Timeline LCA study of the European hake fishery (*Merluccius merluccius*) in the Basque Country

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Abstract The Basque country is one of the most important fishing regions in the European Union. European hake (*Merluccius merluccius)* is one of the main species fished by the Basque fishing fleet, representing around 6% of Basque annual landings and 20% of the total economic value. In this study, the environmental impacts linked to hake extraction have been analysed on a temporal scale, in order to analyse the effect that varying landings may have on reporting environmental burdens. Results suggest that the specific characteristics of European hake, regarding its theoretical low abundance fluctuations, influence the relative low impact of annual variations. Nevertheless to overcome this variability, moving average appears as suitable solution.

1 Introduction

Fishing in the Basque country has been a significant production sector from a social and economic perspective for many centuries [1]. However, target fisheries and species have varied considerably through time due to a set of environmental issues, linked mainly to overexploitation [2], on the one hand, and to a set of social and economic factors, on the other. Currently, one of the most important fishing fleets in the Basque country is the offshore trawling fleet that targets demersal species mainly in the Northern stock (ICES Divisions VIIIabd) and, to a lesser extent, also in the Southern stock (ICES Division VIIIc). The main landed species by this fishing fleet are European hake (*Merluccius merluccius*), megrim (*Lepidorhombus spp.)* and sole (*Solea solea*), all of which are considered species with a medium-high economic value (tab. 1).

Tab.1: Evolution of European hake (HKE) prices (€/kg) since 2001 to 2007.

	2001	2002	2003	2004	2005	2006	2007
HKE	4.65	4.39	4.15	4.08	5.25	4.25	3.84

The mentioned fishery has been strongly influenced by the total allowable catches (TACs) enforced by the European Union (EU), with the aim of ensuring the sustainability of the different stocks in the area. In addition, European hake has a specific regulation establishing measures for its recovery in the Southern stock [3]. In this context, Life Cycle Assessment (LCA) appears as an internationally recognized methodology that aims at measuring environmental impacts linked to fish extraction [4]. To date, fishery LCA studies have been based on short periods of time - in most cases one season or year – [5 – 8], mainly due to the difficulty of obtaining inventory data for a prolonged period of time. These one-season-LCA publications have not taken into account the fluctuations that fisheries may suffer due to a variety of factors, including stock abundance or management regulations [9]. Nevertheless, Mattsson and Ziegler (2004) reported strong correlations between catch rates and energy use in trawling fishing fleets [10].
Therefore, the main objective of this study is to assess environmental impacts associated to industrial activities in the Basque trawling fleet through an extended period of time (2001 to 2007) with the aim of identifying possible environmental time based variations.

2 Materials and methods

2.1 Goal and system definition

As mentioned above, the main aim of this LCA study is to assess the environmental impacts related to European Hake (*Merluccius merluccius*, Linnaeus 1758) extraction by the Basque trawling fleet in ICES Division VIIIabd on a temporal basis, in order to analyze how a long period of time may affect the environmental performance of fisheries reporting.
The selected functional unit (FU) for this particular research corresponded to 1 ton of landed gutted European Hake in Basque ports by the regional trawling fleet. The system under study was made up of the different operational stages performed by the assessed vessels, including diesel and marine oil consumption, anti-fouling and trawl net use and emissions linked to the refrigeration systems. The construction and maintenance of the vessels were also included (Fig. 1). It is

important to note that landing operations included in this study only take into account those performed on board, while on land activities where excluded from the system [5].

