Fishing for what?

Understanding fisher decision-making in southwest England

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"It's not the sort of job that you do in halves. You have got to live for it, love it. No one does it just for the money. It's not like working in an office and really hating it 'cause you have to stick at it. You have got to be in to it 'cause it's not your average job. Part of it is seeing the fish, big hauls of fish…. but the fun of the job is the unknown.

They call us the last of the hunters,

we go out here and we can't see our prey,

we are hunting it down."

(Cornish skipper, May 2008)

Abstract

The links between the behaviour of fishers, the marine environment and fisheries management institutions are poorly understood. There is a widespread lack of compliance with fisheries management, and fisheries policy has failed to develop the ability to understand and anticipate fisher behaviour in advance of regulations, or learn how to shape individual behaviour in ways that promote societal management goals. An in-depth understanding of fisher decision-making is required to design appropriate incentives to improve the ecosystem functioning, the efficiency and profitability of fishing enterprises, and improve the well being of fishing communities.

This thesis attempts to help redress the imbalance between understanding the resource itself and the resource users. It adds to our understanding of the complexity of individual fisher and fishing fleet behaviour by challenging the standard models used to understand behaviour. It examines the behavioural economics of fishers as well as the psychological, cultural and social determinants of individual behaviour. An interdisciplinary methodology was used to unveil the heterogeneity of fisher behaviour as well as the patterns of fisher decision making.

Specifically, this thesis presents a comprehensive review of the literature, synthesising and summarising the approaches used to understand fisher decision making, with particular reference to location choice behaviour. It goes beyond a review of existing approaches by drawing on theory from disciplines outside fisheries research and formed the foundations of the methodology used for understanding fisher decision making in the southwest of England. In examination of individual behaviour, four typologies of fishers' strategic behaviour are identified using a framework drawn from the strategic management literature. A random utility model of location choice behaviour is presented and shows that southwest beam trawlers trade-off economic returns with knowledge transfer within the fleet and risk-aversion tactics. The acute fuel-price shock in 2008 provided the opportunity to examine the ability of, and barriers to, fishing enterprises and fishing communities adapting under changing and uncertain conditions. Increasing costs combined with strong market constraints on ex-vessel fish prices has resulted in lowered profitability for fishers which may have negative consequences for the sustainability and resilience of southwest English fishing fleets and fishing communities.

This thesis shows that understanding aggregate fisher incentives can be achieved using an interdisciplinary approach and could enrich the design of fisheries governance systems for social-ecological sustainability and promotion of healthy fishing communities.

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Chapter 1

Introduction

1. The fisheries management dilemma

Marine fish stocks are in decline on a global scale (Pauly *et al.*, 2002, Pauly *et al.*, 2005, FAO, 2008), the biomass of higher trophic-level species (i.e. the fish humans prefer to eat) in the sea is diminishing (Christensen *et al.*, 2003), and several fish populations may be threatened with ecological or commercial collapse, and local, regional or global extinction (Cook *et al.*, 1997, Dulvy *et al.*, 2003, Dulvy *et al.*, 2006). The Food and Agriculture Organisation of the United Nations reports that globally, 28% of stocks are considered to be overexploited (19%), depleted or recovering from depletion (9%), 52% are fully exploited, and 20% moderately or underexploited (FAO, 2008). An ecological study of ocean ecosystem services published in *Science* predicted the collapse of all the world's wild stocks by 2048, and received great publicity (Worm *et al.*, 2006). While this prediction and other papers that document global fishery declines have widely been considered to be alarmist, (Walters, 2003, Hampton *et al.*, 2005, Essington *et al.*, 2006, Polacheck, 2006, Hilborn, 2007b), there is scientific consensus that many of the world's fisheries are overexploited and over fishing is a serious problem (Worm *et al.*, 2009). The degree of overfishing varies widely between and within geographic areas, but where it exists ecological resilience is compromised (Botsford *et al.*, 1997). This translates directly into economic losses.

Fisheries management systems need to be addressed. It is generally recognised that the future of sustainable fisheries requires less fishing effort and larger fish stocks, a reduction in by-catch (unintentionally caught species) and removal of damaging fishing practices, and a strengthening of governance systems. It is suggested within the fisheries science community that there is a need to move away from legislation designed to extract the maximum sustainable yield (MSY) from fisheries (where fishing capacity is matched to the productive capacity of the resource), or hold back fish stocks from tipping over B_{lim} (the biomass limit reference point beyond which stocks are likely to suffer a reduction in reproductive capacity). Instead, appropriate incentives to reduce fishing pressure and increase stocks, improve stability and profitability for fishers and improve governance should be implemented (Hilborn *et al.*, 2003, Hilborn *et al.*, 2005, Hilborn, 2007b).

We have a good understanding of why fisheries have declined. It is primarily due to fisheries management failing to set appropriate goals and achieve them, or lack of regulation (Peterman and M'Gonigle, 1992, Peterman, 2004). For example, European fisheries are governed by the Common Fisheries Policy (CFP) which was originally designed in 1983 to promote growth, increase income and stability for fishers, while minimising conflict. The CFP did not aim to reflect the complexity of the ecosystem and its services required to promote sustainability, instead fisheries policies were designed to subsidise the fishing industry (Symes, 1997, Jensen, 1999, Hanna, 2001). Similar to other fisheries around the world, lack of appropriate management goals in the past and lack of regulation lead to overcapacity within fleets and overexploitation of marine resources (Holden, 1994, Daw and Gray, 2005). Overcapacity has been attributed to the 'race for fish' which can develop in open access or shared resource fisheries, where users have no rights over the resource and thus incentives are created which emphasise short term gains and few incentives for long term stewardship (Gordon, 1954). Over the years technological creep and subsidised costs have also allowed vessels to successfully exploit new fishing grounds further from shore and in deeper waters and have expanded seafood markets (Morato *et al*., 2006, World Bank and Food and Agricultural Organisation, 2008). Habitats have been destroyed as a result of damaging fishing practices (Jennings *et al.*, 2001, Hiddink *et al.*, 2006, Kaiser *et al.*, 2006); and there is evidence of a negative disruption to the balance of the ecosystem through exploitation, by-catch and discards (unwanted catch thrown away) (Goni, 1998) which further contribute to fishery declines.

In industrialised countries, fisheries policies have tended to use top-down management approaches to achieve MSY or B_{lim}. Input controls restrict access to marine resources through vessel licenses, restrictions on vessel capacity, or seasons and areas closed to fishing. Technical measures such as fishing gear restrictions and prohibition limit the efficiency or selectivity of fishing gears. Output controls regulate catch directly through devices such as total allowable catches (TACs) and limits on by-catch proportions. However, imposed input, technical and output control measures have a high failure rate for a number of reasons. Firstly, these measures on their own are not able to readily adapt to the short-term and unpredictable variability in the trends of fish stocks (Wilson *et al.*, 1994). The complex behaviour of fish stocks and ecosystem interactions has led to insufficiencies of ecological information on which management is based. Also, the management institution often lacks adaptability and resilience to change under uncertainty (Berkes and Folke, 1998). Complicated regulations and the information requirements contribute to lack of legitimacy of fisheries policy among fishers which causes problems of compliance and result in high management costs (Raakjaer Neilsen, 2003).

The failure of traditional management measures has led many to propose an ecosystem based approach to fisheries (EAF) which gives weight to integrated management and emphasises the importance of maintaining whole ecosystem health through addressing fishery-ecosystem interactions (FAO, 2003, Garcia and Cochrane, 2005). A key component of the EAF is to protect key habitats that are critical for ecosystem processes through marine reserves and no-fishing areas (FAO, 2003, Pikitch *et al.*, 2004). The EAF is a step in the right direction, shifting away from target species fisheries management to ecosystem management. Although theoretically it incorporates the human dimension, in practice it tends to overlook the importance of fisher behaviour and creating the right incentives for fishers to achieve ecological and environmental sustainability recommended by a growing number of fisheries economists and social scientists contributing to the fisheries management debate (Grafton *et al.*, 2006). Hilborn (2007b) examined the successful fisheries from which management lessons can be learned and applied, and found that when there was good governance and appropriate incentives for fishing fleets, management was more likely to succeed.

Rights based measures - giving fishers long term secure harvesting or territorial rights that are legally enforceable - are considered key by advocates of incentive based approaches (Hannesson, 2004, Grafton *et al.*, 2006). Allowing fishers to exclude others from fishing provides fishers with two incentives, they protect the value of their assets and encourage the greatest possible sustainable flow from fishing because they suffer by overexploiting and gain through conserving. The types of rights based measures that are being used in fisheries management are individual harvesting rights such as individual transferable quotas (ITQs). Rather than setting industry wide quotas, fishers are allocated individual and trade-able fishing rights, conferring stewardship incentives, and have been shown to improve the economic performance of the fishery (although the ecological links are more tenuous) (Squires *et al.*, 1995, Costello *et al.*, 2008). Group rights, encourages collective action through community-based co-management of their own fisheries. That is, fishers have a significant decision-making role and help in the design of regulations that are more flexible, adaptable, and appropriate to their specific situations compared to generic regulations determined by centralised agencies (Pinkerton, 1989, Jentoft *et al.*, 1998). Territorial user rights (TURFs) are areas of exclusive access to fishing allocated to a group of resource users which they then manage between them. Given their defensive nature, fishing capacity is limited, and newcomers are discouraged. ‘Sole ownership’ improves efficiency, prevents damaging practice and has also been shown to improve wellbeing of fishing communities (Christy, 1992).

Thus, fisheries science and management appears to have a sound knowledge of what is wrong with fisheries and understand the limitations of different management actions. It also has a set of remedies that have been shown to work if adapted in the appropriate way. There is increasing fisher participation in management, and greater efforts to incorporate their views and incentives in the setting of regulations. Yet fisheries management still often fails.

There is still widespread lack of compliance and fisheries management has failed to develop the ability to understand and anticipate fisher behaviour in advance of regulations, or learn how to shape behaviour in ways that promote management goals. The links between the behaviour of the resource users, the marine environment and institutions created by fisheries management are poorly understood (Hanna, 2001). Regulations continue to be developed without taking account of the human systems through which they are implemented. As a result of poor understanding of human motivation, response and adaptation, there is still a large element of surprise in marine ecosystem management (Hilborn and Walters, 1992, Hanna, 2001, Wilen *et al.*, 2002, Hilborn, 2007a). Almost ten years ago Hanna (2001) identified five high priority research questions that are critical to the management of the human-ecological interface in marine fisheries, requiring consideration of both ecological and human dynamics. Hanna (2001) suggested that an interdisciplinary approach encompassing the spectrum of behavioural sciences (anthropology, economics, geography, political science, psychology and sociology) is required to address these questions:

1. *What systems of incentives will work best to promote human behaviour consonant with the multiple objectives for sustainable ecosystems? What options do markets offer that can help management to meet its goals? How has history influenced the current choice of incentives?*
2. *How can feedback among resource managers, user groups, public owners, and ecological systems be strengthened? How can improvements in scientific literacy contribute to this integration of information?*
3. *How can management and ecological scales be reconciled? What are the strengths and weaknesses of alternate management approaches?*
4. *Which performance indicators can be used to adequately represent the socioeconomic and biophysical components of natural resource systems? How can management resilience be measured and monitored?*
5. *How can the design of management be improved to promote effective ecological, economic, and social function in the face of discontinuous change? How do management structures and processes affect the cost and effectiveness of programs and policies?*

Fundamental for answering these pertinent questions is an in-depth understanding of fisher behaviour so that managers can design appropriate incentives to improve the ecosystem functioning, the efficiency and profitability of fishing enterprises, and improve the well being of fishing communities. Understanding fisher behaviour and fishing strategies will improve predictions of how fishers respond to management action and how fishers will respond under uncertain and changing conditions such as climate change and market shifts. Inclusion of the dynamics of the resource users and their fishing communities in the policy design process will also have positive implications for compliance with regulation because of improved legitimacy among fishing groups.

This thesis attempts to help readdress the imbalance between understanding the resource itself and the resource users. It adds to our understanding of the complexity of individual fisher and fishing fleet behaviour, by challenging the standard models used to understand behaviour, examining the behavioural economics of fishers as well as the psychological (personality), cultural and social determinants of individual behaviour. I have used an interdisciplinary methodology and theory from a range of disciplines outside fisheries science to uncover the heterogeneity as well as the patterns of fisher decision making. This thesis shows that understanding aggregate fisher incentives has the potential to enrich the design of fisheries governance systems for social-ecological sustainability and for fishing community resilience.

2. Thesis outline

The five principal chapters of the thesis (Chapters 2 to 6) are written in the form of peer-reviewed papers. One paper was published at the time of submission (Chapter 5). Chapter 2 presents a comprehensive review of the literature, synthesising and summarising the approaches used to understand fisher decision making, with particular reference to location choice behaviour. Models of location choice behaviour dominate the literature and interdisciplinary methods are argued to improve economic modelling approaches. Sets of knowledge and theory drawn from disciplines outside fisheries are introduced and are linked with examples from the fisheries literature to challenge the assumptions of models - that fishers operate as perfectly rational beings and they are homogeneous in the way they make their decisions. Chapter 2 was crucial for forming the foundations for the methodology I used for the remainder of the thesis, Chapters 3 to 6. These data chapters focus on fisheries of southwest England. Chapter 3 aimed to gain insights into the strategic behaviour of fishers in the southwest of England. This chapter used a case study approach and a qualitative methodology using content analysis of in-depth interviews, to develop a new framework for analysis and categorisation of strategic types, drawing typologies used in the strategic management literature. Chapter 4 returns to a key element of fisher decision making – where to fish. Informed by data collected through interviews, this study uses a random utility model (RUM) of fisher location choice to understand and predict where fisher's choose to fish. Chapters 5 and 6 then depart slightly from understanding individual fishers' strategies and tactics, to examining the problems facing fishing communities' ability to adapt under changing and uncertain circumstances. In Chapter 5 I document the impact of the 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. This chapter revealed that in fact the key barrier to fishers in the face of unstable and rising fuel prices was that they were unable to offset increased costs because ex-vessel market fish prices have remained stagnant for at least a decade. The divergence of trends for fuel and fish prices, and the evident inability of fishers to pass cost up through the value chain to buyers, retailers and consumers prompted Chapter 6 which conducts a further empirical econometric and interview-based investigation on the market structures and processes that constrain fishers' ability to set prices to offset their rising costs. I conclude with an overview in Chapter 7, drawing conclusions from my findings and highlighting key priorities for future research.

3. Methodology

3.1. Interdisciplinary approach and mixed methods

This thesis uses an interdisciplinary approach for understanding fisher behaviour. Social approaches (sociology, psychology, social anthropology, political science, geography) have not been embedded into the fisheries management systems despite their ability to understand fishers, fishing, the political processes, institutions and incentives (Jentoft, 1998, Hart, 2003). There is increasing interest and many calls within the fisheries science and management community to incorporate interdisciplinary approaches but it has been difficult to institutionalise so far (Charles, 1995, Jentoft, 2006). Integration of social sciences into fisheries science requires overcoming disciplinary boundaries by merging the different research cultures and epistemological approaches (Degnbol *et al.*, 2006). Interdisciplinary scientists are required who can promote disciplinary cooperation and communication.

For this thesis, I have used a mix of methods to gather and analyse data in order to understand the complexity of fisher behaviour while also attempting to provide generalisable results required for practical policy measures. I spent a total of six months in the southwest of England, gathering data through in-depth semi-structured interviews with skippers and key informants, participant observation (going on fishing trips to sea), quay-side and market observations, questionnaires, document review as well collecting data on fish and fuel prices. These data were used in all Chapters 3-6. In addition, I extracted data from databases stored at the Centre for Fisheries and Aquaculture Science (Cefas) to create a large database of fishing locations and related catch (using vessel monitoring system satellite data and the fishing activity catch data). As a result, the methods I have used in data analysis are diverse. I have combined qualitative and quantitative content analysis of interview transcripts, with econometric modelling and time series analysis.

3.2. The case study approach

The fisheries of southwest England were selected as the case study for this thesis (Figure 1). This region is of importance to English fisheries because with the decline of North Sea stocks, the fishery in the southwest of England now harbours most of the remaining English fleet. Fishing communities in the southwest are representative of many fishing dependent communities across the UK, located in remote areas with few alternatives to fishing for employment. Yet there is little research apart from ecological research undertaken in southwest England.

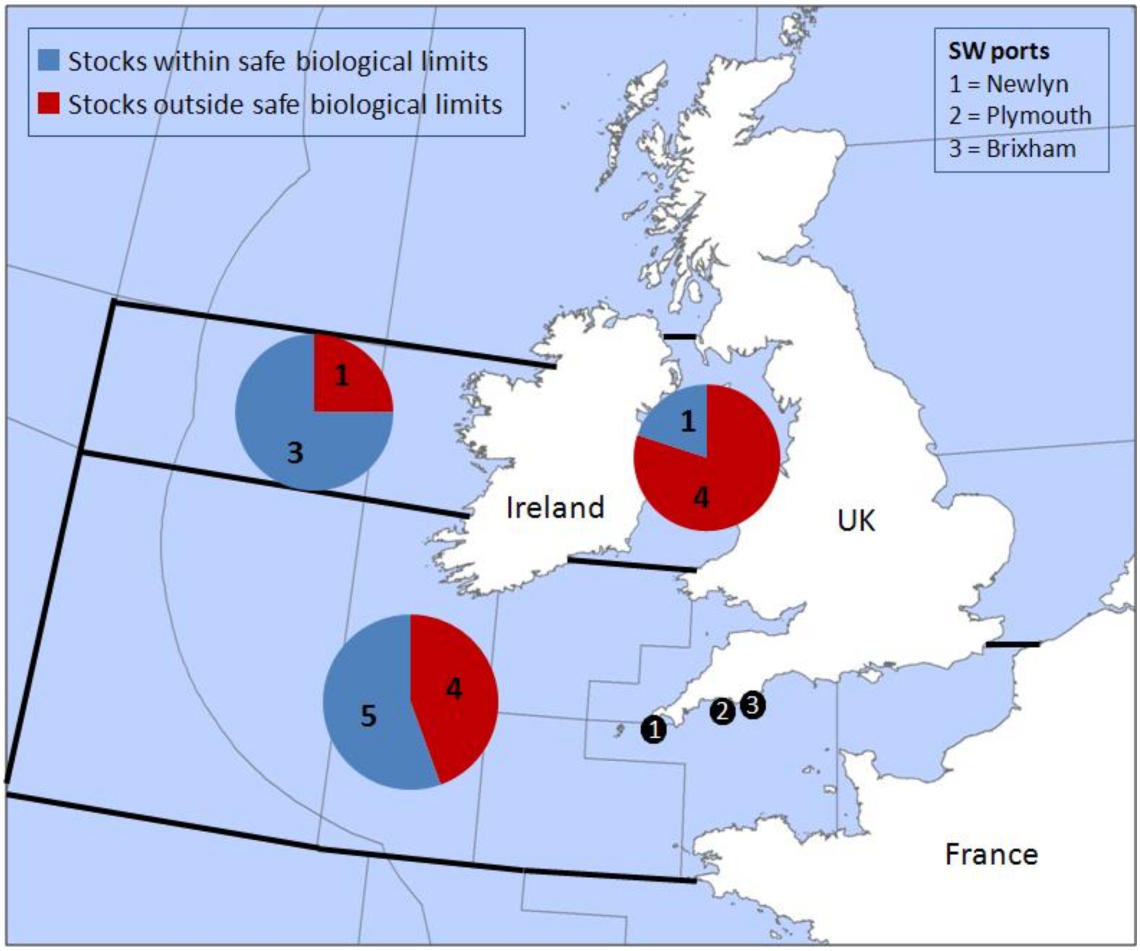

Figure 1. Map of the UK, including the major southwest ports (Newlyn, Brixham and Plymouth) and number of scientifically assessed stocks inside and outside safe biological limits in ICES regions exploited by southwest fishers. Data source: (ICES, 2008).

Researching the fisheries of southwest England also provides an opportunity to explore issues faced by fisheries in general in the European Union. Since 1983, European fisheries have been managed through the Common Fisheries Policy (CFP). It manages all the member states' (including the UK) marine exclusive economic zones (EEZs) and is now effectively one 25 million km^2 EEZ, the largest single management regime in the North Atlantic. In 2009, the European Commission for Fisheries identified that the current methods underpinning fisheries governance required transformation, and is now looking to reform the CFP and the way EU fisheries are managed (European Commission, 2009) with a goal to achieve:

> *"…exploitation of living aquatic resources that provides sustainable economic, environmental and social conditions…"*

However, given the density of fishing, EU fisheries are heavily overexploited. Over the past 50 years fishing effort has significantly increased and there is evidence that many fish populations are declining (Jennings *et al.*, 1999a, Jennings *et al.*, 1999b). The International Council of the Sea (ICES) which provides summary of the status of the stocks managed by the EU, show that 20% of all marine stocks, including approximately half of demersal stocks (roundfish such as cod, haddock, whiting, hake, etc.), are outside safe biological limits (ICES, 2008). There is considerable variation by marine region and species. Nonetheless, EU fisheries have been identified as having inadequate management regimes which has resulted in European fisheries eroding their own ecological and economic basis (European Commission, 2009). The findings of this research in southwest England, may be generalisable to other European fisheries.

3.3. Ethical Considerations

As laid out by the School of International Development ethical guidelines, *'research which involves primary data collection or the use of secondary data that contain personal or confidential/restricted information requires ethical clearance'.* This research was given ethical clearance by the University of East Anglia's Research Ethics Committee. The principles of ethical clearance to which this research has adhered is as follows:

1. *Research should be designed, reviewed and undertaken in a way that ensures its integrity and quality.*
2. *Research staff and subjects must be informed fully about the purpose, methods and intended possible uses of the research, what their participation in the research entails and what risks, if any, are involved.*

3. *The confidentiality of information supplied by research subjects and the anonymity of respondents must be respected.*
4. *Research participants must participate in a voluntary way, free from any coercion*
5. *Harm to research participants must be avoided*
6. *The independence and impartiality of researchers must be clear, and any conflicts of interest or partiality must be explicit.*

The research presented in this thesis was designed, reviewed and approved before it was undertaken through the upgrade procedure. In the School of International Development, this process requires a substantial piece of work, the procedural paper, which is reviewed by the upgrade committee, and presented to faculty and research students in the School.

For interviews, I obtained written consent from all participants, after explaining my research, the purpose, and proposed dissemination of findings, both verbally and in writing. I explained to all participants that individual data was confidential and anonymity would be preserved. I explained that participation was entirely voluntary and that if there was any part of the survey participants did not want to answer, this would be respected. Furthermore, participants were told that they had the right to withdraw entirely from the interview at any time. I stored data securely, keeping identifying markers of individual's data separate from the collected data. My computer was password protected. Interview data were primarily collected in one fishing community in the southwest. Due to the sensitivity of some of the data presented, I was advised to protect the respondents by keeping the field site anonymous. Therefore, throughout the thesis my field site is referred to as a 'SW fishing community'. In published work, I have taken care to prevent the identification of individuals. The issue of rewarding informants is a difficult issue. As skippers were very busy, a token of appreciation was given – cake! To encourage skippers to return questionnaires I gave skippers the opportunity to enter a draw to win a hamper. I gave all respondents my contact details so that they could contact me with any questions they might have after the interview had taken place.

EU Vessel monitoring system data and data from the UK logbook fishing activity database used in modelling (Chapter 3) were extracted at the Centre for Environment, Fisheries and Aquaculture Sciences (Cefas). Data extracted at Cefas were completely anonymised before leaving the Cefas building.

I am confident that the data presented in this thesis was collected, analysed and is presented using ethical and rigorous methods.

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Chapter 2

Where shall I fish today?
The trade-offs fishers make between profit, risk and knowledge, and the role of institutions and incentives on fisher decision making

1. Abstract

Fisheries management aims to alter or constrain incentives on where, when and how to fish in order to change fisher behaviour in ways that make it more compatible with resource conservation, sectoral economic efficiency and/or other management goals. Thus understanding the factors shaping fishers incentives and developing the ability to accurately predict fisher response to changing incentives can inform and improve the effectiveness of resource management. This review synthesises and summarises the approaches used to understand fisher decision making in the European fisheries context. I review modelling approaches to understanding location choice behaviour by fishers - important for management because fisheries are increasingly being managed spatially. I also present an argument for using interdisciplinary methods to improve modelling approaches. I then introduce sets of knowledge and theory drawn from disciplines outside fisheries which challenge the key assumption of most models - that fishers operate as rational profit maximisers at all times.

Using alternative bodies of theory can add depth for understanding the complexities of fisher behaviour and the interactions between individual profit maximisation goals, risk, knowledge and the incentives and institutions that shape decisions. Knowledge of the patterns of resource use that result from the aggregate of individual decisions can help not only in the design of effective management and support accurate predictions of resource users' responses to management, but also help to understand industry-wide responses to challenges, threats and opportunities, particularly in the context of an industry where stock decline is leading to a shifting regulatory environment.

2. Introduction

Fisheries are comprised of two basic components; the fish and the fishers that harvest them. There is a disparity between the amount of information known about these two elements and how they are incorporated into fisheries management. Fisheries research and policy actions are dominated by using data on the dynamics of the fish stocks. Yet almost all management action focuses on the fishing fleets that are in pursuit of the fish. The current fisheries management paradigm in Europe assumes that if stock levels are determined, catch and effort levels can be set, and as long as these are controlled the fishery will be managed more successfully (Punt and Hilborn, 1997, Pauly *et al.*, 2002, Baker and Clapham, 2004). However understanding the fishing fleets and their behaviour is equally important to develop the ability to understand and anticipate fisher responses in advance of regulations, and learn how to shape behaviour in ways that promote management goals (Wilen 1979, Hilborn 1985, Hilborn & Walters 1992).

The problem with the current management paradigm and its assumptions relate directly to a lack of understanding of fisher behaviour. First there is the issue of control. This management regime requires strong control to ensure fishers compliance to regulations, which is determined by the economic deterrents of rule breaking (Beddington *et al.*, 2007) but also by whether the imposed regulations are perceived by fishers as legitimate (Raakjaer Neilsen, 2003). Fishers are often creative in finding ways to bypass regulations (Copes, 1986). Control mechanisms almost always result in a less economically efficient fishery (Branch *et al.*, 2006), therefore in response incentives are created for fishers to try to improve their profitability and increase their efficiency through unregulated aspects of the fishery, known as 'effort creep' (i.e., changing the physical inputs of production such as different technologies and the ways these inputs are used to harvest target species) (Marchal *et al.*, 2007).

Second is that management concentrates on how to assess the state of stocks and thus control fishing effort to be in line with how much fish can be harvested sustainably. Fisheries stock assessments used to estimate the status of fish stocks tend to combine readily available data obtained by fisheries such as commercial catch per unit of fishing effort (CPUE) indices. In its most basic form, CPUE is assumed to be linearly related to fish abundance. However, fisher behaviour can influence the commercial catch data used. Time series of fish length and age data are confounded by fishers altering the gear they use to catch fish, where they go to catch fish and species they target. Branch *et al.* (2006) give a full review of how fisher behaviour can influence the interpretation of CPUE data. The authors assert that management action often targets fishing effort but does not constrain fishing power. One of many examples given is that information exchange between vessels can allow fishers to reduce the time searching for fish. If searching decreases and catches also decline, overall CPUE will not change and the assumption of CPUE-fish abundance proportionality is invalid. CPUE is standardised as much as possible (accounting for vessel characteristics, fishing season, and grounds) in stock assessments, and the scientific and modelling techniques have been advanced considerably in their predictive power and ability to deal with uncertainty in complex systems since their origins in surplus production theory (Shaefer, 1954) and single species population models originally developed by Beverton and Holt (1957) more than 50 years ago. However, when a meta-analysis was undertaken to examine CPUE with independent fish surveys, there was evidence of 'hyperstability' (CPUE remains high while stocks were declining) in 70% of cases (Harley *et al.*, 2001). There is also evidence of CPUE 'hyperdepletion' where CPUE declines but does not affect the stock abundance (Fonteneau and Richard, 2003). If this results in further restrictions of effort controls, this undermines the science underpinning management and gives weight to fishers' arguments of lack of legitimacy of regulations. Branch *et al.* (2006) suggest that CPUE data need to account for fisher behavioural changes.

Since the 1950s there has been consistent recognition that successful fisheries management relies on a detailed understanding of fisher behaviour (Gordon, 1953, Hilborn and Walters, 1992, Charles, 1995, Wilen *et al.*, 2002, Hilborn, 2007). Research on fisher behaviour, mainly how and where fishers allocate their fishing effort, has been undertaken by a variety of academic disciplines using various methodologies over the past 30 years including: biological (Hilborn and Walters, 1992, Gillis *et al.*, 1993), economic (Bockstael and Opaluch, 1983, Hutton *et al.*, 2004) and anthropological (Acheson, 1981, McCay, 1981). However, fisheries managers have not had the opportunity to assimilate this information on fishing fleets into policy decision making. Fisheries now has good ecosystem-level integration of economics, ecology and political science but the conspicuously missing element is the integration of the human element; fisher behaviour and application of more individual based approaches as opposed to ecosystem properties and fluxes. The result is a gap in our understanding of fisher incentives in relation to management.

The purpose of this review is to synthesise and summarise research on fisher behaviour. There have been other reviews of fisher behaviour. Branch *et al.* (2006) reviewed the fisheries dynamics and behaviour literature at the fishing fleet scale of emerging, mature and senescent fisheries using a population dynamics approach to review what determines fishing location, quantity of fish caught, investment and response to regulation and enforcement in large commercial fisheries. Salas and Gaertner (2004) reviewed the literature on small scale fisheries, identifying individual fishing tactics and strategies based on social, economic and behavioural dynamics to help understand the human component of small scale fishery systems. This chapter adds to these reviews by providing a review of approaches used to understand fisher behaviour, critiquing the successes and limitations of different approaches, and arguing for research that draws on the most relevant and successful concepts, models and methods from the full range of social sciences. It examines the heterogeneity of individual fisher behaviour and, with recourse to behavioural economic theory, attempts to explain why this occurs.

This review is limited to the approaches used to understand the location choices of fishers for three reasons. The first is that the decision where to fish is central to the success or failure of a fishing enterprise. Second, it is important to understand the spatial behaviour of fishers because fisheries are often and increasingly being managed spatially. Third, an analysis of the spatial behaviour of fishers can help to understand the criteria that underpin fisher decision making and strategies more generally. This review focuses on temperate commercial fisheries with specific reference to the European fisheries because most of the relevant research has been carried out in temperate commercial fisheries and this thesis specifically focuses on a European fishery in the United Kingdom.

The review begins by arguing for the need to understand fisher behaviour in the European fisheries context. It then reviews the modelling approaches that have been undertaken to understand location choice, and the factors that have be revealed to influence location choice behaviour. I present an argument for using interdisciplinary methods to improve modelling approaches. I then introduce sets of knowledge and theory drawn from disciplines outside fisheries which challenge the assumptions of perfect rationality of fishers and homogeneity of fisher decision-making made in modelling approaches, and inter-link these with examples from the relevant fisheries literature. Using alternative bodies of theory can add depth to understanding the complexities of fisher behaviour and the interactions between individual profit maximisation goals, risk, knowledge and the incentives and institutions present.

3. The blind spot in EU fisheries

Since 1983, European fisheries have been managed through the Common Fisheries Policy (CFP). It manages all the member states' marine exclusive economic zones (EEZs) and is now effectively one 25 million km^2 EEZ, the largest single management regime in the North Atlantic. In 2009, the European Commission for Fisheries identified that the current methods underpinning fisheries governance required transformation, and is now looking to reform the

CFP and the way EU fisheries are managed (The Green Paper (European Commission, 2009)). Its goal is to achieve:

> *"…exploitation of living aquatic resources that provides sustainable economic, environmental and social conditions"…*

And states that:

> *"…Economic and social sustainability require productive fish stocks and healthy marine ecosystems. The economic and social viability of fisheries can only result from restoring the productivity of fish stocks. Ecological sustainability is therefore a basic premise for the economic and social future of European fisheries"…*
>
> *…"The MSY* [maximum sustainable yield] *concept was accepted by all Member States at the 2002 World Summit on Sustainable Development as an objective to achieve by 2015. It was also part of the 1995 UN Fish Stocks Agreement. This international commitment should now be enshrined as a principle for stock management in the future CFP " (European Commission, 2009)*.

This series of quotes taken from the Green Paper reveals that there is definitive progress in terms of understanding there is need for reform of EU policy, that EU fisheries need to be considered as an issue of sustainable development, and environmental, economic and social points of view all require action. However, they reveal the same 'blind spot' that Branch et al. (2006) highlighted in North American fisheries policy:

> *"although objectives are to achieve long term health and viability of fisheries, the prescription is to protect marine ecosystems with no words or thoughts of the dynamics of fishing fleets including their economics and behaviour"*

The EU focus is still to achieve maximum sustainable yield of fisheries, perpetuating the accepted wisdom that if you look after the fish, you manage the fishery. Despite references to adopting a more holistic framework for fisheries management using precautionary and ecosystem approaches, management goals that attempt to reduce the fleet and rationalise it lack understanding of the behaviour of fishers, and policy makers seem unsure of how to actually incorporate resource user dynamics:

"while direct references are made to adopting a precautionary and an ecosystem approach, it is not clear how this relates to economic and social conditions. There are no clear indicators and yardsticks that could provide more concrete guidance or to help measure policy achievements" (European Commission, 2009).

A fundamental gap in the CFP reform is the incorporation of knowledge of how fishers will respond and adapt to management actions. Yet it is widely acknowledged that lack of this knowledge of behaviour can be a primary reason for management failure (Hilborn 1985; Hart 2003). Management can alter fisher incentives unpredictably and can result in behaviour that is not intended by managers, even producing negative environmental, economic and social effects (Hilborn *et al.*, 2004, Pascoe and Mardle, 2005). A recent European example epitomises this type of management oversight. In 2001, the North Sea beam trawl fleet were excluded from the 'cod box' (an area of more than 40,000 square miles closed to protect spawning aggregations of cod) for 75 days. Exclusion from their favoured fishing grounds led to a redistribution of beam trawl effort to the west of the closed area to a previously un-fished area, having a long term negative impact on the sea bed productivity macro fauna (Dinmore *et al.*, 2003). *A priori* assessment of the effects of the management measure on the marine ecosystem was not undertaken and the ecosystem effects were considered to have been negative and the closed area unsuccessful. If the response behaviour of fishers could have been predicted through a greater understanding of how vessels select fishing locations, then the negative effects could have been weighed up against the potential management benefits for the target stock. With better understanding of both the pattern and scale of resource use, in addition to the dynamics and productivity of the resource(s), management might not have failed in this instance.

