Marine Policy ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Stock size matters more than vessel size: The fuel efficiency of Swedish demersal trawl fisheries 2002–2010

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ARTICLE INFO

Article history:
Received 22 February 2013
Received in revised form
28 June 2013
Accepted 28 June 2013

Keywords:
Fuel use
Fisheries
Demersal trawling
LCA
Grid
Baltic Sea

ABSTRACT

Fisheries management determines how much of each stock can be landed when, where and how fishing is permitted. It has been identified to strongly influence the environmental performance of the fishing industry, including fuel use. As fuel data for fisheries is scarce, especially on a detailed level, the aim of this study was to develop an approach for utilizing fleet-wide fuel data to estimate the fuel use of individual fisheries and mapping how fuel efficiency in Swedish fisheries is influenced by management. Swedish demersal trawl fisheries were studied between 2002 and 2010. Results show that the overall fuel efficiency has improved and interesting patterns between different fisheries and vessel sizes emerged. The difference in fuel efficiency per kilo landing between large and small trawlers was generally small, unless catch capacity was lowered e.g. by selective grids. Stock rebuilding was shown to be highly important for fuel efficiency, as fuel use was inversely correlated to the biomass of eastern Baltic cod. However, rebuilding can also lead to trade-offs e.g. in the case of selective trawling, where protection of depleted stocks comes at the cost of higher fuel intensity per landing. Finally, tax exemption of fuel use in fisheries was shown to maintain inefficient fisheries. These results could be used to reduce overall environmental impacts of fishing further by incorporating fuel use as an additional aspect into the fisheries management system.

1. Introduction

1.1. Fisheries and fuel efficiency

Technological development of industrial production is normally followed by increased energy efficiency. When industrial production involves the use of a natural resource, the abundance of the resource is an additional key factor determining energy efficiency [1]. Capture fisheries have shown increasing fuel use per landing over time periods where considerable technological improvement both with regard to engines and fishing gear used, as well as navigation and fish finding technology has taken place [2–4]. In fact, while global fishing capacity has increased tenfold since the 1950s, todays landings are only half compared to then when the increased catch capacity is taken into account [5].

Many other factors than technology play an important role for the energy efficiency of fisheries, most importantly management related issues such as condition of targeted stocks, where and when fishing is permitted, limitation by quota or effort and allocation to gear types or individual vessels [6–8]. From having focused on the targeted species, management has in recent years broadened its perspective and paid increased attention to the wider ecosystem impacts of fishing [9–10]. Fuel use, however, is not an aspect currently considered in Swedish or EU fisheries management, despite having been suggested as a useful indicator of resource use and fishing effort before [4,11] and its importance for overall environmental impacts of fishing.

Beyond fisheries management, fuel efficiency of fisheries is not a new subject, given that fuel cost is often the most important variable cost of fishing [12–17]. The interest in this subject has been tightly linked to the level of oil prices. Economic theory says that due to the importance of fuel economy in fisheries, increasing fuel prices should lead to more fuel-saving behavior and thus higher fuel efficiency, i.e. market mechanisms should drive fuel efficiency. However, this cause-effect chain is distorted by subsidies in different forms [18]. By the same line of reasoning, it is also likely that exempting fisheries from fuel tax contributes to lower fuel efficiency and thereby slows down needed structural adjustments that would lead to increased efficiency [19]. Since increases in world market prices for oil translate into a proportional increase in fuel price for fishers, the sector is more dependent on the world market oil price, due to tax exemption. If the fuel was taxed, the price would be higher, but it would not change as much as market prices.

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0308-597X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpol.2013.06.015

1.2. Growing interest in greenhouse gas emissions

In addition to the importance for profitability, neglecting the development of energy use of the sector is in conflict with policy objectives to mitigate climate change. The potential contribution of fisheries to greenhouse gas emissions has recently led to increased attention, reflected by the rapidly growing number of Life Cycle Assessment (LCA) studies of seafood production systems [20–22] and recent standardization initiatives in the area [23]. LCA is a tool for holistic environmental systems analysis, quantifying resource use and environmental impacts of a product′s supply chain. Studies to date have shown that fuel use during the fishing phase is the main driver of traditional environmental impact categories; it has even been suggested as an indicator of overall environmental performance of fisheries [4] and the resulting seafood products [8,24–25], due to correlation with other types of environmental impacts like by-catch/discard and seafloor impacts. Large variability in the fuel efficiency between different fisheries and individual fishers has been observed, with important explaining factors being fishing method and stock condition [6,8].

Management of fisheries has been the direct subject for evaluation by Life Cycle Assessment methodology in two studies so far. Driscoll and Tyedmers [7] showed that changes in the management system greatly influenced the greenhouse gas emissions of the New England fishery for Atlantic herring (*Clupea harengus*). Hornborg et al. [26] analyzed the broader implications of introducing a species-selective grid in Norway lobster (*Nephrops norvegicus*) trawls and found a management trade-off between energy efficiency and conservation of depleted groundfish stocks in selective trawling. LCA still lacks methods to assess biological impacts of fishing, such as impacts on stocks of target, by-catch and discard species as well as of seafloor damage. However, new methods regarding these aspects are under continuous development [27–31].

