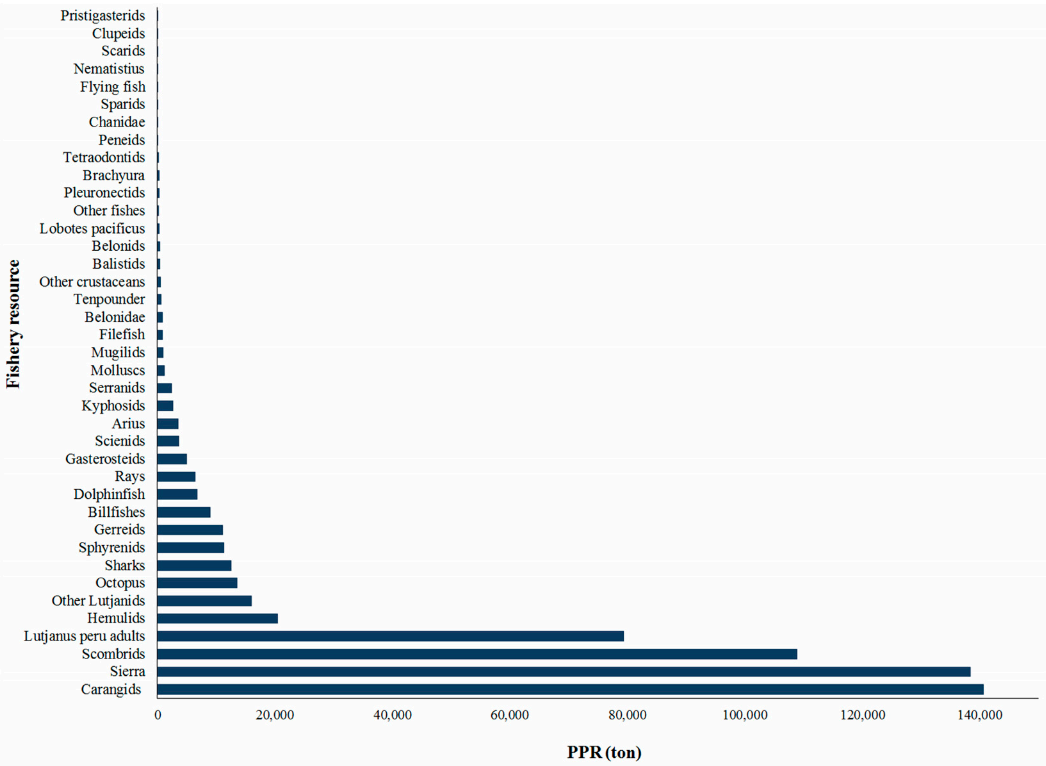
Table 1. Trophic level, trophic category, catch and primary production required (PPR) of fishery production along the coast of Jalisco during the period 2002–2012.

Trophic Group	Trophic Level	Trophic Category	Catch (tons)	PPR (tons)
Carangids	3.63	Carnivorous	2336	140,616
Pacific sierra	3.72	Carnivorous	1869	138,411
Scombrids	4.09	Carnivorous	627	108,850
Lutjanus peru adults	3.17	Carnivorous	3803	79,376
Hemulids	3.00	Carnivorous	1451	20,475
Other lutjanids	2.62	Carnivorous	2727	16,042
Octopus	2.69	Carnivorous	1957	13,525
Sharks	3.79	Carnivorous	144	12,529
Sphyrenids	4.28	Carnivorous	42	11,293
Gerreids	2.78	Carnivorous	1306	11,105
Billfishes	4.03	Carnivorous	59	8921
Dolphin fish	3.57	Carnivorous	129	6763
Rays	2.70	Carnivorous	909	6429
Gasterosteids	3.03	Carnivorous	327	4944
Scienids	3.05	Carnivorous	230	3642
Arius	3.57	Carnivorous	67	3513

