Carbon Footprint of Commercial Fishing In the Northeast United States

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ABSTRACT

Environmental concerns about seafood consumption generally are associated with the status of target stocks as well as bycatch and/or habitat issues. The more recent concept of "food miles" hails from terrestrial food production, and focuses on "consuming locally" in an effort to reduce the carbon footprint of a consumer's diet. Fish is one of the most heavily traded food products in the world. The idea of consumers considering food miles in their consumption decisions has tremendous implications for seafood. Over 40 percent of global production of seafood is traded internationally, and the distances between fishing vessel and dinner plate only seem to grow.

But how important is the carbon footprint of shipping relative to the production of seafood? This paper examines the share of energy consumption associated with the harvest of seafood in the Northeast U.S. Fishing vessel fuel consumption and landings are used to assess energy use per landed (live) weight of seafood. Such information should shed light on the true nature of the carbon footprint of seafood trade.

INTRODUCTION

Environmental concerns about seafood consumption generally are associated with the status of target stocks as well as bycatch and habitat issues. Eco-labeling, certification, and "green products" are focused on the sustainability of the stocks as well as overall ecosystem impact of the fishery. The more recent concept of "food miles" hails from terrestrial food production and focuses on "consuming locally" to reduce the transportation impact of a consumer's diet. The idea of consumers considering food miles in their consumption decisions has tremendous implications since seafood is one of the most heavily traded food products in the world. Consumers becoming "locavores" raises a new set of questions as the distances between fishing vessel, processing, and dinner plate only seem to grow.

How important is the carbon footprint of seafood trade, and what is the relative impact of energy for transportation as opposed to energy consumed in fishing and processing? In economic terms these issues may not matter, but if some consumers are attempting to reduce carbon output through their purchasing decisions based only on transportation, this objective may not be attained. The recent rise in fuel costs has raised the profile of energy inputs for fishing. To address these questions, analyses of the energy input into fishing for U.S. Northeast fleets are presented and compared with results from earlier studies. The implications of these findings for fishery management are highlighted.

BACKGROUND AND CONTEXT

The term "food miles" has become part of the equation for people who consider buying local an important component of their food consumption decisions. A consumer may have many reasons to prefer products grown close to home. Such products may be appealing if they are fresher, taste better, and support the local economy. But are they necessarily better for the environment? The term food miles is often misunderstood and confused with the carbon footprint of a product. Although "food miles" may have become a proxy for a range of beliefs, the concept of food miles is rather simple: it captures only the distance a product travels from producer to consumer. While it is undeniable that products from a farm or a fishery a mile away will take less energy to transport than those from a half a world away, the overall environmental impacts of each particular product are less clear. The term "carbon footprint", in contrast, takes into consideration the whole product lifecycle, including the total energy use and green house emissions. The carbon footprint of a product goes beyond the miles a product travels to the method of production and how the product is transported. In the case of fishery products, many factors affect the carbon footprint. The age and length of a fishing vessel, as well as the size and efficiency of a vessel's engines, constitute one set of factors - but others are equally important, such as the gear type, resource abundance, proximity of the resource to port, and the fisheries management system governing the target resources. Energy used in processing also adds to the carbon footprint of seafood. Ninety percent of fisheries products, which are highly perishable, are traded in processed form [1].

The UN Food and Agriculture Organization (FAO) reports that international trade in fish and fishery products continues to increase [2]. The FAO estimates that 36% of world fishery production was traded in 2006, with all major markets experiencing trade growth with the exception of Japan's. Fish and fishery products are among the most highly traded of all food commodities. Growth in world exports has increased steadily in the last decade with growth rates of about 9.5% in 2005 and 2006. Net export revenue was US$86 billion in 2006. The global trade profile indicates that developing countries are now the source of about 50% of world exports of fish and fishery products and developed countries absorb about 80% of world import value. Much of the exports to the three major import markets – the European Union, Japan, and the United States – are located far from most developing countries. The Organization for Economic Cooperation and Development (OECD) has analyzed the impact of globalization on these trends and predicts a further reshuffling of production, processing and trading patterns [3].

Although food, particularly fish and fishery products, has been traded for centuries, corporate restructuring, increasingly efficient global transport networks, and advances in storage and packaging have accelerated the trend. A consumer in a developed country normally has the capability to buy most desired products. Hence, as long as harvest and processing costs are cheaper in Asia than they are in Europe or the U.S., seafood products will continue to be shipped long distances. However, the environmental costs will depend on the savings in energy in production versus the additional energy used in shipping. In terms of the carbon footprint, the "buying locally" concept may be deceptively simple.