4. What can interdisciplinary research add?

Social approaches (sociology, psychology, social anthropology, political science, geography) have not been embedded into the fisheries management system even though human activities are the study subjects of these disciplines. Non-economist social scientists are conspicuously absent from fisheries decision making processes in EU fisheries despite their potential contributions to understanding fishers, fishing, and the political processes, institutions and incentives that shape the nature of the fishery system (Jentoft, 1998, Hart, 2003). Interdisciplinary approaches to fishery management science have been difficult to institutionalise (Charles, 1995, Jentoft, 2006). There is inertia on the part of the scientists and the institutions because fisheries research has traditionally been the domain of natural scientists (Charles, 1995). Disciplinary boundaries are highly embedded and integration of social sciences requires the merging of entirely different cultures with conflicting views on how the world works (Jentoft, 2006). There are disciplinary boundaries in terms of what the emphasis should be for management solutions, what researchers assume the incentives of fishing practices are, and of course, research methodology differences.

Perhaps because of similar epistemological approaches, economists who use quantitative methods and modelling have fitted more readily into fisheries scientific institutions and collaborations have resulted in the creation and use of quantitative bio-economic models to understand the interactions between the ecology and economics of fishing (Hilborn and Walters, 1992, Grafton *et al.*, 2006, Cunningham, 2008). But the large differences in methodologies between natural and other branches of the social sciences have meant there is reluctance for collaboration. Social complexities of fishing and fisher behaviour are often captured using ethnographic techniques and qualitative data analyses (Firth, 1966, Acheson, 1981, McCay, 1981, McGoodwin, 1990, Jentoft, 2000). Depth of knowledge is provided through qualitative social science methodologies, such as case-study based research, and it is argued that without context-dependant knowledge, one cannot develop an expert understanding of humans and their activities (Flyvbjerg, 2006). Fisheries management is essentially a context-specific activity, with regions and communities fishing within specific stocks and areas. These characteristics lend themselves to social science research, particularly for understanding the dynamics of fisher behaviour. An interdisciplinary or multidisciplinary approach that is achieved by coupling the descriptive and generalisable strength of the natural and economic sciences with the analytical depth of social science methodology, could produce a more holistic and accurate understanding of resource-use dynamics.

5. Location choice behaviour: What do we know so far?

One of the key factors policy makers require in order to know if a policy will meet its objectives, is to understand how fishermen will respond to management in terms of location choice, especially in forecasting where fishing effort will be displaced to in the event of management action (Smith, 2000). Research into understanding and predicting where fishers go to fish has been dominated by modelling and statistical approaches, generalising human behaviour. Models are a key tool in informing fisheries management and are applied to acquire a greater understanding of fishery dynamics over time. They are used by management advisers to evaluate how well the fishery is being managed and how management should be structured in order to deal with uncertainty and unpredictable change. Models are appealing because they provide a structured use of available data for comparing choices, but the limitation is that they require making trade-offs between accurately capturing all the relevant details while still making the model practical and suit the available data. Models "*are mathematical abstractions of non-mathematical processes and there will be uncertainty about whether a given model structure is an appropriate representation of a real system"* (Hill et al., 2007). The individual fisher's action is observed, but the variables that *drive* their choices are limited and cannot be understood using modelling methods, therefore the modeller has to make assumptions about fisher values even though there is no information on what the values are and how they are formed (Smith, 2000). The data used in models may also have reporting bias, for example, fishers may misreport the exact location of fishing success or species caught. Some researchers have been able to overcome this limitation by using data derived from observers at sea (Dorn, 1997, Bertrand *et al.*, 2004, Branch *et al.*, 2005, Murawski *et al.*, 2005). As part of this review, I wanted to investigate the types of modelling methods that have been used to understand location choice behaviour. I reviewed 33 papers that used modelling approaches and examined the resulting factors that influenced location choice of vessels. These are divided into two methodological types. The first type (23 studies) used data derived from fishery databases such as catch and effort data (herein, 'database studies') and a summary of their variables can be found in Table 1. The second type (10 studies) used a more interdisciplinary approach (herein, 'interdisciplinary studies'), using insights from interviews and questionnaires to better classify the dataset and inform the variables used (Table 2). These studies also used the interview and questionnaire data to add qualitative and contextual explanations of the variables and behaviour.

The database studies can be grouped into two main types of model (Table 1): The first group are models based on the concept of utility, which in economics, is defined as the measure of happiness or satisfaction gained from a good, service or activity and rational decision makers are assumed to make decisions based on maximising their utility. The random utility model (RUM) is the most commonly used modelling method and a vibrant literature is emerging aiming to improve the accuracy of these models. The second group of models are based on ecological foraging theory, mainly the Ideal Free Distribution (IFD) (Fretwell and Lucas, 1970) which has commonalities with Gordon's (1954) seminal paper on fishing fleet behaviour. These studies use the null hypothesis that in a fishery, vessels will seek the most profitable fishing grounds and fishing effort will eventually distribute so that profit rates are equal among grounds. This hypothesis has been successful in predicting location choice but the case studies have been relatively simple, with only one or two species caught in a limited number of areas fished by a fairly homogenous fleet of vessels. The RUM overcomes these limitations and is used to characterise more complex multispecies fisheries, such as those in Europe (Hutton *et al.*, 2004, Anderson and Christensen, 2006).

The interdisciplinary studies have attempted to improve models of behaviour by seizing the opportunity of asking fishers what they do and why. Unlike fish, people can explain their behaviour and this information can be used to develop model variables that have the most relevance to the fishery being modelled as long as appropriate and rigorous methods are used for data collection and analysis. One clear example of where interdisciplinary methods lead to more substantiated work is research on the Danish North Sea demersal fisheries (Anderson and Christensen, 2006, Christensen and Raakjaer, 2006). Qualitative in-depth and semi-structured interviews were undertaken with 16 fishers to gain a thorough understanding of each fisher's situation and decision-making processes. Based on this information questionnaires were administered to determine the importance of different factors relating to location choice decisions. These factors were then used to inform the variables for a model of location choice for Danish gill netters. The predictive power of the resulting model was very high (nested random utility model: $R^2 = 0.75$) and the variables were thoroughly explained and contextualised, and conflicting results between the model and interview analyses were identified and discussed. This resulted in a study that was rigorous and contained depth of understanding of location choice behaviour.

I now describe and compare the variables used in database studies with interdisciplinary studies. This review has attempted to review all published location choice studies (See Table 1 and 2 for references). Less than a third of location choice studies reviewed used interdisciplinary methods.   Although each study was undertaken with different objectives and may have concentrated on different aspects of behaviour, this review reveals that using an interdisciplinary methodology can add value to modelling studies. Not only do they provide validation and explanation of variables but variables related to information exchange between vessels are more likely to be revealed (see below). Studies that use only statistical approaches derived from fishery databases uncover a narrower range of variables than interdisciplinary studies. This may be due to the limitations of available data and because of the hypothetico-deductive approach used by statistical and modelling methods, compared to the inductive approach used by interdisciplinary methods and analyses.

Table 1. Summary of database modelling studies variables, split by model type: Random utility models (RUM), Ideal Free Distribution models (IFD) and studies that used various other modelling techniques including variations of general linear models.

Variables affecting location choice	**Number of database studies that found factor significant** (total number of studies: N = 23)		
	RUM (N = 12)	**IFD** (N = 7)	**Other statistical methods** (N = 4)
(a) Profitability of location			
Previous or expected effort, catch or catch revenue at location	**N = 10** (Dorn, 1997, Campbell and Hand, 1999, Mistiaen and Strand, 2000, Smith, 2002, Hutton *et al.*, 2004, Pradhan and Leung, 2004, Strand, 2004, Smith, 2005, Berman, 2007, Valcic, 2009)	**N = 7** (Hilborn and Ledbetter, 1979, Abrahams and Healey, 1990, Gillis *et al.*, 1993, Vignaux, 1996, Rijnsdorp *et al.*, 2000, Swain and Wade, 2003, Powers and Abeare, 2009)	**N = 4** (Lane, 1989, Béné, 1996, Bertrand *et al.*, 2004, Murawski *et al.*, 2005)
(b) Risk-taking behaviour			
Expected variance of revenue at location	**N = 3** (Mistiaen and Strand, 2000, Pradhan and Leung, 2004, Strand, 2004)	**N = 0**	**N = 1** (Béné, 1996)
Distance from port (or fuel cost to location)	**N = 8** (Lane, 1989, Campbell and Hand, 1999, Mistiaen and Strand, 2000, Smith, 2002, Strand, 2004, Smith, 2005, Berman, 2007, Valcic, 2009)	**N = 3** (Hilborn and Ledbetter, 1979, Swain and Wade, 2003, Powers and Abeare, 2009)	**N = 1** (Murawski *et al.*, 2005)
Inertia to change	**N = 1** (Pradhan and Leung, 2004)	**N = 0**	**N = 0**
(c) Knowledge			
Vessel aggregation (presence other vessels at/near location & following behaviour	**N = 3** (Allen and McGlade, 1986, Dorn, 1997, Campbell and Hand, 1999)	**N = 1** (Vignaux, 1996)	**N = 0**
(d) Vessel characteristics			
Vessel age, size, engine power	**N = 2** (Mistiaen and Strand, 2000, Pradhan and Leung, 2004)	**N = 1** (Rijnsdorp *et al.*, 2000)	**N = 1** (Murawski *et al.*, 2005)
(e) Influence of Institutions and incentives			
Remuneration system	**N = 0**	**N = 0**	**N = 1** (Béné, 1996)
Price of fish	**N = 1** (Lane, 1989)	**N = 0**	**N = 0**

Table 2. Summary of modelling studies that used interdisciplinary approaches (using social surveys), and their variables, split by model type: Random utility models (RUM) and studies that used various other modelling techniques.

Factors affecting location choice	Number of interdisciplinary studies that found factor significant (total number of studies: N = 10)	
	RUM + social surveys (N = 8)	**Other statistical methods + social surveys** (N = 2)
(a) Profitability of location		
Previous or expected effort, catch or catch revenue at location	**N = 7** (Eales and Wilen, 1986, Robinson and Pascoe, 1997, Holland and Sutinen, 1999, Curtis and Hicks, 2000, Curtis and McConnell, 2004, Anderson and Christensen, 2006, Smith and Zhang, 2007)	**N = 1** (Durrenberger and Palsson, 1986)
(b) Risk-taking behaviour		
Expected variance of revenue at location	**N = 3** (Holland and Sutinen, 1999, Curtis and Hicks, 2000, Prellezo *et al.*, 2009)	**N = 0**
Distance from port (or fuel cost to location)	**N = 4** (Eales and Wilen, 1986, Anderson and Christensen, 2006, Smith and Zhang, 2007, Prellezo *et al.*, 2009)	**N = 2** (Durrenberger and Palsson, 1986, van Oostenbrugge *et al.*, 2001)
Inertia to change	**N = 2** (Curtis and Hicks, 2000, Prellezo *et al.*, 2009)	**N = 1** (Durrenberger and Palsson, 1986)
(c) Knowledge		
Vessel aggregation (presence other vessels at/near location & following behaviour)	**N = 4** (Holland and Sutinen, 1999, Curtis and Hicks, 2000, Curtis and McConnell, 2004, Anderson and Christensen, 2006)	**N = 1** (Durrenberger and Palsson, 1986)
Information exchange between skippers/vessels	**N = 2** (Curtis and McConnell, 2004, Anderson and Christensen, 2006)	**N = 2** (Durrenberger and Palsson, 1986, van Oostenbrugge *et al.*, 2001)
(d) Vessel characteristics		
Vessel age, size, engine power	**N = 2** (Smith and Zhang, 2007, Prellezo *et al.*, 2009)	**N = 2** (Durrenberger and Palsson, 1986, van Oostenbrugge *et al.*, 2001)
Skipper age	**N = 1** (Smith and Zhang, 2007)	**N = 0**
(e) Influence of Institutions & incentives		
Management constraints	**N = 2** (Smith and Zhang, 2007, Prellezo *et al.*, 2009)	**N = 0**
Price of fish	**N = 1** (Smith and Zhang, 2007)	**N = 0**

5.1. Profit

Studies that used analyses of large databases as their methodology primarily found that the profitability of the location was the most important reason for location choice by fishers - the higher the expected catch, or value of catch, the more likely a location will be selected. There is nothing surprising about this result, given that fishing is an economic activity. Studies that used mixed or interdisciplinary approaches also found profitability to be the most significant decision factor. For simplicity sake I have termed this a 'profitability' variable, but it is measured in almost as many ways as there are studies, and was defined at either the individual vessel level or a fleet-wide level. In general the profitability of a location was measured as the previous catch or catch per unit effort (CPUE); the previous value of catch, value per unit effort (VPUE) or revenue obtained at the location or the relative catch per unit effort to other locations.

5.2. Risk

Variables related to risk-taking behaviour were also commonly found to be significant in influencing location choice in both the database and interdisciplinary studies. There were two commonly-used measures of risk taking behaviour in both methodologies. Variability in returns at a location is used as a measure of risk. In most cases fishermen display risk aversion by deciding to choose sites with less variation in returns. Other fishermen do not avoid areas with high variability, but use other methods to mitigate against risk, such as using knowledge about successful fishing trips rather than average revenue rates or reducing price risk instead by targeting a wide range of species (e.g. Holland and Sutinen, 1999). Distance from port is also used as a measure of risk taking, with fishermen tending to be risk averse and choosing sites closer to port rather than further away. It is not possible to distinguish whether distance from port is a risk variable related to physical danger of being further away from port, or a financial risk variable related to costs of fishing further away in the database studies, whereas studies using interdisciplinary methodology provided this distinction in the discussion of the models.

5.3. Knowledge

The difference between the interdisciplinary and database only methodologies was most apparent when I examined variables related to knowledge. The role of knowledge, and access to knowledge in making decisions about where to fish is more likely to be modelled or analysed using an interdisciplinary approach. Six of the ten interdisciplinary studies considered knowledge as a factor, compared to four out of 23 studies using databases alone. The knowledge variable used in database studies was related to vessel aggregation - vessels fishing close to other vessels could indicate that some vessels follow others movements, and vessels are using where others are fishing as a source of knowledge of good fishing grounds. It could also be considered to be a risk-averse behaviour with vessels preferring 'safety in numbers'. Presence and number of vessels at a location were also considered by interdisciplinary studies. The exchange of information between skippers was only considered by interdisciplinary studies. Interdisciplinary studies were able to identify its importance through interviews and then use suitable proxies for information exchange in their models. Therefore, it appears that using social science methods can help to incorporate knowledge in location choice modelling.

5.4. Vessel characteristics

Vessel characteristics were more likely to be incorporated as variables in interdisciplinary studies, with four out of ten studies using characteristics such as vessel age, size and engine power, compared to four out of 23 database studies. One of the interdisciplinary studies also used skipper age as a variable to measure individual experience which is data that are only likely to be gained through an interview or questionnaire process (Smith and Zhang, 2007).

5.5. Institutions and incentives

Interestingly, the role of institutions and incentives in decision making were considered by very few studies of location choice and the variables vary between studies and across methodologies (three interdisciplinary studies and two database studies). Béné (1996) found that the market constraints and remuneration system of the fishery influenced their location choice using a database study. Similarly, Lane (1989) and Smith and Zhang (2007) found the price of fish was important in deciding what to target and therefore where to fish. Regulations (effort controls and closed areas) were also found to be a constraining factor in two interdisciplinary studies (Smith and Zhang, 2007, Prellezo *et al.*, 2009).

This review of existing literature of location choice behaviour shows that the factors used in models and statistical approaches vary considerably. This is because the variables used are specific to what is being modelled and the aspect of behaviour the authors are trying to understand. What is clear is that the correct specification and use of the model depend on a clear understanding of the behaviour of the fishery, and this can be done by incorporating a social science methodology into research. Using an interdisciplinary mixed methods approach broadens and adds to our understanding of where fishers choose to fish. Simply stated by Durrenberger & Palsson (1986), *"numbers are most useful in the context of ethnographic description" (p 227)*.

6. Towards richer mechanistic understandings of fisher behaviour

> *"…people are not simply rational economic beings, nor are they entirely in harmony with nature, recognising their dependence on the environment's productivity over the long-term. People are social creatures as well." (Iudicello et al., 1999, page 54)*

Neoclassical economic or ecological theory, expressed in static optimisation models such as utility maximisation or the IFD, often fail to predict accurately the spatial distribution of an aggregate group (or fleet) of fishers because the model assumptions are restrictive and over-simplify the decision-making process. However, this is the nature of models. All models are simplifications of reality, and the only way of making them simple enough to use is to make assumptions. However, assumptions need to be explicitly defined by the analyst and taken into consideration when interpreting the results of the model, particularly if they are to be used to inform fisheries policy. The two main assumptions of models of behaviour are that fishers operate with perfect information and perfect economic rationality, and they are homogeneous in the way they make their decisions.

Perfect rationality means that people behave in a way that maximises their utility, and make decisions based on complex deductions in order to achieve their utility – they are capable of thinking through all of the possible outcomes and choose the course of action which will result in the best possible outcome. Assumptions of perfect rationality have been tested through empirical studies of actual behaviour in a wide range of decision-making situations (not restricted to fisheries) and are often contradicted (Dawnay and Shah, 2005, Camerer and Fehr, 2006). For example, Camerer *et al.* (1997) found that New York cab drivers would rather take one day at a time than evaluate choices over many years in relation to their lifetime wealth opportunities – they do not behave in order to maximising their profit, preferring to work shorter hours on busy days and work longer hours on slow days. For fishers, alternative decision theories suggest that decisions may be limited by their risk preferences, the cognitive and situational constraints, and by the institutions (comprising formal constraints such as rules, laws, constitutions, and informal constraints such as norms of behaviour, conventions, self-imposed codes of conduct) and incentive structures they are embedded within.

Models also treat fishers as fixed elements with *"no consideration of individual attitudes based on their operating scales (geographical, ecological, social and economic) and personal goals"* (Salas and Gaertner, 2004). Models assume that fisher goals and knowledge are evenly distributed amongst fishers. They are limited in terms of promoting a deeper understanding of the motives and responses of fishers to the multiple and uncertain changes they face in conducting their fishing operations. The value of applying the IFD theory or economic models to fishers is for the examination of past and current effort allocation, with particular attention to seeking explanations of significant, systematic deviations from standard theoretical expectations. They can be useful starting points for understanding the complex optimisation criteria that determines fisher behaviour. However, deeper understanding of fishers' overarching strategies and the criteria that underpin these is required to predict responses to changing conditions such as management actions or wider environmental influences such as climate change and changes in species abundance and distribution. Béné (1996) defined a fisher's strategy to be *"the set of decision criteria that link a given fishing behaviour with the objective(s) and constraint(s) that have stimulated such behaviour"*. In other words, a long term fishing strategy is the internal decision-making process that is defined by his/her long term objectives as a fisher and the constraints he/she faces. Where a fisher chooses to fish is one of the observable outcomes of this strategy. A fisher's strategy is related to their 'objective function', in other words, what they want to maximise in life. Empirical evidence suggests fishers are heterogeneous in their objective functions. For example, one fisher's objective function may be to make as much money as possible, while another may be to balance time between family and work (Abernethy *et al.*, 2007). In addition, individuals don't necessarily make choices independently of other decision makers (see below). A person's objective function and the interactions they have determine the decisions they make. Thus, when we consider the behaviour of a fleet of vessels, it is necessary to consider that fishers have heterogeneous objective functions, which can lead to heterogeneous decision processes, which can lead to heterogeneous outcomes, such as where to go to fish.

Decision-making that is determined by heterogeneous, complex and shifting optimisation criteria, long-term strategic goals and access to information are the three main challenges to the standard models of location choice. In this section I use alternative behavioural theories and empirical evidence as well as the research in fisher behaviour to provide a comprehensive summary of factors that can influence fisher[1] behaviour beyond what is found in statistical models of location choice. For social and interdisciplinary researchers wanting to understand fisher behaviour this summary may be useful for designing methods for research. Fishers develop different strategies in response to their particular human, social, cultural and economic contexts (Béné, 1996, Allison, 2003). Therefore it is important to consider the trade-

[1] When referring to fisher behaviour, I am primarily talking about skipper behaviour (as opposed to crew) as they are the primary decision makers.

offs against profit-based goals with other objective functions such as well being and consumption satisfaction , risk minimisation, and the constraints of knowledge and ability, competitive or collaborative interactions between fishers, and the institutional and incentive structures present in the fishery.   Drawing upon the existing literature and disciplines outside fisheries science may provide a deeper understanding of fishers' behaviour and how these relate to their fishing decisions.

6.1. Profit

Most formal mathematical models of fisher decision making assume that fishers operate to fulfil individual profit maximisation goals (Pascoe and Mardle, 2005). A direct result of this assumption can be seen in the data-rich location choice models described in Table 1. It is often explicitly stated in these papers that profit-based variables have been selected *a priori* (Campbell and Hand, 1999, Hutton *et al.*, 2004).   While profit will certainly motivate where skippers' choose to fish, it may not be their only motive and it may also be constrained. One study has looked at profit maximisation strategies quantitatively. Christensen & Raakjaer (2006) used interviews and questionnaires to identify three broad strategy types in the Danish demersal fishery and found that less than ten percent of fishers had a strategy based strongly on profit maximisation criteria. They termed this strategy 'pushing the edge', and this smaller section of fishers (8.7% of fishers) owned large boats, had high geographical mobility, they embraced and invested in new technology, fished 24hrs a day, were highly organised and skilful skippers, and were constantly developing new ideas to improve profitability. In comparison, the second fishing strategy was to be risk averse – fishers were minimising costs (47.6% of fishers). These fishers had a family history of fishing and did not want to get into debt like previous generations. They avoided financial risk and accepted lower returns by fishing close to harbour, and could enter and exit the fishery easily through having alternative sources of income. These fishers also placed a high value on leisure time with their family and community. The third strategy was to specialise in one preferred fishing method (43.7% of fishers), despite alternatives to exploit other and potentially more profitable fisheries. They were financially risk averse and careful investors, and depended on a good peer network and a high level of information exchange to catch fish. They tended to either be young fishers who spent a lot of time at sea, or older fishers who valued their leisure time. These other two strategies identified profit maximisation motivation but not to the same extent as the group of 'pushing the edge' fishers and they used different mechanisms to be profitable such as alternative sources of income or specialisation. One can see from this analysis that fishing strategies are highly diverse and many factors contribute to heterogeneity of profit maximisation goals.

6.1.1 Social interactions

The notion that resource users act only to maximise their own self interest is contentious. Hardin's *"tragedy of the commons",* emphasises that open access resources are vulnerable to overexploitation because resource users have no incentive to conserve for the future (Hardin, 1968). This assumption is often a good reflection of open access resources with no societal control, however it is important to distinguish between open access (resources that are not owned by anyone) and common pool resources (resources 'owned' by a group of individuals where access and use is controlled). In a response to Hardin's paper, 'The benefits of the commons' by Berkes et al. (1989), the authors argue and provide evidence that Hardin's model is not always upheld for common pool resources. Individual interest is constrained by institutional arrangements and social pressures can modify behaviour. In other words, because people talk to each other and live within communities, decision making to a degree can be modified by sanctions imposed by social ties and networks. The types of access to resources varies widely between different countries and different fisheries, yet the assumption that resource users are individualistic and rational prevails and underpins fisheries economics.

6.1.2. Satisficing behaviour & wellbeing

Empirical behavioural economics studies have indicated that objective functions are complex, and that pursuit of individual profit maximisation behaviour is traded off with social interactions (Camerer *et al.*, 1997, Dawnay and Shah, 2005, Camerer and Fehr, 2006). Satisficing behaviour is a decision-making strategy that attempts to meet a level of adequacy rather than maximisation. In other words, once a level of need is satisfied, human behaviour is not necessarily motivated by maximising profit alone (Jager *et al.*, 2000, Dawnay and Shah, 2005). In the case of fisheries, fishers may appear to be satisfied with recovering their costs or keeping catch constant. For example, fishers in San Felipe in Mexico have to maintain a catch of 300 kg a month to retain membership in the fishing cooperative, and some concentrate on only meeting this level of catch (Salas 2000 in Salas and Gaertner, 2004). In the Caribbean on the island of Anguilla, a significant proportion of fishers chose to catch lobsters during the day and forgo the higher returns of fishing at night, because they valued their evening leisure time more (Abernethy et al., 2007). This type of satisficing behaviour tends to be more common in small-scale fisheries where lower capital and daily investment is required (Salas and Gaertner, 2004) but has also been observed in larger scale operations where fishing harder and making more money is traded off with leisure time, particularly in older fishers (Christensen and Raakjaer, 2006) (see also Chapter 3). These findings are not contrary to labour economics which include leisure time as a fundamental variable. However, the value of leisure time is not explicitly considered in many fisheries economic models. Other lifestyle considerations such as independence, tradition and community solidarity were emphasised as the objective functions UK inshore fishers sought to maximise, with resulting trade-offs against maximum achievable profits (Allison, 2003).

6.1.3. Rules of thumb

People are often not consistent or coherent in their decision making (Tversky and Kahneman, 1981). Responses under uncertain outcomes can lead to decision-making processes that appear to bypass cognitive deduction and self-maximisation criteria (Dawnay and Shah, 2005). To mitigate lack of knowledge in an uncertain environment, people often use defaults such as habits and 'rules of thumb' (Tversky and Kahneman, 1974, Camerer *et al.*, 1997, Gintis, 2000). Fishers may use simple rules of thumb because the costs of solving complicated optimisation problems are too high. In other words, it is not rational for a fisher to spend a lot of time directly thinking and researching where to fish given all the other tasks he/she may have to do. It may be more 'optimal' for that individual to use simple 'rules of thumb' in the decision making and maximise the time actually fishing. An example of this is Alaskan skippers' choices of where to fish (Gatewood, 1983). Gatewood concluded that it was impossible for skippers to compute an optimal location decision and that skippers tended to follow 'hunches' and then rationalise their decision afterwards. It is also observed that fishers may be habitual, and always choose the same location to fish because of inertia to change (Durrenberger and Palsson, 1986, Curtis and Hicks, 2000, Prellezo *et al.*, 2009).

6.2. Risk

Fishers operate under high levels of uncertainty. For example, there can be uncertainty surrounding where the fish are; the catchability of the fish; what the expected environmental conditions will be during fishing; the fluctuations of the fish market itself; as well as future institutional uncertainties such as changing regulations. Understanding fisher behaviour under uncertainty requires attention to physical risk (to the vessel and crew on board, posed by occupational hazards) and financial risk (variability in returns due to variable fish abundance, fish prices, and regulation change) and the relationship between them. The combination of potential mortality risk and financial risk is said to make fishing a unique profession (Smith and Wilen, 2005) and has led to an assertion by some researchers that all fishers are inherently 'risk-takers' (McGoodwin, 1990). This oversimplifies the economic environment a fisher operates within and ignores potential heterogeneity within a fleet for coping with uncertainty (Smith and Wilen, 2005). In fact, the large uncertainty of income can mean the opposite - that a fisher must have a clear long-term risk strategy for anticipating and coping with risk (Firth, 1966). Similarly Graham and Wiener (1995) at the Harvard Centre for Risk analysis examine risk taking by regulators, and stress that in order to avoid opposing risks (such as physical and financial risks), decision makers need to consider the full set of risk trade-offs to reduce risks. In support of this, in discussions about risks with fishers in southwest England (See Chapter 3), skippers found it difficult to define their attitudes towards physical and financial risk separately, instead they talked about the types of risk trade-offs they made. Spurious conclusions about risk taking or risk aversion may be made if it is presumed that decision makers only consider one form of risk when they are actually managing multiple risks. For example, say fisher behaviour is modelled using a single risk type, there is a possibility that a fisher may have the capacity to offset this risk or understate a fisher's tolerance to risk because another risk is of the same nature rather than in opposition. There are few studies in economics that examine the relationship between financial and physical risk. Using an experimental economics approach, Barsky et al. (1997) found that there was a positive correlation between risk tolerance and undertaking risky behaviours such as smoking and investing in stocks, whereas Slovic's (1972) psychometric research indicated that there was independence between risk tolerance and different behavioural responses according to different types of risk. It has also been shown that there are intercultural differences in risk perception - people from different countries display different perceptions of risk (Sjoberg *et al.*, 2004). Thus there are substantial intercultural and intra-cultural differences in the way people perceive and respond to risks. In the only study of the relationship between physical and financial risks in fisheries, Smith and Wilen (2005) found that there was a correlation between financial and physical risk takers, while the research I undertook in the southwest of England showed that there is not necessarily a relationship between the two types of risk (see Chapter 3). To understand fisher's risk taking behaviour it is necessary to understand that an individual fisher's strategy incorporates tactics to alleviate irreducible uncertainty and they will also have an overarching attitude toward risk which is determined by a person's perceptions of risk - the subjective judgements that people make about the characteristics and severity of a risk.

6.2.1. Risk aversion strategies

Although there is variation, the literature reveals an overall tendency toward risk averse behaviour in commercial fisheries (Eggert and Martinsson, 2004) (see Table 1 and 2). This is consistent with 'prospect theory', which was developed as a psychologically realistic alternative to expected utility theory. It shows that people are more inclined to put more effort into preventing a loss than winning a gain (Kahneman and Tversky, 1979). Profit maximisation behaviour in fisheries is often constrained by financial and physical risk aversion. For example, studies have observed that a significant portion of a fishing fleet will choose to operate close to harbour despite the potential for greater reward at sites further away. This can be for safety reasons (Béné, 1996, Robinson and Pascoe, 1997, van Oostenbrugge *et al.*, 2001, Swain and Wade, 2003), because the cost of fishing further away is too high and returns are uncertain (Hilborn and Ledbetter, 1979), or because of the travel time to market jeopardising the quality of caught fish due to spoiling (van Oostenbrugge et al., 2001). Fishers trade-off the physical risk of fishing against the financial rewards of fishing. However, the trade-offs are heterogeneous within a fleet. Some fishers may choose to take more physical risks because they have a more reliable vessel and experienced crew compared to other fishers, some fishers may take more physical risks because they are under high financial pressure, or other fishers may simply be more risk taking because of their overarching risk preference (Chapter 3) (Smith, 2002, Smith and Wilen, 2005).

A fisher may also trade-off fishing an area of high catch variability with the potential of a windfall, against the financial security of fishing in a known patch with lower catch variability. Fishers have shown risk-averse behaviour choosing lower and consistent returns over higher but more variable returns (McCay, 1981, Bockstael and Opaluch, 1983, Pradhan and Leung, 2004, Abernethy *et al.*, 2007). On the other hand, studies have shown that a portion of fishing fleets are not risk averse, and choose to seek higher returns despite their variability (Holland and Sutinen, 1999, Mistiaen and Strand, 2000, Branch *et al.*, 2006). A clear example of this is the highly threatened Chinese bahaba (*Bahaba taipingensis*) fishery which has declined to 1% of its 1960 population. The bahaba's highly prized and valued swim bladder ($US 20000-64000 per kg in 2000-01) combined with low cost fishing effort incentivises fishermen to target bahaba despite its rarity (Sadovy and Cheung, 2003). It has been suggested that risk-taking behaviour may be related to financial security, with financially secure fishers able to take more financial risks because they have reserves to overcome the shortfall if not successful (van Oostenbrugge *et al.*, 2001, Eggert and Martinsson, 2004). Conversely, risk-taking behaviour has been associated with minimising the likelihood of financial loss. For example a study was carried out on illegal fishing behaviour in the mackerel-rich Norwegian waters. EU vessels caught illegally fishing in the Norwegian zone are subject to fines ranging from £85,000 to £500,000. Hart (1997) found that if the hold of an EU fishing vessel was less than half full by the end of a trip, these fishers were more likely to make up the short fall by risking fishing illegally in Norwegian waters.

It is clear from these studies that fishers' risk preferences and how they make risk trade-offs is very heterogeneous among and within fleets, which can result in very different patterns of behaviour such as location choice. The heterogeneity of risk behaviour appears to be the result of interactions between personality characteristics and risk preferences of the individual fisher, attitudes to uncertainty, individual wealth, and vessel and crew characteristics.

6.2.2. Influence of other fishers

Allen & McGlade (1986) identified two different risk strategies adopted by fishers in the Scotian shelf groundfish fishery, and called them ‘stochasts’ and ‘cartesians’. ‘Stochasts’ are hunters who explore the unknown in search of good catch. They are financial and physical risk- takers, but the rewards are potentially very high. Conversely, ‘cartesians’ are followers, preferring to not take risks and fish where the returns are known even if they are low, or fish where other vessels fish. Following-behaviour in humans is a common social phenomenon that is used to mitigate lack of knowledge. Humans look to others to see how to behave especially if there are ‘experts’ to follow (Cialdini, 1993). A following strategy, where fishers choose to go where others are fishing, has also been observed by many fisheries researchers (Cove, 1973, Vignaux, 1996, Dorn, 1997, Holland and Sutinen, 2000, Ruttan and Tyedmers, 2007). Vignaux (1996) suggests there are three ways that fishers may justify fishing with other vessels and accept lower returns than striking out on their own or exploratory fishing may provide. Firstly, a skipper may choose to fish where other vessels are because it is an indicator of fish location. Secondly, fishing with other vessels minimises the risk that catch will be less than the rest of the fleet. Finally, fishing with other vessels provides a rationale for a location choice. If catch is bad, it can be attributed to ‘bad luck’ rather than poor decision making. There are two other possible reasons for following where others fish. Fishing with others may reduce physical risk because help is at hand if something goes wrong. Following also minimises the computational costs (factoring in variables such as season, weather, tides, costs of distance) of deciding where to go.

Given that there is variation in risk preference, there is also likely to be variation in individual catch rates as a result (Branch et al., 2006). Some skippers repeatedly catch large quantities of fish, often termed ‘highliners’, while other skippers consistently catch lower quantities of fish. Highliners tend to be stochasts - leaders and the innovators in the fishery, usually the first to develop new resources (Allen and McGlade, 1986, Holland and Sutinen, 2000). They also tend to be generalist fishers, with high mobility and flexibility to move between fishery types (Christensen and Raakjaer, 2006). The reason why a skipper chooses one risk strategy over another remains uncertain. It may be simply a factor of a skipper’s personality or financial security. Or, it could be due to the skippers’ ability or knowledge, which can mitigate the risk of being a stochast and/or a highliner.