Table 1. *Cont.*

Trophic Group	Trophic Level	Trophic Category	Catch (tons)	PPR (tons)
Kyphosids	2.94	Herbivorous	215	2642
Serranids	3.10	Carnivorous	133	2363
Mollusks	2.10	Herbivorous	658	1169
Mugilids	2.01	Herbivorous	663	957
Filefish	2.76	Carnivorous	107	869
Belonidae	4.46	Carnivorous	2	814
Ten pounder	4	Carnivorous	4	564
Other crustaceans	2	Carnivorous	327	461
Balistids	3.34	Carnivorous	12	370
Belonids	4.50	Carnivorous	1	446
Lobotes pacificus	4.04	Carnivorous	2	309
Other fishes	3.08	Omnivore	12	204
Pleuronectids	2.69	Carnivorous	34	235
Brachyura	2.02	Omnivore	156	231
Tetraodontids	2.91	Omnivore	18	206
Peneids	2.10	Herbivorous	49	87
Chanidae	2.03	Herbivorous	52	79
Sparids	3.52	Carnivorous	2	93
Flying fish	4.01	Carnivorous	0.2	29
Nematistius	4.50	Carnivorous	0.1	45
Scarids	2.00	Herbivorous	13	18
Clupeids	2.89	Omnivore	1	11
Pristigasterids	3.31	Carnivorous	0.2	6

Figure 4. Primary productivity required in marine catches off the coast of Jalisco.



The footprint of coastal catches in Jalisco for all years analyzed did not exceed the biocapacity of the area. The year with the highest mark was 2008, representing 0.05% of the biocapacity of the fishing area. Consequently, coastal catches in Jalisco State had a positive ecological balance every year, measured in global hectare units (gha). That means the average productivity of the entire area of biologically productive land and sea in the world in a given year (Table 2).

Table 2. Mean trophic level, fishprint, biocapacity and ecological balance of catches on the coast of Jalisco from 2002 to 2012. gha, global hectare unit.

Year	Catch (tons)	Mean Trophic Level	FP (gha)	Biocapacity (gha)	Ecological Balance (gha)
2002	789	3.1	21,716	35,872,580	35,850,864
2003	1025	3.1	28,152	35,840,538	35,812,386
2004	1524	3.1	40,802	35,661,473	35,620,671
2005	1478	3.1	40,494	35,541,767	35,501,273
2006	2382	3.1	69,916	35,192,021	35,122,105
2007	2289	3.2	76,817	35,364,783	35,287,966
2008	1970	3.2	123,126	35,232,310	35,109,184
2009	546	3.0	21,744	34,969,782	34,948,038
2010	2724	3.2	104,556	34,969,782	34,865,225
2011	2074	3.1	103,673	31,975,955	31,872,282
2012	1986	3.1	89,047	31,658219	31,569,172

3. Discussion and Conclusions

In order to promote sustainable fishing practices, the UN Convention on the Law of the Sea requires countries to maintain and restore fisheries using best management practices by controlling their catches. Such measures have been designed to maintain or restore populations at adequate levels to produce the maximum sustainable yield according to environmental and economic factors.

The fishing footprint tool enables users to quantify, with a non-traditional approach, the impact on marine ecosystems and can be used as a tool for assessing the sustainability of catch levels in countries or regions, taking into account the effects of trophic level and the biocapacity of a specific area of the ocean, where the catch is expressed in terms of PPR, which is largely a function of the trophic level of the species caught.

In terms of catch, it is important to consider the unreliability of the official catch data in Mexico, as many other countries, due to the unreported and illegal catch data by fishermen, which was an estimate of 15% of the total catch for the 2000–2003 period in the Eastern Central Pacific region [18].

That means that the real catch for the coast of Jalisco would have been 2283.9 instead of 1986 tons for the year 2012 (Table 2). This fact would affect the PPR, as well as the FP for the same year. However, the ecological balance would still be positive. Even assuming a number over 20% of illegal or unreported catch for this region, PPR and FP would not be modified significantly.

Overfished zones now cover most of the world's oceans, including ones of low productivity [19], coupled with the evident global decline in catches since the late 1990s [7], indicating that fishing has reached its limit.

If biocapacity for marine fisheries is depleted and excessive PPR occurs in many regions of the world, the option for sustainable fishing is to reduce the PPR, focus fishing on lower trophic levels, reduce the high trophic catch level, establish protected areas and eliminate destructive fishing practices.

However, it should be remembered that capture at the maximum sustainable level in the lower trophic levels can also have large impacts on the ecosystem [20].

The results for the coast of Jalisco show that the FP has quadrupled over a period of 10 years, while the biocapacity has decreased and is related to the local population increase. The average trophic level catch between 2002 and 2012 was 3.1, ranging from 3.0 to 3.2, which implies that it has remained at average levels.