LITERATURE REVIEW[d]

Most of the literature on the carbon footprint of seafood production focuses on the fuel consumption of fishing vessels. Tyedmers [4] analyzed the forms and quantities of fuel use in global fisheries, including variations across fleets and throughout time. Over time, fossil fuels have taken the lead over animate (i.e. human muscle) and wind energy. Larger scale, active fishing gear techniques (e.g. trawlers) now account for most of the world's seafood production. Often this energy use is increased by onboard processing, refrigeration, and freezing. Energy use in vessel construction and maintenance is also a consideration, with aluminum and steel vessels (vs. wood or fiberglass) consuming the most. Tyedmers [4] uses a measure of "energy intensity" calculated as liters of fuel burned per live weight metric ton of fish landed. In addition, an edible energy return on investment (EROI) ratio is also derived, calculated as the ratio of edible food energy output to industrial energy input. From a comparison across fisheries (including results from other studies) Tyedmers [4] suggests that most of the variability in energy use stems from differences in abundance/catchability of fish and the type of fishing gear used. It was difficult to make generalizations about gear types as their efficiency varies across target species as well as across countries. Energy performance of industrial fisheries (as measured by EROI) was found to decline over time – likely a reflection of catchability. One shortcoming of the physical/engineering approach to energy ratio calculations is the lack of accounting for relative prices. Subsidies and/or tax breaks for fishing fuel vary across countries, changing input incentives. High-valued fish (such as sushi-grade tuna caught on pelagic longlines) often offer incentives for heavy fuel consumption.

Tyedmers, Watson and Pauly [5] estimated that the global consumption of fuel by fishing vessels was 50 billion liters, compared to overall global production of 80 million metric tons of fish. Based on this fuel consumption estimate, fisheries would account for 1.2% of global oil consumption. The EROI ratios calculated for fishing were higher than for most other animal protein production systems, including beef, milk, swine, and many species of farmed fish. The authors expressed some surprise with this result, but noted that their estimates of energy consumption and carbon impact of fishing were likely low.

Hospido and Tyedmers [6] examined the "life cycle environmental impacts" of the Spanish purse seine tuna fleets. Their analysis was expansive and included operational inputs to fishing activities, such as construction and maintenance, as well as post-harvest transportation of the catch to distant home ports. In terms of total carbon dioxide output, marine transport accounted for 30% while pre-transport diesel use accounted for 60%.

FUEL USAGE IN NORTHEAST U.S. COMMERCIAL FISHING

The Tyedmers [4] study found that fuel directly used by fishing vessels (as opposed to fuel used to produce other inputs into fishing) accounted for 75% to 90% of the "total culturally mediated energy inputs." For most fishing vessels, the direct use of fuel is for propulsion. However, fuel is also used for onboard processing and refrigeration (not very common in the Northeast) and to support other vessel activities. Given that direct fuel use is the major component of energy consumption, this study examines fuel usage by U.S. commercial fishing vessels off the northeastern coast of the United States.

Data

Since the early 1990s, observers from the Northeast Fishery Observer Program (NEFOP) have collected fishing vessel operating cost information while deployed at sea. Information on the cost of a fishing trip, such as expenditures on fuel, oil, ice, food, and fishing supplies are obtained from fishing captains. These data have primarily been used for economic analyses of proposed regulatory actions. The number of observer trips has markedly increased since 2003 -- providing a rich source of operating cost information for a wide variety of gear types and species landed (covering between 2,000 to 4,000 trips per year).

Among the data provided to the observers, the fishing captain provides the amount of fuel used per trip. Observers estimate the weight of each species caught during the trip, but trip landings weights (by species purchased) are also collected from seafood dealers by the National Marine Fisheries Service. This study uses dealer reported weights where possible. Otherwise, observer estimated weights are used.

Methods and Results

Table 1 lists the average liters of fuel used per metric ton of fish landed (live weight) for the major fisheries of the Northeast U.S. Fisheries are defined by gear type and species landed (see Table 2 for individual species included in a species group). As most fishing trips land a number of species, the fuel used on an individual trip was apportioned according to the weight of the species (or species group) landed on the trip. For example, if 2,000 liters were used on a trip that landed 3 tons of flat fish and 1 ton of round fish, it was assumed that 1,500 liters of fuel were used to harvest the flat fish and 500 liters were used to harvest the round fish. This is a simplifying assumption since fuel usage rates vary for different species landed – even when using the same gear. However, it is likely that gear type, rather than species landed, is the primary factor affecting fuel consumption. The alternative would be to use only trips in which just one species (or species group) was landed. However, this would markedly reduce the number of observations available for analysis.

The fuel usage rates in Table 1 were derived by summing the trip-level liters of fuel for a given species and gear type and then dividing by the corresponding sum of tons of fish landed. Table 1 also reports the estimates of liters of fuel used per ton of fish landed in Canada given in Tyedmers [7].