6.3. Knowledge

Even an overriding profit motive does not mean that a fisher will actually obtain high level of profits on any given trip. Foremost, fishers are trying to extract a resource they cannot see. Fishers may have a good understanding of local fish dynamics through experience or via technology such as fish finders, depth finders and GPS, but they may only have a probabilistic knowledge of the value of the resource at each site (Allen and McGlade, 1986, Robinson and Pascoe, 1997). This is particularly true for fisheries that are mixed species or migratory species, typical of coastal shelf sea fisheries (Holland and Sutinen, 1999). If fishers did have perfect knowledge and if behaviour was solely determined by profit maximising decisions, then (a) fishers would always go to where the fish are, and (b) fishing effort would be expected to be distributed so that average profit will equalise among fishing areas of varying fish densities and among fishers (if fishing ability is controlled for) (Gordon, 1954, Hilborn, 1985) which means they would fit the null hypothesis of the IFD. In empirical cases deviations from the IFD have been due to variation in factors discussed above - attitudes toward personal and financial risk, tradition and inertia to change - as well as lack of perfect knowledge of the resource (Holland and Sutinen 1999; Rjinsdorp et al. 2000; Swain and Wade 2003). The role of knowledge and types of knowledge are now discussed.

Gordon's (1954) economic theory of fisheries assumes that fishers are equal in their acquisition of perfect information and are aware of opportunities to increase profits by changing locations. The difficulties associated with finding fish is assumed away (Wilson, 1990). Profit rates in different areas and the overall economic efficiency of the fishery is reduced when the flow of information between fishers is too low (Allen and McGlade, 1986, Holland and Sutinen, 2000). Given that the ocean is large, complex and often undergoes rapid changes means that no individual fisher can have perfect knowledge, and there is heterogeneity in what different people know. Knowledge such as understanding weather systems and the ecology and behaviour of the environment can reduce uncertainty and bring higher rewards (Allen and McGlade, 1986, Abernethy *et al.*, 2007) and an intimate understanding of market demands and fluctuations can help maximise revenues and reduce economic risks. The role of knowledge of fishers has been researched in terms of the value of fishers' knowledge for understanding ecosystems and fishery dynamics for fisheries management (Berkes *et al.*, 2000, Stead *et al.*, 2006):

> *"When it comes to understanding fish behaviour and the many environmental factors that help determine and predict it, marine biologists must often take a*

back seat. This is hardly surprising. There are hundreds of times as many fishermen today than there are marine biologists, and their forebears were plying their trade and passing on their accumulated knowledge tens of centuries before anyone ever heard of marine biology. What is surprising is how little effort has been made by scientists to search out and record this information" (Johannes, 1978).

Determining the complex role of knowledge, the heterogeneity of individual knowledge and the sharing of knowledge for understanding the complexity of fisher behaviour has primarily been undertaken by anthropologists (Johannes, 1978, Acheson, 1981). Knowledge can be divided into three types that can influence behaviour – public knowledge, knowledge through networks, and individual knowledge. Public knowledge, such as national weather forecasts, or new fishing equipment is knowledge potentially equally accessible to all skippers. Although there can be variation in how/if individual skippers access public knowledge, for understanding the heterogeneity of fishers knowledge and how this relates to behaviour such as location choice, it is more important to consider knowledge through networks and individual knowledge, and this is discussed below.

6.3.1. Knowledge through networks

Knowledge through networks is how fishers gain knowledge through other people. Access to this knowledge may not be available to all and a skipper's strategy will depend on which networks he/she belongs to. Many different strategies of knowledge transfer have been reported both between fisheries and within fisheries (Branch et al., 2006). In some cases, competition precludes information sharing (Cove, 1973, Vignaux, 1996), and can even result in deliberate misleading of other skippers (Durrenberger and Palsson, 1986, Palmer, 1990). However information can still be subversively gained in a number of ways such as finding out what other skippers catch was and where (Durrenberger and Palsson, 1986), or using the location of other boats as an indicator of fish location (Cove, 1973, Dorn, 1997, Little *et al.*, 2004). Alternatively, information sharing and collusion can be beneficial. When information is shared, it is often associated with networks of fishers using similar fishing methods, close kin ties and long-standing relationships, and requires reciprocity (Gatewood, 1984a, Palmer, 1991, Crona and Bodin, 2006). This is in line with psychologists and sociologists who argue that individuals are most influenced by others who they have frequent interactions with (Cooley, 1909, Festinger *et al.*, 1950, Homans, 1950, Kadushin, 1966). Therefore it should not be assumed that knowledge acquisition is uniform among a fishing fleet. Social network analysis is a method used to map the patterns of information exchange and has been applied empirically to uncover the knowledge interactions between groups of fishers in fishing communities (Wasserman and Faust, 1994, Scott, 2000, Crona and Bodin, 2006).

Lake Malawi is a particular case where information sharing makes more sense than competition. Artisanal fishers concentrate their fish landings in one place and make the landing location known to others in the fishery. This means that buyers congregate at one landing site and compete for supply, which is good for the prices fishers' receive for their goods. The alternative of keeping location and landing site a secret is that a fisher may arrive at a landing site with a large catch of fish and there are few or even no buyers, and bargaining power on price is drastically reduced. In this fishery there is also a limited range of fishing craft which has the effect of concentrating fishing in one place. Therefore in this case, group location choice is driven by shared information on fishing location and market location (Allison and Mvula, 2002). Thus, it is important to understand the types of knowledge and how knowledge is shared between different groups because this can have implications for fisher location choice and the distribution and concentration of fishing effort.

6.3.2. Individual skipper knowledge and ability

There has been considerable and lively debate surrounding whether some skippers are more skilled at catching fish than others since the 1980s. Anthropologists, interested in folk models and associated ideologies of individuality, embodied knowledge and 'luck', conducted most of the early research and referred to skipper skill as the 'skipper effect'. Now economists and fisheries scientists have entered the discussion as there are potential ramifications of differential skipper ability for fisheries management strategies such as vessel buy-back schemes. Vessel buy-backs are a common management tool for reducing fishing effort in the fishery where the governing body buy out skippers' vessels, reducing the number of fishing boats. However, vessel buy-backs have been shown to be both expensive and ineffective at removing total effort because they remove only the least efficient vessels leading to increased competition and effort among the remaining successful vessels who may invest in better technology. Thus, the effort removed often seeps back into the system which can necessitate another round of buy-backs (Clark *et al.*, 2005, Hentrich and Salomon, 2006). At an extreme, Hilborn (1985) argues that if the skipper effect exists and the aim is to reduce fishing effort, then buybacks should not aim to reduce the number of boats randomly, but remove the most successful skippers. However, if sectoral efficiency and net economic contribution of fisheries is the goal of fisheries policy (e.g., wealth-based fishery management, which puts resource rent at the heart of the management process (Cunningham and Neiland, 2005)), then the most successful and efficient vessels should be encouraged.

Attempts to measure the skipper effect has yielded mixed results. This has been primarily due to confusion of the definition of skipper ability as well as the choice of research approach. Early papers did not attempt to define skipper ability. Instead, researchers assumed skipper ability to be the portion of unexplained variance in catch that could not be attributed to vessel characteristics or effort. One of the first authors to explore this notion was Acheson (1977 in 1981) who found that 39% of the variance in the Maine lobster fishery was unexplained by physical factors, effort or education. Technical efficiency[2] could explain 35% of catch variance in English Channel demersal trawlers, but 65% remained unexplained and was attributed to skipper/crew skill and education (Pascoe and Coglan, 2002). Conversely, Palsson & Durrenberger (1982, 1983, 1984) found little evidence of the skipper effect in Icelandic cod fishers. They found that vessel size and number of trips were better predictors of catch. However a second study repeating the analyses, and using independently collected data in the same region, found unexplained variance for large (63%) and small vessels (25%) (Bjarnason & Thorlindsson, 1993). They also found that a few skippers did consistently well over several consecutive years. In response, Palsson & Durrenberger (1990) accepted that the skipper effect may exist, but it is less important than cultural tradition and folk ideologies suggest, and that the impact of the skipper effect can depend on the society. In some societies differences in success may be better explained by technical factors. However, it has also been contended that technical advantages such as vessel size could be a proxy for skipper skill, with better fishers making more money that can be then invested into larger and better boats (Gatewood, 1984b).

The debate has turned more recently to trying to determine what the causes for differences in catch rates. Once again, there is no clear answer. Higher education level has been found to be a factor explaining increased technical efficiency in commercial fisheries (Kirkley *et al.*, 1998, Almeida *et al.*, 2003, Esmaeili, 2006). Experience and family history of fishing has also been attributed to increased technical efficiency (Pascoe and Coglan, 2002, Esmaeili, 2006). Interestingly, Tingley et al. (2005) found that the value of experience and education was dependent on the type of gear. For mobile gear fishers, technical efficiency increased with education and family history, and decreased with experience. For stationary gear, technical

[2] Technical efficiency measures the ability of vessels to maximise output using a given set of inputs. In this case, (Pascoe and Coglan, 2002) incorporated number of crew, ratio of crew to boat size, ratio of engine to boat size, boat age, a measure of specialisation, a measure o experience in the fishery, and gear type.

efficiency increased with experience, but was negatively influenced by age and formal education. In another study, two skippers who had the same type of vessel, same gear and targeted the same species, were the same age, with the same experience, education, and family history were compared. One skipper was consistently more successful than the other (Kirkley et al., 1998). Deeper reasons for differences in ability are required to understand the 'skipper effect'. It may be that some skippers are better managers (Kirkley *et al.*, 1998), or perhaps some skippers have better access to information about fish stocks (Christensen and Raakjaer, 2006). It could also be a case of success breeding success: if a skipper is successful, then this attracts a good crew and with little turnover, thus increasing the chances of success (Abernethy *et al.*, 2010).

Understanding the heterogeneity of skippers in terms of their knowledge and skill may mean that fishers could be categorised into different groups and their fishing effort and locations could be more accurately predicted than if it is assumed that all skippers/vessels are equal in their knowledge capacity (see Chapter 3 for empirical study of categorisation based partly on knowledge).

6.4. Institutions and incentives

6.4.1. Management

Fisheries management tends to be focussed on the status of the stocks and how to control fishing effort and there is a wide variety of systems designed to do this. Management regimes that regulate access to fisheries are increasing in interest and use, such as marine protected areas (MPAs) and individual transferable quotas (ITQs). The system of management of a fishery can alter efficiency, incentives and therefore constrain and alter fisher behaviour (See Branch *et al.*, 2006 for detailed review, Prellezo *et al.*, 2009). Table 3 provides a summary of potential fisher behavioural responses to different management regimes.

Table 3. Examples of different fisheries management systems and possible fisher behavioural responses observed empirically.

Management system	Fisher behavioural responses	Empirical example
Marine protected areas	Redistributes fishing effort	(Hiddink *et al.*, 2006)
Season length restrictions	Switch from being generalist fisher to specialist fishers, causing market glut and reducing fish prices. Lowered profitability can change fisher behaviour - fishers may increase the risks they take, operating in bad weather	(Pautzke and Oliver, 1997) (Chapter 5)
Vessel and gear restrictions	Switching gear types because of reduced economic efficiency, investing in unregulated inputs.	(Wilen, 1979, Metzner and Ward, 2002)
Total allowable catch and quota	Strategies may change throughout the year as yearly quotas are used up. Fishers may concentrate their fishing effort for a particular species at the start of a season, or decide to wait and target the species when prices are higher. Illegal fishing and misreporting Increased high grading and discards	(Copes, 1986, Revill *et al.*, 2007)
Individual transferable quotas	ITQs provide flexibility to the fisher in terms of when and where to fish. Instead of capital and resources being spent on maximising the volume of catch, strategies may shift to improving the quality of fish caught and increasing the diversity of fish species caught	(Grafton *et al.*, 2006)

6.4.2. Vessel ownership

The ownership structure of the boats in a fishery may impact upon individual fisher strategies. Skippers may own their own boats or work for a firm and differential risk to investment could alter the motivation and incentives for fishing among owner-operators and contract-skippers. For example, non-owner skippers do not need to incorporate decisions about whether to update equipment into their strategy (Mardle and Hutton, 2005) or devote time to market considerations (see Chapter 3). Unlike economic research in agricultural systems (Acharya and Ekelund, 1998), there have been few fisheries studies that have examined the role of ownership in influencing strategies and output - and the results of these few studies have been highly variable. There may be no difference in overall catch and effort by owner-skippered and non-owner-skippered boats (Durrenberger and Palsson, 1986), skipper owners may be more efficient than non-owner skippers (Sharma and Leung, 1999, Esmaeili, 2006, Abernethy *et al.*, 2010), or non-owner skippers may have higher output than skipper owners (Kirkley et al., 2003).

In political science and economics, the principal-agent model provides insights and explains the dynamics underlying the strategies of different types of organisation, or hierarchies which could be applied to skippers in a given fishing operation. The principal-agent setting is the relationship between the principal (e.g. owner of the vessel) and the agent (skipper who works for the principal). Various mechanisms and incentives may be used to try to align the interests of the agent with those of the principal and thus alter observed behaviour. A common mechanism used in fisheries is profit-sharing, where the skipper and crew are paid a share of the revenue of the catch. Stiglitz (1974) explains sharing outputs as an institution to share risks and provide incentives in situations where the monitoring of worker input is costly. Profit-sharing is used in both systems of skipper- and company-owned vessels and the specifics of the profit-sharing arrangement will influence overall strategies of skippers and effectiveness of the crew. For example, when company-owned vessels have a higher output than skipper-owned vessels (Kirkley et al., 2003), it may be due to appropriate share incentives for skippers and crew, alongside financial security that the skipper-owners do not have. On the other hand, the system provided by company-owned vessels may not induce a skipper strategy of highest possible returns. For example, skippers of the Newfoundland offshore fishery were found not to be motivated by gaining the highest catch, but by being the 'best skipper', even though they are paid on a share system. *'I don't really care how much I catch as long as it is 50 more than the next guy"* (Cove, 1973, p254). In this case, skipper jobs were competitive and scarce and by being the 'best' skipper, one gained job security and crew stability (Cove, 1973). Thus the ownership structure and sharing system can alter motivations of fishers and can influence strategies and behaviour.

6.4.3. Market structure of the fishery

Fisher behaviour will also be influenced by the market structure of the fishery – how the fishery is organised in terms of vessels number and the number of owners. Economic theory suggests that in a perfectly competitive market, there should be many firms, any one of which has too small a market share to influence the price of the good. Markets that are dominated by a few firms (oligopoly), two firms (duopoly), or one firm (monopoly) are less competitive (in that order). For example, the system of management can alter the number of participants, alter its competitive nature, and therefore alter fishing decision-making strategies. A widespread observation of the individual transferable quota (ITQ) system is that incentives are redirected away from secretive and competitive behaviour, and towards cooperation in joint ventures (Pearse and Walters, 1992). This inevitably results in harvesting rights concentrated among a few operators, an oligopoly market structure (Grafton, 1996). This has been observed in New Zealand which has a comprehensive ITQ system of fisheries management. In this case, there has been a reduction in the number of firms, most acute in fisheries that originally had a wide range of vessels and gears (Stewart and Callagher, 2003, Newell *et al.*, 2002). This has been at the cost of social equity, and an erosion of the family-based units, and an increase in ecologically damaging practices such as discarding marketable fish when new catches bring individuals of higher value (high-grading) (Symes and Crean, 1995).

6.4.4. Market for fish

The market for fish and the influence of fish prices and buying companies can determine decision making strategies (see Chapters 5 and 6). The market price of fish can fluctuate, which can influence target species choice (Béné, 1996, Holland and Sutinen, 1999), and can have knock on effects for location choices at sea (Lane, 1989, Dupont, 1993, Abernethy *et al.*, 2010). Market price can also influence the fishing method used which may change patterns of effort. For example, adding value to seafood products through differentiation such as premium and eco-friendly products can command higher prices at market (Babcock and Weninger, 2004, Revill *et al.*, 2007, Nautilus Consultants Ltd, 2008). This creates incentives for fishers to pursue these opportunities given there are appropriate interventions in the market chain creating consumer demand (e.g. via certification schemes).

The institutional set up of the market can also influence fisher behaviour. Even though all fish markets operate slightly differently, they tend to be auction markets in Europe. The price received at market is generally dependant on the amount of fish being sold on a given day. When supply is low, or there is high demand, buyers compete harder with each other and prices are likely to be higher. Therefore, the fish buyers have the price-setting power, which in turn can impact fishers choice of species to target, choice of location and time to land (Abernethy *et al.*, 2010). The more competition there is between buyers, the better fish prices tend to be, and the less power fish buyers have. The price setting power of buyers can be challenged and altered via fishermen's marketing cooperatives (Kitts and Edwards, 2003).

Altering the structure of supply chains may influence the spatial distribution of fishing. The supply chain and consumer demand determines the relative value of different seafood products. In the UK, different fish markets specialise in different species that are caught in the region. This can result in price differentials between ports for the same species and vessels choose to land at ports with higher prices, forcing a concentration of landings at fewer ports (see Chapters 3 and 6). If vessels adapt their fishing to target different species and sell at different markets in response to market forces, then this changes where they fish and where they fish from. Economic geography looks at the organisation of the spatial patterns of production. In other words, the location choice of firms not just in pure economic terms, but through an understanding of economics related to location choice in space (Lloyd and Dicken, 1977). They use formal mathematical models of location and are particularly interested in clustering of firms, which may be useful for understanding vessel responses to market forces. There is more literature that is theoretical than empirical, but empirical research does support the theory with industry level agglomeration benefits playing an important role in location decisions (Head *et al.*, 1995). Economic geographers try to link location choices to the geography of demand and also of supply. The goal of economic geography is to talk simultaneously about the centripedal forces that pull economic activity together and centrifugal forces that push it apart (Fujita and Krugman, 2004) and how the geographical structure of an economy is shaped by the tension between these forces. Key to this approach is the recognition that the attractiveness of any location for production (for fisheries, the fish market) is represented by an index of market potential derived from underlying economics and it is the market potential that drives location choice. This body of theory may be of use for predicting where vessels will concentrate to sell their goods and therefore where they will fish.

6.5. Can greater understanding of fisher behaviour be useful for management?

In the previous sections, the literature on the factors that influence human and fisher behaviour has been comprehensively reviewed. There are an enormous number of factors that need to be considered in order to completely understand the heterogeneity and complexity of fisher behaviour, and a number of theories from disciplines outside fisheries that can contribute and frame our understanding. The value of this review is primarily for fisheries scientists who want to understand fisher strategies and want to know the factors to be aware of when designing methods for research. In this section a framework is presented for how understanding fisher strategies and behaviour fit into the wider picture of fisheries management.

Based on Raakjaer Neilsen's (2003) framework for understanding compliance and legitimacy in fisheries management, the costs of fisheries management are examined. They are made up of information costs, decision making costs and monitoring, control and enforcement costs[3] (Figure 1.).

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[3] Operational costs - the costs of undertaking fishing activities, the cost effectiveness of the fishing operation in relation to CPUE, price optimisation and side effects (such as socio-economic, bycatch, high grading, discards etc) of the management system in lace – are not included in this summary. See Raakjaer Neilson (2003) for details.

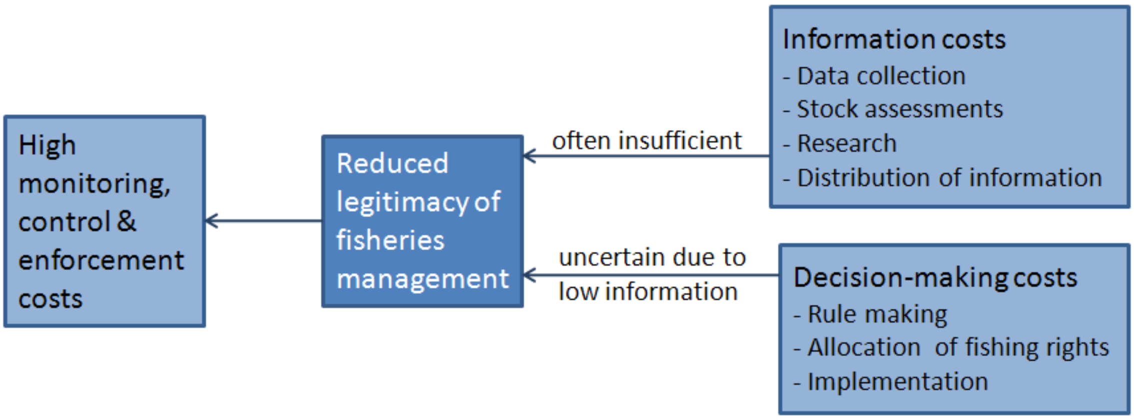

Figure 1. The relationship between costs of management and legitimacy of management information is critical for fisheries management and is the main determinant of the total costs of management. There is often insufficient information, which increases the uncertainty of the decisions made for management action, which reduces the legitimacy of management for fishers. This increases the costs of monitoring, control and enforcement required to prevent non compliance by fishers.

The cost of fisheries management may be reduced if information on the strategies of fishers is incorporated (Figure 2). In order to understand strategies, the trade-offs between profit, risk and knowledge need to determined as well as the constraints placed by the institutions and incentives present in the fishery. Incorporating information on strategies may alleviate fishers' legitimacy concerns and improve compliance because management will be better informed about how fishers are likely to respond to management action. Furthermore, understanding fishers' strategies may help to understand a fishing communities ability to adapt to uncertain and changing conditions (Chapter 3).

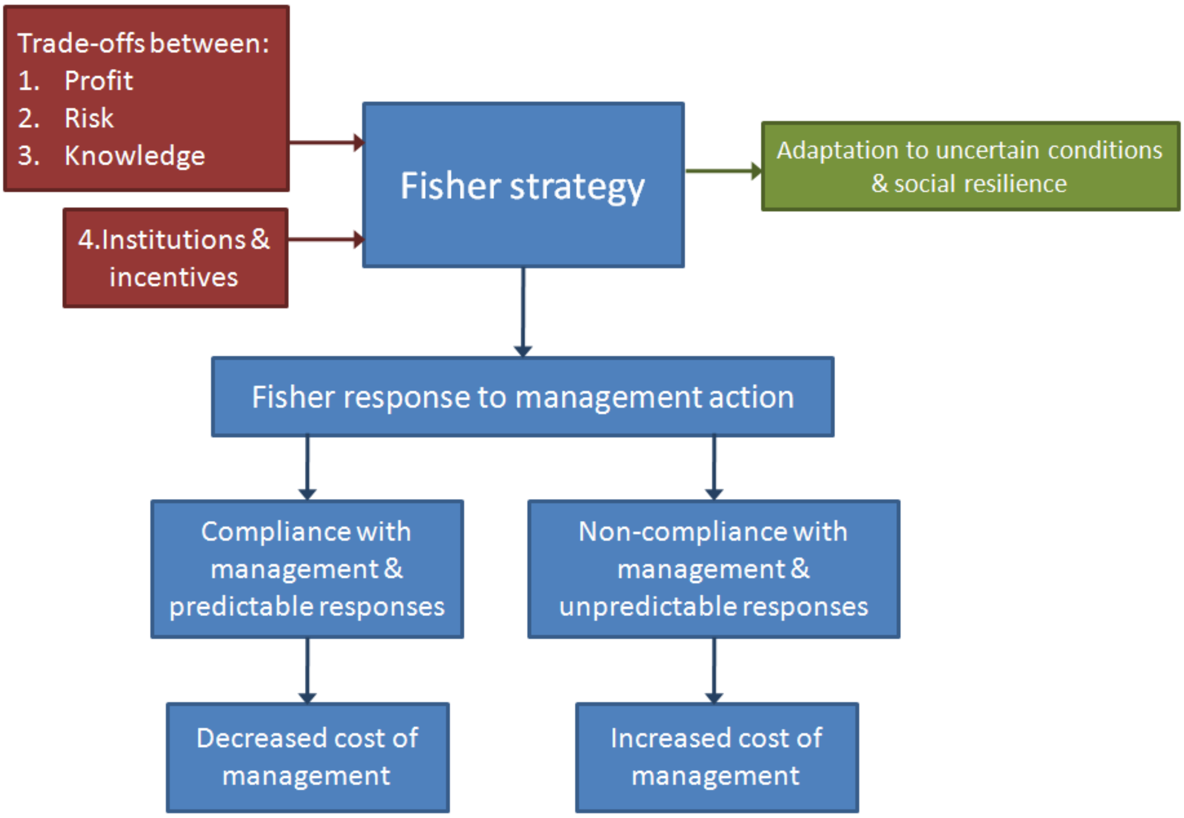

Figure 2. The role of incorporating fisher strategies for compliance and cost of management; and adaptation to uncertain and changing conditions. Understanding fisher strategies include knowledge of the tradeoffs between profit, risk, knowledge and the institutions and incentives present.

7. Conclusion

This review has highlighted the consequences of not incorporating fisher behaviour in the management of fisheries. It has also shown there is a wealth of theory from a number of disciplines and empirical evidence from which to improve research into fisher behaviour. In order to understand the heterogeneity of fisher behaviour, social approaches are required. However, these approaches need to fit and compliment current fisheries research and management goals. Therefore, interdisciplinary research which can use social approaches to uncover different fisher strategies and then incorporate these into approaches that are practical for fisheries policy makers to use, such as models that predict location choice in response to management actions, seems to be the most appropriate methodology.

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Chapter 3

Fishers' strategic behaviour in southwest England

1. Abstract

Fisheries managers recognise that there is a fundamental need to understand fisher behaviour to design appropriate incentives and disincentives. Policy often does not account for possible fisher behaviour in reaction to changes in fishery regulations, and policy frequently treats fishers as a homogeneous group without consideration of the heterogeneous strategies that underpin fisher decision-making within their particular individual, social, and economic contexts.

This study aims to gain insights into the strategic behaviours of fishers. A case study approach is used, and a new framework for analysis is developed, drawing on the strategic management literature and specifically the Miles and Snow (1978) typology. The framework enabled integration of both fishers' strategic choices and their individual characteristics to explain why fishermen fish where they do, choices made in how they fish, and what factors explain why some fishers continue to exist while others don't. Fishers are classified into four strategic archetypes – Prospectors, Defenders, Analysers and Reactors – for the fishery in the southwest of England based on a qualitative methodology using content analysis of in-depth interview transcripts. The implications of understanding the strategic archetypes of fishers are discussed for predicting the efficacy of different management regimes with a focus on policy directed at fleet capacity management.

This study is exploratory and results are preliminary but this approach encompasses previous and current thinking on fisher strategies and may be useful for overcoming existing disciplinary boundaries to enable a wider integration of fisher behaviour with fisheries management.

2. Introduction

Fishers are hunters, searching for prey they cannot see. Fishing is an economic activity but is also a deeply embedded social activity (McCay, 1981, Jentoft, 2000). To be effective, a fisher needs to make decisions based on experience and knowledge of the distribution of resources and potential competitors, against a backdrop of opportunities, constraints and hazards that shape their choice of where, when and how to fish. Fisheries management seeks to influence opportunities and impose constraints on fishing activity through the use of incentives that aim to change fisher behaviour in ways that make it more compatible with resource conservation, sectoral economic efficiency and/or other fishery management and biodiversity conservation goals. Thus, understanding the factors shaping fishers behaviour and developing the ability to accurately predict fisher response to changing incentives can inform and improve the effectiveness of resource management.

Although fisheries management advisors recognise that there is a fundamental need to understand fisher behaviour to design appropriate incentives (Hilborn, 2007), EU fisheries policy, for example, does not account for possible fisher behaviour in reaction to changes in legislation, price or stock availability, or fishery regulations – including the widespread revisions suggested to EU fisheries policy in 2002. Policy frequently treats fishers as fixed elements with *“no consideration of individual attitudes based on their operating scales (geographical, ecological, social and economic) and personal goals”* (Salas and Gaertner, 2004). Studying the strategic behaviour of fishers can help build resilience to and mitigate against the failure of fishery management policy by informing policy makers of the heterogeneous strategies that underpin fisher decision-making within their particular individual, social, and economic contexts. Although this adds a layer of complexity to designing fisheries management policy, without this understanding, fishery management initiatives such as closed area, have been shown to fail (Rijnsdorp *et al.*, 2001, Dinmore *et al.*, 2003). Understanding existing institutional frameworks can pay dividend in terms of increased compliance and reduced enforcement costs. The key is to design a means of predicting fisher behaviour that will encompass enough of the complexity and heterogeneity of their behaviour while also yielding user-friendly outputs to make inclusion practical for policy design.

Research has been undertaken to attempt to define the fishing strategies which drive fishing tactics such as location choice. This research was conducted to challenge the relevance of assuming that all fishers are homogeneous in their pursuit of optimal efficiency or profit. Allen & McGlade (1986) identified two different strategies adopted by fishers in the Scotian shelf groundfish fishery, and called them 'stochasts' and 'cartesians'. 'Stochasts' are hunters who explore the unknown in search of good catch. There are financial and physical risks but fishers take the risk as they believe the rewards are sufficiently high to compensate. Conversely, 'cartesians' are followers, and are risk averse. They fish where the returns are known even if they are low, and typically follow other fishing vessels. Following-behaviour in humans is a common social phenomenon that is used to mitigate lack of knowledge. Humans look to others to see how to behave especially if there are 'experts' to follow (Cialdini, 1993). This behaviour has been observed by many fisheries researchers (Cove, 1973, Vignaux, 1996, Dorn, 1997, Holland and Sutinen, 2000, Ruttan and Tyedmers, 2007).

Other researchers have classified fishers into conceptually similar categories. Since the 19th century skippers who repeatedly catch large quantities of fish are called 'highliners'. Highliners tend to be leaders and the innovators in the fishery, usually the first to develop new resources (Allen and McGlade, 1986, Holland and Sutinen, 2000). Holland and Sutinen (2000) provide evidence that the type of strategy a fisher follows can predict a fisher's location choice. They use income as a proxy to define highliners. Those earning in the top 20% of the fleet's income distribution by vessel are classified as highliners. By including a highliner strategy dummy variable in their model they found that highliners were more likely than other fishers to try new locations and suggested these individuals may be more informed than other fishers. In contrast, others have observed that some fishers are habitual, and always choose the same location to fish because of inertia to change (Durrenberger and Palsson, 1986, Curtis and Hicks, 2000, Prellezo *et al.*, 2009).

Since the 1980s, there has been considerable and lively debate surrounding whether some skippers can be categorised as being more skilled at catching fish than others. Anthropologists, interested in folk models and associated ideologies of individuality (e.g. embodied knowledge and 'luck') conducted most of the early research and referred to skipper skill as the 'skipper effect'. One of the first authors to explore this notion was Acheson (1977 in 1981) who found that 39% of the variance in the Maine lobster fishery catch was unexplained by physical factors, effort or education and concluded that there was a 'skipper effect'. Conversely, Palsson & Durrenberger (1982, 1983, 1984) found little evidence of the skipper effect in Icelandic cod fishers and observed that vessel size and number of trips were better predictors of catch. However, it has also been suggested there is a relationship between the skipper effect and characteristics of vessels and that the technical advantage associated with vessel size could be a proxy for skipper skill; i.e., that better fishers have the resources to invest in larger and more technologically advanced boats (Gatewood, 1984).

Christensen & Raakjaer (2006) qualitatively identified three broad strategy-types in the Danish demersal fishery using interviews and questionnaires. The first fishing strategy was risk aversion – fishers were minimising costs (47.6% of fishers). These fishers had a family history of fishing and did not want to get into debt like previous generations. They avoided financial risk by fishing close to harbour, were flexible in terms of their target species and gear used, and could enter and exit the fishery easily through having alternative sources of income. These fishers also placed a high value on leisure time with their family and community. The second strategy was to specialise in one preferred fishing method (43.7% of fishers). These fishers were highly mobile and could easily move to better fishing grounds. They were financially risk averse and careful investors, and depended on a good peer network and a high level of information exchange. They tended to either be young fishers who spent a lot of time at sea, or older fishers who valued their leisure time. The third strategy was called 'pushing the edge', and this smaller section of fishers was defined as profit-maximisers (8.7% of fishers). They owned large boats and had high geographical mobility, they embraced and invested in new technology, fished 24 hours a day, were highly organised and skilful skippers, and were constantly developing new ideas to improve profitability.

In thinking how to move beyond the phenomenological or idiosyncratic contradictions in interpretation of fisher behaviour in the fisheries literature, it is useful to look to disciplines outside fisheries research which explain human behaviour and identify strategy types. In non-fishery contexts, empirical studies of human behaviour have tended to test assumptions of homogeneity of behaviour and perfect rationality (Dawnay and Shah, 2005, Camerer and Fehr, 2006). These alternative decision theories suggest that fisher strategies may develop in response to their particular human, social, cultural and economic contexts (See Chapter 2 for detailed discussion). This includes: trade-offs against profit-based goals with other objectives such as well being, consumption satisfaction and risk minimisation; the constraints of knowledge and ability; competitive or collaborative interactions; and the institutional (comprising formal constraints such as rules, laws, constitutions, and informal constraints such as norms of behaviour, conventions, self-imposed codes of conduct) and incentive structures regulation imposes (Durrenberger and Palsson, 1986, Béné, 1996, Robinson and Pascoe, 1997, van Oostenbrugge *et al.*, 2001, Allison, 2003, Branch *et al.*, 2006).

This study aims to gain insights into the strategic behaviour of fishers. I use a case study approach, and develop a new framework for analysis and identification of the strategic choices of fishers and their individual characteristics. It is argued that without context-dependant knowledge, one cannot develop an expert understanding of human behaviour (Flyvbjerg, 2006). Without this knowledge it is difficult to develop policies aimed at changing that behaviour. Therefore this study may provide some guidance for fisheries management that accounts for fishers' behaviour and specifically the diversity in behaviour and strategies. In order to gain understanding of fisher strategies, qualitative data were gathered primarily using repeated in-depth interviews with fishers in southwest England. To define fishers into robust easily-communicable strategy types I looked outside fisheries research to a widely-used framework developed in the strategic management literature to analyse and interpret our data. This framework has been examining and empirically defining the strategic typologies of firms in a number of industries for over 30 years. Our rationale is that the robustness of this approach has been forged through repeated application and refinement to encompass a wide array of human endeavours. Strategic behaviour is defined in this literature as behaviour directed towards managing environment risks and matching organisational capabilities with the opportunities offered by the environment (Hofer and Schendel, 1978). The framework presented is straightforward and hence easy to communicate, provides quantifiable results, is applicable to fishers and can provide insights into the strategic behaviour in different fisheries contexts. While the study is exploratory and results preliminary this approach may develop current thinking on fisher strategies and may be useful for overcoming the disciplinary boundaries that exist to integrating fisher behaviour with fisheries management (Charles, 1995, Jentoft, 2006).