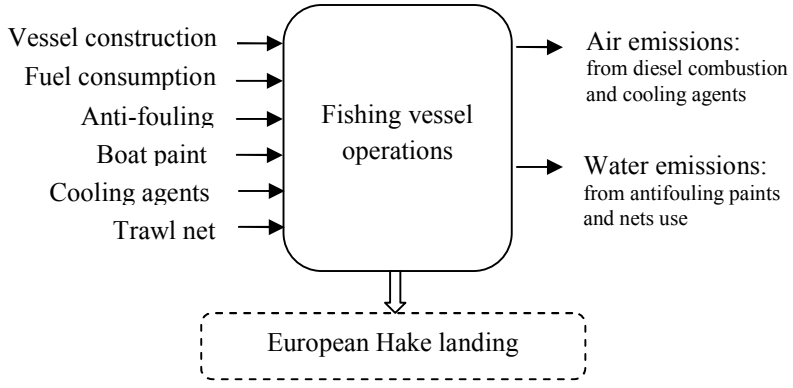

Fig.1: Diagram of the studied system

European Hake was identified as the main target species of the assessed fleet. In fact, at least 80% of total landings were linked to this species during the studied period, although a series of by-catch species such as Whiting (*Merlangius merlangus* Linnaeus, 1758), Bib (*Trisopterus luscus*, Linnaeus, 1758) or Monkfish (*Lopgiidae spp*.) may also be landed.

2.2 Data acquisition

The samples used for this study corresponded to a set of pair trawling vessels obtained depending on the availability for the different years. The primary data for fishing vessel operations were obtained mainly from a specific Basque register of fish at first sale (AZTI 2010). Landings, vessel characteristics (beam, tonnage, etc), fishing operations and fishing areas were the most relevant data obtained from the register. Furthermore, a series of additional information, such as the number of trawl nets used per vessel or the consumed ice were obtained from bibliography [5]. Background data associated with the production of diesel fuel, nets or anti-fouling and boat paint were obtained from the ecoinvent database [11].

2.3 Life cycle inventory

Inventory data regarding this fleet were obtained from a range of 20 to 6 vessels depending on the assessed year, representing roughly 60% of landed hake from VIIIabd in Basque ports (Table 2 and Fig. 2).

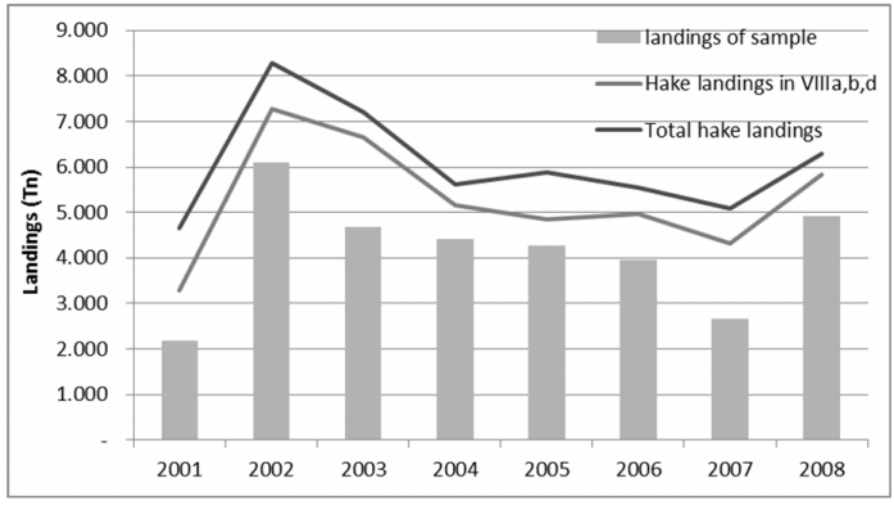

Fig.2: Histogram of total HKE landings (ton); HKE landings (ton) in ICES Division VIIIabd; and HKE landings (ton) of the sample.

Tab.2: Sample description.

	2001	2002	2003	2004	2005	2006	2007
Nº of sampled vessels	16	20	17	19	16	13	9
% of sampled hake over total	47	74	65	79	73	71	53
Average GRT (Gross Register Tonnage)	234	233	227	218	245	232	241

A simplified inventory summary regarding the main inputs and outputs of the studied system is shown in Table 3.

Tab 3: Inventory respect to the FU (1 ton of landed gutted European Hake in Basque ports by trawling vessels) in 3 selected years of the studied period.