Equations for Table 1:

1) At the trip level for all species:

$$\text{Liters of fuel}_{\text{species 1}} = (\text{Total liters per trip}) * (\text{Tons landed}_{\text{species 1}} / \text{Tons landed}_{\text{all species}})$$

2) Aggregate from the trip level to the species/gear level for all species and gears:

$$\text{Liters per ton}_{\text{species 1, gear 1}} = (\Sigma\ \text{Liters of fuel}_{\text{species 1, gear 1}}) / (\Sigma\ \text{Tons landed}_{\text{species 1, gear 1}})$$

The fuel usage values by gear type and species provide some insight into the relative fuel efficiency of different fisheries. However, seafood consumers are usually unaware of which gear was used unless it is specified on the package. Of more interest to consumers may be the overall fuel usage rate by species, regardless of gear type (see Table 3). Since observer coverage of fishing trips by gear and species is not directly proportional to the types of fishing activity occurring at sea, a simple ratio of fuel to landings at the species level based on the observer data would misrepresent the true average. Therefore, an alternative method was used which applied the species/gear liters per ton values from Table 1 to the universe of landings by species and gear type.

Two National Marine Fisheries Service fishing activity reporting systems, the seafood dealer reporting system and the fishing vessel logbook program, provide good estimates of total fishing activity – both the gear used and the weight of the species landed. The data from both systems (for 2006) were used to determine total landings of each species category by gear used (see last column of Table 1 for a percentage breakdown). The fuel usage rates obtained from the observer data were then multiplied by the corresponding tons of actual fish landed (by species and gear). The result was then summed over all gear types used for a particular species. Dividing the species specific liters of fuel by the total tons of that species landed, as observed in the dealer and vessel logbook data, generated species level estimates of fuel consumption rates. The results are reported in Table 3. Note that the rates in Table 3 are expressed in live weight, and that any subsequent processing (including heading, gutting, shucking, filleting, etc.) would typically reduce the weight to the final consumer thereby increasing the fuel used per kilo (or pound) of product actually consumed.

For 12 of the 13 fish species listed in Table 3, more than 80% of the total species landings are attributed to gear types covered by the observer program. For scup, however, only 66% of the commercial landings are from bottom trawlers. There are two reasons for not attributing 100% of landings to a gear type. The first is that some of the reported landings do not designate a gear type. The second is that some landings are attributed to miscellaneous gear types not sufficiently sampled by the Observer Program.

Equations for Table 3:

3) Apply fuel usage rates derived from observer data to landings records by species and gear:

$$\text{Liters of fuel}_{\text{species 1, gear 1}} = (\text{Liters per ton (from eq. 2)}_{\text{species 1, gear 1}}) \; * \; (\text{Tons landed (from landings records)}_{\text{species 1, gear 1}})$$

4) Aggregate to species level:

$$\text{Liters per ton}_{\text{species 1}} = (\Sigma \text{ Liters of fuel (from eq. 3)}_{\text{spec 1, all gear}}) \; / \; (\Sigma \text{ Tons landed}_{\text{spec 1, all gear}})$$

Comparison with Previous Studies

Column 5 of Table 1 reports fuel consumption rates from the Tyedmers [7] study. Both the current study and the Tyedmers [7] study have similar fuel usage rates for sea scallop dredging, and for purse seining for herring. However, for none of the other species/gear types are the values from the two studies similar. This may be due to different time frames, differences in vessels and/or gear, and differences in the stocks fished (and the management measures for these stocks). Another factor may be the different methods used to estimate the fuel usage rates.

The Tyedmers [7] study used an engineering approach for determining generic fuel consumption rates based on data from 186 vessels. Using the product of vessel horsepower and days-at-sea as a measure of effort, a statistical relationship was determined between fuel consumption and effort. This relationship was then applied to a fishery using fishing effort and catch data. For a particular fishery, the total fuel usage was estimated by inserting average vessel horsepower and total fleet days-at-sea into a fuel consumption regression equation. Dividing the result by total catch resulted in estimates of liters of fuel used per ton of fish landed.

The present study uses direct observations of fuel used and live weight of fish landed, by species, on a per trip basis, acquired from nearly 13,000 records over a five year period. Such detailed data should provide consistent estimates. The major source of potential error is the degree to which the fisheries observed represent the characteristics of the true population.

Table 1. Liters of Fuel Used per Metric Ton of Fish Landed in Northeast U.S. Fisheries by Species and Gear (based on observer data)

		Number of trips observed	NEFOP data estimates (Liters/ton)	Tyedmers [7] Canada estimates (Liters/ton)	Landings by gear type within species category (based on 2006 landings records)
Groundfish/Flat fish	Gillnet	1,985	492		2.9%
	Longline	52	570		0.1%
	Otter Trawl	3,425	957	370	89.5%
Groundfish/Round fish	Gillnet	2,699	297	1,430	29.3%
	Longline	494	396	489	4.6%
	Otter Trawl	2,941	963	454	62.2%
Groundfish/Small mesh species	Otter Trawl	760	631		89.6%
Summer flounder	Gillnet	472	566		0.7%
	Otter Trawl	2,276	1,338		86.9%
Scup	Otter Trawl	653	579		66.0%
Black Sea Bass	Gillnet	64	311		1.1%
	Otter Trawl	694	1,457		32.2%
	Pots/traps	18	921		49.0%
Dogfish	Gillnet	1,192	199		60.4%
	Longline	71	385		10.7%
	Otter Trawl	427	824		20.6%
Herring	Purse Seine	63	25	20	13.3%
	Mid-water pair trawl	233	82		53.2%
	Single Mid-water trawl	83	147		15.3%
Mackerel	Mid-water pair trawl	42	49		34.7%
	Single Mid-water trawl	20	103		41.7%
	Otter Trawl	139	230		19.6%
Scallops	Otter Trawl	969	1,405		1.6%
	Dredge	686	347	339	95.3%
Monkfish	Gillnet	3,172	315		56.0%
	Otter Trawl	3,484	985		35.1%
	Dredge	311	445		6.2%
Surf Clam/Ocean Quahog	Dredge	40	71		99.8%
Squids	Otter Trawl	1,093	313		94.1%