The trophic level decreasing phenomenon in fisheries catch was released in 1998 [21]; since, then researchers have been looking for evidence at regional and local scales.

While average catch trophic level is noted as an indicator of the sustainability of catches, it is important to note that the decline of the trophic level of fish catch can not only be due to ecological problems, but also to changes in the price of fish products, leading to the capture of specific resources, as well as to the natural increase of low level trophic species or the development of new fisheries targeted at low level trophic species.

The existence of species at lower trophic levels in the Jalisco coast can be explained by the fact that in this area, the continental shelf is narrow, and the presence of an oxygen minimum zone represents a physiological barrier to vertical migration [22].

Other environmental characteristic of the area that may have an influence, in days' or months' scale, in the biological behavior of the species providing favorable or unfavorable habitat conditions, is the presence of a shallow thermocline in the area [23].

The productivity of the coastal zone [2] is related to spatial heterogeneity, since there may be significant differences between littoral and pelagic systems and particularly between biotopes: bays, beaches, estuaries and coastal lagoons [24,25]. Moreover, the small variation in the trophic level over time is consistent with multispecies fisheries, low technological levels and ecosystems with high biodiversity [26,27].

In the same way that the world fisheries exceed biocapacity of the ocean [14] at the national level, Mexico presented a negative ecological footprint and biocapacity balance, while the FP at the coast of Jalisco represented less than 1% of the biocapacity of the fishing area, probably due to the type of fishing performed in the area. It is then concluded under this approach that on the coast of Jalisco, a healthy fishery exists, since there is a positive balance between biocapacity and FP in the area.

The average fishprint at the country level was calculated as 1017.17 million gha/year for Mexico in 2003 [15]. The one we calculated for Jalisco's small scale fishing was 65,458 gha/year (just 3% of the country level), but it cannot be compared to another fishprint along the coast of Mexico, because this approach has not been used to assess fisheries.

The low fishprint can be explained on the basis of the characteristics of fisheries along the coast of Jalisco, which are very similar to the artisanal fishing along the rest of the country. The main characteristic is that Jalisco's marine biocapacity is big enough, but little fishing is done. Jalisco State contributes only 1.3% to the national catch volume. The catch volume is related to the ability for fishing, so although there are 44 fishing cooperatives, they have small boats, mostly less than 30 feet in length, that operate largely without a motor, and till 2011, there were only two docks for unloading catch [6]. Under these conditions and the physical ones already mentioned, the catch is minimal compared nationally.

In addition, fishermen need less fuel for boats and are aware of their dependence on marine resources [26]. The catch is done using fishing gear, like gillnets, hand lines, cast nets, long lines, seines, crab rings and diving equipment, in a few cases. In general, it is more selective, up to 20-times more than industrial fishing [6]. All of these characteristics contribute to sustainability.

Although our results indicate sustainable fishing in the region it can not only be an outcome of FP assessment, it should also include the results of other socioeconomic and environmental indicators, but it is an important tool for fisheries management.

4. Method

4.1. Data Collection

Official reported fish catch data were obtained for the coast of Jalisco between 2002 and 2012. These were clustered by taxonomic groups, and the total catch wet weight in tons (biomass) per year for each group was obtained. Then, each one was assigned to a trophic level category, as proposed by Froese and Pauly [28], Galvan-Piña and Arreguín-Sánchez [29] (Table 3).

Table 3. Source for trophic level assignation.

Trophic Groups	Author
Lutjanus peru adults	Galvan-Piña and Arreguín-Sánchez (2008)
Arius	Froese and Pauly (2010)
Balistids	Froese and Pauly (2010)
Belonids	Froese and Pauly (2010)
Filefish	Froese and Pauly (2010)
Brachyura	Galvan-Piña and Arreguín-Sánchez (2008)
Carangids	Galvan-Piña and Arreguín-Sánchez (2008)
Chanidae	Froese and Pauly (2010)
Ten pounder	Galvan-Piña and Arreguín-Sánchez (2008)
Clupeids	Froese and Pauly (2010)
Dolphin fish	Galvan-Piña and Arreguín-Sánchez (2008)
Scienids	Galvan-Piña and Arreguín-Sánchez (2008)
Scombrids	Galvan-Piña and Arreguín-Sánchez (2008)
Gasterosteids	Galvan-Piña and Arreguín-Sánchez (2008)
Gerreids	Galvan-Piña and Arreguín-Sánchez (2008)
Hemulids	Galvan-Piña and Arreguín-Sánchez (2008)
Kyphosids	Froese and Pauly (2010)
Lobotes pacificus	Froese and Pauly (2010)
Mollusks	Galvan-Piña and Arreguín-Sánchez (2008)
Mugilids	Froese and Pauly (2010)
Nematistius	Froese and Pauly (2010)
Other crustaceans	Galvan-Piña and Arreguín-Sánchez (2008)
Other lutjanids	Galvan-Piña and Arreguín-Sánchez (2008)
Other fishes	Galvan-Piña and Arreguín-Sánchez (2008)
Peneids	Galvan-Piña and Arreguín-Sánchez (2008)

