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Fuelling the decline in UK fishing communities?

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Volatile fuel prices are a threat to the viability of UK fishing communities. The economic and social impacts of rising fuel costs for fishers and communities in southwest England are examined. Fuel prices doubled between early 2007 and mid-2008, whereas fish prices remained relatively stable throughout as a result of the price-setting power of seafood buyers. It was the fishers who absorbed the increased costs, resulting in significant loss of income, reduced job security, and problems in recruiting crew. All gear types were affected, but fishers using towed gears were most adversely impacted. Fishing vessels with recent investment have greater fuel efficiency, so appeared to be more able to cope and to adapt to increased fuel costs. Fishing behaviour also altered as skippers attempted to increase fuel efficiency at the cost of reduced catches. Most skippers reported fishing closer to port, reducing their exploratory fishing, and ceasing experimentation with fishing gears with lesser environmental impact. Therefore, a threat to fishing community viability may have linked environmental effects. The impacts of this fuel price volatility foreshadow a likely future impact of rising fuel prices attributable to climate change adaptation and mitigation and forecasts of rising oil prices. Without proactive planning and policy development, rising fuel prices have the potential to cause job losses and economic hardship additional to problems that may arise from poor management and stock decline, in all fishing-related sectors of the industry.

Keywords: adaptation and coping strategies, fisher behaviour, fisheries, fuel prices, resilience, uncertainty.

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Introduction

Many European fish stocks are overexploited, and the fleets suffer from excess capacity, threatening the profitability of EU fisheries (Cook *et al*., 1997; Piet and Rice, 2004; Dulvy *et al*., 2005; FAO, 2006). The economic performance of many sectors of the EU fishing fleet has been further constrained by restrictive management policies and lowered quotas implemented in response to the declining stocks. In 2004, the overall profitability of European fishing fleets was estimated to be hovering around zero (Beare and McKenzie, 2006). The decline in profitability has largely been masked by technological creep and subsidized fuel, which has allowed vessels to exploit new fishing grounds successfully, in areas farther from shore and in deeper water (Morato *et al*., 2006; World Bank and FAO, 2008). In short, there is now a smaller total rent (broadly, net economic benefit) from EU fisheries to share.

The profitability and economic sustainability of fisheries in the EU has been further weakened by the recent volatility in fuel price. The price of crude oil rose rapidly, peaking at more than US$140 per barrel in July 2008. Since then it has more than halved. However, the recent oil price shock may well foreshadow future oil prices. World oil prices are predicted to exceed US$100 a barrel again within a few years and US$200 a barrel by 2030 (IEA, 2008). This does not account for any price increases that may be associated with measures to decarbonize societies through climate-change adaptation and mitigation measures. The fisheries sector, and particularly large-scale commercial fisheries, is a major consumer of global oil, accounting for ~1.2% of global oil consumption (Tydemars *et al*., 2005; Pauly, 2006). For many fisheries, including North Atlantic demersal fisheries, the energy content of the edible protein landed is <10% of the fuel energy burned to catch it (Tydemars, 2004). The fuel efficiency of fisheries therefore seems to be poor, but overall, fisheries have a higher percentage of edible protein-energy return on fuel-energy input than other animal protein sources such as beef, pork, and lamb (Tydemars *et al*., 2005). In other words, many fisheries are a more fuel-efficient method of food production than other agricultural systems. Most fuel is consumed while actually catching the end-product, at a fishing vessel level. There are few major energy inputs required before harvesting wild marine fish. In comparison, other food production methods, such as intensive animal-rearing, require energy expenditure throughout the production chain, including feeding, watering, and sheltering the animals (Pimentel, 2004; Tydemars *et al*., 2005).

As fuel consumption by the fisheries sector is concentrated at the fishing-vessel level and comprises a significant proportion of fishing vessel costs, there has been policy interest in the potential effects of high fuel prices (Tietze *et al*., 2005; Graham, 2006). Increasing and variable fuel prices could be considered therefore

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to be an additional problem facing the fleets that are already struggling to be profitable. As a result, recent research has questioned what the likely scenarios will be for the future sustainability of fisheries. The emphasis so far has been on the ecological impacts and the resulting economic consequences. The rise in fuel costs and hence fishing costs may be good in terms of future resource sustainability and conservation, because the less-fuel-efficient vessels are likely to go out of business (Arnason, 2007). Given that it is widely acknowledged that fishing capacity (number of fishers or amount of fishing effort) is currently too high to sustain fisheries, ecologically or economically, a reduction in the number of vessels may benefit fisheries in the long term (Pauly *et al.*, 2002; Sumaila *et al.*, 2008). Arnason (2007) adds weight to this argument with a surplus-production bioeconomic model which predicts that the long-term effects of reduced fishing effort will result in less environmental damage and a decreased chance of stock collapse and increased sustainable yield (attributable to less effort and more fish), potentially resulting in an industry being in a better position to be profitable. Hence, increased fuel costs could be socially beneficial in the long term.

A key limitation of the bioeconomic analyses described above is that the idea of equilibrium pervades the models and assumes that any deviation (in a free market) results in a correction that eventually leads to optimal economic configuration, however far the system departs from it in the short term. However, there are some potentially detrimental and non-linear consequences of increased costs that need to be considered alongside the potential benefits presented by bioeconomic models. Although effective management and appropriate capacity is necessary for healthy fishing communities to exist, the reverse is also true—socially cohesive, strong, well-functioning communities are an essential contribution to the preservation of healthy fisheries (Jentoft, 2000). The short-term losses that may be triggered by increased fishing costs, such as high fuel prices, putting fishers out of business, may jeopardize the underlying infrastructure of the fishery (e.g. markets, processors, and shore workers), which can then result in the degradation of a fishing community and the community as a whole (Rossiter and Stead, 2003; Stead, 2005). This type of consequence may not be fully reversible even if stocks return to levels high enough to sustain a viable fishery. This reasoning has been applied to the ecological side of fisheries, with the increased recognition that overfishing can result in an ecosystem shifting to an irreversible alternative stable state (Lees *et al.*, 2006). However, such reasoning has not been applied to the human component of the fishery socio-ecological system.