Table 2. Species Group Definitions

SPECIES GROUP NAME	INDIVIDUAL SPECIES NAME
Dogfish	Dogfish, smooth Dogfish, spiny Dogfish, not classified
Groundfish/Flat fish	Flounder, winter Flounder, witch Flounder, yellowtail Flounder, American plaice Flounder, windowpane
Groundfish/Round fish	Cod, Atlantic Haddock Hake, white Redfish Pollock
Small mesh	Hake, red Ocean pout Hake, silver
Squid	Squid, long fin Squid, short fin Squid, not classified

Table 3. Liters of Fuel Used per Ton of Fish Landed in Northeast U.S. Fisheries by Species

	Liters/ton	Percentage of landings associated with the gear types listed in Table 1
Groundfish/Flat fish	942	92.5%
Groundfish/Round fish	733	96.1%
Groundfish/Small mesh species	631	89.6%
Summer flounder	1,332	87.6%
Scup	579	66.0%
Black Sea Bass	1,122	82.3%
Dogfish	361	91.7%
Herring	85	81.8%
Mackerel	109	96.0%
Scallops	364	96.9%
Monkfish	565	97.3%
Surf Clam/Ocean Quahog	71	99.8%
Squids	313	94.1%

Fisheries Management Implications: Northeast Groundfish

As previously mentioned, one non-technical factor that could affect fuel consumption rates is the manner in which fisheries are managed. Since fuel costs are the largest component of variable trip costs in U.S.Northeast fisheries, fuel consumption per unit of landed fish is a crude indicator of efficiency - as there are many inputs to fishing and a true measure of efficiency would encompass all inputs together with all the outputs. However, more germane to the carbon footprint issue is that the choice of fishery management measures can directly affect fuel consumption per unit of fish. This section addresses this issue in more detail.

The NEFOP data was used to estimate annual fuel usage rates in the Northeast multispecies groundfish fishery during 2003 through 2007. This fishery is one of the most important in the Northeast relative to numbers of vessels engaged in the fishery and total ex-vessel revenues. Over the five-year time period, significant management changes have occurred -- particularly the implementation on 1 May 2004 of Amendment 13 to the Northeast Multispecies Fishery Management Plan. This amendment reduced the amount of fishing days allocated to the groundfish fleet, imposed limits on the amount of fish landed per trip, closed fishing areas, and established sector allocations and day-at-sea trading, among other measures. A number of subsequent management alterations also occurred from 2005 through 2007.

For this analysis, only trips which had combined landings of round fish, flat fish, monkfish, and skates greater than 50% of total landings were examined. The 50% trips were selected as these were most likely to be affected by the days-at-sea restrictions.

Figures 1 and 3 show the change in fuel consumption rates during 2003-2007 for flat fish, round fish, monkfish, and skates caught by gillnet gear and otter trawl gear, respectively. For gillnet gear, vessel fuel consumption rates for round fish, monkfish, and skates remained relatively constant during the 5-year period – at about 300 liters of fuel per ton of fish for round fish and monkfish and about 120 liters per ton for skates (Figure 1). However, the rate for flat fish species increased from 360 liters per ton in 2003 to a high of 669 liters per ton in 2006 (an increase of 86%). For all four gillnet species categories combined, fuel consumption during 2003-2006 remained rather stable at about 250 liters per ton, but declined to 200 liters in 2007.

For otter trawl gear, vessel fuel consumption rates for round fish, flat fish, and monkfish increased from about 800 liters per ton in 2003 to a high of about 1,100 liters per ton in 2006 (an increase of 38%). Fuel consumption rates for skates during 2003-2007 remained constant at about 700 liters per ton. For all species combined, otter trawl vessel fuel consumption increased from 800 liters per ton in 2003 to slightly more than 1,000 liters per ton in 2006, and then declined to about 900 liters in 2007.

The two primary factors that affect fuel consumption per unit of fish are fishing effort and catch. Figures 2 and 4 depict changes in the average number of days-at-sea per fishing trip and the average pounds of fish landed per fishing trip during 2003-2007 for Northeast gillnet and otter trawl vessels, respectively. Average days-at-sea per trip was derived from all trips in the NEFOP database as many trips had landings of all four species categories. Average days-at-sea for gillnet vessels increased from 0.43 days in 2003 to 0.71 days in 2007, a 65% increase (Figure 2). Had the total weight of fish landed per trip remained constant, the fuel consumption rates would be expected to increase with the increase in effort. However, for round fish and monkfish, the average catch per trip also increased which kept the fuel consumption rates for those two species constant. For flat fish caught with gillnet gear, landings per trip declined from an average of 207 pounds per trip in 2003 to a low of 113 pounds per trip in 2006 (a decrease of 45%). This reduction combined with the increase in fishing effort may explain the marked increase in the gillnet/flat fish fuel consumption rate.