Table 3. *Cont.*

Trophic Groups	Author
Billfishes	Galvan-Piña and Arreguín-Sánchez (2008)
Pleuronectids	Galvan-Piña and Arreguín-Sánchez (2008)
Pristigasterids	Froese and Pauly (2010)
Octopus	Galvan-Piña and Arreguín-Sánchez (2008)
Rays	Galvan-Piña and Arreguín-Sánchez (2008)
Belonidae	Froese and Pauly (2010)
Scaridae	Froese and Pauly (2010)
Serranids	Galvan-Piña and Arreguín-Sánchez (2008)
Sierra	Galvan-Piña and Arreguín-Sánchez (2008)
Sparids	Froese and Pauly (2010)
Sphyrenids	Froese and Pauly (2010)
Tetraodontids	Galvan-Piña and Arreguín-Sánchez (2008)
Sharks	Galvan-Piña and Arreguín-Sánchez (2008)
Flying fish	Froese and Pauly (2010)

4.2. Primary Productivity Required to Sustain Fisheries

In order to calculate the PPR for capturing each group of species or to sustain fishing in a determined trophic level, the following equation [30] was used:

$$PPR = CC \times DR \times \left(\frac{1}{TE}\right)^{TL-1} \tag{1}$$

CC is the carbon content of the total catches, *DR* is the discarded rate by catch, *TE* is the transfer efficiency of biomass between trophic levels and *TL* is the trophic level of the group or species. A ratio of 9:1 was used to convert units of wet weight (ton) to grams of carbon. An overall average value of 1.27 for all species is assigned for *DR*, which means that for each ton of fish obtained, 0.27 tons constitute the catch [12]. This rate is used due to the lack of local by-catch data, as a constant factor in the corresponding equation, assuming that the by-catch trophic level is the same as that of the species caught. The *TE* value is also constant and equal to 0.1 for all groups, meaning that 10% of the biomass is transferred to successive trophic levels [12].

The corresponding trophic level for each group for the coast of Jalisco was taken from that proposed by Galvan-Piña and Arreguín-Sánchez [29]; the missing data in this study were obtained from the Fishbase [28] for the central Mexican Pacific area.

4.3. Fishing Footprint and Biocapacity

The footprint of a given area *A* in a year is:

$$FP_A = \frac{TPP_{A_y}}{YFPP_{G_y}} \times EQF_{NPP} \tag{2}$$

where TPP_{Ay} is the total primary productivity required in the area, $YFPP_{Gy}$ is the overall yield factor, calculated dividing TPP_{Ay} by the global biocapacity for marine fisheries (*BCg*), and EQF_{NPP} an equivalence factor for marine fisheries (1.66). This factor convert a specific land type into a global hectare, a universal unit of biologically productive area.

In turn, the global biocapacity of marine fisheries was calculated by multiplying the open ocean area, including its equivalency factor by the surface of the exclusive economic zone (EEZ) with its equivalence factor. Table 4 provides the calculations and indicates a marine biocapacity of 33.94 billion global hectares.

Table 4. Global marine fisheries biocapacity [14].

Region	Area (billion ha)	Equivalence Factor	Biocapacity (billion ha)
Exclusive economic zones	13.88	1.66	23.18
Open oceans	22.41	0.48	10.76
Total	36.29	0.94	33.94

The fishing area biocapacity (BC) for the coast of Jalisco State was obtained through the following formula:

$$BC = \frac{BC_G}{POP_G} \times POP_A \tag{3}$$

BC_G is the global biocapacity of marine fisheries (equivalent to 23.18 billion hectares), which is obtained by multiplying the area of EEZ (13.88 billion hectares) and equivalence factor EEZ (1.66); POP_G is the world population (taken from Population Reference Bureau [31]), and POP_A is the population of the area of Jalisco State (taken from National Population Council (CONAPO) [32]).