2.1. A strategic management perspective to understanding fishers' strategic choices

The fisheries literature recognises that fishers adopt different strategies and that these strategies are influenced by individual fisher attributes. However, the existing attempts to understand fisher behaviour have used a range of conceptual starting points and provide highly context-specific results (see Chapter 2). In addition, efforts to define broad fishing strategies have been limited to a small number of studies and therefore guidance for policy makers to effectively integrate fisher behaviour into management design has not been clear. In this study a new framework for analysing fishers strategic behaviour that will facilitate comparison to the diversity of behaviour employed in other industries and businesses is proposed. The strategic management literature provides such a framework. Fishers run a small business and make a number of strategic choices that influence the viability of their business. The management literature is similarly interested in the strategic choices firms make in relation to the product-market domain; technology and scale of operation; structure and processes associated with their operations. The strategic management literature is interesting in understanding which configuration of choices will achieve optimal outcomes for the firm in order to inform practice. I draw on this literature to develop a framework for understanding fishers' strategic behaviour. I combine the individual characteristics of fishers, identified in the fishers' behaviour literature and also in the management psychology literature, into this framework.

The strategic management literature uses a number of typologies to classify firms' strategic choices (Miles and Snow, 1978, Porter, 1980). I draw on the Miles and Snow typology to examine fishers' strategic behaviour for several reasons. First, it continues to be widely used to classify large and small firms' strategic position (Miller and Toulouse, 1986a, Covin and Slevin, 1989, Borch *et al.*, 1999, Hambrick, 2003) and subjected to considerable psychometric assessment (Snow and Hrebiniak, 1980, Hambrick, 1983, Shortell and Zajac, 1990). Second, it is a typology that captures the three broad problems and solutions faced by small and large firms in any industry including fishing firms: (1) the entrepreneurial problem; (2) the engineering problem; (3) the administrative problem. Third, researchers have used both quantitative and qualitative methods to operationalise the typology. I thus use this typology as an integral part of the framework for analysing rich qualitative data collected from fishers to provide findings that have the potential to inform policy on fishery management.

Miles and Snow (1978) identify three viable strategic archetypes – Prospectors, Defenders and Analysers, and one non-viable strategic type - Reactors. Each type has its own unique strategy for relating to its chosen market(s), and each has a particular configuration of technology and administrative processes that are consistent with its market strategy.

- Prospectors are firms which continually search for market opportunities, regularly experiment with emerging trends, are the creators of change and are at the forefront of new technologies.
- Defenders seek to create a stable domain, producing a limited set of products and organise themselves to be highly expert in their domain and do not search for new opportunities.
- Analysers are a combination of Prospector and Defender, on the one hand have a stable strategy and particular products they have expertise in, while also watching their competitors including Prospectors, and follow change, after observing the success of others
- A fourth type of organisation is called the Reactor; a form of strategic 'failure' in that it is unstable, and inconsistencies exist amongst its strategy, technology, structure and process (for a full description of strategy types by Miles and Snow, see Appendix 1).

These typologies have some similarities with those used in the fishers' behaviour literature. For example, 'stochasts', 'highliners' and the 'pushing the edge' strategy are conceptually similar to what Porter (1980) would classify as a 'differentiation' strategy; or what Miles and Snow (1978) would classify as a 'Prospector' strategy. The 'cartesians' are similar to the Miles and Snow 'defender' strategy.

This study captured data on three strategic qualities of fishers identified in the management literature and applied in the fisheries context, namely dynamism, innovation, and adaptability. Dynamism relates to a fisher's short term flexibility, innovation relates to fishers' long term flexibility and adaptability is fisher's ability to adapt to changing and uncertain conditions. I then use these qualities to identify their strategic approach to fishing (e.g., where to fish; how responsive they are to changes in environment) and their approach to solving the 'engineering problem' (primarily in relation to gear type and technology). This enabled classification of fishers into four strategic archetypes – Prospectors, Defenders, Analysers and Reactors – for the fishery in the southwest of England based on a qualitative methodology using content analysis of in-depth interview transcripts. I also examine the administrative processes that allow fishers to pursue their strategy (the 'enablers') based on Miles and Snow (1978). These enablers include the degree of interactions (communication and cooperation with others within and outside the southwest fishery), the type and level of planning the individuals undertake in the short and long term, the level of financial and physical risk-taking (putting themselves and/or vessel in danger), and the stability of their business (such as crew turnover, level of maintenance and focus on quality of product).

Following previous research in the fishers' literature I also explore whether there are individual characteristics that influence the strategic position adopted, such as the time horizon, level of household dependence on fishing income and their personal fishing ethic. Personal characteristics of individuals have also been used in the management literature to understand managerial behaviour (Miller and Dröge, 1986, Miller and Toulouse, 1986a, Miller and Toulouse, 1986b). The framework used to study fishers' strategic behaviour, adapted from the Miles and Snow (1978) typology, is presented in Figure 1.

The purpose in undertaking this study is to draw on management theory to provide a research framework which will inform our understanding of the strategic behaviour of fishers. By examining the relationship between strategic position, administrative practices, and individual fisher characteristics, this study will improve our understanding of why some fishers are successful and some aren't. It will provide insights for policy makers when developing fishing regulations that can cater to, and predict responses of different strategic archetypes, and how to develop incentives to influence strategies for better fisheries management outcomes.

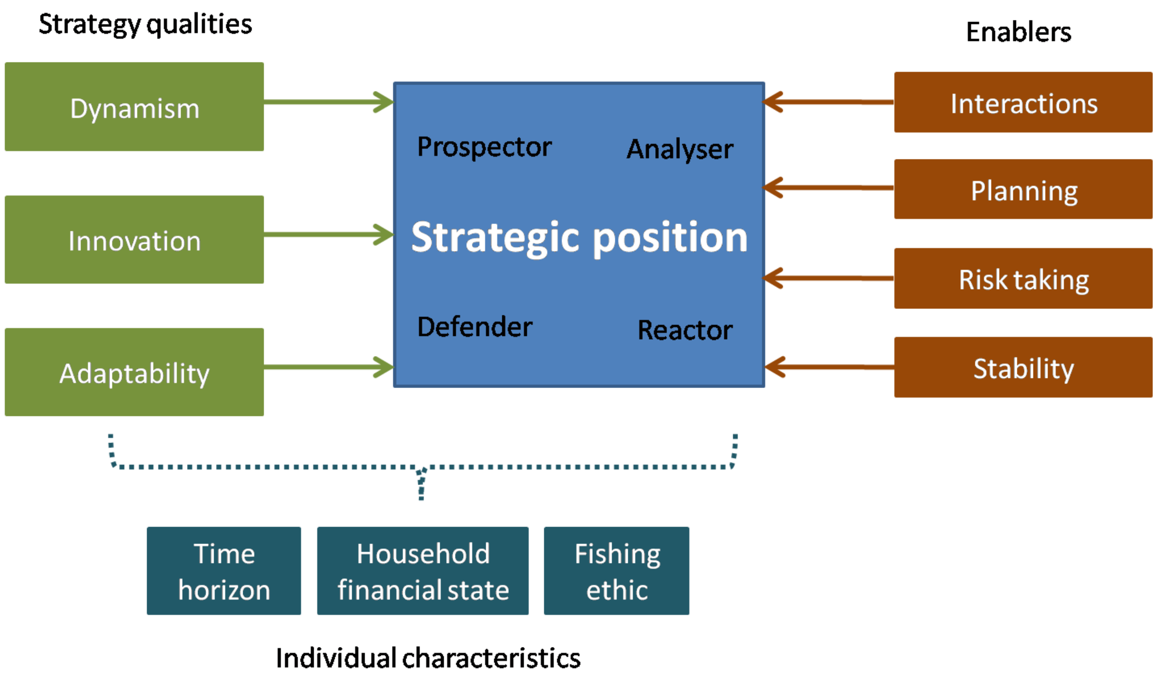

Figure 1. Typology framework for understanding fishing strategies

3. Methods

3.1. The study location

The study was undertaken in a fishing community in the Southwest of England. The field site has been anonymised and is referred to throughout the chapter as a 'SW fishing community'. With the decline of North Sea stocks, the fishery in the southwest of England now harbours most of the remaining English fleet. The southwest fishery is termed a 'mixed fishery': diverse in terms of gear type and species caught. The five main types of vessels over 10 metres in length are beam trawlers and otter trawlers which catch up to twenty different demersal species such as monkfish *(Lophius piscatorius)*, megrim *(Lepidorhombus whiffiagonis)* and Dover sole *(Solea solea)*; fixed netters which also target mixed species such as hake (*Merluccius merluccius*)and pollack *(Pollachius pollachius)*, crab potters which mainly catch brown crab *(Cancer pagurus)* and lobster *(Homarus gammarus)* and scallop (*Pecten maximus)* dredgers.

The three largest ports and markets in England are Newlyn, Brixham and Plymouth (Barratt and Irwin, 2008) (Fig. 2.). In 2007, 18% of the over ten-metre fleet were registered in the SW fishing community, catching 9% of the total reported English landings and representing 12% of the total value of catch landed in England in 2007 (Barratt and Irwin, 2008). The fishery operates primarily in ICES Area VII (Fig 2.). ICES Area VII contributed 28% of UK registered vessel landings (163,300 tonnes), constituting 27% of the value of landings (£169.9 million) by UK vessels in 2008[4].

The SW fishing community in this study is representative of many fishing dependent communities across the UK, located in remote areas with few alternatives to fishing for employment (Prime Minister's Strategy Unit, 2004). An estimated 34% of employed people in the SW fishing community are fishermen or work within the fishing industry (Nautilus Consultants Ltd, 2008). Fishing communities like this community have been considered vulnerable for a number of years as the fishing industry in the UK has contracted.

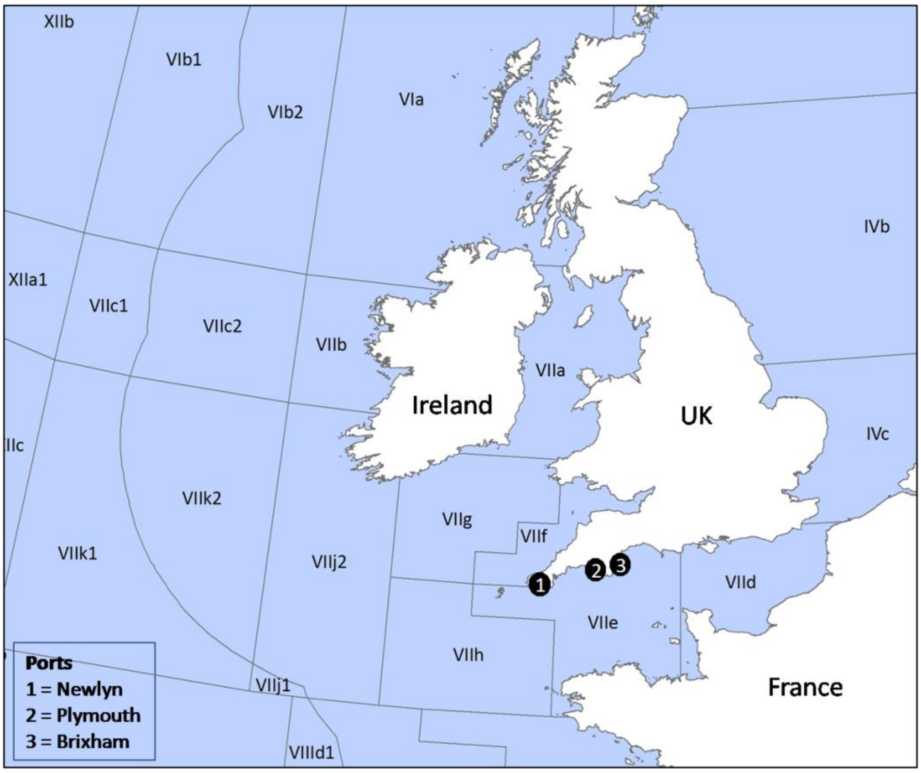

Figure 2. Map of the UK and ICES Area VII. ICES Area VII is further subdivided into Areas VIIa-k. Main Southwest ports/markets, Newlyn, Plymouth and Brixham are also identified on the map.

3.2. Background on fisheries management

In this paper I discuss how fishery management can accommodate different strategy types. This section gives a short history and current structure of fisheries management in the EU and UK. I highlight the gaps in fisheries policy that require understanding fisher behaviour and also how the overall aim of current fishery management is conducive to using new frameworks and

[4] Landings into the UK and abroad by UK vessels

an interdisciplinary approach to integrate social science in fisheries policy. Since 1983, European fisheries have been managed through the Common Fisheries Policy (CFP). Under the UN Law of the Sea (1977) all coastal nations were allocated exclusive exploitation rights up to 200 nautical miles from their coastlines (known as exclusive economic zones, EEZs). This caused problems for the once open-access unregulated fishing that vessels enjoyed in European seas. The CFP was put into place in 1983. It manages all the member states' EEZs and is now effectively one 25 million km^2 EEZ, the largest single fishery management regime in the North Atlantic. The sustainability problems that are facing the EU today can largely be traced to the objectives of fishery management in the past and, more recently, the inertia to substantially change the management regime. European fisheries management and the 1983 CFP were originally designed to promote growth, increase income and stability for fishers, and minimise conflict. It did not explicitly aim to reflect the complexity of the ecosystem or prioritise promoting environmental sustainability of its services (Symes, 1997, Jensen, 1999, Hanna, 2001). As a result the CFP has undergone reforms. The second reform, in 2002, emphasised environmental and economic sustainability. The 2002 reform identified that Total Allowable Catches (TACs) and technical measures (such as mesh sizes) were not sufficient as management measures. The focus for the new reform was to have a longer term, ecosystem approach to fisheries (EAF) - an adaptive integrated management system that aims to promote both biodiversity conservation and sustainable resource use by managing the ecosystem as a whole. Despite best intentions, it has been very difficult to transform the fisheries management system into the more holistic EAF and there have been few practical implementations in the EU to date (Caddy and Seijo, 2005, Branch *et al.*, 2006). The fishery management system is widely regarded as failing to conserve fish stocks. EU fishing capacity is estimated to be at least 40% too high (too much fishing by too many vessels), with 50% of the entire fleet estimated to be experiencing poor profitability and more than a third actually operating at a loss (Hentrich and Salomon, 2006). Decommissioning or vessel 'buy-backs' are a common management tool in the EU and UK for reducing fishing effort in the fishery where the governing body effectively buys skippers' vessels, reducing the number of fishing boats (fishing capacity). However, decommissioning has been shown to be both expensive and ineffective at removing total effort because they remove only the least efficient vessels and the effort removed often seeps back into the system which can necessitate another round of decommissioning (Clark *et al.*, 2005, Hentrich and Salomon, 2006).

The current foundation for fisheries management in the EU is spatial zoning. In basic terms, EU waters have been carved up into what are known as ICES[5] Areas (see Fig. 2). Based on scientific advice, the EU annually allocates a total allowable catch (TAC) for each species to each ICES Area. TACs are allocated to EU member states based on historical fishing rights, and scientific advice given by the Advisory Council on Fisheries Management (ACFM) and the Assessment Working Groups of the International Council for the Exploration of the Sea (ICES), an independent scientific body. TACs are then allocated by the Council of Ministers in the form of individual vessel fixed quota allowances (FQAs) which are based on historical fishing effort attached to fishing licences[6]. Each country is then responsible for managing their own fishing fleets. English fisheries are administered by DEFRA (Department of Environment, Food and Rural Affairs) and policed by the MFA (Marine Fisheries Agency). Structural policies are aimed at fishing effort controls[7], such as quotas, gear restrictions and reductions in fleet capacity; as well as temporal and spatial closures while conservation policies regulate the quantity of fish caught through quotas. To further limit fishing effort, no new licences are given. Instead, licences are bought and sold, and quota is leased and traded between vessels.

3.3. Data and information sources

Data were collected using interviews with skippers and key informants, participant observation, and questionnaires. These data capture skippers' strategic behaviour and their individual characteristics.

3.3.1. Semi structured interviews

Interviews were held with 34 skippers from large vessels (i.e., over ten metres in length). This represents 62% of the larger vessels registered in the SW fishing community in 2008. This percentage of vessels is approximate because although vessels are registered in the SW fishing community, their actual home port may be elsewhere and vice versa. It may also be an underestimation because there are several large vessels registered to the port 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

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[5] ICES is the International Council for the Exploration of the Seas - the (non-political) organisation that coordinates and promotes marine research in the North Atlantic. More than 1600 scientists from 20 member countries make up the intergovernmental panel.

[6] Although a FQA is attached to a licence, these are paid for separately. Licence fees are based on the size and capacity of the vessel (VCU), while FQA fees are based on the previous fishing effort of the licence holder.

[7] Fishing effort is regulated by Defra but within six nautical miles from the coastline, regional Sea Fisheries Committees (SFCs) regulate fishing methods, fishing gear, restrict fishing seasons, set minimum sizes for fish and shellfish and protect the seabed or control fishing for environmental purposes through byelaws.

skippers, completely statistically randomised respondent selection was not feasible. However, I ensured that the sample of fishers interviewed represented diversity of individuals within the fleet using relevant background variables that could be associated with different strategies such as gear types, size of vessel, age of vessel, ownership structure and experience (see Appendix 2 for respondent codes and details).

This SW fishing community is an interesting and somewhat unique port in terms of the ownership structure of fishing vessels. There is one large company that owns a fleet of beam trawlers. It is the UK's largest privately-owned family fishing business, and in 2008 owned 20 beam trawlers. The company is fundamental to the infrastructure of the community. It not only owns vessels, it also runs the fish market and the daily fish auction, it supplies fuel, and is a fish merchant. Their fleet are large vessels that are old (Table 1); only 14 of these vessels were actively in service during the time of the study (from this point onwards these vessels are referred to in the paper as 'company' vessels). The other vessels are independent and are either owned individually by the skipper, generally as part of a small family business, or are owned individually but skippered by an employee (from this point onwards these vessels are referred to in the paper as 'independent' vessels). These vessels are significantly newer and smaller in length (vessel age: $t_{32} = -3.20$, $p = 0.003$; vessel length: $t_{32} = -4.50$, $p < 0.001$). All respondents were skippers of large vessels (>10 m), consisting of beam trawlers (*n* = 17), otter trawlers (*n* = 3), gillnetters (*n* = 8), scallop dredgers (*n* = 4), and crab/lobster potters (*n* = 2).

Table 1. Mean and standard deviation (SD) of age and length of company vessels and independent vessels in the study

Vessel type	N	Mean age	SD age	Mean length	SD length
Company	10	41	7.7	28.8	2.8
Independent	24	26	14	19.1	6.5
Total	34	30	14.2	22.0	7.2

The interviewing approach was based on anthropologist H. Russell Bernard's guidelines for the conduct of 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. In order 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, I spent six months in Cornwall in 2008 and 2009, interviewed each respondent two or more times, and conducted 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 were conducted on the quayside every day and during trip at sea, and detailed field notes were taken. All interviews were recorded and transcribed verbatim and field notes were used where possible to verify responses.

In the repeat interviews, skippers were asked questions to get to know the respondent; his[8] history in fishing, details about his current fishery and management of his business; his present and past annual fishing patterns; and his decision-making from a short term perspective (at the trip level). Questions were asked about planning in the short term and for the future; the types and nature of interactions with skippers and within the wider industry; physical risk taking; trade-offs between financial and physical risk in both the short term and long term. Follow-up questions aimed to gain an understanding of how these factors influence his fishing strategy. Questions were open and allowed for a natural conversation to take place and were phrased in such a way that answers were not prompted by the interviewer.

3.3.2. Questionnaires

Questionnaires were also given personally to skippers, after the semi-structured interviews, to gain specific quantitative information that would have disrupted the flow and engagement of skippers in the semi-structured interviews. These questionnaires were used for other aspects of this PhD research; therefore not all questions in them pertain to this particular chapter. All skippers interviewed also responded to the questionnaire. Information in questionnaires included specific details of background of skipper; gear and technology used; crew details; fishing patterns; short term tactics; investments and costs and earnings (see Appendix 3 for questionnaire).

3.3.3. Participant observation

When the opportunity arose, fishing trips were participated in. These consisted of 1-8 days in duration, carried out throughout the field season and subject to weather conditions. Onboard observations were important for a number of reasons. First, participant observation gave a strong intuitive understanding of how fishing vessels operate and the decision processes skippers make. Second, it allowed time to build trust within the fishing community and

[8] There were no female skippers!

undertake more in-depth interviews described in the previous section without time constraints. The micro decisions that skippers made were observed and understood while skippers were making decisions at sea. Third, observations provided confirmation (or not) of interview data already collected. Detailed field notes were taken to record observations and conversations and were used in triangulation of interview data.

3.3.4. Key informant interviews

Unstructured surveys with key informants were also conducted on a number of occasions with members of the wider fishing industry including: the regional producer organisation (a fishers' cooperative that manages quota, promotes produce, and represents the views and opinions of fishers); Seafood Cornwall (which collaborates with fishers, fish merchants, and harbour authorities to promote Cornish-caught fish, improve quality standards, and encourage sustainable practice); fish merchants; retired skippers; vessel owners; vessel crew; market workers; and fisheries scientists/observers throughout the study period. These unstructured surveys were used to obtain skipper contacts, to gain a broader perspective of the workings of the port, general issues facing the fishery and to verify skipper responses to interviews.

3.4. Analyses

Transcripts and field notes were systematically coded using qualitative analysis software, (NVivo 7) according to each theme of interest, to ensure that data were not used selectively. Data were coded according to themes based on the conceptual framework presented in Figure 1. The themes for coding are listed and described in Table 2. Where possible, Likert-type scales (Likert, 1932) were created for each of the strategic qualities (i.e., dynamism, innovation, adaptability); for the enablers; and for the individual characteristics. This allows some inferential statistical analysis of the data. Dynamism, Innovation and Adaptability themes were used to identify fishers' behaviour in relation to what Miles and Snow call the 'entrepreneurial problem' and the 'technology problem' and allowed classification of each fisher strategy type (i.e., Prospector, Analyser, Defender or Reactor). Enabling behaviours (i.e., what Miles and Snow call 'administrative processes') were separated into themes of interactions, planning, risk taking (split into physical and financial risk taking) and stability.[9] Individual characteristics were also examined to see if they correlated to the strategic archetype of each fisher. They were classified into themes of time horizon, household financial state and fishing ethic. These are discussed in more detail in the following section.

[9] Miles and Snow (1978) define a number of administrative processes for each strategic archetype. Given the small size of operation for most of the fishers many of these were not relevant for this study.

Skippers were categorised as ‘company’ or ‘independent’ skippers. The strategic position of company skippers was highly likely to be influenced and constrained by the company itself. It may also be true that choice of employment (i.e., independent operator versus company employee) is influenced by individual characteristics. This selection bias warranted analysing ‘company’ and ‘independent’ skippers separately.

Table 2. Themes of analysis

Theme	Description of theme
Strategic quality	
Dynamism	The short term (within a year) dynamics of a skipper such as the fisheries he targets, his fishing gear use, and fishing location.
Innovation	The long term innovation of a skipper such as the degree of experimentation with fishing gear, searching for fishing locations, and use of technology.
Adaptability	The skipper’s ability to respond to changing conditions.
Enablers	
Interactions	The degree of communication and cooperation between skipper and others.
Planning	The degree of planning of fishing activities.
Physical risk taking	The degree of risk taking at sea.
Financial risk taking	The degree of risk taking with fishing investments.
Stability	The stability of the business such as the stability of employees (crew), maintenance of vessel, and focus on quality of product.
Individual characteristics	
Time horizon	Where the skipper is in his fishing career.
Household financial dependence	The dependency on fishing income to household income.
Fishing ethic	The skipper’s attitude towards fishing as a lifestyle choice.

3.4.1. Strategic quality

After coding, strategic qualities were determined using two related methods:

(i) Content analysis of the three strategic quality themes was undertaken and skippers were categorised as Prospector, Analyser, Defender or Reactor types for each theme individually based on the framework outlined in Figure 1. This iterative analysis revealed that skippers don't always fit perfectly into one strategy type, and may behave with a tendency towards a secondary strategy.

(ii) Using the thematic content analysis, a ranking system was used to give each skipper a strategy score. Each strategic theme was divided into appropriate indicators (four indicators for dynamism, three indicators for innovation and adaptability) and then each skipper was scored on that indicator on a 1-5 scale (Table 3.). An average weighted score was determined for each strategic theme for each skipper. These were then summed to give a total strategy score for each skipper. To examine the relationships between strategic quality indicators, a principle components analysis (PCA) was also undertaken.

3.4.2. Enablers

Content analysis was undertaken for each enabler theme and skippers were categorised accordingly. The resulting categories are presented in Table 4. Scores were given according to category, i.e., Category 1: Score = 1, Category 2: Score = 2, Category 3: Score = 3, and Category 4: Score = 4. These scores are Likert-type with low scores reflecting a low level of interaction, planning, risk taking and stability and progressively higher score reflecting higher levels of interaction, planning, risk taking and stability. The scoring for interaction was not as straightforward as the other enabler themes. Category 2 to 4 are sequential in terms of the amount of people the skippers communicate with. Category 2 skippers have minimal communication, Category 3 skippers communicate with others in the local fleet and industry, and Category 4 skippers communicate with others locally and also further afield (UK and Europe). Category 1 skippers were identified as those who try to get as much information from other skippers as possible but this is mainly through indirect sources such as listening in on radio conversations and picking up pieces of information on the quayside. These skippers do not have strong relationships with others who they share information with like Category 3 and 4 skippers, therefore were given a value of '1'.

Table 3. Indicators and their scoring system for each of the three strategy themes

Strategy indicators	Description of score allocation (scale 1 to 5)
Dynamism	
Switches fisheries** *(changes target species)*	1 = does not switch between fisheries throughout year 5 = switches many times between fisheries throughout year
Switches gear type** *(changes gear type to exploit different opportunities)*	1 = does not switch gear types throughout year 5 = switches many times between gear types throughout year
Switches location* *(changes locations to exploit different opportunities)*	1 = does not switch fishing locations throughout year 5 = switches widely between fishing locations throughout year
Switches port** *(changes the landing port)*	1 = uses only one port 5 = switches widely between landing ports
Innovation	
Experiments with gear types* *(experiments with gear types to exploit different fisheries or make gear more sustainable/efficient)*	1 = never experiments with fishing gear used 5 = experimented many times with fishing gear used
Searches for new locations* *(searches for unexploited or undiscovered locations)*	1 = never searches for new locations to fish 5 = always is searching for new locations to fish
Uses new technologies** *(e.g. ground discrimination software)*	1 = uses minimal fishing technology 5 = is at the forefront of new fishing technology
Adaptability	
Responds to changing conditions* *(e.g. market changes and demands)*	1 = does not respond to changing conditions 5 = alters practices in response to changing conditions
Future trends* *(e.g. consumer changes, environmentally sustainability)*	1 = does not examine fisheries trends 5 = looks for future trends and opportunities in fisheries
Adapted to fuel crisis* *(In 2008 fishing fuel costs rapidly increased, see Chapter 5)*	1 = was not able to adapt practices in response to fuel crisis 5 = was most able to adapt practices in response to fuel crisis

* Scores were derived from qualitative content analysis.
**Scores were derived from questionnaires (Switches fisheries: Q27; Switches gear type: Q17-21; Switches port: Q29-32; Uses new technologies: Q22-23) and qualitative content analysis.

Table 4. Categories of enabler themes

Enabler themes	Category 1	Category 2	Category 3	Category 4
Interactions*	Gets as much information as possible from other skippers but he doesn't necessarily give information to others	Has minimal communication and cooperation with other skippers	Has select skippers and people in the industry within the fleet only who he communicates and cooperates with	Has select people to cooperate and communicate with. These are people in fleet, as well as people further afield than Category 3.
Planning*	Spends minimal time planning short term or long term	Plans short term fishing (trip level) only	Spends a lot of time planning short and long term fishing but focuses is on improving the same practice	Spends a lot of time planning short and long term fishing but also focuses on new practices and innovations
Physical risk taking*	Does not take any physical risks	Trades off physical risks with profit	Takes physical risks with fishing gear and/or crew safety	Takes physical risks by fishing in bad weather
Financial risk taking**	Has no financial investment in fishing practice	Has some financial investment in fishing practice	Has high financial investment in fishing practice	
Stability				
Stable crew**	Unstable crew	Semi-stable crew	Stable crew	
Maintenance level**	Low level of maintenance	Mid level of maintenance	High level of maintenance	
Focus on quality*	Low focus on quality of fish	Some focus on quality of fish	High focus on quality of fish	

*Scores were derived from qualitative content analysis.
**Scores were derived from questionnaires (Financial risk taking: Q6-13, 40-46; Crew stability: Q25, Maintenance: Q47-48) and qualitative content analysis.

3.4.3. Individual characteristics

Time horizon, or where the skipper is positioned in his career lifespan was hypothesised as influencing his strategic type. All respondents started their fishing career almost always straight from secondary school (mean age ± SD, 17 ± 2.6 years old). The common retirement age for skippers was considered to be around 65 years old. Therefore skipper age was used as an indicator of where a skipper was in his career lifespan.

The personal financial pressure and responsibility of a skipper and the number of people dependent on his income was also hypothesised to influence his strategic type. Household number and relative contribution of income data were collected. Household financial dependence on fishing was calculated as number of people in household multiplied by the percentage household income attributable to skipper income (data derived from questionnaire: Q49-53).

Skipper ethic, or his attitude towards fishing as part of his lifestyle, was hypothesised to influence his strategic type. Skipper ethic was measured using the question (questionnaire: Q16) “Would you give up fishing if you won the lottery tomorrow?” (Response set: yes, no, I don’t know). This response was verified and discussed in interviews.

4. Results

4.1. Strategic archetypes

Content analysis revealed that skippers do not fit neatly into one of the four strategy types; Reactors, Defenders, Analysers and Prospectors. They have a tendency towards a particular strategy but the edges of that strategy can be considered to be blurry which shows that there is a continuum of strategy type. In most cases the boundaries were unclear with skippers with Analyser strategies. For example, an Analyser may have more qualities similar to classic Defender strategies, or an Analyser may have more Prospector qualities. Figure 3 shows the categorisation of skippers into strategy type with their tendencies, and separated into company and independent skippers.

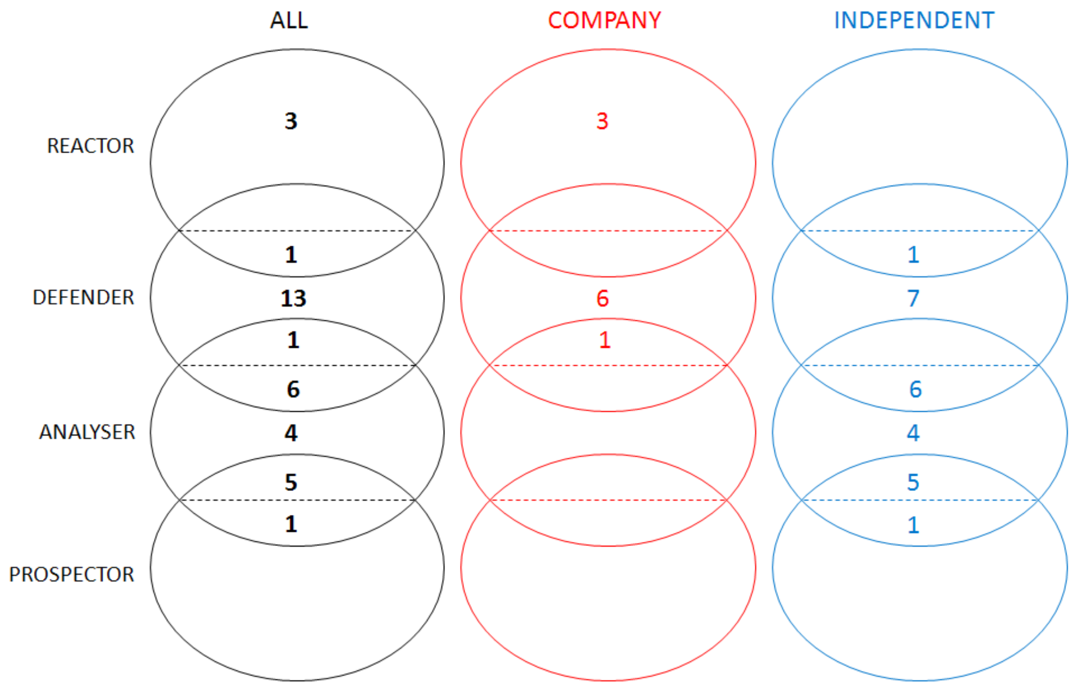

Figure 3. Skipper strategic archetypes based on content analysis. The number of all skippers is presented, company skippers and independent skippers are also presented separately.

Strategy scoring further revealed that there is a continuum of strategy scores, in line with the finding from the content analysis. In presenting these results it is possible to see the continuum of strategy scores (Figure 4), but I have also simplified the content analysis and categorised skippers into one of the four strategic archetypes. Reactors remained as they were (n = 3). Defenders included the strategies (n = 15): Defender, Defender with Analyser tendency, and Defenders with Reactor tendencies. Analysers included the strategies: Analysers, and Analysers with Defenders strategies (n = 10). There were no skippers who fell purely into the Prospector archetype, but Prospectors with Analyser tendencies and Analysers with Prospector tendencies had distinct strategies from those skippers who were defined as Analysers, therefore these two groups were defined as Prospectors (n = 6). Most skippers were either Analysers or Defenders. Skippers who worked for the company were either Reactor or Defender-types only, where as independent skippers were Defender, Analyser or Prospector-types. To illustrate the strategy scores, Figure 4 shows the strategy score given to each individual and their strategy type as defined by the thematic analysis. Fishers who scored highly on dynamism, innovation or adaptability had high strategy scores, in other words, a skipper with Prospector characteristics tends to be highly dynamic, innovative and adaptable, compared to Analysers who scored more highly than Defender-type skippers. The least dynamic, innovative and adaptable are the Reactor-type skippers. These relationships are examined further in the following section.