A similar pattern exists for flat fish and monkfish caught by otter trawls. Average days-at-sea increased from three days per trip in 2003 and 2004 to four days in 2005 through 2007. At the same time, flat fish average landings per trip decreased from between 4,000 and 5,000 pounds in 2003 through 2005 to 3,000 pounds in 2007. Monkfish average landings per trip declined from a high of 4,700 pounds in 2003 to 2,900 pounds in 2007. Round fish and skate average landings did not exhibit a clear upward or downward trend except for large spikes in 2007. The combined species average landings per trip varied from just under 16,000 pounds to just over 18,000 pounds suggesting that the upward trend in the combined species fuel consumption rate is primarily due to the increase in fishing effort.

There are a number of plausible explanations why fuel consumption rates for some gear/species combinations increased. Increases in average effort and decreases in landings per trip are certainly factors. However, there may be other drivers. Fishing vessel owners and captains seek to optimize multiple social and economic objectives given multiple constraints (including regulatory constraints). Seeking these objectives means choosing various input mixes as constraints shift. Resulting changes in fuel consumption rates do not necessarily imply that owners and captains are not acting optimally with regard to their objectives since fuel is just one input in the mix. Furthermore, changes in fuel consumption rates for particular species categories may be a result of substituting catches of other species. For example, Figure 1 shows a relatively constant fuel consumption rate for all four gillnet species categories combined, while the rate for flat fish is increasing. The substitution of other species for flat fish may explain the rise in flat fish fuel consumption rates while the all species rate remains constant. That is, the revenue returned per dollar of fuel cost may not have changed. Also, during this time period, trading of days-at-sea was authorized. It is possible that the mix of vessel types (vessel size, horsepower, etc.) has changed through the time series. For example, days could have been leased from vessels with lower horsepower to vessels with higher horse power.

Although there are a variety of reasons for changing fuel consumption rates, it is still worthwhile to consider why average landings declined for some species. There are two plausible reasons for the reduction in average flat fish landings per trip in both the gillnet and otter trawl fleets. One is that the limits on landings per trip may have become constraining. The other reason may be that flat fish stock sizes have declined. Figure 5 depicts relative biomass indices (kilograms per tow) for flat fish from 1967 to 2005 in NEFSC autumn research vessel surveys [8]. Between 2003 and 2005, the combined flat fish biomass index declined by about 39% and this decline is expected to continue through at least 2007.

In addition to days-at-sea trading and trip limits, there are other management measures that may affect fuel consumption rates. While groundfish management measures intended to increase stock size may ultimately reduce fuel consumption rates, some may result in shorter term increases in fuel consumption. Closing areas to fishing may cause vessels to steam further to reach productive fishing grounds, gear restrictions decrease catch at a given level of effort, and trip limits not only restrict the total level of catch but may cause fishermen to take shorter and more frequent trips resulting in a higher ratio of steam time to fishing time.

The suggestion is not being made that fisheries management changes should be made for the sole purpose of reducing fishing's carbon footprint. However, since fuel consumption is likely closely tied with economic efficiency, regulations that promote the efficient use of all inputs may warrant further consideration for their added environmental benefits. Sector allocations (a form of rights-based fisheries management in which landings quota is allocated to self-selected groups of limited access permit holders) in the groundfish fishery will exempt fishermen from certain management measures and a will give them greater flexibility in the choice of harvest strategy. For example, fishing groups may choose to fish their quota with fewer vessels thereby gaining greater efficiencies and potentially consuming less fuel.