Understanding who will be the winners and losers if fisheries move towards a more economically viable fishery structure is important, particularly for remote communities that are more fisheries-dependent. Fisheries provide a contribution to food security and employment, and "economic and social hardship requires [immediate attention] while tackling systematic overcapacity" (CEC, 2008). The importance of creating a stable future for both the industry itself and for the communities that depend on it was recently emphasized for the UK (Prime Minister's Strategy Unit, 2004), but fisheries policy has tended to focus on removing excess capacity and effort from the fishing fleets. Wider policies are required to take the difficult next step—addressing the practical implementation of improving fishing-dependent communities' ability to cope and adapt with change under uncertainty. First, the issue of social adaptation is not often addressed because it is complex, context-specific, and highly dynamic, and it is difficult to develop general methods of application (Berkes and Folke, 1998; Walker *et al.*, 2002; Kallstrom and Ljung, 2005). It requires difficult decisions about product and labour markets, technology, and investment, as well as wider policy commitments of regional development, and provision of services in the community, such as health, education, infrastructure, and finance (Jentoft, 2000). Second, it specifically requires the creation of incentives for the fishing community to play an active role in preventing their own collapse, a difficult task given that fishers often have little incentive to participate in long-term resource management because of the uncertainty they face in terms of resource availability and imposed restrictions. This needs to be addressed aggressively, so as to not undermine the move towards more participatory governance of fisheries in the EU.

Here, we document the impact of an acute fuel-price shock in 2008 on the structure, behaviour, and relative vulnerability of different sectors of the UK's southwest fishing fleet to identify who might be the winners and the losers in the face of uncertainty. Specifically, we conducted an analysis of the effects of fuel price and fish prices on profitability in this fleet, one of England's largest remaining fleets, its structure, fisher behaviour, and the perceived impacts on the fishing community such as downstream effects for infrastructure. Our research is based on interview data from skippers and vessel owners, vessel characteristics data from national statistics, and data on fuel and fish prices. First, we investigated the relationship between fuel prices and market fish prices to show that increased fuel costs are not being balanced by increased fish prices, reducing profitability. Second, we examined the effect of the increase in fuel price on different gear types and vessel ownership structures to determine who is being affected. We then examined the effect of vessel characteristics on fuel consumption of different vessels to determine why different vessels are affected. We also carried out an analysis to investigate how fishers were being affected, i.e. how it was affecting their business and fisher behaviour. Third, we investigated the community impacts of rising fuel prices and the concerns that it has further increased the vulnerability of the fishing community.

Methods

The study was undertaken in Newlyn, Cornwall, southwest England. With the decline in North Sea stocks, the fishery in the southwest of England now harbours most of the remaining English fleet. Newlyn is one of the three largest ports and markets in England, the other two being Brixham and Plymouth, also located in the southwest (Barratt and Irwin, 2008). In 2007, 18% of the >10-m fleet were registered in Newlyn, catching 9% of the total reported English landings, representing 12% of the total value of catch landed in England in 2007 (Barratt and Irwin, 2008). The Newlyn fishery is termed a mixed fishery: diverse in terms of gear type and species caught, and ranging from small boats that handline for mackerel (*Scomber scombrus*) to large beam trawlers fishing in deeper water more than 100 nautical miles offshore.

Data and information sources

Three types of data were collected for this study: fuel prices, fish prices, and skipper interviews. Fuel-price data and fuel-duty data for the past 10 years were obtained through the records of a supplier of fuel to vessels in Newlyn. Fuel prices used were minus the duty. The fishing industry uses red diesel, which the European Commission taxes at a lower rate than roadside diesel. Fuel duty is set by the UK government and vessel owners can claim back the duty paid. (The rate changes each year: in June 2008, the rate was £0.0969 l^{-1}) Fish-price data were obtained for the same period (spanning January 1998–July 2008) from "Fishing News", a UK weekly fishing industry newspaper that reports fish prices by port and by species (http://www.intrafish.no/fn/). Data for the four main species caught in Newlyn were recorded: monkfish (*Lophius piscatorius*), sole (*Solea solea*), hake (*Merluccius merluccius*), and megrim (*Lepidorhombus whiffiagonis*).

We also interviewed 34 skippers from the larger (>10 m) vessels. This represents 68% of the larger vessels registered in Newlyn in 2008. This percentage of vessels is approximate because although vessels are registered in Newlyn, their actual home port may be elsewhere, and vice versa. It may also be an underestimation because there are several large vessels registered in Newlyn that are not in service. Owing to the general difficulty in getting fishers to participate in surveys because of factors such as interview fatigue and time constraints and the lack of a central register of skippers, completely statistically randomized respondent selection was neither feasible nor possible. However, we ensured that the sample of fishers interviewed represented relevant background variables such as gear types, size of vessel, age of vessel, ownership structure, experience, and participation in fisheries politics.

The skippers interviewed were either owners of the vessel (skipper owners) or paid on a share system by a company (company skippers). All interviewees were skippers of large vessels (>10 m), consisting of beam trawlers ($n = 15$), otter trawlers ($n = 3$), gillnetters ($n = 7$), scallop dredgers ($n = 5$), and crab/lobster potters ($n = 4$). Vessel characteristics data for each skipper interviewed were collected using the Fishing Vessel List statistics compiled by the UK Marine and Fisheries Agency (MFA; MFA Statistics Fishing Vessel Lists, UK, http://www.mfa.gov.uk/statistics/vessellists.htm, last accessed 1 August 2008), including vessel size, age, and engine power. A semi-structured interview technique was used, and skippers were asked a series of closed questions to elicit further information about their vessel characteristics, including details about the frequency of engine maintenance, time since last engine refit, fuel consumption, and fuel cost per hour as a percentage of the gross earnings from a fishing trip now, and 12 months previously. Fuel consumption is monitored closely by skippers, especially over the past few years when fuel prices have concerned them. Skippers tended to answer the question in terms of the number of litres of diesel burned each day. Taking into consideration the number of hours per day skippers fished, fuel consumption per hour was calculated as the consumption per day divided by the number of hours fished per day.