1.3. Swedish fisheries

In 2010, Swedish fisheries comprised the activities of 1417 registered vessels, employing 1765 people, landing 205,000 t of fish and crustaceans at a total value at landing of EUR 103 million using 34,000 m^3 of diesel fuel [15]. Fishing activities of Swedish vessels are concentrated in the Baltic Sea and in the North Sea (including the Skagerrak and Kattegat) with Atlantic herring, European sprat (*Sprattus sprattus*), Atlantic cod (*Gadus morhua*), Norway lobster, northern prawn (*Pandalus borealis*) and Atlantic mackerel (*Scomber scombrus*) as the main species targeted.

The EU separates the fleet into nine segments according to the gear type used, vessel length and target species for the purpose of economic data collection [15], see Table 1. The most important segments in terms of both volume and value of total landings are demersal trawl and seine fisheries (split into three vessel length ranges) and pelagic trawling and seining (split into two vessel length ranges). Pelagic trawlers and seiners of all sizes target herring and sprat in reduction fisheries in the Baltic Sea and in the North Sea (29 vessels in 2009). Both in volume and value of landings, pelagic trawlers and seiners dominate Swedish fisheries. The largest demersal trawlers (24–40 m, 31 vessels in 2009) mainly target cod in the Baltic Sea or northern prawn in the North Sea (Skagerrak). Medium-sized demersal trawlers (12–24 m length, 160 vessels in 2009) target either cod in the Baltic Sea, or in the North Sea (Skagerrak) Norway lobster or northern prawn. Demersal trawlers under 12 m length (64 vessels in 2009) mainly target vendace (*Coregonus sp.*) in the Baltic Sea and *Nephrops* in the North Sea (Skagerrak); mixed trawling targeting both fish and *Nephrops* is also important in this fleet segment.

Cod and other groundfish used to be important target species, but as in particular cod stocks have become depleted and demersal fisheries highly restricted by quotas and effort [32–33], crustaceans have become increasingly important. By-catch of gadoids has instead become a constraint for *Nephrops* and *Pandalus* fisheries. Current regulation partly stems from a cod recovery plan first implemented in 2004 [34], then revised in 2008 [35], requiring use of a species-selective grid to allow fish to escape in crustacean trawling. Species-selective grid trawling is excluded from effort restrictions under the cod recovery plan, as it is considered to have low impact on cod stocks [36]. Today, the only fishery of significance targeting cod in Sweden is the Baltic cod fishery.

The overall fuel demand of the Swedish fishing fleet has been more than halved since 2004. This is a result of a decreasing fishing fleet, limitation of fishing effort and increasing importance of pelagic fisheries [13]. Estimates of total fuel demand vary slightly: in 2005, the fuel use was estimated at 56.000 m^3 [14], 57.980 m^2 [19] and 59.000 m^3 [37], the former two being based on the same input data. The latter survey [37] evaluates the contribution of the fishing sector to the overall energy use in Sweden every five years and is not directly related to landings. Anderson et al. [14] also show that landings decrease at a slower rate than fuel use over time, implying that the overall energy efficiency of Swedish fisheries has been increasing since at least 2002, which is in contrast to temporal trends in fuel use reported in literature [2–4]. Yet another estimation of the fuel use in Swedish fisheries between 1990 and 2004 showed that 70.000–94.000 m^3 were used annually [38]. However, different methodologies to estimate fuel consumption were used in studies covering different periods and caution should therefore be taken in interpreting temporal trends using different studies. These coarse statistics give an indication on overall trends, but they do not tell anything about the energy efficiency of specific fisheries (as e.g. shrimp and cod trawling belong to the same segment). Large resources are needed to collect data detailed enough each time fuel use of fisheries is studied. Therefore it would be valuable if the data collected and

Table 1
Fleet segments of Swedish fisheries as defined by the JRC, BS=Baltic Sea, NS=North Sea including the Skagerrak and Kattegat.

Fleet segment defined by JRC	Description of main fisheries in segment
Demersal trawlers and seiners 0–12 m	Vendace trawling (BS), *Nephrops* trawling (NS)
Demersal trawlers and seiners 12–24 m	*Nephrops* trawling and cod trawling (BS)
Demersal trawlers and seiners 24–40 m	Cod trawling (BS, NS) or *Pandalus* trawling (NS)
Pelagic trawlers and seiners 24–40 m	Herring and sprat trawling (BS)
Pelagic trawlers and seiners over 40 m	Herring and sprat trawling (BS)
Passive gears 0–12 m	Gillnetters targeting cod (BS) and creelers targeting *Nephrops*, eel (*Anguilla anguilla*), crab (*Cancer pagurus*) and European lobster (*Homarus gammarus*) (NS)
Gears using hooks 10–12 m	Line-fishing for cod (BS)
Drift nets and fixed nets 12–24 m	Targeting cod (BS)
Non-active vessels 0–12 m	

Please cite this article as: Ziegler F, Hornborg S. Stock size matters more than vessel size: The fuel efficiency of Swedish demersal trawl fisheries 2002–2010. Mar. Policy (2013), http://dx.doi.org/10.1016/j.marpol.2013.06.015