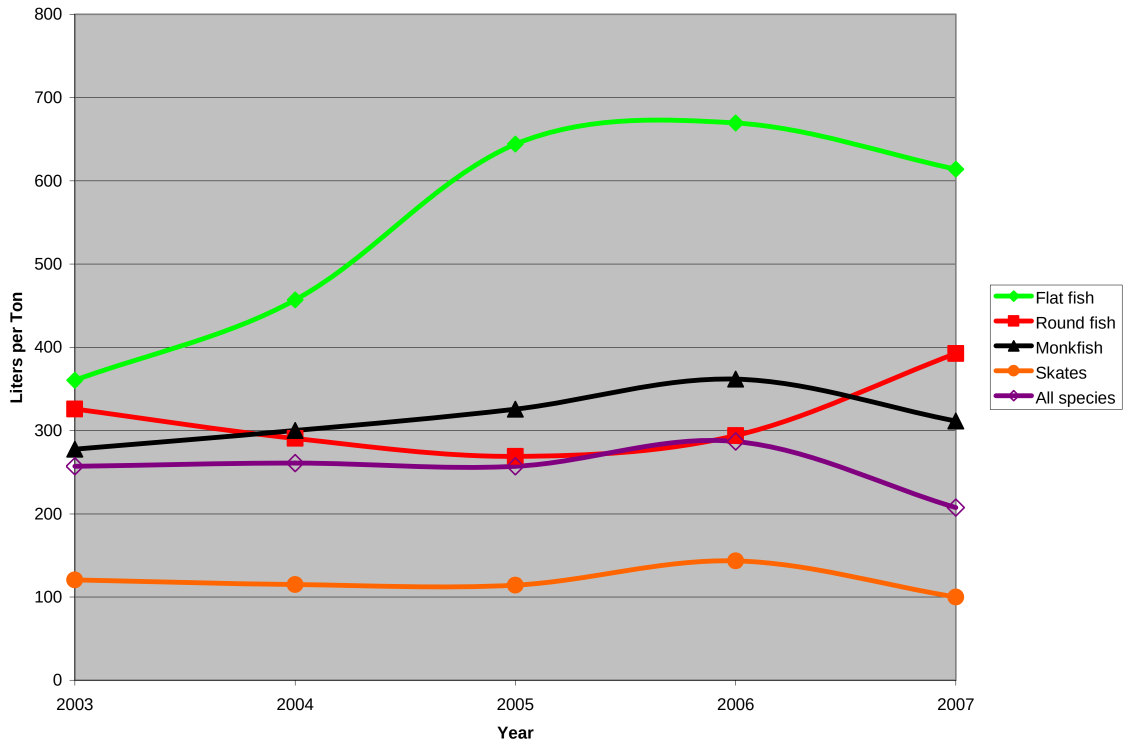

Figure 1. Gillnet gear: liters of fuel per ton landed weight

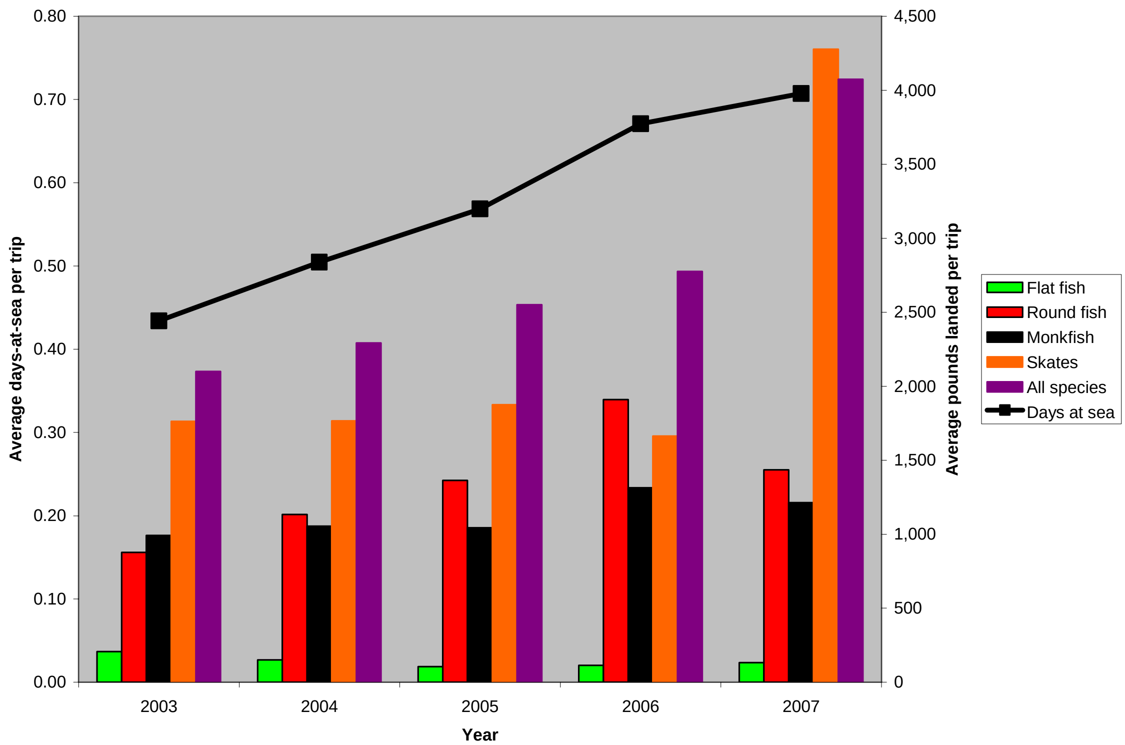

Figure 2. Gillnet average effort and catch

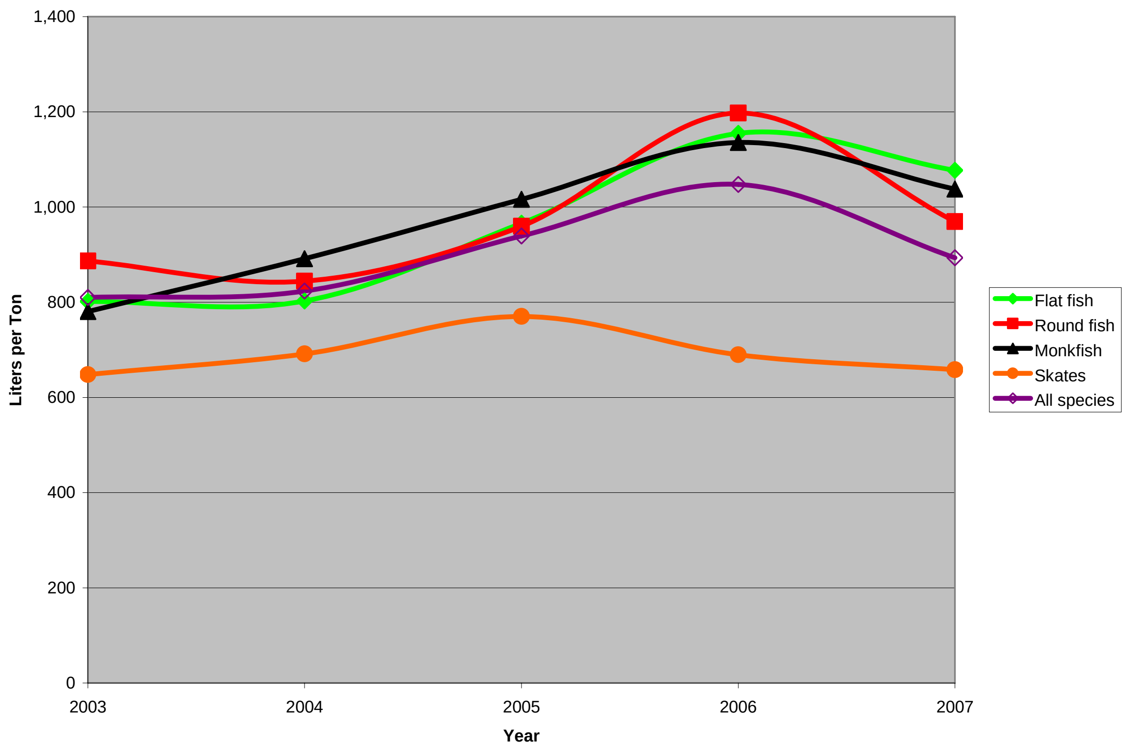

Figure 3. Otter trawl: liters of fuel per landed weight

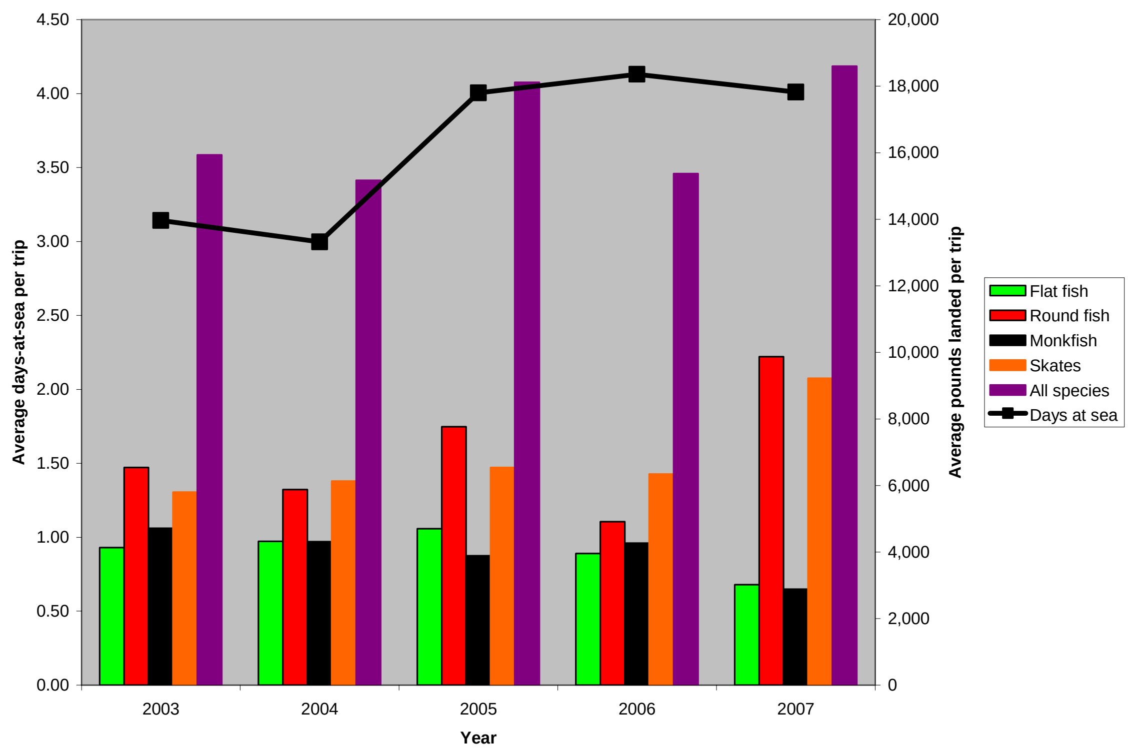

Figure 4. Otter trawl average effort and catch

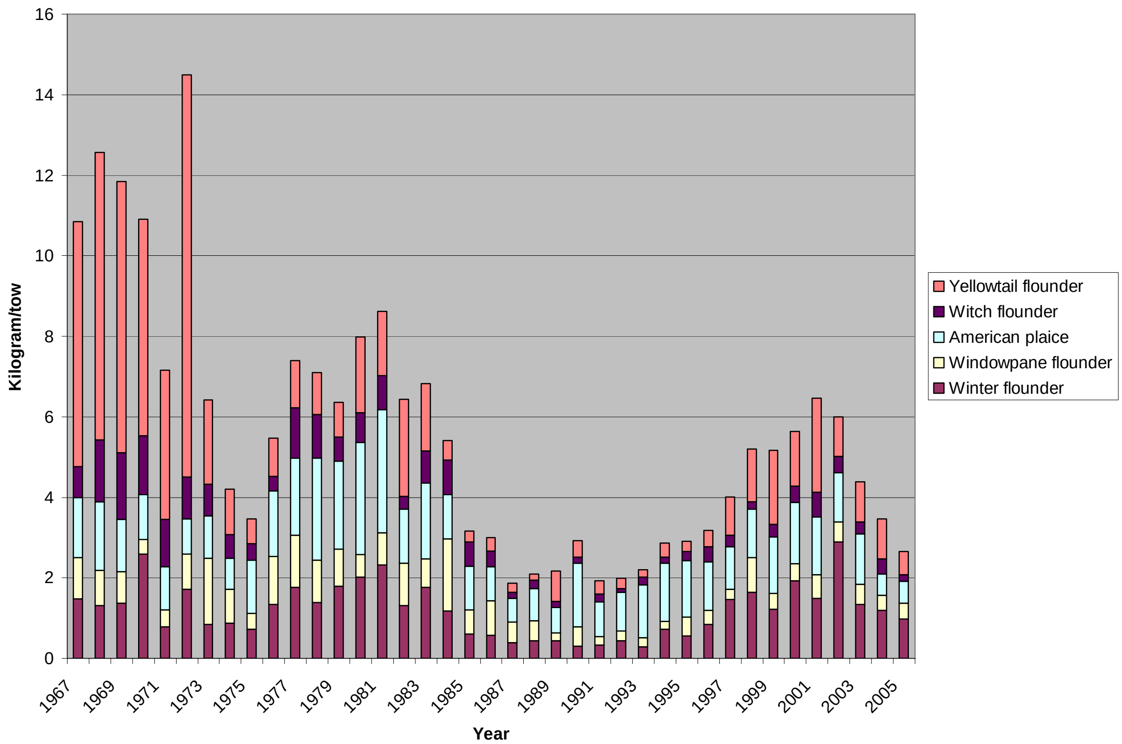

Figure 5. NEFSC autumn research vessel relative biomass indices for flat fish

CONCLUSIONS

Consumer interest continues to grow regarding the carbon footprint of food products. Consumers purchase seafood for a numerous reasons (health, quality, taste preferences, etc.) and there is a wide variety of seafood from which to choose – much of it hailing from around the world. The impetus for this paper was to examine the role of both production and transportation in evaluating the total carbon footprint of seafood. Since data on transportation were not readily accessible, this study focused on production.