Skippers routinely keep track of fuel costs per trip, because they take the cost of fuel from the gross earnings of a trip before they pay themselves and the crew. Skippers were asked to estimate the fuel costs and the earnings of a typical fishing trip in July 2007 and July 2008. The percentage changes in fuel costs and earnings between July 2007 and July 2008 were calculated during the interview and verified by the skipper.

The skippers were then asked a series of open-ended questions on the influence of fuel price on their decision-making onshore and at sea, how their fishing behaviour had changed as a result of fuel price increases, and what they believed would be the future of fishing for their community (see Table 1 for an interview guide).

Table 1. Quantitative and qualitative (marked by asterisk) questions asked of skippers ($n = 34$).

Ownership of vessel
Gear type used
Engine age
Time since last major engine refit
Fuel consumption per hour
Fuel cost as a percentage of a trip gross in July 2008
Fuel cost as a percentage of a trip gross 12 months earlier (in July 2007)
The impact of increased fuel cost on their fishing in general, including constraints now faced*
If there was any impact of the increased fuel cost on their fishing behaviour*
The impact of the increased fuel costs on the community in which they live*

Our approach to interviewing was based on Bernard's ideas for semi-structured interviews (Bernard, 1994). Knowing that the respondent can influence the direction of the interview, the interviewer needs to ensure that the overall objectives of the interview guide are covered to a sufficient depth without leading the respondent. To get fishers to talk about their fisheries openly and in detail, time was invested to build mutual trust and to improve reliability of the responses. Therefore, the field researcher (KEA) interviewed each respondent two or more times, as well as conducting several informal interviews and conversations on the quayside. Triangulation was employed to increase confidence in the accuracy of the data collected through fisher interviews. Triangulation is a method of establishing the accuracy of information by comparing three or more types of independent points of view on data sources (Bruce *et al.*, 2000). In addition to repeat interviews, observations on the quayside were conducted every day and used where possible to verify responses. Unstructured surveys with key informants were also conducted with members of the wider fishing industry including the regional producer organization (a fishers' cooperative that manages quota, promotes produce, and represents the views and opinions of fishers) and Seafood Cornwall (which collaborates with fishers, fish merchants, and harbour authorities to promote Cornish-caught fish, improve quality standards, and encourage sustainable practice). Unstructured surveys were also conducted with fish merchants, ex-skippers, market workers, and fisheries scientists/observers throughout the study period. These unstructured surveys were used to gain understanding of the general issues related to the rise in fuel prices for fishers and the community within which they live and to verify skipper responses to interviews.

Analyses

Trends in fuel and fish prices over time

We chose simply to calculate the changes in absolute prices and percentage changes from the best linear model fitted to smaller sections of the data (as specified below, in the Results section). Daily and monthly patterns are apparent in the fish-price data, so we estimated the annual trend while accounting for daily and monthly effects.

Who is affected by increased fuel prices?

Using interview data, we determined which gear type (who) was most affected by increased fuel prices, and compared the difference in fuel consumption ($\log_{10}$-transformed) for each gear type using a one-way analysis of variance ANOVA, and fuel consumption between towed gears (beam trawling, otter trawling, and scallop dredging) and static gears (gillnets and crab pots), using an independent samples *t*-test. To assess the extent of the impact of fuel price increases on the costs of fishing for different types of fisher, the fuel cost as a percentage of a trip gross in July 2008 was compared with that in July 2007 for different gear types.

Why are different vessels affected by increased fuel prices?

We used a general linear-modelling framework with model selection to examine which vessel characteristics (derived from data gathered during interviews and the MFA Fishing Vessel List) influenced the fuel consumption of different vessels. All vessels pay the same price for fuel, so there was no need for its inclusion as a variable. Vessel characteristics used included categorical variables, i.e. gear type (towed or static gear) and ownership structure (skipper owner or company skipper), and continuous variables, i.e. vessel size (using vessel capacity units, VCUs), vessel age (years), engine size (kW), engine age (years), and time since last refit (years). All continuous predictor variables were $\log_{10}$-transformed to ensure normality. To avoid multicollinearity, we eliminated redundant predictor variables: vessel size and engine size were highly correlated ($R_p = 0.980$, $n = 33$, $p < 0.001$), as were vessel and engine age ($R_p = 0.591$, $n = 33$, $p < 0.001$). Only vessel size and engine age were retained for analysis. Possible interactions between predictor variables were decided *a priori* based on the interviews with fishers and were also included in the model. All predictor variables were included to fit a maximum model, and the least significant variables were systematically excluded one by one based on small sample size Akaike Information Criterion (cAIC), ΔAIC, and AIC weights (Burnham and Anderson, 2002; Crawley, 2003). To test whether the level of investment into vessels was influenced by the ownership structure (owner skipper vs. company skipper), *t*-tests were undertaken on vessel age, engine age, and time since last major engine refit.

How are fishing businesses and the community affected by increased fuel prices?

Fishers were questioned on how fuel prices had affected fishing practices, behaviour, and their business. Questions were posed so that answers were not prompted by the interviewer. Skippers were free to list what they felt were their greatest concerns. Interviews were tape-recorded and transcribed verbatim. Transcripts were systematically coded using qualitative analysis software (NVivo 7) according to each variable of interest, to ensure that data were not used selectively. The frequency of each answer type was calculated. During interviews, skippers were also asked about how increased fuel prices were affecting their community now and likely in future.