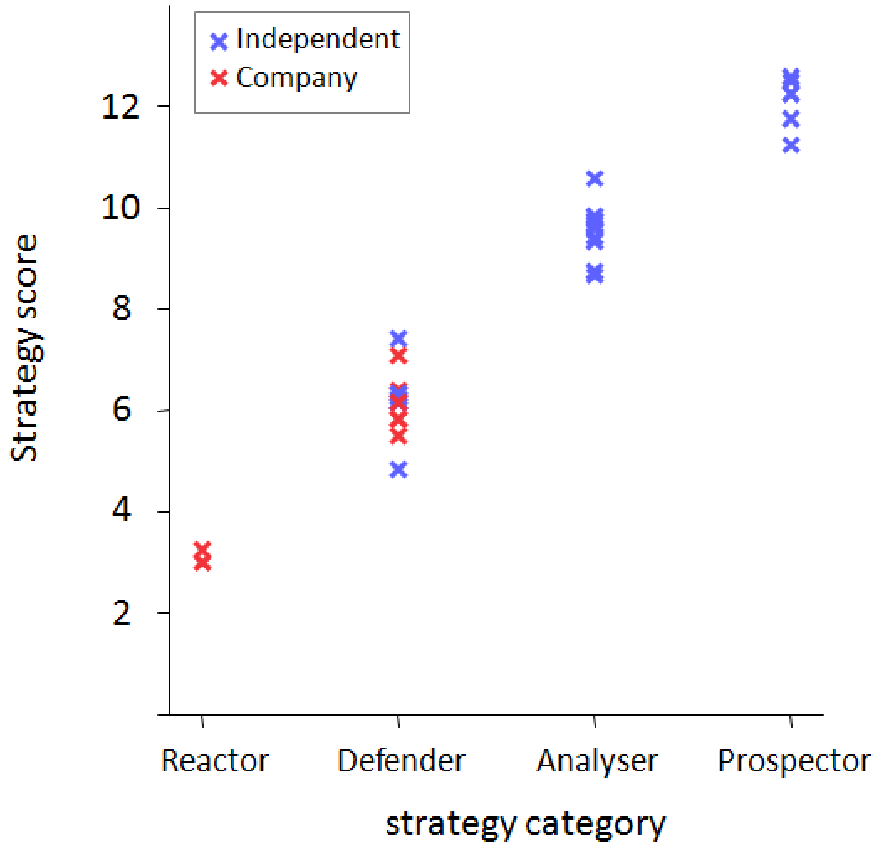

Figure 4. The strategy score for the four strategy archetypes; Reactors, Defenders, Analysers and Prospectors. Red crosses show company skippers and blue crosses show independent skippers.

A principle components analysis was also undertaken to further examine the patterns of correlations of the indicators of strategic qualities (dynamism: switching fisheries, switching gear, switching location and switching port; innovation: gear experimentation, searching for new locations and using new technologies; and adaptability: responsiveness to changing conditions, looking for future trends and ability to adapt to fuel crisis) for which each skipper was scored a 1-5 scale (Table 5). The main axis of variation (factor 1) represented 62% of the variation and showed that if skippers scored highly on one strategic quality indicator, they tended to score highly on all strategic quality indicators. The second axis of variation (factor 2) was comprised of two dynamism indicators; switching fisheries and switching gear types, and one innovation indicator; experimentation with gear (12% of variation), suggesting that these three indicators are related.

Table 5. Principle component factors describing strategic quality indicators. All factor loadings for each indicator are included, with loadings >0.4 highlighted in bold.

Strategic quality indicators	Principle components	
	Factor 1	**Factor 2**
Dynamism		
Switches fisheries	**0.59**	**0.63**
Switches gear	**0.67**	**0.53**
Switches location	**0.84**	-0.27
Switches port	**0.70**	-0.40
Innovation		
Experiments with gear	**0.79**	**0.45**
Searches for new locations	**0.82**	-0.23
Uses new technology	**0.85**	-0.02
Adaptability		
Responds to changing conditions	**0.91**	-0.22
Looks for future trends	**0.83**	-0.12
Adaptability to fuel crisis	**0.82**	-0.08
Variance explained	62.12%	12.39%

4.2. Enabling behaviours

For independent skippers, there were significant and positive correlations between all strategic qualities and almost all enabling behaviours. Dynamic, innovative and adaptable skippers had high level communication/cooperation and planning behaviour. They tended to be financial risk takers with high investment and also had a stable crew and high level of maintenance. However only innovative skippers took physical risks, such as pushing the weather and gear in order to catch fish and these skippers did not have a focus on quality of product (Table 6.).

In comparison, for company skippers, there were fewer significant relationships between strategic quality and enabling behaviours. The more dynamic, innovative and adaptable skippers had more communication/cooperation and planning behaviour. There was no relationship between physical risk, or stability of crew and strategic quality. Financial risk was not considered because the skippers had no investment in their vessel. Only the more innovative skippers in the company had higher levels of maintenance and a focus on quality of product (Table 6).

For independent skippers levels of communication/cooperation, planning, financial risk and maintenance were positively correlated. The level of physical risk-taking was positively correlated with level of planning and negatively correlated with quality. The skippers who take physical risks, putting themselves and their vessels in more danger, are unrelated to any behavioural characteristic in terms of communication/cooperation, financial risk taking, stability of crew, or level of maintenance. Skippers who focus on quality of product had a higher level of communication and cooperation, a stable crew and higher maintenance (Table 7).

In comparison, for company skippers, there were fewer relationships between enabling behaviours than independent skippers. Skippers with higher levels of planning were more likely to have more communication/cooperation with other skippers, have a more stable crew and higher maintenance. Higher level of maintenance was also related to higher stability of crew and a greater focus on quality of product (Table 7.).

Table 6. Correlation (Spearman rank order) matrix of strategic qualities and enabling behaviour of independent skippers and company skippers

Strategic qualities	**Skipper type**	**Enabling behaviours**						
		Interactions	Planning	Physical risk	Financial risk	Crew	Maintenance	Quality
Dynamism	Independent	0.63**	0.70**	0.12	0.46*	0.46*	0.54**	0.44*
Innovation	*(n = 24)*	0.69**	0.86**	0.41*	0.62**	0.54**	0.63**	0.40
Adaptability		0.69**	0.87*	0.31	0.76**	0.64**	0.59**	0.42*
Strategy score		0.70**	0.88**	0.22	0.67**	0.58**	0.65**	0.45*
Dynamism	Company	0.77**	0.83**	0.28	-	0.28	0.43	0.42
Innovation	*(n = 10)*	0.70*	0.91**	0.06	-	0.57	0.83**	0.72*
Adaptability		0.71*	0.69*	-0.18	-	0.52	0.58	0.32
Strategy score		0.75*	0.83**	0.17	-	0.36	0.67*	0.54

* $p < 0.05$, ** $p < 0.001$

Table 7. Correlation (Spearman rank order) matrix of enabling behaviours of independent skippers and company skippers

Enabling behaviours	**Skipper type**	**Enabling behaviours**						
		Interactions	Planning	Physical risk	Financial risk	Crew	Maintenance	Quality
Interactions	Independent		0.71**	0.08	0.61**	0.29	0.53**	0.40*
Planning	*(n = 24)*			0.42*	0.67**	0.49*	0.57**	0.16
Physical risk					0.34	0.12	0.03	-0.47*
Financial risk						0.52**	0.74**	0.26
Crew							0.57**	0.40*
Maintenance								0.44*
Quality								
Interactions	Company		0.85**	-0.06	-	0.58	0.59	0.46
Planning	*(n = 10)*			0.13	-	0.62*	0.68*	0.53
Physical risk					-	-0.49	-0.25	-0.05
Financial risk						-	-	-
Crew							0.63*	0.41
Maintenance								0.65*
Quality								

* $p < 0.05$, ** $p < 0.001$

4.3. Individual characteristics

4.3.1 Time horizon

Although there was no significant correlation between the strategy score and age of the skipper (used as a proxy for skippers stage of career) for either independent skippers or company skippers. Figure 5 shows that there is a general trend, where skippers in later stages of their career tend to have a lower strategy score than younger skippers at the beginning of their career, suggesting that the stage in career may influence a skippers strategy, and it is more likely a skipper will have a tendency towards a Defender strategy if he is in the later stages of his career:

> *"The likes of me, I think I've done the hard work in a sense, the challenge of it all is over like, my kids are 22 and 24 years old, so like I feel like I have succeeded and don't need to prove anything anymore".* (D24)

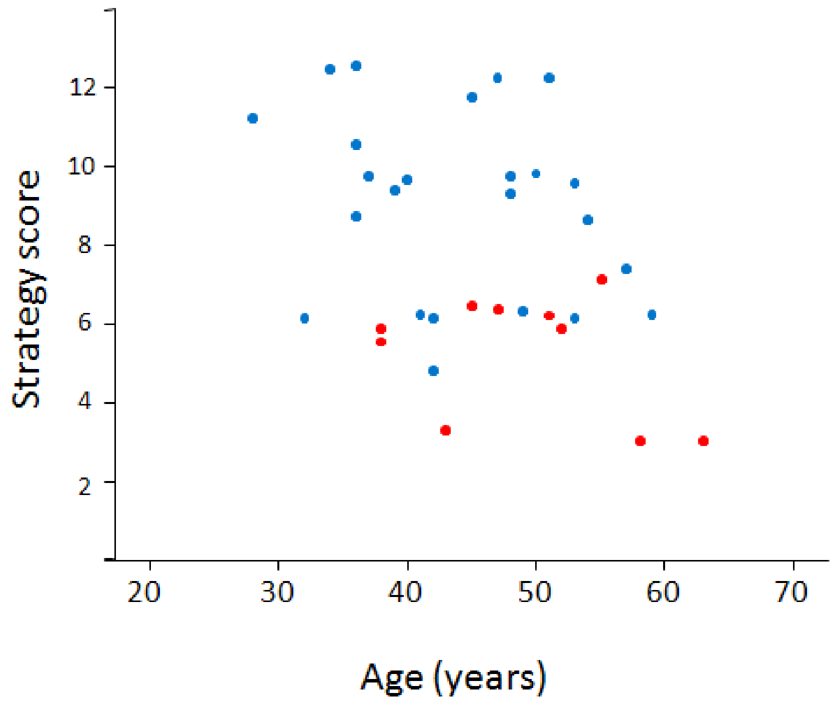

Figure 5. The relationship between age of skipper and strategy score for independent skippers (blue dots) and company skippers (red dots) (Independent skippers: $R_P = -0.26$, n = 24, not significant; Company skippers: $R_P = -0.36$, n = 10, not significant).

4.3.2. Household financial dependence

The percentage of a skipper's income contributing to a household and the number of people dependent on his income is a significant predictor of fisher strategy score for independent skippers. Those skippers with a higher level of financial pressure on them at home with more people that depend on his income tend to have a lower strategy score, suggesting a more risk averse, defensive strategy. Interestingly, there doesn't appear to be a relationship between strategy and household financial dependence with the company skippers (Figure 6.)

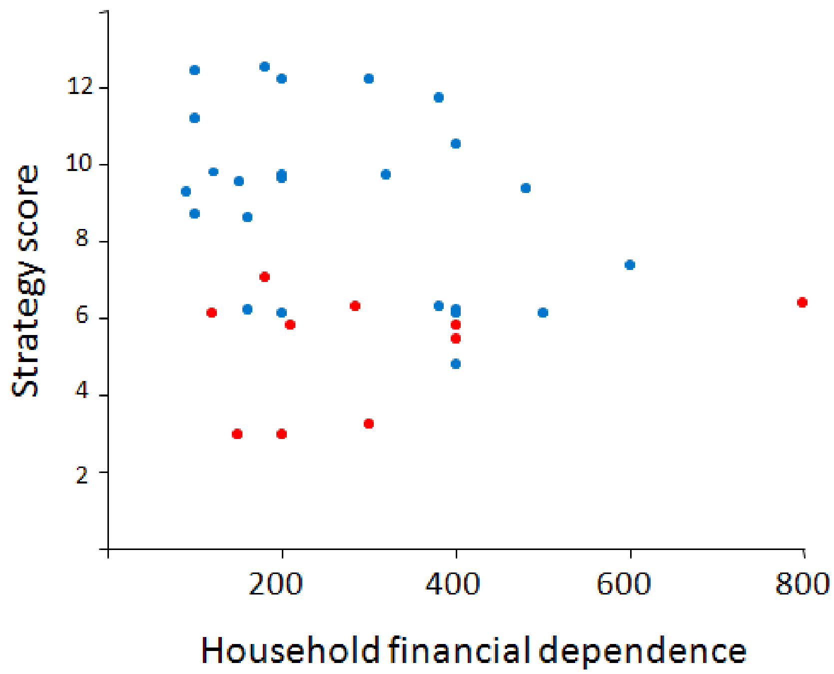

Figure 6. The relationship between skippers household financial dependence (number in household x percentage income attributable to fishing income) and their strategy score for independent skippers (blue dots) and company skippers (red dots) (Independent skippers: R_P = -0.41, n = 24, p = 0.05; Company skippers: R_P = 0.28, n = 10, not significant).

4.3.3. Skipper ethic

The skipper's attitude towards fishing as a lifestyle choice influences his strategic position for independent skippers (Fig. 7.). Skippers who tended toward Analyser and Prospector strategy archetypes were more likely to say they would not give up fishing, even if they (hypothetically) won the lottery.

> *"I'll still fish, definitely"* (A8)

> *"I'll carry on as long as I'm able to get down to the pontoon and keep the boat pumped out [of water]. I can see myself carrying on past 70."*(P2)

> *"In some way I will fish all my life, even if it's in a little punt catching mackerel."* (P26)

In comparison, a typical answer for those skippers who would stop fishing if they won the lottery was*:*

> *"Fishing at the minute is stuffed. I've had enough of this fucking job, I can't be dealing with it."* (D17)

Most of the company skippers (seven out of ten skippers) would give up fishing if they could.

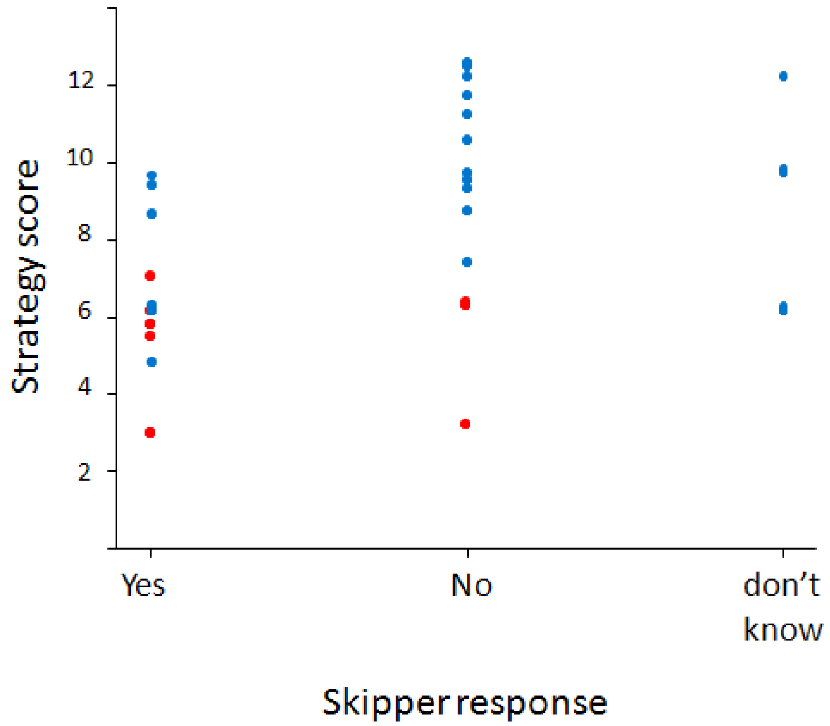

Figure 7. The response of independent skippers (blue dots) and company skippers (red dots) to the question "Would you give up fishing if you won the lottery tomorrow?" and their strategy score (Independent skippers: One way ANOVA, $F_{2,21} = 5.91$, n = 24, p = 0.009; Company skippers: t-test, $t_8 = -0.12$, n = 10, not significant).

4.4. Strategic Archetype, strategic qualities, enabling behaviours & individual characteristics

In this section the data pertaining to strategic indicators, enabling behaviour and individual characteristics are drawn together using the framework outlined in Figure 1 to present a typology of each strategic archetype (Figure 8-11).

4.4.1. Prospector tendencies

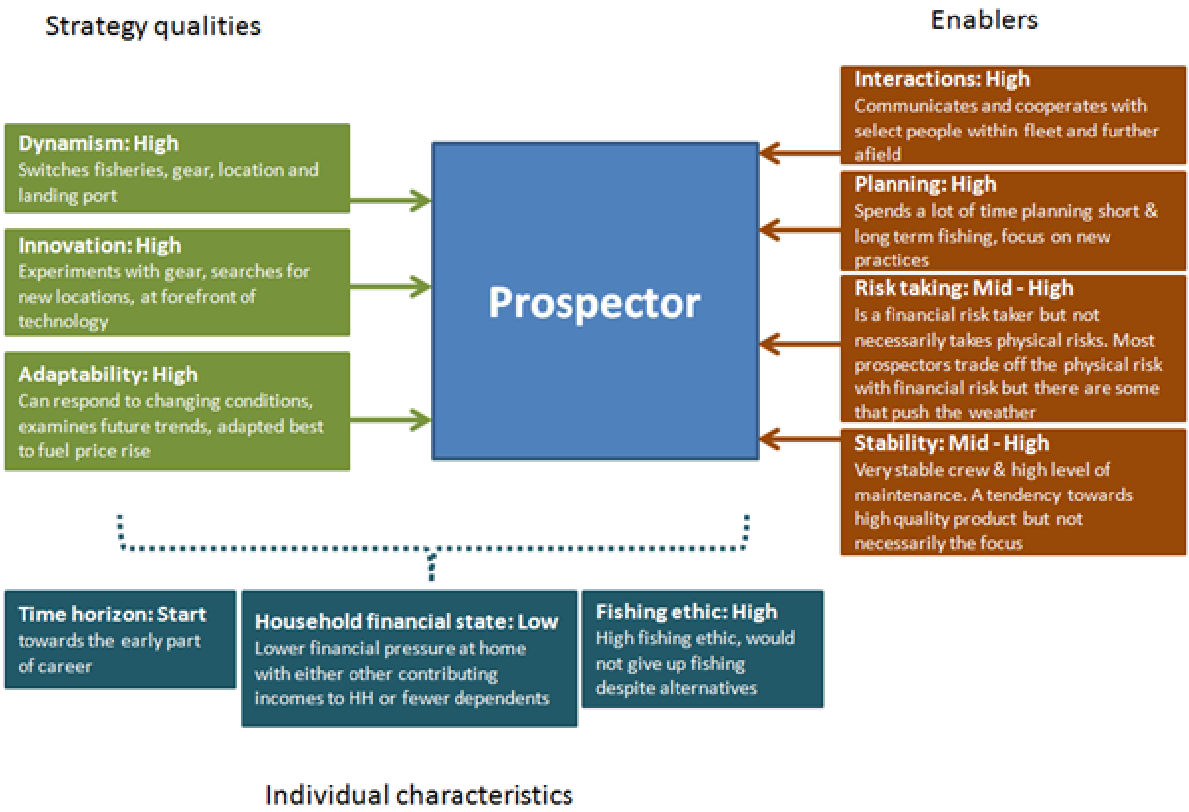

Figure 8. Strategy qualities, enabling behaviours and individual characteristics of Prospectors

Prospectors were all born into a family that has been fishing for generations. Some have pursued higher education before becoming a fisherman, however, fishing was such a large part of their lives that they either left higher education prematurely or returned to fishing after completing. None of these fishers were beam trawlers because it was not interesting and challenging enough as a type of fishing. They preferred fisheries where they had to 'hunt' more for their catch.

Skippers with prospector tendencies were very dynamic in the short term (annual). They tend to move between fisheries throughout the year targeting different species or species mix, changing the gear type they use, are *"very nomadic"* (P23), moving around the region or the country to exploit different fisheries, and using different ports to land their fish in order to try to gain the best prices for their product.

> *"You have to stay one step ahead of everybody else. By doing that, we change our gear, we change our ports, that's what you have to do. Personally that's what I think, and that's what we do and hopefully we are doing the job."* (P2)

The prospector strategy is also highly innovative, and skippers experiment with new gear types in order to exploit new fisheries, to fish more efficiently, and to respond to consumer trends for sustainably sourced fish. These skippers tend to invest time in searching for new locations to fish where other skippers don't, and are at the forefront of new fishing technologies such as the most recent ground discrimination software which digitally maps the sea bed.

> "*Yeah, there's places where we've shot where we have never shot before and we've had fish. We've spent two and a half days just steaming around having a look, mapping the bottom. We've spent a fortune on experimenting, and on different sorts of gear, because we don't have the normal every day sort of rig."* (P31)

Prospectors take pride in being innovative and are often imitated by other fishers.

> *I like having this boat, I like having people saying have you seen that mans conveyers, have you seen that mans gear? That makes me feel like I'm doing my job right."* (P28)

Prospectors are the most adaptable in uncertain and changing conditions because they are flexible in the fish they can target and the gear available to them to use. These skippers also tend to know what the industry trends are and look forward and try to predict the future in order to improve their capacity for adaptation.

> *"I just think some people have it and some people don't. Some people are determined to get to the top and other people are happy just dodging along. I'm always keeping my eye on what's going on."* (P33)

In mid 2008, during the field work for this study, fuel prices rose rapidly which threatened the viability of many fishing operations in the SW fishing community (Abernethy *et al.*, 2010). This provided a unique opportunity to access the adaptability of fishers to rapidly changed circumstances or ‘shock’. Skippers with prospector tendencies were more able to *“weather the crisis”* (P2) and adapt because of their flexibility in fishing approach.

> *"This situation will correct itself. It’s just when. And I can definitely hold on and survive until it does. ‘Cause there is good thing about having this boat, she is the most efficient, she is the best boat here. She is the most efficient boat here, but she is also expensive to run. So the thing that makes me the strongest is also the thing that could kill me. That’s the problem. I could get out of this today and buy a wee boat that burns fuck all and survive. But I don’t want to do that. I don’t want to survive, I want to be the best at what I do.”* (P28)

Prospectors communicate widely within the fishing industry and often speak to fishing contacts in other regions of the UK and abroad to stay up to date with new advances in technology. They also tend to be more involved than other fishers in regional and fishery committees, participating in fisheries policy discussions. Prospectors also have certain skippers that they cooperate with and speak to at sea, who have the same strategy tendencies. They spend a lot of time researching their fishery and planning their fishing activities with a focus on innovation and new practices. These fishers have a clear objective to make money, they are business-minded, organised, and they like hard work, spending a lot of time at sea relative to other fisher types. They have invested heavily in increasing efficiency, in catch handling equipment, improving working conditions and comfort of their crew, and in maintaining their vessel. Prospectors have a very low turnover of experienced crew whom they trust which means that alongside high levels of maintenance they can trade off the physical risks of fishing, such as working in poor weather, to stay at sea and continue fishing. Quality of fish is important to some of these skippers, who take measures to improve quality in search of higher prices. However, not all prospector-type skippers made quality of product a priority.

Prospector skippers tended to be in the early part of their career. They had a partner at home who contributed to the household income and had fewer dependents than other strategy types which meant that investment in innovation was possible. They were determined to always be fishers and saw themselves continuing to fish long after retirement age.

4.4.2. Defender tendencies

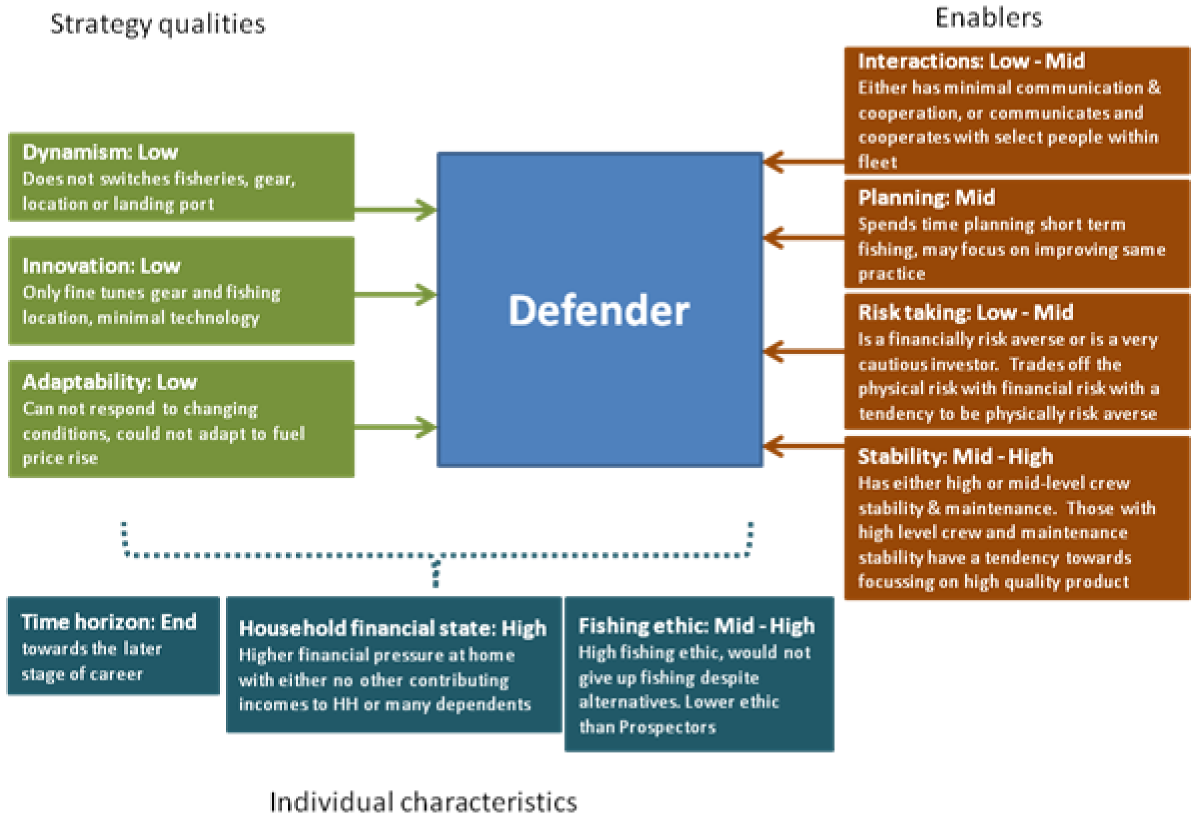

Figure 9. Strategy qualities, enabling behaviours and individual characteristics of Defenders

Skippers with defender tendencies also are usually born into a fishing family, and started fishing at an early age, although some were encouraged by their families to pursue a different career. The majority of the Defender-types are beam trawlers although the other gear types are also represented.

Skippers with defender tendencies are not dynamic; they have a fixed fishery they exploit throughout the year.

> *"So the species we target, we invest in those species and we stick to those species, which I don't know if it's a good thing or a bad thing."* (D21)

These skippers may only fine-tune their gear *("if it's not broken then don't fix it."*(D11)*)* and do not go to different locations to improve catch and efficiency. Common Defender-type comments were:

"I always like to go there, you've been there just so many times, and you know you can make a week's worth from there." (D3)

"You can't catch other people's fish really, you just gotta go out and go where you normally go." (D11)

Defenders either try to create a stable niche and defend their position in the market place, or are simply content with what they do. Therefore they do not experiment with gear types or try new locations to fish. Defenders tend to have the standard technology and do not invest in new fishing technologies like Prospectors:

"I'm probably old fashioned, I don't really use [technology] I've got the ground I used to work 20 year ago and we still go back to that ground, same tows, same bit of ground that I worked ever since I can remember." (D13)

Given the narrow set of product Defenders catch and their limited flexibility, Defenders are not readily able to adapt to changing conditions and struggled to maintain their business viability during the fuel price rise in 2008. For these skippers their future *"looked bad"* and they felt they were *"finished if the price of diesel keeps going the way it is"* (D21). One beam trawl skipper sums up the Defender strategy, talking about how making money from beam trawling is about keeping the gear fishing in the water for as much time as possible, going over the same fishing grounds and this is possible by making sure the vessel and gear are maintained to do the job:

"This job is, keep it wet, keep it in the water, keep it whole, keep it going up, down, up, down, time over distance." (D27)

In pursuit of their strategy, Defenders have limited need for communication and cooperation with other skippers. They are either very competitive and do not want to reveal their tactics to others, or they only trust a few individuals to share information with. Defenders tend not to look outside their own fishery in the Southwest to gain information. The majority of these skippers only spend time planning short term fishing (on a trip by trip basis), with some skippers spending very little time planning because they always follow the same pattern and make the same choices. Defender skippers that do spend time planning tend to focus on improving what they are already doing. These skippers are cautious investors and financially risk averse. Company skippers tend to be Defender-types and therefore have no long term financial investment in fishing (see next section for discussion of company skippers). Skippers with Defender tendencies also tend to be very risk averse towards putting themselves, their crew and their vessel in danger. Skippers with higher trust in their crew's experience and who have a more regular crew, and higher maintenance if their vessel, are able to trade off the physical risks with financial risks at sea and can push the weather more in search of fish.

Skippers with Defender strategies can be divided in to two age groups. The Defender skippers in the earlier stages of their career tend to have a high level of dependency on their income at home and have made a decision to actively defend their niche. Defenders also comprise older skippers nearing the end of their careers. These skippers have fewer dependents and are more satisfied with their present situation and desire only a reasonable income until they retire. Consequently, these skippers would like to stop fishing if they had an alternative source of money.

4.4.3. Analyser tendencies

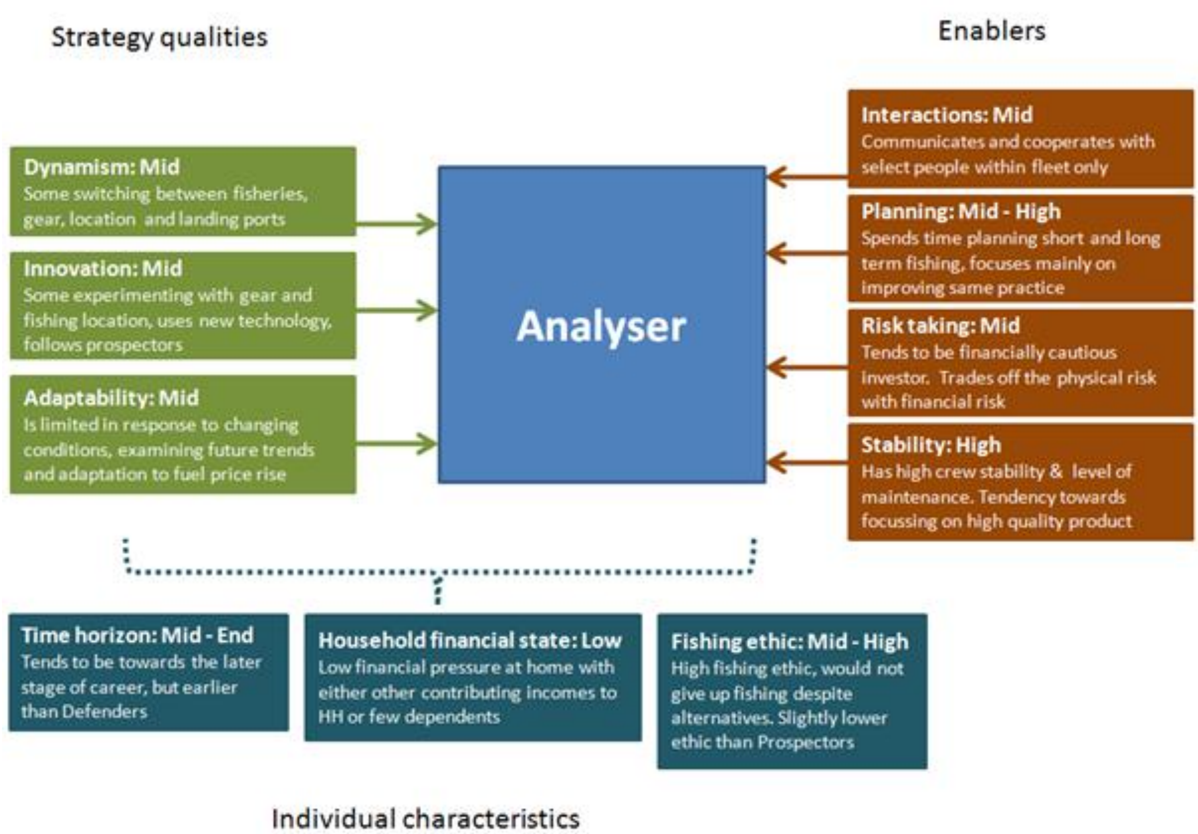

Figure 10. Strategy qualities, enabling behaviours and individual characteristics of Analysers

Skippers who are defined as Analysers also have a long family tradition of fishing. They do not include any company skippers. There are Analysers present in each type of fishery, beam and otter trawlers, gill netters, scallop dredgers, and crab potters.

Analysers tend to be a balance between Prospectors and Defenders. On the one hand they are dynamic and flexible, switching gear types and locations in order to exploit a couple of different fisheries throughout the year. They are innovative and experiment with gear and search for new locations. However, Analysers do not alter gear and locations in the short or long terms to the same degree as Prospectors. They tend to use new technology but not as quickly as Prospectors, tending to wait a couple of years when it becomes cheaper to buy. Analysers are similar to Defenders in that they maintain their core fishery that they target and continue to improve upon. For example, one Analyser skipper said:

> *"The sole fishery that has always interested me. It makes good money and we've invested in it….we try to broaden our horizon and will go to [other locations in the UK] to look for fish too."* (A7)

Analysers tend to be cautious, maintaining defender-like qualities, but also observe Prospectors' innovations. They are flexible yet stable. After Prospectors have tried and tested a new innovation and Analysers observe its success and limitations, they may decide to follow the same innovation with improvements to its efficiency.