Previous studies have assessed energy use in producing seafood at the fishery level. This paper provides some results for the Northeast U.S. fleet. Using NEFOP data, estimates of liters of fuel used per metric ton of fish landed were derived for a number of species/gear combinations. Across a spectrum of different species, otter trawl gear is the most fuel intensive gear. When aggregated across gear type to the species level, surfclam/ocean quahog harvest is the least fuel intensive and summer flounder is the most fuel intensive species per unit of live weight landed. During 2003-2007, the rate of fuel used per unit of flat fish species landed significantly increased. While many plausible reasons exist for this increase, there may be a connection to fisheries management and stock sizes.

With the recent spike in fuel prices, the energy cost of fishing raises a number of questions relative to the selection of appropriate management measures to ensure an ecosystem approach to sustainable fisheries. For example, a number of fisheries have a prohibition on the use of spotter planes – e.g. the New England bluefin tuna harpoon fishery. If spotter planes reduce search time and therefore fuel consumption, perhaps such prohibitions deserve reexamination. Time/area closures can also result in increased steaming distances and therefore increased energy use. Certain gear types may be more fuel intensive; it is likely that market prices of fuel will become an incentive for some vessels to switch to other gear types; however, the regulatory framework may need additional flexibility to address and accommodate these changes. Finally, rights-based approaches which generally result in greater efficiencies may also hold promise for reduced fuel consumption.

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ENDNOTES

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