Results

Trends in fuel prices and fish prices over time

Fuel prices for fishers in Newlyn increased by 359% from 1998 to 2008. In contrast, fish prices have remained relatively stable. Fuel price remained stable over the decade from 1987 to 1996, with prices averaging £0.12 l^{-1}, then dipped and subsequently rose near the end of 2000. Since 2003, prices have increased by £0.05 l^{-1} annually ($F_{1,4} = 39.2$, $p = 0.003$). Average fuel prices increased by 45% from mid-2007 to mid-2008, from £0.31 l^{-1} in 2007 to £0.45 l^{-1} by the end of May 2008. By mid-2008, they had reached £0.57 l^{-1}, resulting in an average price of that year by then of £0.45 per litre. Accounting for day and month effects, where significant, average monkfish prices increased by £0.146 per year (18.6% increase from 1998 to 2008), sole by £0.39 (48.2% increase), hake by £0.066 (15.5% increase), and megrim by £0.35 (129.6% increase; Figure 1).

Who is affected by increased fuel prices?

Fishers using different gear types are impacted differently by the increase in fuel cost, so fuel consumption was significantly different among gear types. Fishers who used towed gears were more affected by fuel price increases because they consumed significantly more fuel than vessels that used static gear (mean consumption litre per h ± s.e.: towed gear, 81.00 ± 9.14, $n = 11$; static gear, 21.33 ± 2.96, $n = 23$; $t_{32} = -4.43$, $p < 0.001$; Figure 2). The realized fuel costs doubled in the 12 months studied, on average, for all gear types (Figure 3). Given that vessels that use towed gears burn more fuel than the static gears, they were more seriously affected by the rise in fuel costs.

Why are different vessels affected by increased fuel prices?

To examine the link between the fuel use and the characteristics of vessels, average fuel consumption per hour was regressed on VCUs and on dummy variables that indicated whether the skipper was the owner and whether the vessel used towed or static gear (Table 2). The following diagnostic tests were conducted: the RESET omitted-variable test supported the null hypothesis that no variables were omitted ($F_{3,26} = 1.65$; $p = 0.2013$). The mean variance inflation factor of 1.81 indicated that multicolinearity was not a problem. The Breusch–Pagan/Cook–Weisberg test also accepted the null hypothesis of homoscedasticity ($\chi^2(1) =$

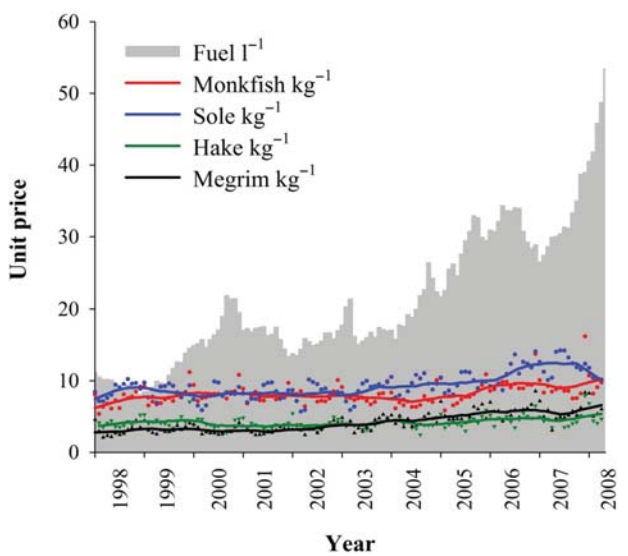

Figure 1. The price of fuel (excluding tax duty) in UK pence (£0.01) per litre paid by vessels in Newlyn from January 1998 to July 2008, and the average monthly price of the four main species of fish in UK pounds sterling per kilogramme landed at the market, for the period January–July 2008. Points are the average monthly price for each fish species, and lines of the same colour are loess-smoothed curves to show the overall trend and to help in interpretation.

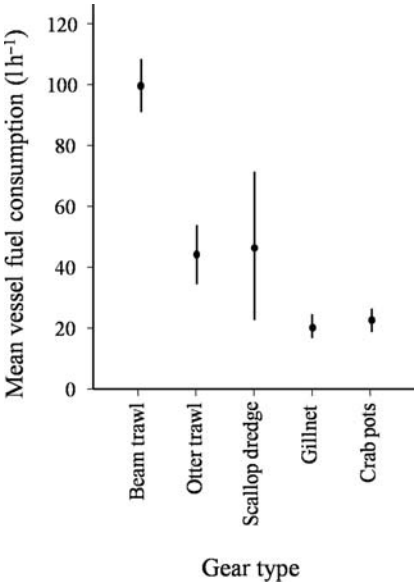

Figure 2. Average fuel consumption by Newlyn vessels for five different gear types. Values are the mean $\pm$ 2 s.e.

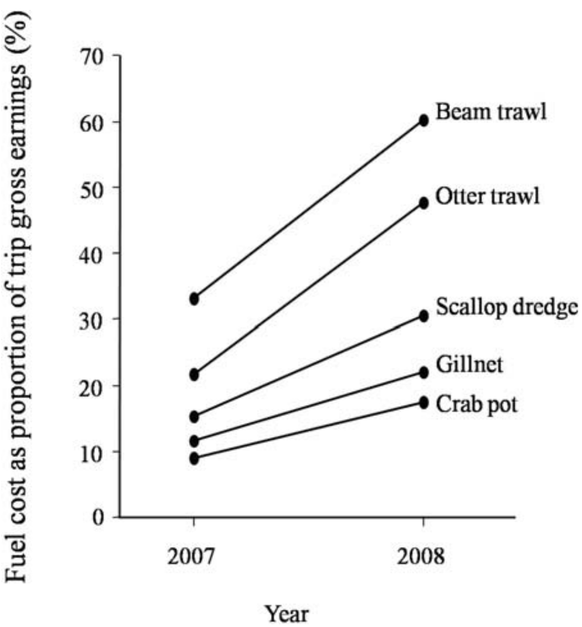

Figure 3. Comparison of fuel consumption as a percentage of fishing trip gross earnings between July 2007 and July 2008 for five different gear types.

2.07; $p = 0.1499$); despite this, to make results comparable with the regression used later, we used robust standard errors.