> *"For the cuttle*[fish]*, changing over to a twin rig probably makes a difference but that's a lot of expense for 2 or 3 months of the year. So, hmmm, I'm not convinced. I'm gonna wait and see what the* [other vessel] *will do."* (A18)

Analysers also fall between Prospectors and Defenders in their ability to adapt. They are not as adaptable as Prospectors because they don't have the same degree of flexibility and have invested in a strategy which limits their fishing opportunities like Defenders. In response to the fuel price rise in 2008, they had a survival mentality and felt that they would:

> *"survive, I'm sure we would. Even the way the fuel is now, I hope it doesn't go up any more but it probably will. We are going ahead, only slowly but we are still going ahead."* However, they are *"pretty much stuck with what we've got now anyway. You have to turn up to work and just keep going, you can't afford to tie*

> *up against the wall, I can't. I can't afford to tie up…I've started to worry where am I going to be in five years time."* (A8)

Skippers who are Analysers communicate and cooperate with a select group of skippers who they trust and have the same strategy tendency while at sea. They also seek information from outside sources to make choices but tend to speak to people within the southwest region. Analysers seek information from Prospectors on their practice and success in order to make informed decisions about new technologies. A significant amount of time is spent planning short and long term fishing and while Analysers seek new opportunities, they primarily spend time planning ways to improve their current fishing practices. Like the Defender, the Analyser is a cautious financial risk taker but is prepared to invest in increasing efficiency, improving working conditions and comfort of their crew, and in maintaining their vessel, once they have spent time determining the most cost efficient solution. Like Prospectors, high maintenance level of their vessel is paramount, and alongside a trustworthy, experienced and long standing crew, Analysers can trade off physical risks to make money by fishing in poor weather. The Analysers try to keep costs as low as possible and also get as much money per kilo of fish and therefore they have a high focus on the quality of their fish in order to attain a high price.

Analyser skippers tend to be older than Prospectors but younger than Defenders and have less financial pressure at home than Defenders. They either have partners who contribute to the household income or fewer dependents than Defenders. Analysers are determined to have a full and prosperous career as a fisher and felt they were unlikely to give up fishing even if they won the lottery.

4.4.4. Reactor tendencies

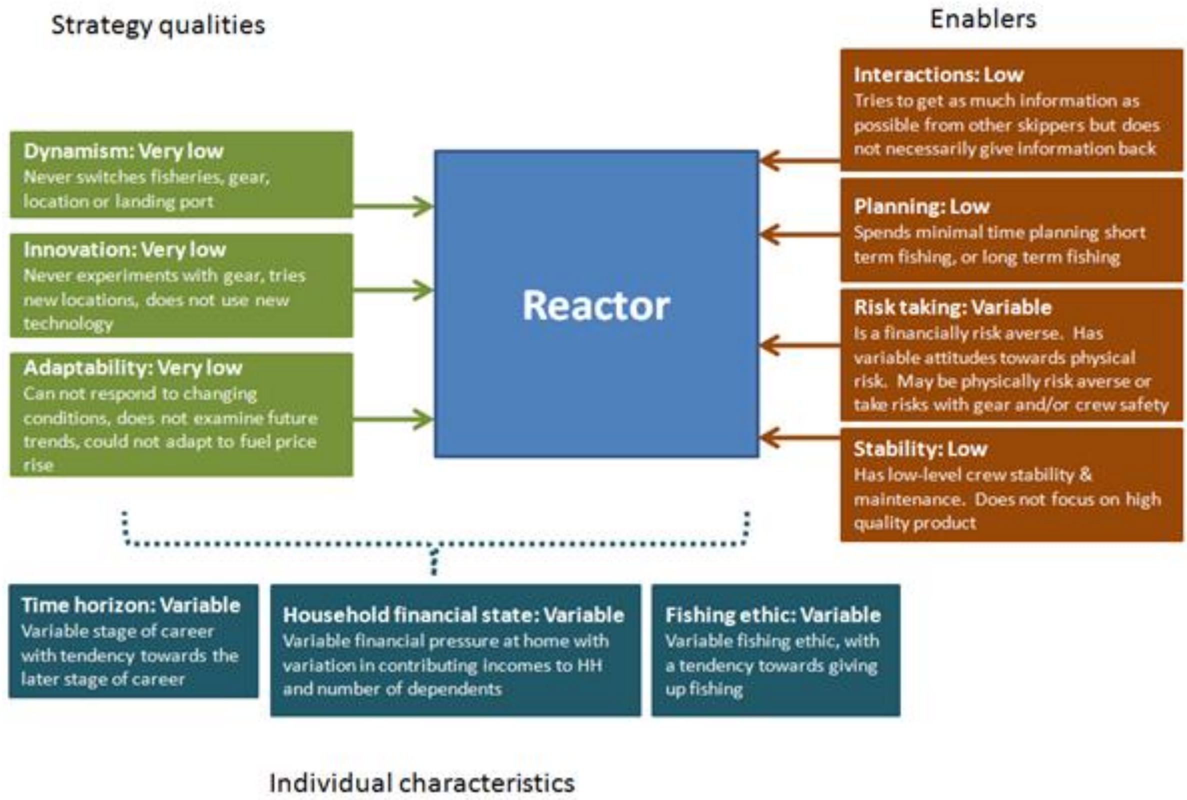

Figure 11. Strategy qualities, enabling behaviours and individual characteristics of Reactors

There were only three Reactors in the sample of skippers surveyed. Like the majority of skippers in the SW fishing community, they came from fishing families. The Reactors were all beam trawlers and company skippers. These skippers never had any intention of attending further education and became fishers because *"all my mates went fishing"* (R20) and because of limited alternative opportunities. Reactors tend not to be viable, and according to economic theory, they would not survive. In the strategic management literature this group receives little or no attention because they either do not exist or are in a state of collapse. However, as discussed in the next section, the Reactors persist because of the way the company is managed.

Reactors definitively do not switch fisheries, gear or locations throughout the year and always land to the same port. One Reactor skipper said:

> "[other fishermen] *might have patterns, but I don't, I'm just happy come lucky, if it's* [the fish] *there, it's there, if it's not it's not. Well, probably then you start fuckin shitting yourself*". (R10)

Reactors are also not innovative; they do not experiment with gear or search for new locations and are not interested in new technology. For example, the attitude of one Reactor toward new technology was:

> *"I don't particularly want [ground discrimination software], and plus you've got to pay an extra £50 a month for the fuckin thing. So at the end of the day, it don't bother me one bit."* (R6)

Reactors were habitual, and stubbornly continued to fish the same way they have done throughout their career, despite changing conditions:

> *"So you go where you know. Its smaller fish, but at the end of the day, you'll hopefully have enough of it. And plus, we're in TV range. I like my TV. I like my sport and my TV, and I'm lost without it."* (R6)

As a result of this unstable and inflexible strategy, Reactors are unlikely to be able to adapt to changing conditions. The fuel price rise in 2008 resulted in these skippers feeling like their future career in fishing was over. When one Reactor-type skipper was asked what he was going to do in response to the fuel 'crisis', he said:

> *"The future is looking bleak, very bleak. And personally myself, the days of fishing are finished…I'll go on the dole. I'll have to, because I can't do anything else. So I can't see a future. None whatsoever."* (R20)

Skippers with Reactor tendencies tended to try to obtain as much information as possible from other skippers and then choose to either use this information to make decisions such as where to go fishing, or choose to ignore the information if it was outside their habitual fishing practice. Reactors did not give as much information as they received, and skippers with other strategy types did not seek information from them. Given that Reactors were largely habitual, they spent minimal time planning fishing trips and often only thought about what they were going to do after they had left port. Reactor skippers were financially risk averse as they were company skippers which did not require investment in fishing. They tended to be physical risk takers but not necessarily by what they thought was their choice. Reactors took risks with gear, and had a reputation for destroying gear on hard ground. Two of the three Reactor vessels were going to sea with one crew member short. This was because they couldn't make a wage with an extra crew member and also because they found it difficult to retain regular crew. Maintenance on Reactor's vessels was minimal and other skippers often mentioned that they would not set foot on these boats even while they were tied up to the quayside. There was very little emphasis on fish quality and lack of company investment in these vessels meant that the quality of fish tended to be poor.

Reactor skippers tended to be closer to the end of their career or were contemplating changing jobs. There was no identifiable relationship with household financial dependence, although all of these skippers contributed 100% of the household income. Reactor skipper ethic towards fishing was not as enthusiastic , compared to Analysers and Prospectors. It was considered to be just a job and Reactors would give up fishing completely if they had an alternative source of income, even considering going on the dole rather than fishing.

4.5. Independent and company skippers

There was a clear difference between the distribution of independent skipper strategy types and company skipper strategy types. Independent skippers were Defenders, Analysers or Prospectors and also tended to have characteristics that made simple categorisation difficult, while company skippers were either easily classifiable Reactors or Defenders, with one company skipper having some Analyser qualities. I did not conclusively collect data to be able to determine if company skippers developed Reactor/Defender strategy because of the strategy of the company or because of their own strategic position, i.e. would company skippers have the same strategic position if they owned their own business?

When questioned in interviews about their decision to work for the company instead of owning their own vessel, company skippers tended to respond either with a statement which referred to financial risk aversion and not wanting the responsibility of a fishing business:

> *"It's easier skippering a boat for somebody because if anything happens, you just come in and the owner is there and you say fix that. It has to be fixed before going to sea again, and then you go home."* (D5)

Or, company skippers did not have the financial means to own a vessel in the first place because his family did not pass a fishing business on to him:

> *"20 year ago, perhaps I should have bought a boat, but I didn't. And money comes into it as well. 'Cause I'm not a fishing family either. I'm the only fisherman in my*

> *family, so it's not like I had a boat to start off with. A lot of* [independent skippers] *start off with a small boat from their family and then build up from there. So I never had that either like."* (D16)

The evidence to suggest strategy types are influenced by the company is the presence of Reactor archetypes. Economic theory suggests that Reactors should not exist because they will be unprofitable. Company skippers do not pay for the cost maintenance or fishing gear. Their earnings are determined by how much they catch, minus the trip expenses only. Independent skippers often demonstrated surprise that some of the company vessels were fishing at all given their high running costs:

> *"They live in a kind of inertia, they've never gone out and looked at what happens in the rest of the industry".* (P2)

As a result, Reactors still earned a (low) wage despite their vessel being unprofitable to the company. Given the company has a fleet of vessels they can afford to keep the business running with some unprofitable vessels. This also allows an unstable strategy for skippers. For example, taking risks with gear. As company skippers do not pay for their gear, they can more easily take the risk of *"smashing the gear up"* (D27) in order to catch fish on rough ground.

Company skippers are also constrained by the company to pursue other strategies. They have limited influence on their ability to be innovators because the company limits the availability of technology, the ability to switch gear types and experiment with different fisheries and gears, and the ports that they can land to.

In comparison, independent skippers tended to have a different outlook and passion for fishing and many independent skippers responded to questions about why they chose to be a fisherman and have their own business with statements such as:

> *"Fishing is a strange thing, once you get the bug for it, it's like a disease, it's great, you know"* (A18)

and

> *"I grew up in places like this, listening to old men's sea stories and I thought it were great, watching the old men and kicked about with them"* (P28)

Independent skippers also demonstrated determination, a need to be in control and have business-like qualities: When asked why a skipper invested in his own vessel independent skippers tended to have responses similar to the following:

> *"I decided if I was making money for somebody, why can't I make it for myself?"* (D24)

> *"I have controlled every aspect of my life. I've controlled whether I am successful or not successful. How successful I am has depended on how much I put in".* (P28)

> *"We're businessmen, and we work hard".* (A7)

5. Discussion

The United Kingdom has a vision to develop:

> "*a long term strategy for the sustainable future of the UK marine fishing industry. The strategy should be based on the need for sustainable management of marine resources and ecosystems, and take account of the diverse and changing circumstances of fishing and related industries, and the social and economic development of communities which depend on fishing activity.'(Prime Minister's Strategy Unit, 2004)*

The objectives of this study are to inform policy designed to achieve this vision. There are two primary objectives. First, I wanted to contribute to our understanding of fishers' strategic behaviour and used a framework developed in the strategic management literature to do so. The framework enabled integration of fishers' strategic choices as well as their individual characteristics, and explain why fishermen fish where they do, choices made in how they fish, and what factors explain why some fishers continue to exist while others don't. Current understanding of fisher strategic behaviours are under-developed, yet understanding how fishers use marine resources, alongside understanding the dynamics of the resource itself is fundamental for achieving the United Kingdom's vision of sustainable fisheries management. Although widely recognised that understanding fisher dynamics is required, fisheries lacks a toolkit for defining and understanding the heterogeneity of fisher behaviour. Therefore, I looked outside the fisheries literature and draw on the strategic management research to construct the framework and adapted the robust strategic typology developed by Miles and Snow (1978) to a fishing context.

The second objective was to test the framework by classifying the strategic behaviour of skippers in Southwest England. This analysis revealed that fishers' strategic behaviour can be classified on a continuum that captures the degree to which each skipper is dynamic, innovative and adaptable to changing conditions. These three strategic qualities map into the Miles and Snow (1978) typology. This typology provides a practical simplification of the continuum and allows classification of each fisher into one of four strategy types: Prospectors (18%), Defenders (44%), Analysers (29%) and Reactors (9%). It was identified that a skipper's strategic position is 'enabled' through use of administrative processes and decisions captured by the degree of communication, cooperation, planning, financial and physical risk taking they undertake and their emphasis on stability. It was also found that skipper individual characteristics such as time horizon in terms of career, the financial pressure and responsibilities at home and also their ethic towards fishing determine a skipper's strategy. Whether a skipper worked for a company or operated independently also informed their strategy type. There is evidence to suggest that company skippers' strategic behaviour was informed by the overarching company strategy. It was also found that individual characteristics of the skipper influenced their choice to work for a company or to operate independently.

Although the findings of this study need to be interpreted with some caution due to sample size and methodology, the preliminary evidence presented here does have a number of potential implications for designing policies that can *'maximise the return to the UK of the sustainable use of fisheries resources and protection of the marine environment'* while setting clear social objectives of *'providing valuable income and employment to remote communities which would otherwise make higher calls upon public funds…*[by] *helping smaller and vulnerable communities continue to have access to fishing opportunities' (Prime Minister's Strategy Unit, 2004)*. Firstly, in order to achieve these goals, the UK has emphasised the need to regionalise fisheries management, applying management solutions that are appropriate to the context specific needs. In order to operationalise regional management, identifying fishing communities' composition may be useful because each fishing community is likely to be different. This analysis of a remote and vulnerable fishing community in the southwest of England revealed that the composition of skipper strategy types is dominated by skippers who are not flexible or innovative and hence have little ability to adapt to changing conditions (Reactors and Defenders make up 53% of skipper sample). These fishers are primarily skippers using beam trawl gear. The domination of this strategy type could suggest that the fishing community is potentially in decline and could be heading towards becoming a 'sunset industry'. However, at the same time, the southwest fishery is the most important region for fisheries in England, with the most potential for growth. If the government wants to encourage growth in fisheries and prevent the vulnerable communities becoming a drain on society in this region, the social objectives for this fishing community requires more attention. Decisions about product and labour markets, technology, and investment, to encourage adaptable strategies are needed (as well as wider policy commitments of regional development, and provision of services in the community, such as health, education, infrastructure, and finance).

The second implication of this study is that understanding the strategic choices of fishers can assist in predicting the efficacy of different management regimes and regulations. If policy is at odds with the strategic choices of fishers and/or their individual characteristics there will be problems of compliance. Fishers will either ignore, avoid, or even worse subvert the initiatives implemented (Wilen *et al.*, 2002, Raakjaer Neilsen, 2003, Raakjaer Neilsen and Mathiesen, 2003). This response to regulatory policy by the fishers creates a never ending cycle of supplementing regulation to solve problems created by former legislation. (Vestergaard, 1997, Christensen and Raakjaer, 2006, Degnbol *et al.*, 2006). In 2009, the European Commission for Fisheries identified that the current methods underpinning fisheries governance required transformation, and launched a wide ranging debate (The Green Paper) on the way EU fisheries are managed (European Commission, 2009), looking to reform the Common Fisheries Policy in order to achieve its goal of *'exploitation of living aquatic resources that provides sustainable economic, environmental and social conditions' (European Commission, 2009)*. The Green Paper calls for fundamental reform that addresses the issues of over-capacity and compliance, suggesting a shift towards regionalised rights-based management, individual transferable quotas, and closed areas to protect sensitive habitats. By identifying the strategies and motivations underlying fisher behaviour, the impacts of any such changes in fisheries management regimes and how they may influence different fisher groups, could potentially be predicted and policy designed to accommodate different user groups and/or influence strategy types that are more in line with management objectives.

The third implication of this study's finding relates to policy directed at fleet capacity management. Overcapacity remains the fundamental issue facing EU and UK fisheries. The target is to maintain a fleet whose harvesting capacity is proportionate to the size and productivity of available fish stocks. The EU has repeatedly implemented structural policies to reduce the fleet, such as decommissioning schemes. However, this has not been effective at reducing capacity as it can remove only the most inefficient vessels, and the effort seeps back into the system through technological creep. Using the categorisation of strategy types, the likely influences of decommissioning on each strategy can be examined. Vessels that seem likely to be most attracted to decommissioning schemes are those skippered by Reactors. Reactors are skippers of vessels who are largely unprofitable and in this case only exist because the company employer effectively subsidises their operation. They have an unstable strategy, and have little interest in changing their practice unless they are forced to. These skippers are already looking for a way out of fishing and it seems likely that in response to a major shock, they may be finally pushed out of the industry. Therefore, if Reactors do successfully apply for decommissioning, vessels that are using up resources without being profitable are removed which could have a positive effect on the efficiency of remaining vessels. But on the other hand, these vessels may already be about to leave the industry anyway and it may be financially wasteful of resources to remove Reactors if the desired outcome is to remove a proportionate amount of excess capacity.

Defenders may also be attracted by decommissioning as their inflexible strategy means they are struggling to adapt to the uncertain and changing conditions in fisheries. In the case of this SW fishing community, many of the Defender type skippers used beam trawl gear, a highly fuel intensive method of fishing. With fuel prices inevitably rising again in the near future (International Energy Agency, 2008), these skippers have an uncertain future. As a result, if they had an alternative source of income, many Defender types said they would leave the industry to work in other marine sectors (Abernethy *et al.*, 2010). However, the problem arises when Defenders do not have an alternative source of income and are trapped in an inflexible and marginally profitable sector of the industry. A large proportion of Defenders tend to be older fishers and nearing retirement age (fishers who used to be more flexible and innovative in the past have now settled for a Defender strategy to end their career). Therefore, if these vessels are decommissioned, it may be removing capacity that may exit the fleet in the near future anyway. The other sub-type of defenders not considered yet are the younger skippers who very deliberately choose a defender strategy, defending the niche they have created for themselves in the market place, focusing on a narrow set of species they catch, focussing on a high quality product, working hard and are largely successful at being the best at what they do. They can be heavy exploiters of a small number of species and can be very profitable because of their efficiency at doing so. These skippers are unlikely to be attracted by decommissioning as they have a high fishing ethic, and a determination to remain in fishing. However, due to their inflexibility, Defenders may also be the fishers most unlikely to comply with regulations because they have to limit the impact of regulation on their economic viability. Given their predictable and stable patterns of resource use, Defender skippers may positively respond to rights based instruments of management such as cooperatives and territorial use rights (TURFs). TURFs are rights to fishing grounds allocated to a group of resource users which they then manage between them. Given their defensive nature, newcomers wanting to enter the fishery would probably find it very difficult to gain membership of such a collective association, therefore fishing capacity would be limited.

Some operators who have applied for EU decommissioning have used it to their advantage, simply factoring in the premium they received for scrapping their vessel into future fishing investment decisions, using the money to purchase more efficient vessels (European Commission, 2009). Analyser or Prospector skippers may be the type of skippers who would tend to make those decisions. It is difficult to know how to manage innovative, dynamic and adaptable strategy types. On the one hand their flexibility allows them to readily adapt to changing regulatory conditions which can cause pressure on resources. But on the other hand, Prospectors and Analysers plan for the future, want to have longevity in their career and continue to fish. They are more aware of sustainability issues and agree that fishing capacity needs to be more in line with resource availability. These fishers are also more likely to adapt their practice in response to changing consumer preferences towards sustainably sourced fish. However, heavy regulatory restrictions limit their ability to be profitable and therefore, in a recent crisis driven by fuel-price hikes, limited their openness to sustainable practices (See Chapter 5). This suggests that these vessels should be allowed to perform, be efficient and profitable to encourage good practice. Therefore limiting the number of these vessels may be beneficial for efficiency (Hilborn, 1985). Or, if sectoral efficiency and net economic contribution of fisheries is the goal of fisheries policy (e.g. Wealth-based fishery management, which puts resource rent at the heart of the management process (Cunningham and Neiland, 2005), then flexible strategy types should be encouraged and policy and management systems designed to facilitate flexible behaviour. For example, individual transferrable quota rights have been shown to result in the rationalisation and improved economic profitability of fleets in Denmark and Spain (MRAG *et al.*, 2009) (although there would need to be safeguards in place to prevent concentration of ownership of rights). In addition, market driven incentives used to encourage sustainable practices, and incentives such as grants and competitions to encourage development of gear changes that are in line with consumer demands for sustainability could also be useful tools for this type of strategy.

6. Conclusion

This study is preliminary and designed to improve our understanding of the strategic behaviours of fishers with a view to informing fishery management policy directed at changing behaviour. It is the first study, of which I am aware that has attempted to apply the Miles and Snow (1978) strategic typology in the fishery context. The typology was adapted for this study and I do not claim to have tested empirically the typology *per se* but rather used it as a framework for 'sense making' of behaviour phenomena (Dervin, 1992). As with most research studies there are limitations and many questions remain unanswered particularly those directed at informing policy choices. Firstly, using a methodology which uses classification or archetypes can be contentious in itself (Greenwood and Hinings, 1993). This study first identified that there was a continuum of strategic type because of overlapping strategic qualities and indicators. However, in order to classify strategic archetypes, decisions were required in terms of cut-off points, which may result in limitations for predicting responses according to each strategic type. Secondly, questions that remain unanswered are: Is strategy typing and routine inclusion of strategy types of fishers in management practical? Given that fisheries management tends to focus on the vessel and not the individual skipper, is it possible to manage individual strategy types? How can the fact that skippers may change their strategy types throughout their careers be accounted for? This study does, however, indicate that fishers do adopt a configuration of behaviours that reflect strategic qualities; technology employed and processes used. Future research could build on this study and identify proxies that capture the key features of each strategic archetype. Trade-offs between cost of design and implementing a data capture system and the benefits in terms of effective policy would be required. Another question is whether it is ethical or fair to make decisions based on individual qualities of people? How would fishers react if they knew policy was informed by this type of information?

This study does not attempt to address specifically how to incorporate these findings into the design of fishery management policy. This study is exploratory and further research is required to establish the validity of the theoretical framework used to interpret the findings as well as to refine the method used to understand the relationships between the constructs studied here. Despite the potential limitations, this study is the first to employ a framework well developed and empirically tested in the strategic management literature. This framework provides a more sophisticated approach to understanding fishers' strategic behaviour.

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8. Appendices

Appendix 1a. Strategic typing based on Miles and Snow (1978).

TABLE 1. Characteristics of the Defender

Entrepreneurial Problem	Engineering Problem	Administrative Problem
Problem: How to "seal off" a portion of the total market to create a stable set of products and customers.	*Problem:* How to produce and distribute goods or services as efficiently as possible.	*Problem:* How to maintain strict control of the organization in order to ensure efficiency.
Solutions: 1. Narrow and stable domain. 2. Aggressive maintenance of domain (e.g., competitive pricing and excellent customer service). 3. Tendency to ignore developments outside of domain. 4. Cautious and incremental growth primarily through market penetration. 5. Some product development but closely related to current goods or services.	*Solutions:* 1. Cost-efficient technology. 2. Single core technology. 3. Tendency toward vertical integration. 4. Continuous improvements in technology to maintain efficiency.	*Solutions:* 1. Financial and production experts most powerful members of the dominant coalition; limited environmental scanning. 2. Tenure of dominant coalition is lengthy; promotions from within. 3. Planning is intensive, cost oriented, and completed before action is taken. 4. Tendency toward functional structure with extensive division of labor and high degree of formalization. 5. Centralized control and long-looped vertical information systems. 6. Simple coordination mechanisms and conflict resolved through hierarchical channels. 7. Organizational performance measured against previous years; reward system favors production and finance.
Costs and Benefits: It is difficult for competitors to dislodge the organization from its small niche in the industry, but a major shift in the market could threaten survival.	*Costs and Benefits:* Technological efficiency is central to organizational performance, but heavy investment in this area requires technological problems to remain familiar and predictable for lengthy periods of time.	*Costs and Benefits:* Administrative system is ideally suited to maintain stability and efficiency but it is not well suited to locating and responding to new product or market opportunities.

Source: Raymond E. Miles and Charles C. Snow, *Organizational Strategy, Structure, and Process* (New York: McGraw-Hill, 1978) Table 3-1.

Appendix 1a *continued*. Strategic typing based on Miles and Snow (1978).

TABLE 2. Characteristics of the Prospector

Entrepreneurial Problem	Engineering Problem	Administrative Problem
Problem: How to locate and exploit new product and market opportunities.	*Problem:* How to avoid long-term commitments to a single technological process.	*Problem:* How to facilitate and coordinate numerous and diverse operations.
Solutions: 1. Broad and continuously developing domain. 2. Monitors wide range of environmental conditions and events. 3. Creates change in the industry. 4. Growth through product and market development. 5. Growth may occur in spurts.	*Solutions:* 1. Flexible, prototypical technologies. 2. Multiple technologies. 3. Low degree of routinization and mechanization; technology embedded in people.	*Solutions:* 1. Marketing and research and development experts most powerful members of the dominant coalition. 2. Dominant coalition is large, diverse, and transitory; may include an inner circle. 3. Tenure of dominant coalition not always lengthy; key managers may be hired from outside as well as promoted from within. 4. Planning is comprehensive, problem oriented, and cannot be finalized before action is taken. 5. Tendency toward product structure with low division of labor and low degree of formalization. 6. Decentralized control and short-looped horizontal information systems. 7. Complex coordination mechanisms and conflict resolved through integrators. 8. Organizational performance measured against important competitors; reward system favors marketing and research and development.
Costs and Benefits: Product and market innovation protect the organization from a changing environment, but the organization runs the risk of low profitability and overextension of its resources.	*Costs and Benefits:* Technological flexibility permits a rapid response to a changing domain, but the organization cannot develop maximum efficiency in its production and distribution system because of multiple technologies.	*Costs and Benefits:* Administrative system is ideally suited to maintain flexibility and effectiveness but may underutilize and misutilize resources.

Source: Raymond E. Miles and Charles C. Snow, *Organizational Strategy, Structure, and Process* (New York: McGraw-Hill, 1978), Table 4-1.

Appendix 1a *continued*. Strategic typing based on Miles and Snow (1978).

TABLE 3. Characteristics of the Analyzer

Entrepreneurial Problem	Engineering Problem	Administrative Problem
Problem:	*Problem:*	*Problem:*
How to locate and exploit new product and market opportunities while simultaneously maintaining a firm base of traditional products and customers.	How to be efficient in stable portions of the domain and flexible in changing portions.	How to differentiate the organization's structure and processes to accommodate both stable and dynamic areas of operation.
Solutions:	*Solutions:*	*Solutions:*
1. Hybrid domain that is both stable and changing. 2. Surveillance mechanisms mostly limited to marketing; some research and development. 3. Steady growth through market penetration and product-market development.	1. Dual technological core (stable and flexible component). 2. Large and influential applied engineering group. 3. Moderate degree of technical rationality.	1. Marketing and engineering most influential members of dominant coalition, followed closely by production. 2. Intensive planning between marketing and production concerning stable portion of domain; comprehensive planning among marketing, engineering, and product managers concerning new products and markets. 3. "Loose" matrix structure combining both functional divisions and product groups. 4. Moderately centralized control system with vertical and horizontal feedback loops. 5. Extremely complex and expensive coordination mechanisms; some conflict resolution through product managers, some through normal hierarchical channels. 6. Performance appraisal based on both effectiveness and efficiency measures, most rewards to marketing and engineering.
Costs and Benefits:	*Costs and Benefits:*	*Costs and Benefits:*
Low investment in research and development, combined with imitation of demonstrably successful products, minimizes risk, but domain must be optimally balanced at all times between stability and flexibility.	Dual technological core is able to serve a hybrid stable-changing domain, but the technology can never be completely effective or efficient.	Administrative system is ideally suited to balance stability and flexibility, but if this balance is lost, it may be difficult to restore equilibrium.

Source: Raymond E. Miles and Charles C. Snow, *Organizational Strategy, Structure, and Process* (New York: McGraw-Hill, 1978), Table 5-1.

Appendix 1b. Strategic typing taken from (Conant *et al.*, 1990) based on Miles and Snow (1978).

Table 1. Dimensions of the Adaptive Cycle and Strategic Type Characteristics[a]

Adaptive cycle components	Dimensions	Strategic Types			
		Defenders	Prospectors	Analyzers	Reactors[b]
Entrepreneurial problems and solutions	Product-market domain	Narrow and carefully focused	Broad and continuously expanding	Segmented and carefully adjusted	Uneven and transient
	Success posture	Prominence in 'their' product market(s)	Active initiation of change	Calculated followers of change	Opportunistic thrusts and coping postures
	Surveillance	Domain dominated and cautious/strong organizational monitoring	Market and environmentally oriented/ aggressive search	Competitive oriented and thorough	Sporadic and issue dominated
	Growth	Cautious penetration and advances in productivity	Enacting product market development and diversification	Assertive penetration and careful product market development	Hasty change
Engineering problems and solutions	Technological goal	Cost-efficiencies	Flexibility and innovation	Technological synergism	Project development and completion
	Technological breadth	Focal, core technology/ basic expertise	Multiple technologies/ 'pushing the edge'	Interrelated technologies/ 'at the edge'	Shifting technological applications/ fluidity
	Technological buffers	Standardization, maintenance programs	Technical personnel skills/diversity	Incrementalism and synergism	Ability to experiment and 'rig solutions'
Administrative problems and solutions	Dominant coalition	Finance and production	Marketing and R&D	Planning staffs	Trouble-shooters
	Planning	Inside/out . . . control dominated	Problem and opportunity finding/ campaign (program) perspective	Comprehensive with incremental changes	Crisis oriented and disjointed
	Structure	Functional/line authority	Product and/or market centered	Staff dominated/ matrix oriented	Tight formal authority/ loose operating design
	Control	Centralized and formal/ financially anchored	Market performance/ sales volumes	Multiple methods/ careful risk calculations . . . sales contributions	Avoid problems/ handle problems . . . remain solvent

[a] Constructed by the authors based on a formative review of Miles and Snow (1978). For an overview of the adaptive cycle and the eleven underlying dimensions see pages 13–93 of Miles and Snow (1978).
[b] Conventionally, reactors have been presented as a 'residual' type lacking consistent response characteristics.

Appendix 2. Interview respondent codes. Prefix P indicates Prospector strategy-type, D = Defender- type, A = Analyser-type, R = Reactor-type. Primary gear type used, whether the respondent was a company or independent skipper, the age of skipper and interview date are also given.

Respondent code	Gear type	Company/Independent	Age	Interview date
D1	crab/lobster potter	Independent	59	16.04.2008
P2	otter trawler	Independent	34	18.04.2008
D3	gillnetter	Independent	42	22.04.2008
D4	beam trawler	Company	38	26.04.2008
D5	beam trawler	Company	51	06.05.2008
R6	beam trawler	Company	43	07.05.2008
A7	beam trawler	Independent	48	07.05.2008
A8	beam trawler	Independent	39	08.05.2008
A9	gillnetter	Independent	37	09.05.2008
R10	beam trawler	Company	63	09.05.2008
D11	beam trawler	Independent	53	10.05.2008
D12	beam trawler	Company	45	12.05.2008
D13	beam trawler	Company	55	14.05.2008
A14	beam trawler	Independent	50	21.05.2008
A15	beam trawler	Independent	54	22.05.2008
D16	beam trawler	Company	52	24.05.2008
D17	beam trawler	Independent	41	24.05.2008
A18	otter trawler	Independent	36	30.05.2008
A19	crab/lobster potter	Independent	40	02.06.2008
R20	beam trawler	Company	58	07.06.2008
D21	gillnetter	Independent	42	11.06.2008
A22	gillnetter	Independent	36	11.06.2008
P23	otter trawler	Independent	47	12.06.2008
D24	gillnetter	Independent	49	12.06.2008
A25	scallop dredger	Independent	48	13.06.2008
P26	gillnetter	Independent	36	18.06.2008
D27	beam trawler	Company	47	30.06.2008
P28	scallop dredger	Independent	51	01.07.2008
D29	scallop dredger	Independent	57	02.07.2008
A30	scallop dredger	Independent	53	02.07.2008
P31	gillnetter	Independent	28	04.07.2008
D32	beam trawler	Company	38	07.07.2008
P33	gillnetter	Independent	45	07.07.2008
D34	beam trawler	Independent	32	08.07.2008

Appendix 3. Questionnaire

SOUTH-WEST QUESTIONNAIRE: UNDERSTANDING SKIPPER DECISION-MAKING

Thank you for participating in this questionnaire. It provides me with invaluable data for my PhD research. I realise I have already taken your time with the interview that we did prior to giving you this questionnaire. This questionnaire is simply some additional questions about you that I did not ask in the interview because they tend to be tick-box type questions more suited to questionnaires. These questions relate to your background as a fisher and your general fishing patterns. I am also asking some questions about the sorts of financial pressure you are under. This is to see if there is a relationship with financial pressure and risk taking (that we talked about in the interview). I realise financial questions are a sensitive area for some people, and I have tried to keep the questions as un-intrusive as I can.

Let me reassure you again that your name or any facts that could identify you will **not** appear in any report of this study. All of your answers will be kept **confidential** and **cannot be traced back to you**. Once the questionnaire has been returned to me, this page with your name on it will be removed from the questionnaire. The questionnaire itself will be kept in a filing cabinet that is locked. All computer files I generate will not have your name on them.

I really appreciate the time you have given me.
So, all skippers who return their questionnaire to me will go into a draw to win a hamper worth £100

Please complete this questionnaire as soon as you can. If you have any questions about the questionnaire, don't hesitate to give me a call. My number is XXX. Once you have finished, you can send me a text or give me a call and I can come and collect it. If I haven't heard from you within a week, I will give you a call to arrange a time to come and collect it.

Kirsten Abernethy

Please fill in the following: *(this page will be removed once the questionnaire is returned to Kirsten)*

Name of skipper:

Contact details:

Date of birth:

Vessel name:

Vessel PLN:

Producer organisation membership:

[ ] CFPO

[ ] SWFPO

[ ] OTHER, please specify

……………………………………

[ ] NONE

SECTION A.

This section aims to understand a little of your background and history as a skipper. It also aims to understand your general and current fishing patterns, including the types of gear you use, and some information about your crew.