The calculation takes into account the fact that the fishing fleet in a given country can catch fish in different parts of the world. Some countries have international or bilateral agreements allowing them to capture fish in a much larger area than their own EEZ. Another advantage of this approach is the implication that landlocked countries also have biocapacity, which by default would be that its fishing footprint exceeds its biocapacity.

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Author Contributions

Bravo-Olivas and Chávez-Dagostino designed the research, collected data and wrote the paper. López-Fletes collaborated in the literature review, performed research, checked the statistical results and extensively updated the paper. Espino-Barr co-designed the research and edited the paper. All authors read and approved the final manuscript, analyzed the data and took part in the discussion conjointly.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1. National Institute Of Statistics and Geography (INEGI). *Los Municipios de Jalisco. Colección: Enciclopedia de los Municipios de México*; Secretaría de Gobernación: Ciudad de México, Mexico, 1995; p. 264. (In Spanish).
2. Lara-Lara, J.R.; Arenas, F.V.; Bazán, G.C.; Díaz, C.V.; Escobar, B.E.; García-Abad, M.C.; Gaxiola, C.G.; Robles, J.G.; Sosa, A.R.; Soto, G.L.A.; *et al.* Los ecosistemas marinos. In *Capital Natural de México. Volume I: Conocimiento Actual de la Biodiversidad*; Comisión Nacional para el Conocimiento y Uso de la Biodiversidad: Ciudad de Mexico, Mexico, 2008; pp. 135–159. (In Spanish)
3. Roden, G. Termohaline structure and baroclinic flow across the Gulf of California entrance and in the Revillagigedo Island region. *J. Phys. Oceanogr.* **1972**, *2*, 177–183.
4. Gallegos, A.; Rodríguez R.; Márquez, E.; Lecuanda, R.; Zavala, J. Una climatología de la temperatura de la superficie del mar de las aguas oceánicas adyacentes a las costas de Jalisco, Colima y Michoacán, México: 1996–2003. In *Los Recursos Pesqueros y Acuícolas de Jalisco, Colima y Michoacán*; Jiménez-Quiroz M.C., Espino-Barr, E., Eds.; Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación: Manzanillo, México, 2006; pp. 17–28. (In Spanish)
5. Food and Agriculture Organization (FAO). CWP Handbook of Fishery Statistical Standards. Available online: http://www.fao.org/fishery/cwp/handbook/h/en (accessed on 29 October 2014).
6. Martínez-González, P.; Corgos, A. Pesca artesanal en la costa de Jalisco. Conflictos en torno a la conservación biocultural. *Obs. Desarro.* **2013**, *7*, 38–46. (In Spanish)
7. Food and Agriculture Organization (FAO). *The State of World Fisheries and Aquaculture 2012*; Fisheries and Aquaculture Department: Rome, Italy, 2012; p. 209.
8. Food and Agriculture Organization (FAO). *Indicators for Sustainable Development of Marine Capture Fisheries*; Fisheries and Aquaculture Department: Rome, Italy, 1999; p. 68.
9. Food and Agriculture Organization (FAO). *The State of World Fisheries and Aquaculture 2014*; Fisheries and Aquaculture Department: Rome, Italy, 2014; p. 223.
10. Food and Agriculture Organization (FAO). *The State of World Fisheries and Aquaculture 2008*; Fisheries and Aquaculture Department: Rome, Italy, 2009; p. 196.
11. Wackernagel, M.; Rees, W. *Our Ecological Footprint. Reducing Human Impact on the Earth*; New Society Publishers: Philadelphia, PA, USA, 1996; p. 160.
12. Pauly, D.; Christensen, V. Primary production required to sustain global fisheries. *Nature* **1995**, *374*, 255–257.
13. Christensen, V.; Pauly, D. The ECOPATH II—A software for balancing steady-state ecosystem models and calculating network characteristics. *Ecol. Model.* **1992**, *61*, 169–185.
14. Talberth, J.; Venetoulis, J.; Wolowicz, K. Recasting Marine Ecological Fishprint Accounts. Available online: http://rprogress.org/publications/2006/Fishprint%20Technical%20Supplement.pdf (accessed on 10 September 2014).
15. Tyedmers, P.; Watson, R.; Pauly, D. Fueling global fishing fleets. *AMBIO* **2005**, *34*, 635–638.
16. Galván-Piña, V. Impacto de la Pesca en la Estructura, Función y Productividad del Ecosistema de la Plataforma Continental de las Costas de Jalisco y Colima, México. Ph.D. Thesis, Centro Interdisciplinario de Ciencias Marinas-Instituto Politécnico Nacional, La Paz, Mexico, 2005; p. 106. (In Spanish)