The finding was that higher fuel consumption is associated with towed gears and larger vessels. For example, towed-gear vessels on average used some 24 l h^{-1} more than static gears. Similarly, the hourly consumption of fuel increased by 0.2 l for each additional unit of VCU. An interesting but rather weak result (significant only at 10%) from this regression is the observation that, on average, vessels skippered by owners used less fuel than company skippers. There is a strong significant interaction between gear type (towed) and ownership. In Table 2 (column b), in addition to the variables included in column (a), an interactive term between skipper owner and towed gear type is included. This regression also passed the diagnostic tests mentioned above except that for heteroscedasticity. The RESET omitted-variable test supported the null hypothesis ($F_{3,25} = 0.20$, $p = 0.8929$). The mean variance inflation factor of 3.87 indicates that multicolinearity is not a problem. The Breusch–Pagan/Cook–Weisberg test rejected the null hypothesis of homoscedasticity ($\chi^2(1) = 7.18$, $p = 0.0074$). Hence, the regression uses robust standard errors. In the regression, the independent owner effect was no more significant, but the interactive term was highly significant, the implication being that the fuel saving associated with skippers owning their own vessels mainly worked through the ownership of towed-gear vessels. In other words, ownership really makes a difference in fuel efficiency where fuel consumption is higher (towed-gear vessels use more fuel than static ones).

Table 2. Regression of fuel consumption on vessel characteristics.

	Fuel consumption (l h^{-1})	
Coefficient	**(a)**	**(b)**
Skipper owner	−12.23* (6.46)	4.69 (6.66)
Skipper owner × towed gear	–	−38.76** (11.20)
Towed gear	24.12** (6.29)	49.95** (10.10)
Vessel size (VCUs)	0.22** (0.02)	0.16** (0.02)
Constant	−12.59 (8.27)	−11.76* (6.24)
Observations	33	33
r^2	0.88, $F_{3,29} = 86.68$**	0.91, $F_{4,28} = 75.91$**

Robust standard errors in parenthesis.
*$p < 0.1$.
**$p < 0.01$.

The extent of investment in the upkeep of fishing vessels depended on the ownership structure. Vessels skippered by their owners were newer, with newer engines and more recent and regular engine maintenance (Figure 4).

How are fishing businesses and the community affected by increased fuel prices?

The declining income from fishing attributable to rising fuel prices led to a vicious cycle for the skippers remaining in fishing. Almost all (88%) skippers mentioned that they had experienced a significant drop in income over the 12 months of study. Despite management restrictions remaining, the issue of greatest concern for skippers of relatively fuel-efficient vessels using static gear (netters and potters) was that increased fuel prices still had a significantly negative effect on income. Across all gear types, as a result of lowered wages, one-third (34%) of skippers interviewed stated that they were having problems recruiting deck crews because "by the time you take out the fuel expenses, there's nothing left for the crew, so all the crew are leaving at the moment". Without crew the boat cannot go to sea, and the skipper needs to seek alternative employment. Of the skippers experiencing crew problems, 67% were company skippers. Skipper owners tended to have fewer problems recruiting crew, with many having family members as crew or having had the same crew for a number of years, crew prepared to stay and to weather the bad financial times. These difficulties in crew recruitment were closely associated with the fuel-price rise and the

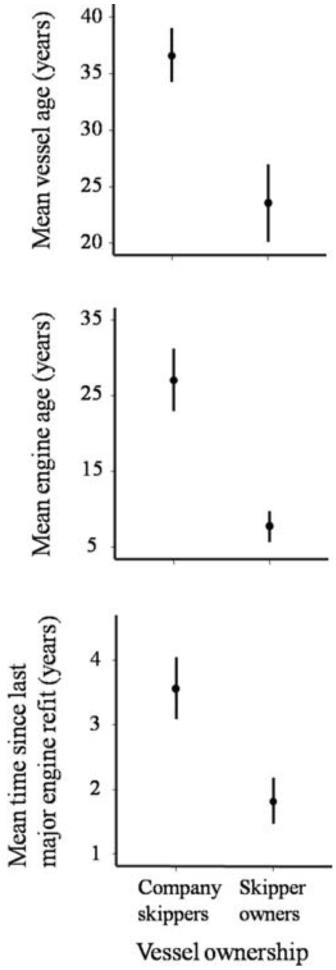

Figure 4. Comparison of average vessel age ($t_{32} = -3.1$, $p = 0.004$), engine age ($t_{32} = -3.9$, $p < 0.001$), and time since the last major engine refit ($t_{32} = -2.8$, $p = 0.009$) for skipper- and company-owned fishing vessels.

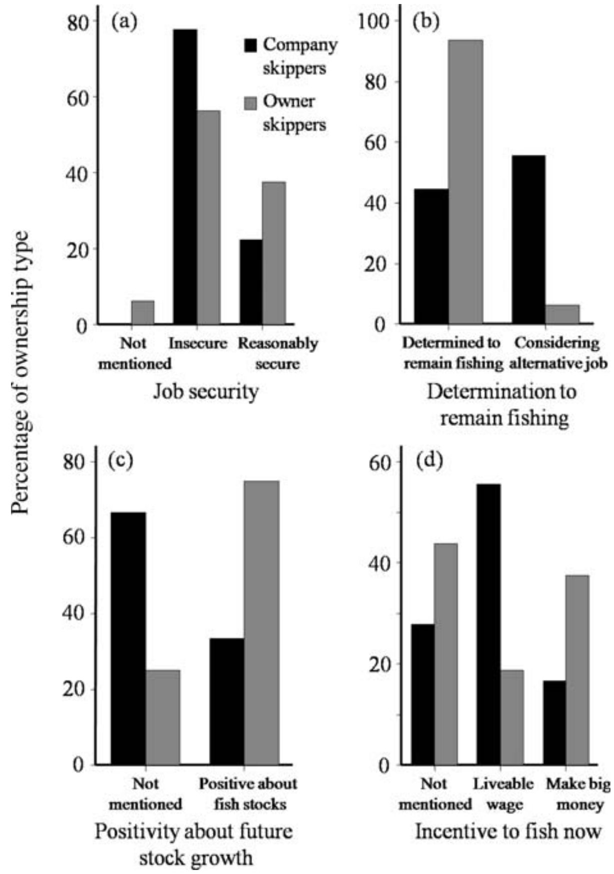

Figure 5. The percentage of skipper owners (grey) and non-owner skippers (black) who (a) had concerns about the security of their job, (b) were determined to remain in fishing, (c) felt positive about the future of fishing with respect to the fish stocks and, (d) felt their incentive to fish had diminished given the rising cost of fuel.