(i) ***Brief background.***

1. What year did you start fishing?

____

2. What year did you start fishing in the South-west of England?

(If the answer is the same as question 1, put *NA*)

____

3. What year did you first become a skipper?

____

4. Do members of your family fish for a living? (tick as many as appropriate)

1 [ ] YES, my sibling(s)

2 [ ] YES, my parent(s)

3 [ ] YES, my grandparent(s)

4 [ ] YES, my great grandparent(s)

5 [ ] YES, my child(ren)

6 [ ] NO

5. Please specify which qualifications you have (tick more than one if appropriate):

[ ] Secondary school (left at/before age 16)

[ ] CSCs

[ ] GCSCs

[ ] O LEVELS

[ ] A LEVELS

[ ] University degree, specify: ____________________.

[ ] Skipper Class 2 (or equivalent)

[ ] Skipper Class 1 (or equivalent)

[ ] Other, specify: ____________________.

6. Do you currently own the boat that you skipper?

1 [ ] YES

2 [ ] I part own the boat I skipper (please specify your % ownership) ______

3 [ ] NO (go to question **11**)

7. In which year did you buy the boat you currently skipper?

____

8. In which year did you buy your first boat?
(If your current boat is your first boat, go to question **10**)

____

9. How many boats have you owned over your career?

For each boat, please list the type of boat, percentage ownership, and the years owned

Boat type	**% ownership**	**Years owned**

10. Do you expect to need a new boat at some point in your fishing career?

1 [ ] YES, in _____________ years (please fill in the gap) (go to question **14**)

2 [ ] NO (go to question **14**)

11. Who owns the boat you currently skipper?

____

12. Do you intend to buy your own boat in the future?

1 [ ] YES

2 [ ] NO (go to question **14**)

13. In how many years do you plan to buy your own boat?

____

14. How many more years do you plan to fish for?

____

15. If you had to give up fishing, what would you do to earn a living?

____

16. Would you give up fishing if you won the lottery tomorrow?

1 [ ] YES

2 [ ] NO

3 [ ] I DON'T KNOW

(ii) Gear types used.

17. What is the main type of fishing gear you currently use on the boat you skipper? (tick the **one** most appropriate box)

1 [ ] Beam trawl – Stonemat gear

2 [ ] Beam trawl – Open gear

3 [ ] Otter trawl

4 [ ] Twin otter trawl

5 [ ] Triple otter trawl

6 [ ] Scallop dredge

7 [ ] Gill nets

8 [ ] Seine nets

9 [ ] Pots

10 [ ] Other, specify: ____________________.

18. Did you use any gear types other than your main gear type in **2007**?

1 [ ] YES

2 [ ] NO (go to question **20**)

19. There are 3 things you need to do for this question.

1. List each gear type you used in **2007**

2. List which months of the year you used the gear type

3. Estimate the proportion of your total fishing income that that you got from the gear type in **2007**. *(I have put an **example** in the first line)*

1. Gear type	2. Month(s) gear was used	3. Proportion of total income
Beam trawl	January - June	60%
		TOTAL = 100%

20. Did you use other gear types than your main gear type in **2006**?

1 [ ] YES

2 [ ] NO (go to question **22**)

21. There are 3 things you need to do for this question.

1. List each gear type you used in **2006**

2. List which months of the year you used the gear type

3. Estimate the proportion of your total fishing income that that you got from the gear type in **2006**:

1. Gear type	2. Month(s) used	3. Proportion of total income
		TOTAL = 100%

22. What types of technology do you use while fishing? (tick as many as are appropriate)

1 [ ] GPS

2 [ ] Fish finder

3 [ ] Plotting software

4 [ ] Sonar

5 [ ] Ground discrimination

6 [ ] Seabed mapping software

7 [ ] ARPA radar

8 [ ] AIS/Vessel Identification software

9 [ ] Satcom e-mail

10 [ ] Other, specify: ____________________.

11 [ ] Other, specify: ____________________.

23. Do you have deck machinery to sort fish?

1 [ ] YES

2 [ ] NO

(iii) ***Crew.***

24. On average, how many crew (excluding yourself) do you currently have on a fishing trip?

____

25. How often do you get new crew members? (tick the **one** most appropriate box)

1 [ ] I have a completely different crew every fishing trip

2 [ ] I have at least one new crew member every fishing trip

3 [ ] I have at least one new crew member on most fishing trips

4 [ ] I have at least one new crew member on half the fishing trips

5 [ ] I occasionally have a new crew member

6 [ ] I rarely have a new crew member

7 [ ] I have had the same crew for more than one year

8 [ ] I have had the same crew for more than five years

26. Please describe the wage system:

After expenses (please specify what these are)

____

____

The total boat owner share is _________________ %

The total crew share is _________________ %

Please outline how the crew share is split:

____

____

____

(iv) ***General fishing patterns*.**

27. This question is about what species you target throughout the year.
For each month, please list the main species you target.
Please make sure you have all the months of the year covered. If a new target species is targeted half way through the month, please make a note of it. If you take time off during the year please indicate when that is.

Month	**Target species**
January	
February	
March	
April	
May	
June	
July	
August	
September	
October	
November	
December	

28. What is the current home harbour of your boat? (tick the **one** most appropriate box)

1 [ ] Newlyn 4 [ ] Padstow 7 [ ] Dartmouth

2 [ ] Brixham 5 [ ] Shoreham 8 [ ] Teignmouth

3 [ ] Plymouth 6 [ ] Salcombe 9 [ ] Exmouth

10 [ ] Bideford 11 [ ] Other (please specify)___________________

29. In **2007**, did you land fish at any other harbours?

1 [ ] YES

2 [ ] NO (go to question **32**)

30. Please tick all the harbours you used in **2007**

1 [ ] Newlyn 4 [ ] Padstow 7 [ ] Dartmouth

2 [ ] Brixham 5 [ ] Shoreham 8 [ ] Teignmouth

3 [ ] Plymouth 6 [ ] Salcombe 9 [ ] Exmouth

10 [ ] Bideford

11 [ ] Other (please specify) ___________________________

12 [ ] Other (please specify) ___________________________

13 [ ] Other (please specify) ___________________________

14 [ ] Other (please specify) ___________________________

31. Was **2007** typical of the last five years? (Choose the **one** most suitable answer)

1 [ ] Yes, I normally use this many harbours to land my fish.

2 [ ] No, I normally use more harbours to land my fish.

3 [ ] No, I normally use less harbours to land my fish.

4 [ ] No, I normally use only one harbour to land my fish.

32. Choosing a harbour to land and sell at. Please choose the **one** most suitable answer.

1 [ ] I always land at my homeport and sell my fish at my homeport market

2 [ ] I always land at my homeport but will transport my catch to the market with the best price

3 [ ] I will land at ports other than my homeport but will always transport my catch to my homeport

4 [ ] I land at different ports and always sell at the port I land at

5 [ ] I land at different ports and transport my catch to the market with the best price

33. How many days were you at sea in **2007**? (an estimate is fine)

____

34. Was the number of days at sea in **2007** typical of the last five years?

(Choose the **one** most suitable answer)

1 [ ] Yes, I normally fish about the same number of days in a year.

2 [ ] No, I normally fish more days in a year.

3 [ ] No, I normally fish less days year.

35. In **2007**, on average, and if weather was good and constant, how long was each fishing trip?

____

36. Was the length of trip in **2007** typical of the last five years? (Choose the **one** most suitable answer)

1 [ ] Yes, the length of trip has been the same as 2007 for the past five years

2 [ ] No, trips have usually been longer in the past.

3 [ ] No, trips have usually been shorter in the past

37. On average, how many hours/days do you have off between fishing trips? (please indicate if you are including the landing day)

____

38. This question is about the factors that are important to you when deciding where to fish **before you leave the harbour**. Please rank the following factors from 1 to 14, giving the most important factor for you a value of 1, and the least important factor a value of 14.

Factor	**Ranking**
Season	
State of the tide	
What was caught on the previous trip	
What species you want to target	
The availability of quota	
Cost of fuel	
Availability of crew	
Seabed (hard/soft ground, wrecks, cables)	
The weather when steaming out	
The forecast for while at sea	
Market prices of fish	
What other boats in fleet have landed and where	
Reference to personal logbooks/diaries	
Information and news from contacts (other skippers)	

39. Please list other factors that are not on the above list that affect your decision about where to fish

____

____

SECTION B. Investments & financial risk

The purpose of this section of questions is to see if there is a relationship between the decisions you make and the amount of financial pressure you are under.

I realise that some of these questions are quite personal and I totally understand if you do not want to answer these questions. Feel free to leave this section blank if you feel strongly that you do not want to answer these questions. But, let me reassure you again that this is for my research only. I am interested in general patterns only, not individuals. This type of information will be extremely useful for my research.

(i) Vessel investments

(**To be answered by skippers who own their boat only**. If you do not own your boat, go to question **49**)

40. Do you own your vessel outright?

1 [ ] YES, I have paid off my vessel (go to question **42**)

2 [ ] NO, I still owe some money on my vessel

41. After paying for your running costs (fishing trip costs including crew wages, insurance, maintenance, gear, administration costs) after each trip, please estimate the percentage of your earnings that goes to paying your vessel loan.

______________ %

42. Have you had to invest in rebuilding your vessel in the last 5 years?

1 [ ] YES

2 [ ] NO

43. Have you invested in any new mechanical equipment in the last 5 years?

1 [ ] YES

2 [ ] NO

44. Have you invested in any new electronic equipment in the last 5 years?

1 [ ] YES

2 [ ] NO, I lease electronic equipment

3 [ ] NO

45. Have you invested in any new catch handling equipment in the last 5 years?

1 [ ] YES

2 [ ] NO

46. Have you invested in any new equipment to improve safety/working conditions/comfort on your vessel in the last 5 years?

1 [ ] YES

2 [ ] NO

47. Please list the types of regular maintenance you do on your boat in a year and how often you do it.

Type of maintenance	**I do this maintenance every…..**
	Months
	Months
	Months
	Months
	Months
	Months
	Months

48. Have you had to do any major maintenance to your boat in the last 5 years?

1 [ ] YES, please specify

____

____

2 [ ] NO

(ii) ***Non-vessel investments and costs*** (To be answered by **ALL** skippers)

49. How many people are there in your household? Please tick and where appropriate give the number.

[ ] SPOUSE

[ ] CHILDREN (number) ___________

[ ] OTHER RELATIVES (number) ___________

[ ] FRIEND (number) ___________

[ ] LODGER (number) ___________

50. Do you have sources of income, other than from fishing, coming into your household?

1 [ ] YES

2 [ ] NO (go to question **53**)

51. Please list your other sources of income.

____

____

____

52. Please estimate the percentage of income that your fishing represents of the total household income.

[%]

53. What are your current major areas of expense, **excluding** fishing related costs and general living expenses (food, electric, gas, water, council tax)?

(tick as many factors suitable answers)

1 [ ] Mortgage

2 [ ] Rent

3 [ ] Car loan

4 [ ] Car expenses

5 [ ] Home renovations

6 [ ] Additional property

7 [ ] School fees

8 [ ] Other (please specify) ___________________________

9 [ ] Other (please specify) ___________________________

10 [ ] Other (please specify) ___________________________

54. Have you undertaken any industry courses that help you to managing finances?

1 [ ] YES

2 [ ] NO

(iii) Costs and earnings from fishing

55. Please estimate your total fishing costs for the latest financial year (2007/2008). If you do not own your own vessel, then please put down your claimed expenses

____

56. Please estimate your total earnings from fishing for the latest financial year (2007/2008).

____

57. Please estimate the number of fishing trips you did in the latest financial year (2007/2008).

____

THANK YOU VERY MUCH!

Chapter 4

Modelling fishing location choice for the beam trawl fleet in southwest England

1. Abstract

How do fishermen choose where to fish? A logistic random utility model (RUM) of fisher location choice by beam trawlers in the southwest of England was used to help answer this question. The RUM was parameterised using data from the EU vessel monitoring system, the UK logbook Fishing Activity database and the UK Fishing Vessel Register from 2005 to 2008. Individual vessel location choices and model variables were aggregated to ICES statistical rectangles (approximately 30 nautical miles square) by month. The model outputs show that vessels in southwest England made location choices (in 2005 - 2007) based on recent economic returns (value of catch per hour fished) in the month prior and in the previous year in the same month. Vessel skippers also made decisions based on the economic returns of the entire fleet; and tended to choose locations that yielded higher economic returns to the fleet compared to other available locations. This suggests a transfer of knowledge on what others in the fleet are catching and where. Beam trawlers also appeared to be risk-averse, preferring to fish locations closer to their homeport, and at locations with less variance in the value of catch per unit effort at a location, even if the economic returns could be high. Vessels also preferred to fish in deeper water, particularly the larger vessels of the fleet. To evaluate the model's predictive ability, I compared 2008 location choices with predicted choices using the 2005 – 2007 model coefficients. The model correctly predicted vessels not fishing in a rectangle in 97% of cases and correctly predicted where vessels fished in 56% of cases. The predictive ability of the model varied by ICES statistical rectangle and month and the spatial density of predicted choices corresponded closely to the observed choice densities. This study shows that a RUM approach can be of practical use for policy makers who want to determine the factors that influence location choice of fishers and with further model development may be useful for predicting fisher response to management action.

2. Introduction

Since the 1950s there has been consistent recognition that successful fisheries management relies on a detailed understanding of fisher behaviour (Gordon, 1953, Hilborn and Walters, 1992, Charles, 1995, Wilen *et al.*, 2002, Hilborn, 2007). It is widely acknowledged that a primary reason for management failure is lack of knowledge of how fishers will respond and adapt to management (Hilborn 1985; Hart 2003). Without a clear understanding of how fishers make decisions, the management regime can result in behaviour that is not intended by managers, even producing negative environmental, economic and social effects (Hilborn *et al.*, 2004, Pascoe and Mardle, 2005). This lack of insight into such a fundamental component of fisheries management is surprising since management attempts to change incentives and costs in order to change fisher behaviour (Pascoe, 2006). Fisheries policy continues to be informed primarily by biological information, and it has been assumed that if catch, effort and stock levels can be determined, then the fishery will be managed more successfully (Punt and Hilborn, 1997, Pauly *et al.*, 2002, Baker and Clapham, 2004). Progress toward incorporating fisher behaviour and the decision-making processes that underpin behaviour into policy decisions has been limited.

A key area of fisher decision making that requires integration into fisheries policies is the choice of fishing location - where to fish. Fishers will have different returns depending on their location choice because of patchiness and spatial heterogeneity in the marine ecosystem. Consequently there is increasing interest in restricting or modifying spatial location choice through the use of spatially explicit policies for the management of the marine environment (Christie, 1992, United Nations, 2002, IUCN, 2003, Hannesson, 2004, CBD, 2006, Roberts *et al.*, 2006, Wood *et al.*, 2008). A current example of this is in the UK, where the government has committed to put in place an ecologically-coherent network of marine protected areas (MPAs) by 2012 for the conservation and recovery of marine biodiversity and ecosystems (Marine and Coastal Access Bill, November 2009). Although the proposed protected areas gives weight to biodiversity conservation, there are also clear commitments to *"finding space for the competing range of activities in our seas, for example fishing… and manage them in a holistic way"* (Defra, 2009). A key factor policy makers require in order to know if spatial policies will meet objectives, is to understand how users of the marine environment will respond, such as where fishing effort will be displaced to if areas are closed (Smith, 2000).

Research into understanding and predicting where fishers go to fish has been dominated by modelling and statistical approaches. However, sets of knowledge can be drawn from social approaches in fisheries research and alternative disciplines and be used to add contextual depth to understand the reasons underpinning location choice behaviour, including the interactions and trade-offs between individual profit maximisation goals, risk, knowledge and the incentives and institutions present (See Chapter 2 and 3 for detailed discussion and application). For this chapter I focus on the use and value of modelling location choice, and examine how modelling can explore the relative contribution of profit, individual knowledge, information exchange between fishers, financial and physical risk taking, as well as vessel characteristics on location choice decisions . There have been two main types of models used in the location choice literature. The first type of model is based on ecological foraging theory, the Ideal Free Distribution (IFD) (Fretwell and Lucas, 1970), and the second type of model is a random utility model (RUM) which is based on the economic concept of utility (McFadden, 1974).

In his seminal paper, Gordon (1954) proposed that in a fishery, vessels will seek the most profitable fishing grounds and fishing effort will eventually distribute so that profit rates are equal among grounds. In the ecological literature this is known as the Ideal Free Distribution theory (Fretwell and Lucas, 1970) and has been used to model fisher location choice (Abrahams and Healey, 1990, Gillis *et al.*, 1993, Swain and Wade, 2003). This hypothesis has been successful in predicting location choice but the case studies have been relatively simple, with only one or two species caught in a limited number of areas fished by a fairly homogenous fleet of vessels. The model relies on assumptions that may be inaccurate and lead to erroneous conclusions when applied to more complex fisheries. First, fishers are assumed to have homogeneous characteristics and motivations. Second, fishers are assumed to have perfect information about the resource they exploit: the problem of finding fish is assumed away (Wilson, 1990). Therefore this model is less relevant to many fisheries, such as in Europe where a mix of species are caught, the mix of fish is highly seasonal, fishers can choose between numerous grounds and use different size of boats and different gears to catch the same fish. Furthermore, perfect information about the resource is never available. The complex choice set a fisher faces combined with uncertain resource availability and management restrictions reduces an individual's ability to know what the relative profitability will be for all alternative locations (Anderson and Christensen, 2006).

The random utility model (RUM) is increasingly used to understand location choice in temperate fisheries (e.g. Bockstael and Opaluch, 1983, Eales and Wilen, 1986, Holland and Sutinen, 1999, Mistiaen and Strand, 2000, Smith, 2002, Hutton *et al.*, 2004, Anderson and Christensen, 2006). The RUM is based on the concept of utility which, in economics, is defined as the measure of happiness or satisfaction gained from a good, service or activity. Rational decision makers are assumed to make decisions based on maximising their utility (subject to constraint). Therefore, in the RUM, utility is assumed to drive individual choice. Utility *(U_{ij})* is defined as a linear combination of deterministic explanatory variables *(z_{ij})* (that together make up the non-random part of the model) with a coefficient β, and a stochastic error term *(ε_{ij})* (the random component):

$$U_{ij} = \beta z_{ij} + \varepsilon_{ij}$$

where, for a given person-time event, *i* (such as a fishing trip by an individual), a choice *j* (such as location) is made. The explanatory variables *(z_{ij})* can consist of the attributes of the choice *(x_{ij})* and the characteristics of the individual *(w_{ij})*. A logit distribution of the error term *(ε_{ij})* is most widely used in practical applications of RUMs in fisheries, to reflect a 0 or 1 choice. The simplest of these is the conditional logit model (McFadden, 1974) which assumes that the choice of location is unordered. So, the probability that individual *i* will go to location *j,* or not, is given by:

$$\Pr(Y_i = j \mid z_{i1}, z_{i2}, \ldots z_{iJ}) = e^{\beta zij} / \textstyle\sum_J e^{\beta zij}$$

The original RUM paper modelled the choice of which fishery to pursue (Bockstael and Opaluch, 1983), and the literature since has focussed on location choice decision-making, explaining observed location choices and predicting them (Holland and Sutinen, 1999, Hutton *et al.*, 2004). The explanatory variables considered relate primarily to profit maximisation, and given that fishing is an economic activity, this is no surprise. Expected profitability (catch, value of catch, or catch/value of catch per unit of fishing effort) is used as a variable in all models and has been found to be a significant predictor of location choice (e.g. Holland and Sutinen, 1999, Curtis and Hicks, 2000, Smith, 2002, Hutton *et al.*, 2004). However, fishers need to know where the fish are in order to be successful, therefore previous individual vessel profitability has also been used as a proxy for skipper knowledge and experience (e.g. Wilen *et al.*, 2002, Smith, 2005). Information exchange has been identified as being important in the search for fish, and variables that include fleet wide profitability have been considered to be a proxy for information exchange among the fleet (e.g. Curtis and McConnell, 2004, Anderson and Christensen, 2006). RUMs have also included variables related to risk-taking behaviour, and generally show that profit is traded off with risk aversion. This has been measured using the variability of returns at a location, with vessels choosing locations that have lower variability of returns than high variability of returns (e.g. Pradhan and Leung, 2004). Risk has also been measured using distance from port, with vessels tending to select fishing sites closer to port rather than further away (e.g. Smith, 2002, Smith, 2005, Anderson and Christensen, 2006). Vessels have also been shown to rely on traditional fishing grounds, showing inertia to change, in order to reduce uncertainty or habit (Holland and Sutinen, 2000). Some models have also incorporated vessel specific characteristics, such as age and size of the vessel, showing that different classes of vessel exploit different locations (Mistiaen and Strand, 2000, Pradhan and Leung, 2004, Smith and Zhang, 2007, Prellezo *et al.*, 2009). In summary, profit, knowledge, risk and vessel characteristics have been shown to influence location choice in RUM models. Therefore, I include variables related to all of these factors in the model presented in this study.

In this chapter, I apply a RUM to understand and predict the location choice behaviour of the beam trawl fleet in Southwest England. I provide insights into the assumptions, strengths and weaknesses of this approach, as well as the data requirements. For this study I start by using the simplest of models, the conditional logit model, to determine predictors of vessel location choice from 2005-2007. I derived the variables for the model based on the literature (See above and Chapter 2 for full literature review) and the data available. The variables were vetted and informed by in-depth knowledge of the SW beam trawl fishery and fisher decision-making strategies (See Chapter 3). I considered variables relating to individual vessel characteristics, and tested the effects of size, age and home port[10] of the vessel. I looked at the influence of individual experience using vessels previous value of catch per unit fishing effort (VPUE). I also considered variables related to the location itself using the depth of the location (the only habitat-type data available). I explore the degree of knowledge transfer of what the beam trawl fleet are currently catching and where, using fleet-wide VPUE in a location. I examine the risk preference of vessels using the variance of VPUE of the beam trawl fleet in that location and if vessels choose locations close or far from their home port. A range of models are explored and presented which examine the effects of different variables of interest and their interactions. I specifically explore the interactions between vessel size, rectangle depth, rectangle VPUE and variation of VPUE. I then use the resulting model to predict location choice for 2008 and compare the results with actual location choice data for 2008.

3. Methods

3.1. Description of the study location and fleets

With the decline of North Sea fisheries, the southwest of England now holds most of the remaining English fleet. The southwest (SW) fishery is termed a 'mixed fishery': diverse in

[10] In other RUM models, all vessels have used one home port or it is controlled for. If this has not been explicitly controlled for in the models, this may be an oversight.

terms of gear type and species caught, and ranging from small inshore day boats to large trawlers fishing on week-long trips in deep water over 100 nautical miles offshore. The fishery operates primarily in ICES Area VII (Fig. 1) and this area contributed 28% of UK registered vessel landings (163,300 tonnes), constituting 27% of the value of landings (£169.9 million) into the UK and abroad by UK vessels in 2008. There are three major landing ports and markets in SW England; Newlyn, Plymouth and Brixham and in 2008, total landings into these three ports constituted 44% of the total landings in England, which represented over half of the total value of English landings (52%). Demersal (bottom dwelling)species make up a significant proportion of fisher incomes in the SW (all landing statistics: Marine and Fisheries Agency, 2009). In 2008 one third of total landings into Newlyn, Plymouth and Brixham were demersal species, such as monkfish *(Lophius piscatorius)*, megrim *(Lepidorhombus whiffiagonis)* and Dover sole *(Solea solea),* which comprise of some high value species and represented 61% of the total value of landings over the three ports.

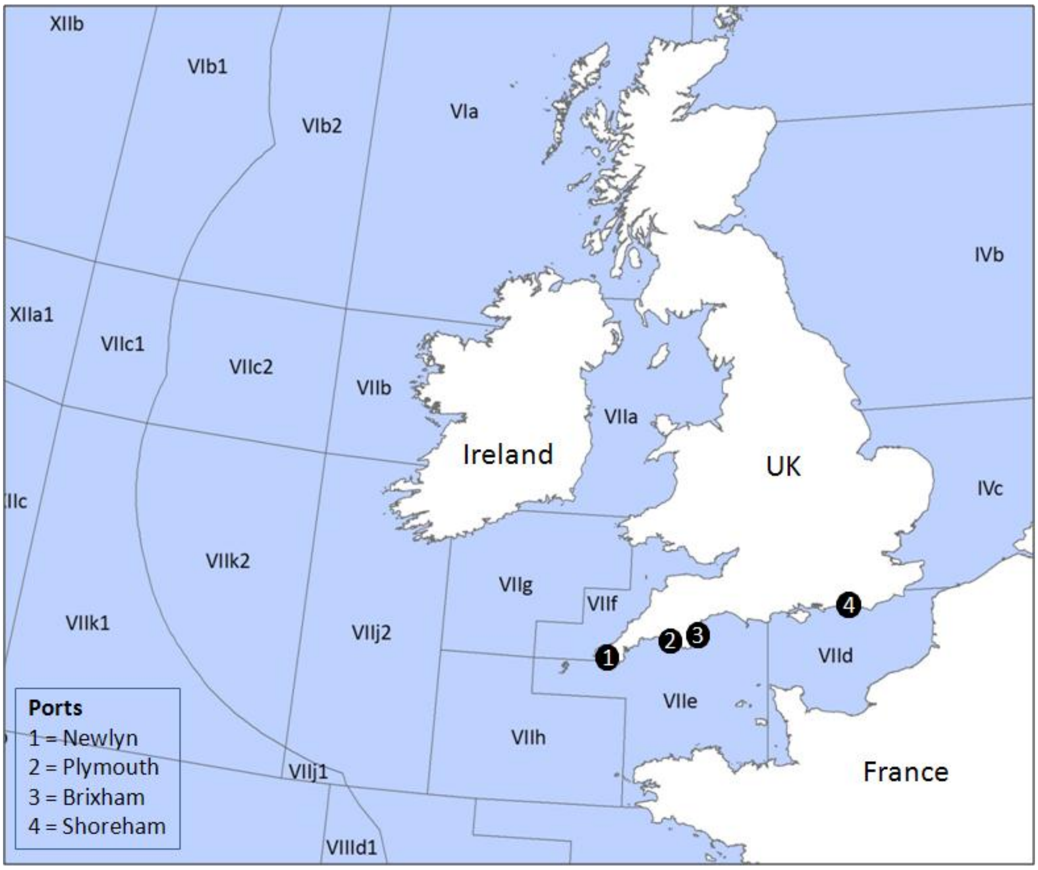

Figure 1. Map of the UK and ICES Area VII. ICES Area VII is further subdivided into Areas VIIa-k. Main Southwest ports/markets, Newlyn, Plymouth, Brixham and Shoreham are also identified on the map.

This study examines the location choice behaviour of the SW beam trawl fleet of vessels over 15 metres in length from 2005 to 2008. The beam trawl fleet targets a range of species and can catch 15-20 different species in one trip (Fig. 2). However beam trawlers tend to target a core mix of species. Some species caught are also very seasonal, for example, beam trawlers catch high quantities of cuttlefish for a few months in autumn/winter. In terms of the characteristics of SW beam trawl vessels, there does not appear to be a large amount of variation within fleet in length of vessel (mean ± SD = 27.93 ± 4.04 metres, n= 46), although vessels do vary substantially in terms of tonnage (mean ± SD = 153.29 ± 53.27 tonnes) and engine size (mean ± SD = 555.23 ± 243.06 kW). Vessels also tend to be old (mean ± SD = 36 ± 12 years).

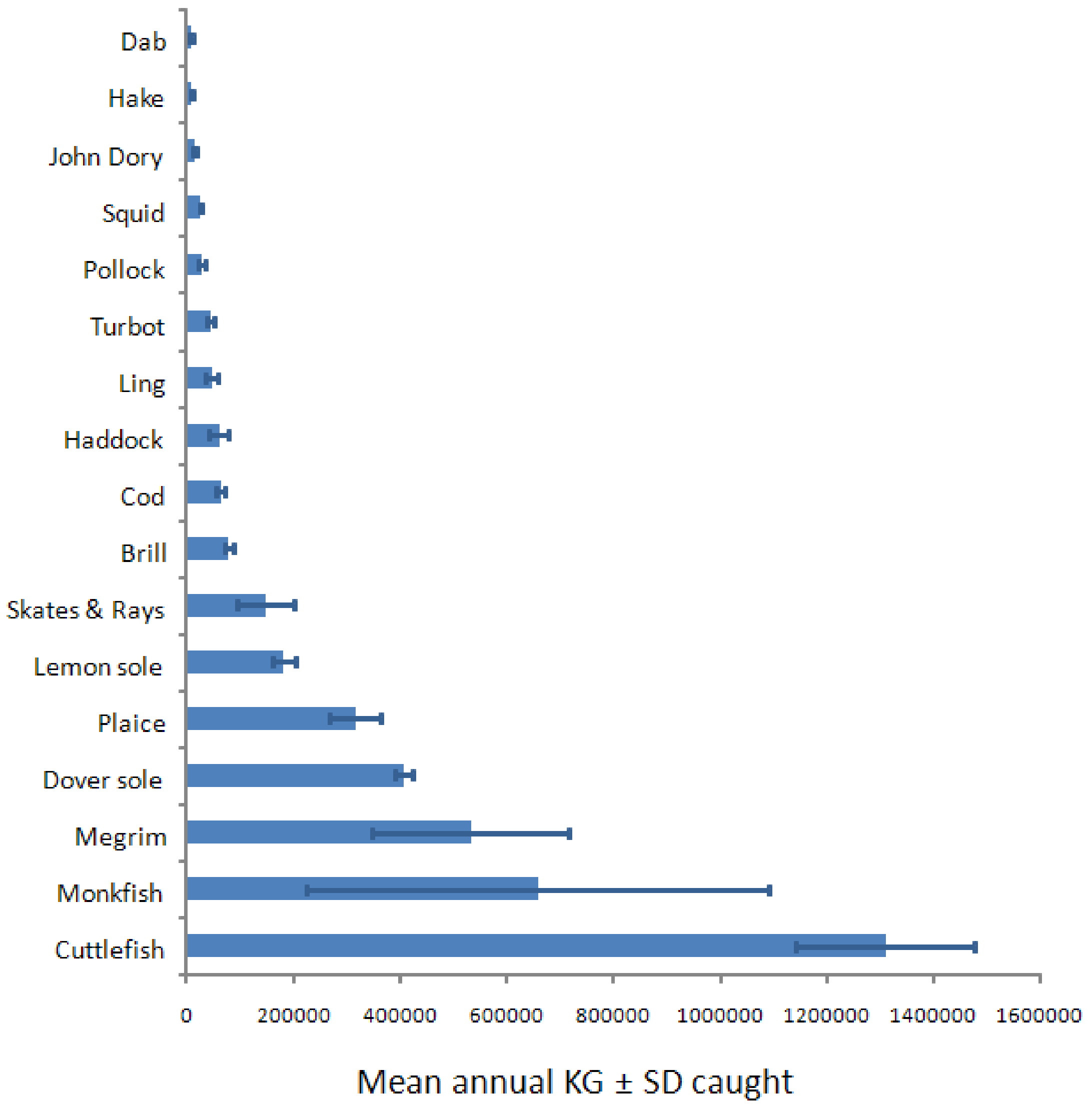

Figure 2. Mean annual KG and SD of species caught by the SW beam trawl fleet (2005-2008).

3.2. Data sources

Data were extracted from three national fishery databases from 2005 to 2008; the EU vessel monitoring system (VMS), the UK logbook Fishing Activity database (FAD) and UK Fishing Vessel Register (FVR). Since 2005, all UK registered fishing vessels over 15 metres have been fitted with VMS, a satellite tracking device that records the vessel position every two hours. This was linked using the fishing trip unique identifier to landings data held in the FAD. FAD provides data on the total catch (KG), value of catch (£) for each species caught, and the gear type used for each trip. Using the vessels unique registration number, the data were also linked to the FVR which provides vessel characteristics data such as the vessel size, age, and home port (the harbour where vessel is kept). Data were extracted into a Microsoft Access database linked with mapping software, ArcGIS 9.2, where distances from fishing position to home port was calculated and bathymetry data (depth) incorporated.

3.3. Data selection

This large dataset was reduced to consider only the 22 rectangles that encompassed approximately 95% of fishing effort, catch and value; and the 46 vessels with complete records for vessel characteristics. Firstly, SW beam trawlers exploit different subdivisions within ICES area VII. Visual estimations were made of 2005 maps of fishing effort and ICES areas were selected that looked to include all fishing effort: ICES Areas VII d, e, f, g and h. Then the spatial resolution of the model was set at the size of the ICES statistical rectangle, which is 0.5° latitude x 1° longitude (approximately 30 nautical miles square). Rectangles were selected where 95% of the average annual effort took place (2005-2008). Rectangles where 95.16% annual effort took place also had 94.76% of the annual average catch weight, and 94.21% annual average catch value. In some cases the rectangle included a proportion of land; I accounted for this in the model by including the calculated percentage of sea as a covariate. I eliminated vessels (19 vessels) without complete records of vessel characteristics (vessel size and age, homeport, etc) and those whose characteristics changed over time, e.g. due to alteration or change of owner. These vessels were removed to reduce any bias in the sample.

The VMS data contained all vessel observations every two hours over the course of a fishing trip. This included fishing observations where the vessel was fishing or steaming to a fishing ground. To select fishing only observations, a speed filter was used (Mills *et al.*, 2006). For beam trawlers, if the vessel was travelling between 2-8 knots it was considered to be fishing. Other observations were assumed to be steaming observations and were removed from the data sets. FAD data were then linked to the VMS data using a unique fishing trip identifier, and catch weight and value of catch were divided equally among observations for each fishing trip.

This is clearly a limitation of the data available but unfortunately there are no data of fine enough resolution which can attribute catch to a specific ICES rectangle.

Catch value data were imputed for 6% of the total fishing observations. Catch weight and value are highly correlated for all species (all species, $R_P > 0.9$) and therefore, rather than delete the missing cases, the value of catch was imputed for each species (Nakagawa and Freckleton, 2008). In 1.3% of total observations there were no data for value of catch or weight of catch. This portion of the dataset was examined to see if there was any systematic bias or pattern which could explain the missing data, but as none was found these observations were therefore removed. In total, there were 212,624 fishing observations (satellite positions) between 2005 and 2008. The data were then aggregated to month and rectangle. Therefore, the analysis was restricted to 22 rectangles, for 46 vessels in 48 months, yielding a total of 48,576 observations.

3.4. Conceptual model

The model predicts the probability of a vessel choosing a given location (ICES rectangle) in a month. In the time period the TAC and quotas for most of the demersal fish species in the SW was relatively stable and annual changes in quota were assumed to have a minor influence on choice of target species.