17. Ulanowicz, R.E. *Growth and Development: Ecosystems Phenomenology*; Springer-Verlag: New York, NY, USA, 1986; p. 203.
18. Agnew, D.D.; Pearce, J.; Pramod, G.; Peatman, T.; Watson, R.; Beddington, J.R.; Pitcher, T.J. Estimating the worldwide extent of illegal fishing. *PLoS One* **2009**, *4*, 1–8.
19. Swartz, W.; Sala, E.; Tracey, S.; Watson R.; Pauly, D. The spatial expansion and ecological footprint of fisheries (1950 to present). *PLoS One* **2010**, *5*, 1–6.
20. Smith, A.D.M.; Brown, C.J.; Bulman, C.J.; Fulton, E.A.; Johnson, P.; Kaplan, I.C.; Lozano-Montes, H.; Mackinson, S.; Marzloff, M.; Shannon, L.J.; *et al.* Impacts of fishing low-trophic level species on marine ecosystems. *Science* **2011**, *333*, 1147–1150.
21. Pauly, D.; Christensen, V.; Dalsgaard, J.; Froese, R.; Torres, F. Fishing down marine food webs. *Science* **1998**, *272*, 860–863.
22. Hendrickx, M.E.; Serrano, D. Impacto de la zona de mínimo de oxígeno sobre los corredores pesqueros en el Pacífico Mexicano. *Interciencia* **2010**, *35*, 12–18. (In Spanish)
23. Filonov, A.E.; Monzón, C.; Tereshchenko, I. Acerca de las condiciones de generación de las ondas internas de marea en la costa occidental de México. *Cienc. Mar.* **1996**, *22*, 255–272. (In Spanish)
24. Caddy, J.F.; Sharp, G.D. *An Ecological Framework for Marine Fishery Investigations*; FAO: Rome, Italy, 1986; p. 152.
25. Longhurst, A.; Pauly, D. *Ecology of Tropical Oceans*; Academic Press: San Diego, CA, USA, 1987; p. 407.
26. Bravo-Olivas, M.L. Huella Ecológica de las Pesquerías Ribereñas en la Costa de Jalisco. Ph.D. Thesis, Universidad de Guadalajara, Puerto Vallarta, Mexico, 2014; p. 167. (In Spanish)
27. Reyes-Bonilla, H.; Calderón-Aguilera, L.E.; Aburto-Oropeza, O.; Díaz-Uribe, J.G.; Pérez-España, H.; del Monte-Luna, P.; Lluch-Cota, S.E.; López-Lemus, L.G. La disminución en el nivel trófico de las capturas pesqueras en México. *Ciencia* **2009**, *60*, 1–9.
28. Froese, R.; Pauly, D. *FishBase 2010: Conceptos, Estructura y Fuentes de Datos*; Froese, R., Pauly, D., Eds.; ICLARM: Manila, Philippines, 2010; p. 322. (In Spanish).
29. Galván-Piña, V.H.; Arreguín-Sánchez, F. Interacting industrial and artisanal fisheries and their impact on the ecosystem of the continental shelf on the Central Pacific coasts of Mexico. In Proceedings of the 4th World Fisheries Congress, Vancouver, BC, Canada, 2–6 May 2004; pp. 587–600.
30. Pérez-España, H.; Abarca-Arenas, L.G.; Jiménez Badillo, M.L. Is fishing-down trophic web a generalized phenomenon? The case of Mexican fisheries. *Fish. Res*. **2006**, *79*, 349–352.
31. Haub, C.; Kaneda T. *2012 World Population Data Sheet*; Population Reference Bureau: Washington, DC, USA, 2012; p. 20.
32. National Popularion Council (CONAPO). Dinámica demográfica 1990–2010 y Proyecciones de Población 2010–2030. Available online: http: //www.omi.gob.mx/es/CONAPO/Proyecciones_Analisis (accessed on 10 September 2014). (In Spanish)