resulting rapid decline in profit-share income. They are not thought to have been the consequence of a more general lack of willingness for people to enter the fishery because of improved opportunities in other sectors of the economy. At Newlyn, most crew are local from Cornwall, or from previously important English fishing ports such as Fleetwood, Grimsby, and Lowestoft, or from Scotland or Ireland, who had moved down to the southwest when their own local fishing industries collapsed. Some boats have taken to recruiting eastern Europeans with success, but this is becoming harder as the economies of those countries themselves improve. Most of the eastern European workers in the industry at Newlyn work in processing.

Many skippers felt they were experiencing job insecurity ("the way fuel is going it is seriously worrying"), notably skippers who do not own their vessels (78%) and skippers of fuel-intensive beam trawlers (Figure 5a). Those skippers were considering job alternatives, and ironically many were considering "going to the North Sea to work for the oil and gas rigs", another declining industry. Skippers who owned their own boats tended to be more positive, having "a good feeling about the fishing still", and were hence more likely to be determined to remain fishing for as long as possible (Figure 5b). They tended to believe that fish stocks were increasing slowly (Figure 5c) and that there was a future for them within the fishing industry.

The rise in fuel prices also changed skippers' incentive to fish. Among company skippers, more than half (56%) mentioned that they were now more concerned with survival, i.e. making enough money to support themselves and their families rather than profiting or "making big money", which was the incentive of just 17% of company skippers. By comparison, changing incentives were not mentioned as frequently by skipper owners (56% of skipper owners mentioned incentives compared with 72% of company skippers). Almost one-fifth (19%) of skipper owners mentioned that their incentive to fish had changed to making a "liveable wage", compared with 38% of skipper owners who wanted to make big money (Figure 5d).

The rapidly increasing fuel prices clearly changed how skippers fished and hence the amount they caught (Table 3). Skippers used a number of methods to reduce fuel consumption, including fishing with the flow of the tide and not against it, steaming and fishing more slowly, fishing in fine weather only, fishing closer to port, spending less time in exploratory fishing, and reducing gear experimentation. The consequence was that these behaviours decreased the amount of fish caught on a trip. Even if a vessel caught a comparatively large quantity of fish at one location, it may still not have been cost-effective to stay on that patch of productive ground if it meant towing against the flow of the tide.

Table 3. Skipper responses to the open question "How have skippers changed their fishing practice as a consequence of increased fuel prices?"

Skipper response	Number of responses	Percentage of responses
Skipper now uses the tide more when fishing owing to the increased cost of fuel	23	67.6
Skipper has reduced steaming and towing speed owing to increased cost of fuel	13	38.2
Skipper has reduced the number of days at sea because he no longer leaves port in poor weather owing to the increased cost of fuel	16	47.1
Skipper now pushes the weather more to increase his days at sea owing to increased cost of fuel and the lower profit margins	5	14.7
Skipper does not make shorter fishing trips owing to the increased cost of fuel (the cost of steaming to the grounds is too high for a short trip)	8	23.5
Skipper has reduced the distance travelled on fishing trips owing to the increased cost of fuel	7	20.6
Skipper has increased the distance travelled to find larger catches owing to the increased cost of fuel	2	5.9
Skipper can no longer afford to carry out any (or reduced) exploratory fishing owing to the increased cost of fuel	18	52.9
Skipper can no longer afford to experiment with gear or has reduced experimentation owing to the increased cost of fuel	11	32.3
Skipper has attempted to increase the quality of fish caught to improve his income as a response to rising costs	21	61.8
Skipper now examines each haul carefully and calculates whether it is profitable or not as a result of the increasing cost of fuel	27	79.4
Skipper has invested in fuel-efficiency measures	19	55.9

Table 4. Skipper responses to the open question "What do skippers feel about the future of fishing for the fleet, and the community in which they live?"

Skipper response	Number of responses	Percentage of responses
Expressed uncertainty about the future of the fishing industry in their community	32	94.1
Believes there will be a significant reduction in fishing fleet as a result of increasing fuel prices, pushing fishers out of business	34	100
Mentioned a likely loss of jobs ashore (engineering, processing, harbour working, etc.)	24	70.6
Believes that shrinkage of the fishing fleet will result in a loss of continuity of supply for and viability of the fish market	6	17.6
Believes that shrinkage of the fishing fleet will have a negative impact on the wider community in which he lives, which itself depends on the fishing industry for infrastructure and employment	24	70.6

According to skippers, slower steaming and towing meant that it took longer to reach the fishing grounds, reducing the fishing time per trip and the total catch. Almost half the skippers interviewed said that their total days at sea had also been reduced because they "just wouldn't go out in poor weather". Poor weather reduces the amount and quality of fish caught because the gear tends not to fish effectively, and with high fuel prices, it was no longer economically viable to operate in such conditions. However, a small number (15%) of skippers now saw fewer boats fishing in poor weather as being to their advantage, and actively used that in their fishing strategy by going to sea in such periods. Fewer vessels fishing in poor weather results in less fish on the market too, with the consequence that seafood buyers compete harder with each other, and bid higher to ensure that their orders and commitments are met, driving fish prices up.