INPUTS				
From the technosphere				
Materials and fuels	**Units**	**2001**	**2004**	**2007**
Diesel	kg	2,776	2,625	2,007
Steel	kg	23.48	21.61	15.11
Anti-fouling	g	626	561	372
Boat paint	g	126	113	74.2
Marine lubricant oil	kg	7.04	6.66	5.09
Trawl	kg	6.59	6.01	3.95
OUTPUTS				
To the technosphere				
Products	**Units**	**2001**	**2004**	**2007**
European Hake	t	1	1	1
Co-product: other landed fish	t	0.509	0.144	0.242
To the environment				
Emissions to the atmosphere				
1. CO_2	kg	8,801	8,322	6,364
2. CO	kg	20.54	19.43	14.86
3. NO_x	kg	200	189	145
4. VOC	g	6.66	6.30	4.82
5. SO_x	g	27.76	26.25	20.08
6. R22	g	618	564	370
Emissions to the ocean				
1. Xylene	g	3.04	2.63	1.73
2. Copper, ion	g	130	116	77
3. Zinc, ion	g	58.7	52.5	34.9
4. Nylon	g	754	688	452
5. Lead	g	167	152	100

2.4 Allocation strategies and other assumptions

Mass allocation was the selected strategy for this particular study, given the similar economic value of the species captured by this fleet. Additionally, the landed species are all obtained from the same process, so the inputs and outputs taken into account affect all targeted species in the same way [5].

2.5 Impact category selection

CML baseline 2000 method was selected as the computational framework for the LCA analysis (Guinée et al. 2001). The impact categories that were included in the assessment were: Abiotic Depletion Potential (ADP), Acidification Potential (AP), Eutrophication Potential (EP), Global Warming Potential (GWP), Ozone Layer Depletion Potential (ODP) and Marine aquatic Eco-Toxicity Potential (METP). The software that was used for the computational implementation of the inventories was Simapro 7.2 [12].

3 Results

As expected, diesel consumption is the main factor that contributes to the environmental impact in all of selected impact categories analysed, except for ODP, in which emissions from cooling agents have a remarkable relevance.
Regarding the impact variability between evaluated years, a series of differences were found (Table 4). Nevertheless, the variability showed through the years for five of the six impact categories selected has the same tendency due to the fact that these impact categories are strongly influenced by diesel consumption related burdens. For instance, these impact categories contributions variation ranged from 5% in 2004 to 35% in 2003 with respect to the year with maximum impact potential (2001) around 35% from the máximum impact potential in year 2001 to minimum in year 2003. Finally, ODP presented impact reduction from 39% in 2007 to 7% in 2004, also with respect to 2001.

Tab 4: Percentage of environmental impacts potentials for the average vessel per FU.

I.C.	Unit	2001	2002	2003	2004	2005	2006	2007
ADP	%	100	68,28	64,65	94,55	72,37	73,24	72,25
AP	%	100	68,29	64,60	94,56	72,34	73,25	72,30
EP	%	100	68,29	64,62	94,55	72,36	73,24	72,28
GWP	%	100	68,08	65,80	94,24	73,01	72,85	71,11
ODP	%	100	66,25	76,32	91,44	78,88	69,33	60,67
METP	%	100	67,50	69,02	92,73	74,98	71,12	67,53

When comparing the tendencies on variability for the impact categories with the amount of fish landed per vessel, years with high landings (years 2002 or 2007)

appeared to have the lowest impact potential, and on the contrary, years with less landings presented higher impact potential (fig. 3.).