Fishing locations also changed: 21% of skippers said they had reduced their distance from port to reduce higher fuel costs. On the other hand, a small number of fishers felt that they had to travel farther in search of larger fish catches. More than half the skippers said they no longer explored new fishing grounds because they could not take the risk of not catching fish. Experimentation with gear changes was also reduced for the same reason. "There is no incentive any more to try out different gears". We do not know whether the aggregate effect of these changes in behaviour is positive or negative for fish-stock status.

The impact of rising fuel prices and relatively little change in the price fishers receive for their fish also raised serious concerns for the vulnerability of the communities in which they lived (Table 4). Most skippers (94%) expressed uncertainty about the future of the fishing industry within their community and said that it "looked bleak". All the skippers interviewed believed that many "boats would go to the wall" and that the fishing fleet would contract significantly as a direct result of increased fuel prices. More than 70% of skippers also expressed concern that a reduced fleet would also result in "losing a lot of onshore jobs", such as the people working at the harbour, and in the fish marketing, engineering, and processing sectors. Almost one-fifth of the skippers interviewed believed that the fish market itself could be at risk; with fewer boats landing fish, the continuity of fish supply would be lost, reducing the number of fish buyers, reducing competition, and eventually undermining the viability of the market. The loss of fishing industry infrastructure raised serious concerns with skippers. For example, a common thread in skippers responses was that the industry "was finished if the price of diesel keeps going the way it is", and given that the "fishing industry keeps Newlyn going", "what will people do and what will happen to Newlyn without the fishing industry?" "In this neck of the woods where we are, possibilities are limited. It's a downward spiral".

Discussion

Fuel prices for fishers doubled between 2007 and mid-2008 culminating in protests, strikes, and blockades of ports by fishers throughout Europe, including the UK (Hughes, 2008). The "fuel crisis" was headline news in the UK fishing press, with reports of fishers "tying up boats" because they could not afford to go to sea, and of fishers preparing to leave the industry (European Commission, 2008b; Lockley, 2008; MacDonald, 2008). Our research at Newlyn demonstrates that the consequence of this recent fuel-price shock combined with stagnant fish prices was a significant reduction in income for fishers and a loss of job security. The most impacted sectors of the fleet were those who use towed gears, because fuel makes up a more significant percentage of their fishing costs than it does for static-gear vessels and for those vessels that had not invested in fuel-efficiency measures before the rise in the fuel price.

Despite global oil prices dropping significantly since the time of this study, fuel prices are predicted to rise again to the same level as in mid-2008 and even higher (IEA, 2008). In such a case, given the reaction observed in 2008, and on top of declining fish stocks, chronic overcapacity, and seemingly unsuccessful management, it seems inevitable that the fishing sector will consolidate further, with fuel-inefficient vessels leaving the industry and fuel-efficient vessels surviving. This seems to be the case for EU fisheries as a whole, and there is direct evidence that this is the trend facing Newlyn. A reduction in effort follows the predictions of bioeconomic models. Other results captured in this study further strengthen the predictions made by those models, such as a reduction in the effort of fishing vessels, with fewer days spent at sea, and fuel-consumption reduction measures reducing the quantity of fish caught. Bioeconomic model results indicate a long-term potential growth in the overall profitability of the industry (Pauly *et al*., 2002; Arnason, 2007; Sumaila *et al*., 2008). However, this case study has additionally captured some potentially detrimental and irreversible consequences of increased costs that cannot be predicted by bioeconomic models, with unknown outcomes for vulnerable fishing-dependent communities such as Newlyn and with potential knock-on effects for the European fish supply chain. The rapid change in the economic conditions in 2008 intensified the pressure on fishing businesses and highlighted the susceptibility of the community to financial shocks. The primary concern was that the community would experience further job losses (crew, shore workers, and downstream processors), reducing the industry to a level where key parts of the infrastructure of the fishing industry in Newlyn, such as some onshore businesses, the fish market, fish merchants, and processors, may disperse. The concern with such a situation in Newlyn is that such losses may generate irreversible effects for the viability of the fishing industry, causing erosion of the community, as previously observed in other parts of the UK (Rossiter and Stead, 2003; Stead, 2005).

The key barrier to fishers in the face of unstable and rising fuel prices is that they have been unable to offset the increased costs, so reducing their ability to cope with and adapt to change. To offset costs, there are two alternatives available to skippers: the first is to fish for longer and/or to catch more fish, and the second is to improve the price of fish at the first point of sale. Our research revealed that most fishers were unable to fish more because the increased costs often outweighed the value of the quantity they could catch, so their strategy was to reduce their fishing to times where fishing was likely to be more efficient and profitable. Although a small percentage of skippers responded to increased fuel prices by increasing the number of days at sea, working in poor weather to gain a market advantage (a strategy also observed in Micronesia by Rhodes *et al*., 2008), almost half the skippers interviewed said that they had reduced the number of days they fished. Skippers also used a variety of means to reduce fuel consumption, all of which reduced their total catch. However, the reduced catches combined with the higher costs resulted in lower wages available to recruit scarce crew, delaying skippers wanting to leave for the fishing grounds even further, and reducing fishing time and profitability. Fishers' cost-mitigation measures were compounded by the fact that skippers already had catch limitations imposed as a result of the decline in some fish stocks and their associated quota, and bycatch limitations, and also by the potential overcapacity already within the fleet.

The second alternative to offset increasing costs would be to improve the price of fish at first point of sale. However, ex-vessel market fish prices in Newlyn have remained stagnant for the past 10 years, mirroring the trend in market fish prices across European fishing nations. Consequently, fishers, like farmers, have been unable to pass on increased costs down the market chain and also "have been unable to benefit from reduced supply and rising retail prices" throughout Europe (Joe Borg EC Fisheries Commissioner; European Commission, 2008c). It is difficult to obtain specific data on trends in retail prices in Europe because most retail data are collected and commercialized by private companies (FAO, 2008). However, there are indications that retail prices do not reflect the same pattern as fish prices at the first point of sale, but that they have been increasing. Evidence of this is the FAO fish price index for whitefish (based on import values), which suggests that import prices have been rising over the past 10 years (Tveteras, 2008). In addition, CEPESCA's (the Spanish Confederation of the Fishing Industry) recent analysis of auction price data compared the hake price at the end of 2007 (€11.25) with that at the end of 2008 (€4.00), a 64% decline in the value of hake at the market despite rising fishing costs. At the same time, the price paid by the consumer fell only slightly, from €18.79 to €18.47 (Fishing News International, 2009).