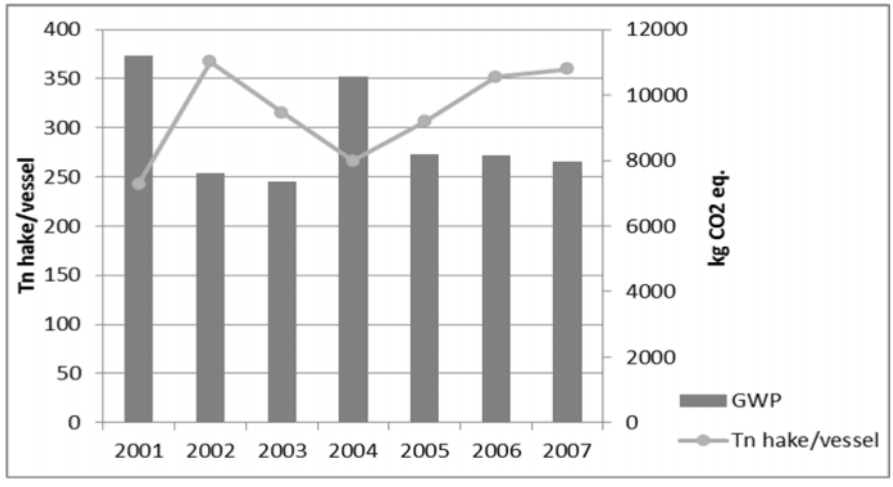

Fig. 3: Histogram of total HKE landings (ton); HKE landings (ton) in ICES Division VIIIabd; and HKE landings (ton) of the sample.

4 Discussion

Contrary to common industrial processes, extraction of wild resources presents important variability regarding data over time. Therefore, this article proposes the use of a time-line perspective analysis for fishing fleets, subject to varying captures over time. Nevertheless, according to the results obtained in this particular study, environmental impact potentials showed a variability of up to 30% over the studied years, which is a substantially lower variation than that observed for pelagic fisheries in the Basque country where variations of up to 300% were observed between years [13].

However, regarding the impact potentials, results obtained for European Hake fishing activity in the Basque Country show similar ranges to those observed in previous studies that analyze hake fisheries [14].

Therefore, obtained results suggest that yearly results are relatively stable with respect to other fishing fleets. Nevertheless, they also suggest that an increase in the timeframe for fisheries LCA is an important improvement when it comes to assessing the representativeness of the given values through time. Additionally, as can be seen in Fig 4, a three year moving average is proposed when it comes to

reporting the environmental impacts of this fishery, in an attempt to attain a value that reflects the state of the art of the fleet for a wider range of time [13, 15].

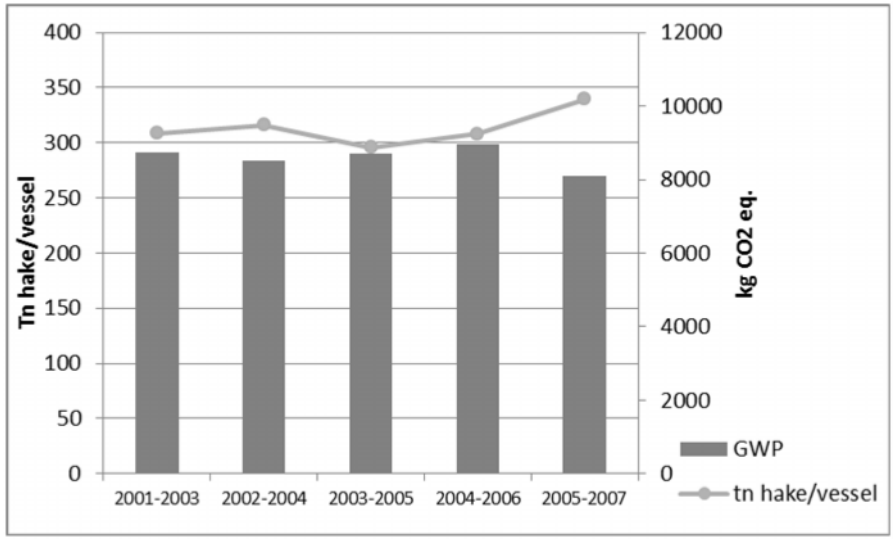

Fig. 4: Three years moving average for GWP impact category

It is remarkable the fact that for Atlantic Mackerel fishing activity, five-years moving average was required to establish interannual variability, however for European Hake fishing three-year moving average would be sufficient, due to the low interannual variability of the potential impacts of the European Hake [13].
In conclusion, impact potential obtained in this study were according to previous studies [14], and as expected fuel consumption and cooling agent emissions were the most relevant factors which contributes to the selected impact categories.
Finally, it is also significant annual variability showed, and therefore the needed for further timeline based analysis specially for fishing activities. Nevertheless, to overcome this variability, moving averages appear as suitable solution.

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