This divergence of price trends at different points in the market chain prompted further investigation and revealed local and global barriers to fishers receiving higher prices for their fish. At a local level, the barrier to fishers receiving higher prices is the institutional set-up of the market. Fish buyers have price-setting power. Although all fish markets operate slightly differently, their similarity is that they tend to be auction markets, and the price received at the market generally depends on the quantity of fish being sold on a given day. When daily supply is low, and there is high demand, buyers compete harder with each other and prices tend to be higher. At Newlyn, most vessels land and sell their fish at the Newlyn market, where buyers bid in person each morning. Approximately 80% of all the fish landed at Newlyn are then sold to buyers in continental Europe, mostly Spain and France, with the rest sold on the domestic market (pers. comm. with a Newlyn fish merchant, 1 November 2008). Given the advantage of low supply driving the price up, fishers attempt to land and sell their own fish when few other boats are landing. Information on the number of boats predicted to land on a certain day is readily available at sea and is used by skippers. Therefore, to some degree at least, fishers collude and make decisions about when to land to obtain the best price. However, there is no formal network or coordinated mechanism in place, and communication is mostly between small groups of skippers who have social ties. Wider coordination of landing times could strengthen fishers' market power and improve the prices. However, the limitations to fishers being able to strategize and successfully play the market are that fresh fish is a perishable product and cannot be stored without additional costs, and uncontrollable factors such as weather override any strategy they might develop, and determine the landing date and time.

There are also global barriers to improving fish prices for fishers. Fish prices at the first point of sale throughout Europe have been maintained low because of the strong buying power of processors and marketing chains which have access to fish products at low import prices from the global market, including large volumes of illegal, unregulated, and unreported fish (European Commission, 2008a). In the UK, the supermarket share of fish rose from 16% in 1988 to 66% in 2001, at the expense of fishmongers whose market share dropped from 49% to 18% (Murray and Fofana, 2002). This trend in fish sales concentrating in supermarkets is evident across Europe (Guillotreau, 2004). Moreover, there is a concern that less fuel-intensive aquaculture products may permanently capture the market share over marine captured fish, effectively capping fish prices (World Bank and FAO, 2008). The growth of aquaculture has allowed predictability of supply, which better suits large retail chains whose economies-of-scale are built on efficient supply of large, reliable volumes. Therefore, it is the instutional set-up of the seafood market at both local and global levels that create barriers to fishers effectively passing on their costs and improving the price they receive, with negative consequences for the sustainability and resilience of coastal fishing communities.

Given the limitations fishers face in offsetting costs, what can be done to improve the viability and stability of fishing industries in the face of volatile and rising fuel prices? A common response from the fishing industry is to call for increased subsides (BBC News, 2008). Fuel is already subsided heavily throughout the world and in the UK. Globally, US$5.08 billion of the estimated US$7.75 billion spent on fisheries subsidies in developed countries in 2000 were for fuel, mostly in the form of foregone taxes (World Bank and FAO, 2008). Despite subsidies being widely considered to have harmful long-term effects on fish stocks (World Bank and FAO, 2008), their total removal would undeniably cause economic and social suffering for fishers and fishing-dependent communities, especially with uncertainty in the oil price. However, increasing the subsidies would negate any potential positive environmental or economic impacts increased fishing costs might have by keeping unprofitable enterprises operating (Sumaila *et al*., 2008; World Bank and FAO, 2008). Further, using subsidies as a solution to such industry-wide problems creates perverse incentives that mask economic reality, and potentially encourage greater investment and effort, which would, in the long-term, exacerbate financial hardship in the fishing sector.

To survive, vulnerable fishing communities need to improve their ability to cope and adapt to changing conditions without relying on subsidies. The acute fuel shock reported here is a glimpse into a future of high oil prices. Given that fleet contraction seems inevitable, then any transition to a new fishing industry requires careful planning and management so that destabilization of the industry itself and the communities dependent on it is minimized. Policy-makers, the fishing industry, and the fishing communities themselves all have a role in this. At the top level, governance needs to change from being centred on the biological to being informed by the biological, with greater emphasis on the economic and social processes and benefits fishing brings to communities, alongside resource conservation needs. Social objectives for fishing communities need definition, because there is no real platform without such definition from which to create an environmentally and economically sustainable fishery (Jentoft, 2000). If policy-makers do not shift the emphasis of governance and management, and continue without reform, the result will undoubtedly be further decline in fish stocks, increased inefficiency in operations, and growing poverty in fishing-dependent communities. Failure to act would imply a sector that becomes a drain on governments and society rather than a contributor to society at large (World Bank and FAO, 2008).

Our research has indicated that it may be important to understand that the players will alter as a consequence of the increased costs of fishing, as will fishing incentives and behaviour. Vessels remaining in the industry need to be efficient, well-managed, and adaptable to weather increasing and uncertain costs. However, we have also demonstrated strong market constraints on the ability of fishers to cope and to adapt, constraints not often considered by fisheries scientists and bioeconomists. Opportunities and interventions in the market chain to encourage prices to be more responsive to fishing costs, and to improve the price of fish at the first point of sale, would improve the adaptive capacity of fishing communities. This is necessary because the more constraints fishers face, the less opportunity there is for adaptability and innovation within the industry to move towards sustainable practice, as indicated by the reduction of pro-environment gear experimentation by skippers. The constraints promote a further barrier to social cohesion that is not an enabling framework for resource conservation or a move towards more participatory management. The 2008 fuel crisis brought complex economic and social objectives to the fore of policy debates on fishing in the UK, which perhaps may have been a further step towards aligning environmental, economic, and social objectives in fisheries management.

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