The conceptual model takes the following form and explanatory variables are described in detail in the next section:

Probability of a vessel choosing to fish in a rectangle in a month

= β_1*(Fixed vessel characteristics, e.g. size, homeport)*

+ β_2*(Fixed rectangle characteristics, e.g. depth, variance off fleet VPUE in rectangle)*

+ β_3*(Vessel previous value of catch per unit effort (VPUE) in rectangle)*

+ β_4*(Vessel distance from homeport)*

+ β_5*(Fleet VPUE in rectangle)*

+ ε

Using the model coefficients from 2005-2007 data, I then predict the probability of a vessel choosing a rectangle in a month for 2008. I compare the predicted 2008 choices with actual choices in 2008.

3.5. Model Variables

3.5.1. Vessel level explanatory variables

(a) Fixed vessel characteristics:

I restricted the variables to Vessel Capacity Units (VCU) and vessel age only. Vessel age was taken as age in 2008. A PCA analysis for possible variables showed that the main axis of variation was comprised of size-related vessel characteristics (factor 1), and vessel age (factor 2; Table 1.). The data available for this analysis were vessel length (metres), vessel tonnage (tonnes), engine size (kW) and vessel capacity units (VCU) which is a value that takes into account vessel length (mt), breadth (mt) and engine size (kW) of the vessel *(VCU = length x breadth x 0.45kW)*, age of the vessel (in years in 2008) and the vessel homeport. There were four home ports, Shoreham (n =2), Plymouth (n = 4), Newlyn (n = 25) and Brixham (n =15). The vessel size variables are all highly related, therefore I chose VCU which integrates them. Age of vessel varied by home port (One-way ANOVA, VCU: $F_{3,42}$ = 3.354, p = 0.028; Vessel age: $F_{3,42}$ = 15.34, p < 0.001; Fig 3.). Shoreham vessels are smaller compared to the other ports, and Newlyn and Brixham vessel are old when compared to Plymouth and Shoreham vessels, to account for this I included home port as a dummy variable in the model.

Table 1. Principle component factors describing fixed vessel characteristics. All factor loadings for each characteristic are included, with loadings >0.4 highlighted in bold.

Fixed vessel characteristics	**Principle components**	
	Factor 1	**Factor 2**
VCU	**0.983**	0.005
Engine size	**0.956**	0.004
Tonnage	**0.954**	-0.202
Length	**0.921**	0.187
Age	-0.174	**0.943**
Home port	0.263	**0.412**
Variance explained	62.52%	18.29%

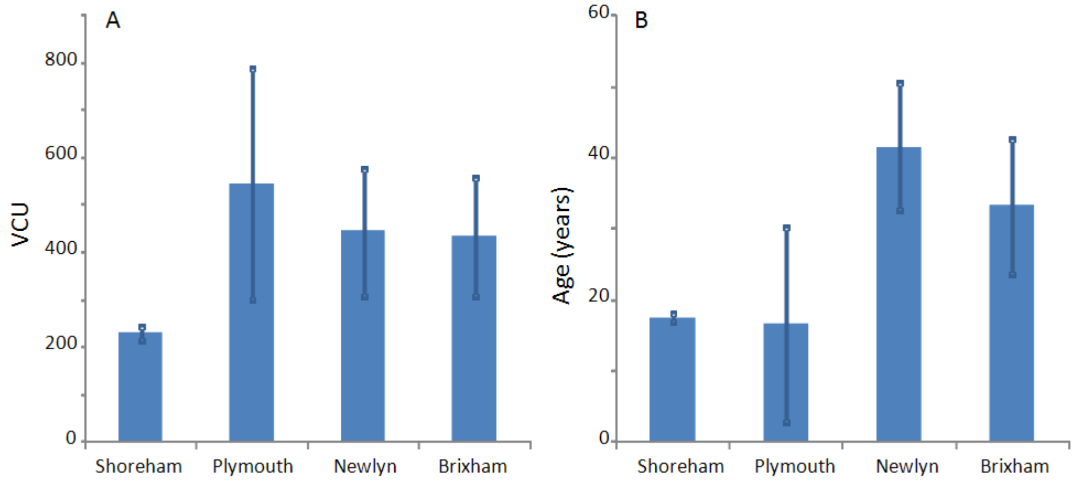

Figure 3. Home port and A) VCU of vessels and B) Age of vessels (years). Shoreham: n=2, Plymouth: n=4, Newlyn: n=25, Brixham: n=15.

(b) Time variant characteristics of vessels:

Vessel previous catch value per unit effort (£ per hour fishing; VPUE) in month in rectangle was highly correlated with catch weight per unit effort (KG per hour fishing). VPUE was the variable used.

I examined lags of one to twelve months for VPUE (Fig 4.) and also examined the lags for value of catch and fishing effort separately. For catch value and fishing effort, all lags are significantly related to the current value of catch and effort. As expected, the previous month (lag 1) has the highest correlation coefficient, this then decays in subsequent lagged months and then grows again to be highly correlated at 12 months prior. For VPUE the pattern is the same but the correlation coefficient does not build again towards the 12 month lag. This indicates that the catch value, VPUE and fishing effort are related to recent catch value, VPUE and fishing effort; and catch value and fishing effort are also related to annual catch value and effort. Lagged VPUE (months 1-12) are included as variables in the model.

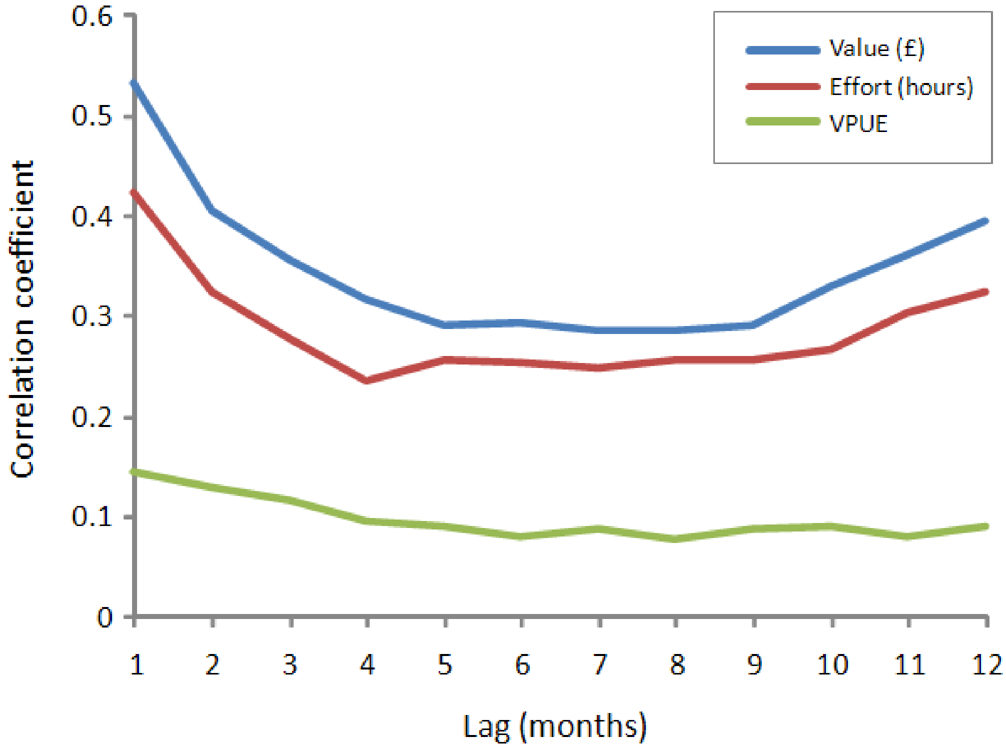

Figure 4. The correlations coefficients between vessel current value of catch (£), fishing effort (hours) and VPUE and lags of one to 12 months. All correlations were significant, $p < 0.01$.

For each vessel the distance (kilometres) from the centre point of each rectangle to the vessels homeport was calculated and included as a variable.

3.5.2. Rectangle level explanatory variables

(a) Fixed rectangle characteristics:

The mean and standard deviation (SD) of rectangle depths (metres) were included as variables in the model. The mean depth of rectangle varied from 25 to 167 metres (Fig. 5.). Depth was considered to be an important ecological factor to include as it can determine the catch composition and value, and also may constrain certain vessels that do not have the appropriate fishing gear to trawl in deeper water.

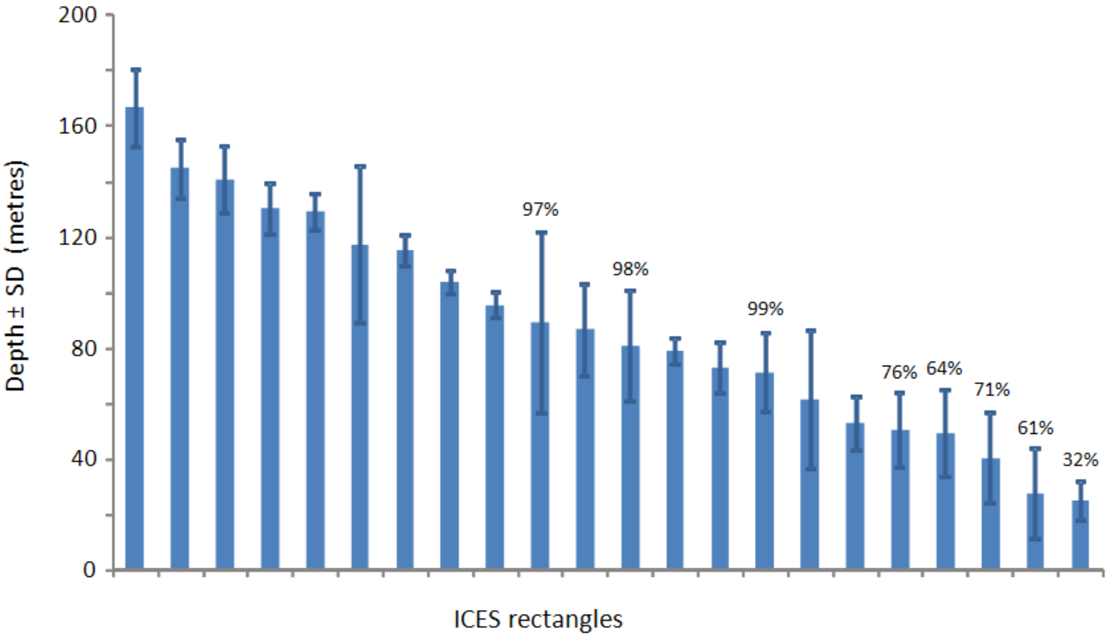

Figure 5. Mean and standard deviation (SD) of rectangle depths used in model. Percentages above columns indicates the percentage of sea in a rectangle (if less than 100%)

Given that the variance of catch in a rectangle has been shown to influence whether a vessel will choose a location or not, the coefficient of variation of VPUE of the fleet over the time period was calculated as a variable:

CV VPUE = Standard deviation VPUE in rectangle/ Mean VPUE in rectangle (fleet)

(b) Time variant rectangle characteristics:

Rectangle (or total fleet) VPUE in a month was considered. As I was interested in the selection of one rectangle over another, I calculated the relative VPUE for a rectangle compared to all the other rectangles in that month (VPUE in rectangle/VPUE in all rectangles). Rectangle catch weight per unit effort (CPUE) was also considered but was highly correlated with VPUE. Therefore, similar to the vessel VPUE variable, rectangle VPUE was used.

The relationship between vessel and rectangle VPUE was examined. Vessel VPUE was significantly and positively related to rectangle VPUE (VPUE: $R_P = 0.408$, $n = 7683$, $p < 0.001$).

3.5.3. Control variables

Month (January to December), year (2006 and 2007), and the percent of sea in a rectangle (Fig. 5.) were all included in the model as control variables.

4. Results

4.1. Random utility model results

The results of the random utility model of location choice using 2005 – 2007 data for the Southwest beam trawl fleet are presented in Table 2. Seven final variations of the same baseline model are presented, which examine the effects of different variables of interest and their interactions. Model 1 is the baseline model with all variables included and no interaction terms. Models 2-7 explore the effect of removing variables or adding interaction terms. All seven models are highly significant at the 1% level. In this section, the variables that consistently show the same results across models are discussed as well as the points of interest of the different model iterations.

As expected, for all models, vessel's previous VPUE (Vessel VPUE Lag1-12) in a rectangle was a significant predictor of location choice, indicating that if vessels had high VPUE in a location in previous months, there was a high probability it would return to that location. All lagged months were highly significant predictors ($p < 0.01$) except for the sixth month lag which was not significant. The strongest coefficients were one and two month lags, and the 12 month lag (compared to other lags). This suggests that recent VPUE and VPUE in the same month but the year before were important individual vessel characteristics predicting location choice.

The size (Vessel VCU) and age (Vessel Age) of vessel did not influence the probability of a vessel choosing a location in a month in the basic model (Model 1). However, given the expectation that the probability of a vessel choosing a rectangle may be related to both the size of the vessel and the depth of a location, this was investigated further. The model with depth variables (Rectangle mean depth, Rectangle SD depth) removed did not influence the predictive power of vessel size (Model 3). However, when the interaction term, Vessel VCU x Rectangle mean depth was included (Model 2), it was highly significant, indicating that there was a greater probability of a larger vessel choosing a deeper location. These results show that the effect of VCU is strongly mediated through mean depth of rectangle. Therefore, without controlling for this interactive effect between VCU and mean depth, the effect of VCU is confounded and the coefficient is not significant. When the interaction between VCU and depth is controlled for, VCU has a negative influence on location choice, which means that overall, larger vessels have a lower probability of fishing in a rectangle than smaller vessels.

The distance from homeport to the rectangle the vessel is fishing in (Distance to home port) is a significant predictor of location choice in all model iterations (Models 1-7). Vessels show a decreasing probability of fishing in a rectangle the further away from home port. Four home port dummy variables were included, Shoreham home port, Plymouth home port, Newlyn home port and Brixham home port. Brixham was used as the reference homeport. In most of the model iterations, there was no significant effect of individual home ports.

Individual vessels tend to select the most productive areas, in terms of the fleetwide VPUE. The relative VPUE of the whole fleet in a rectangle (Rectangle Relative VPUE) was an important indicator of location choice of a vessel (Models 1-7). Rectangle Relative VPUE is the total VPUE for all vessels in a rectangle in a month, relative to all the other rectangles in that month. Therefore, a high VPUE in a location relative to other locations in a month will result in a higher probability that a vessel will choose that rectangle in that month.

The mean depth of a rectangle (Rectangle mean depth) significantly affects the probability of a vessel choosing a location to fish there (Model 1, 4-7). A vessel is more likely to choose a fishing location if the water is deeper. This may be because one of the main species caught by beam trawlers in the SW are megrim, and these tend to be caught only by the larger vessels in deep water. The variation in depth (Rectangle SD depth) is a significant and negative variable in three of the six models, but is only significant at the 5% level in model 4. This may indicate that vessels prefer to choose locations where there is less variation in depth.

The variation in VPUE in a rectangle over the whole time period (CV VPUE) is an important factor affecting a vessels probability of fishing in a rectangle. Model results suggest that vessels are risk averse, preferring to choose rectangles that have less variation in VPUE. This is an interesting finding, therefore several iterations of the model were run to examine this variable further. Firstly, to find out if the rectangle variation in VPUE was related to depth, the model was run without the depth variables (Model 3) and found the significance of CV VPUE remained the same as the basic Model 1. The model was also run without the CV VPUE variable (Model 4) and found the significance and coefficient for depth variables remained the same. Secondly, the model was run using an interaction term; Rectangle mean depth X CV VPUE (Model 5). The interaction term was highly significant and negative, suggesting if the location is deep and there are variable returns, vessels are less likely to fish there. When there is the interaction term in the model, the CV VPUE variable becomes positive and significant, but the overall effect is that variation of VPUE is negative. I also wanted to examine if there was an interaction between the CV VPUE and the Relative VPUE in a rectangle (Model 6). This coefficient was highly significant and negative, which suggests that if there is high variability in VPUE in a rectangle, even if VPUE is high, there is a decreased probability that vessels will choose to fish that location, with the risk associated with the variability dominating the effect of high returns.

For all models (1-7) all months of the year were significant variables. December was used as the reference month and there was a higher probability that a vessel will fish in a rectangle in all months compared to December. Vessels may fish less in December because of the Christmas holiday period when fish markets are closed, and it is also likely they fish less due to poor weather at that time of year. Year was also a significant variable. 2007 was used as the reference year, and 2006 had a negative coefficient in all models, meaning vessels were significantly less likely to fish in a rectangle in 2006 compared to 2007. Therefore location choice appears to vary from year to year while controlling for other variables.

Model 7 includes all variables and all interaction terms, and the coefficients are used for the predictive model.

Table 2. Southwest beam trawl RUM iterations (Models 1 -7), including variables, coefficient (β) estimates, standard errors (s.e.), model estimates.

Variable	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7	
	β	s.e.	β	s.e.	β	s.e.	β	s.e.	β	s.e.	β	s.e.	β	s.e.
Vessel VPUE Lag1	0.83***	0.03	0.83***	0.03	0.84***	0.03	0.83***	0.03	0.83***	0.03	0.83***	0.03	0.82***	0.03
Vessel VPUE Lag2	0.29***	0.03	0.28***	0.03	0.29***	0.03	0.29***	0.03	0.29***	0.03	0.29***	0.03	0.28***	0.03
Vessel VPUE Lag3	0.19***	0.03	0.18***	0.03	0.19***	0.03	0.19***	0.03	0.18***	0.03	0.19***	0.03	0.18***	0.03
Vessel VPUE Lag4	0.16***	0.03	0.16***	0.03	0.16***	0.03	0.16***	0.03	0.16***	0.03	0.16***	0.03	0.15***	0.03
Vessel VPUE Lag5	0.09***	0.03	0.09***	0.03	0.10***	0.03	0.09***	0.03	0.09***	0.03	0.09***	0.03	0.09***	0.03
Vessel VPUE Lag6	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.02	0.03
Vessel VPUE Lag7	0.12***	0.03	0.12***	0.03	0.13***	0.03	0.12***	0.03	0.12***	0.03	0.12***	0.03	0.12***	0.03
Vessel VPUE Lag8	0.16***	0.03	0.16***	0.03	0.17***	0.03	0.16***	0.03	0.16***	0.03	0.17***	0.03	0.16***	0.03
Vessel VPUE Lag9	0.10***	0.03	0.09***	0.03	0.10***	0.03	0.10***	0.03	0.10***	0.03	0.09***	0.03	0.09***	0.03
Vessel VPUE Lag10	0.10***	0.03	0.10***	0.03	0.11***	0.03	0.11***	0.03	0.10***	0.03	0.11***	0.03	0.10***	0.03
Vessel VPUE Lag11	0.14***	0.03	0.14***	0.03	0.15***	0.03	0.14***	0.03	0.14***	0.03	0.14***	0.03	0.14***	0.03
Vessel VPUE Lag12	0.25***	0.03	0.24***	0.03	0.25***	0.03	0.25***	0.03	0.24***	0.03	0.24***	0.03	0.24***	0.03
Vessel VCU	-0.11	0.20	-11.54***	1.82	-0.06	0.20	-0.10	0.20	-0.11	0.20	-0.11	0.20	-11.95***	1.83
Vessel Age	0.03	0.17	0.21	0.18	0.03	0.17	0.03	0.17	0.03	0.17	0.03	0.17	6.27***	0.96
Vessel VCU X mean depth			6.05***	0.95									0.22***	0.18
Distance to home port	-1.19***	0.10	-1.26***	0.10	-0.88***	0.08	-1.19***	0.10	-1.25***	0.10	-1.22***	0.10	-1.34***	0.10
Shoreham home port	-0.30	0.22	-0.37*	0.22	-0.36	0.22	-0.29	0.22	-0.32	0.22	-0.29	0.22	-0.40*	0.22
Plymouth home port	-0.04	0.12	0.02	0.12	-0.03	0.12	-0.04	0.12	-0.04	0.12	-0.04	0.12	0.02	0.12
Newlyn home port	-0.07	0.06	-0.08	0.06	0.03	0.06	-0.05	0.06	-0.08	0.06	-0.06	0.06	-0.09	0.06
Rectangle Relative VPUE	1.24***	0.13	1.25***	0.13	1.19***	0.13	1.22***	0.13	1.24***	0.14	2.71***	0.36	2.72***	0.36
Rectangle % Sea	-0.75*	0.42	-0.34	0.44	0.74**	0.28	-0.47	0.41	-0.50	0.44	-0.93**	0.43	-0.20	0.46
Rectangle mean depth	1.17***	0.25	-14.76***	2.53			1.11***	0.25	2.32***	0.34	1.26***	0.25	-14.01***	2.54
Rectangle SD depth	-0.17*	0.10	-0.18*	0.10			-0.23**	0.10	-0.11	0.10	-0.15	0.10	-0.08	0.10
CV VPUE	-0.15**	0.07	-0.14**	0.07	-0.15**	0.07			3.37***	0.75	2.96***	0.68	6.83***	1.01
Rectangle Rel. VPUE X CV VPUE											-1.57***	0.34	-1.60***	0.34
Rectangle mean depth X CV VPUE									-1.96***	0.42			-2.12***	0.42

*p < 0.1, **p < 0.05, ***p < 0.01

Table 2 *continued*. Southwest beam trawl RUM iterations (Models 1 -7), including variables, coefficient (β) estimates, standard errors (s.e.), model estimates.

Variable	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7	
	β	**s.e.**	**β**	**s.e.**	**β**	**s.e.**	**β**	**s.e.**	**β**	**s.e.**	**β**	**s.e.**	**β**	**s.e.**
January	0.64***	*0.13*	0.65***	0.13	0.66***	*0.13*	0.64***	*0.13*	0.63***	*0.13*	0.72***	*0.13*	0.72***	0.13
February	0.42***	*0.13*	0.43***	0.13	0.43***	*0.13*	0.42***	*0.13*	0.43***	*0.13*	0.45***	*0.13*	0.46***	0.13
March	0.85***	*0.12*	0.86***	0.12	0.86***	*0.12*	0.85***	*0.12*	0.85***	*0.12*	0.87***	*0.13*	0.88***	0.13
April	1.06***	*0.12*	1.06***	0.12	1.06***	*0.12*	1.06***	*0.12*	1.06***	*0.12*	1.05***	*0.12*	1.07***	0.12
May	0.30**	*0.13*	0.30**	0.13	0.31**	*0.13*	0.30**	*0.13*	0.30**	*0.13*	0.31**	*0.13*	0.32**	0.13
June	0.61***	*0.13*	0.62***	0.13	0.64***	*0.13*	0.62***	*0.13*	0.62***	*0.13*	0.61***	*0.13*	0.62***	0.13
July	0.59***	*0.13*	0.59***	0.13	0.61***	*0.13*	0.59***	*0.13*	0.59***	*0.13*	0.59***	*0.13*	0.60***	0.13
August	0.74***	*0.13*	0.74***	013	0.76***	*0.13*	0.74***	*0.13*	0.74***	*0.13*	0.74***	*0.13*	0.75***	0.13
September	0.73***	*0.13*	0.74***	0.13	0.75***	*0.13*	0.73***	*0.13*	0.73***	*0.13*	0.74***	*0.13*	0.74***	0.13
October	0.49***	*0.13*	0.49***	0.13	0.50***	*0.13*	0.49***	*0.13*	0.49***	*0.13*	0.51***	*0.13*	0.51***	0.13
November	0.72***	*0.13*	0.73***	0.13	0.73***	*0.13*	0.72***	*0.13*	0.72***	*0.13*	0.73***	*0.13*	0.73***	0.13
Year 2006	-0.15***	*0.05*	-0.15***	0.05	-0.15***	*0.05*	-0.15***	*0.05*	-0.15***	*0.05*	-0.13**	*0.05*	-0.13**	.048
Constant	-0.26	*0.91*	29.06	4.70	-2.79***	*0.79*	-0.72	*0.89*	-2.60**	*1.04*	-2.88**	*1.09*	24.82***	4.76
N	24288		24288		24288		24288		24288		24288		24288	
-2 log likelihood	12469.79		12428.58		12500.95		12474.66		12446.73		12445.19		12377.12	
χ^2	8505.25***		8546.46***		8474.09***		8500.38***		8528.31***		8529.86***		8597.93***	

*p < 0.1, **p < 0.05, ***p < 0.01

4.2. Predictive model results

The RUM using 2005-2007 data was used to predict 2008 location choice behaviour for the SW beam trawl fleet. Coefficients derived from Model 7 (see Table 2) were entered into the logistic regression equation with the actual 2008 values to obtain the predicted probability of a vessel choosing a rectangle in a month[11]. Predicted probabilities with values ≥ 0.5 were given a value of 1 (Vessel is fishing in rectangle in month), and values < 0.05, a value of 0 (Vessel is not fishing in rectangle in month). These predicted values for 2008 could then be compared with the actual 2008 data to determine the predictive ability of the model (Table 3.).

Table 3. Actual 2008 fishing location data compared to Predicted 2008 fishing location data using RUM derived from 2005-2007 data. 0 denotes 'Vessel not fishing in month in rectangle', 1 denotes 'Vessel is fishing in rectangle in month'. Values are the frequency of observations. Total observations for 2008 was 12,144.

		Predicted 2008 values			**% correct**
		0	**1**	**Total**	
Actual 2008 data	**0**	10000	341	10341	96.7
	1	800	1003	1803	55.6
	Total	10800	1344	12144	90.6

The model correctly predicted vessels not fishing in a rectangle in 97% of cases and correctly predicted vessels fishing in a rectangle in a month in 56% of cases. The total effort in 2008 compared to predicted effort in 2008 is shown in the maps of Figure 6. This shows there is a higher density of effort closer to the English coastline than further away, and further highlights that the predictive model tends to underestimate the density of fishing effort. To explore this further, Figure 7 shows the percentage of fishing observations correctly predicted by the model. It shows that effort is less likely to be accurately predicted in ICES rectangles further away from the English coastline.

[11] Logistic regression equation: $Pr(Y) = 1/1 + e^{-}(b_0 + b_1X_1 + b_2X_2 + \ldots + b_nX_n + \varepsilon_i)$

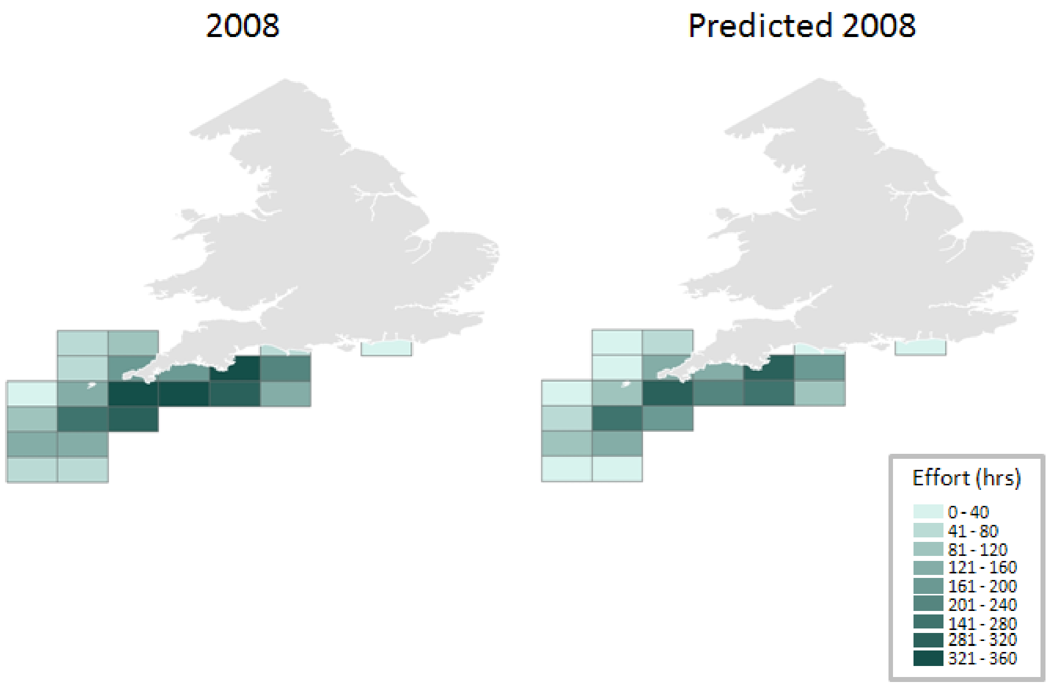

Figure 6. Actual 2008 fishing effort (hours) data compared to Predicted 2008 fishing effort data.

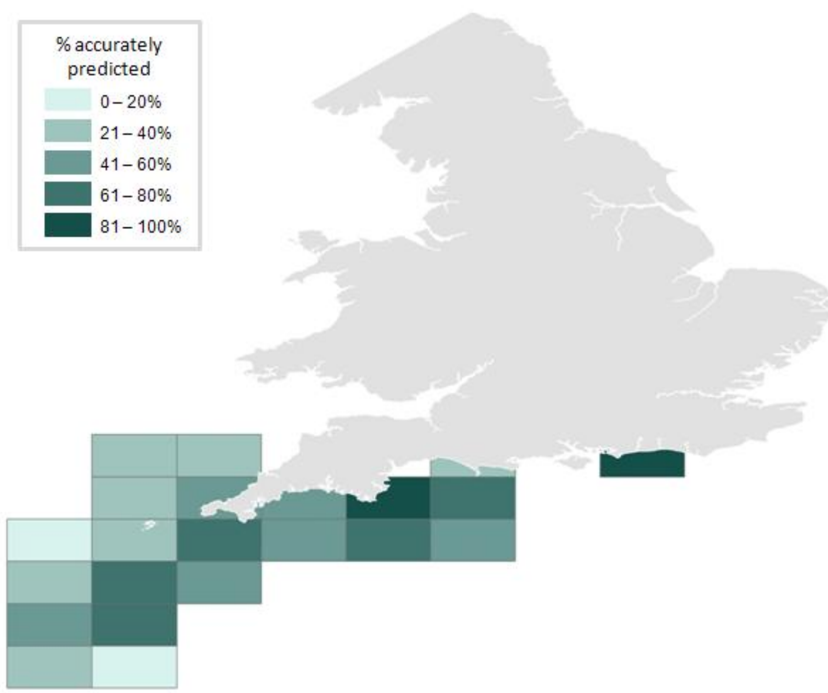

Figure 7. Percentage of accurately predicted fishing observations in 2008 in each ICES statistical rectangle.

In order to examine if the predictive model by month, Figure 8a-c show the actual fishing effort in 2008 compared to the predicted effort for 2008 for each month.

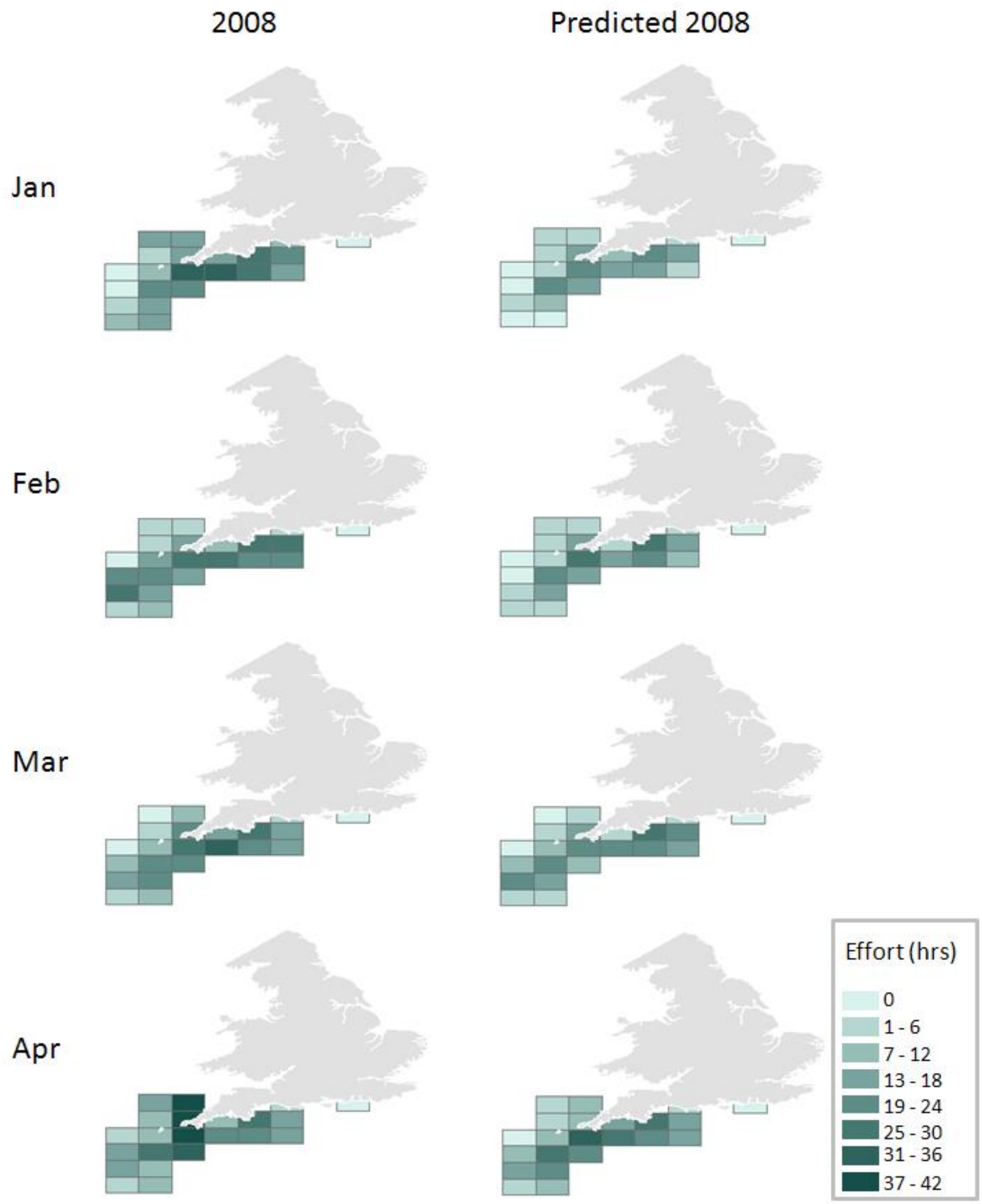

Figure 8a. Actual 2008 fishing effort (hours) data compared to Predicted 2008 fishing effort data, January to April.

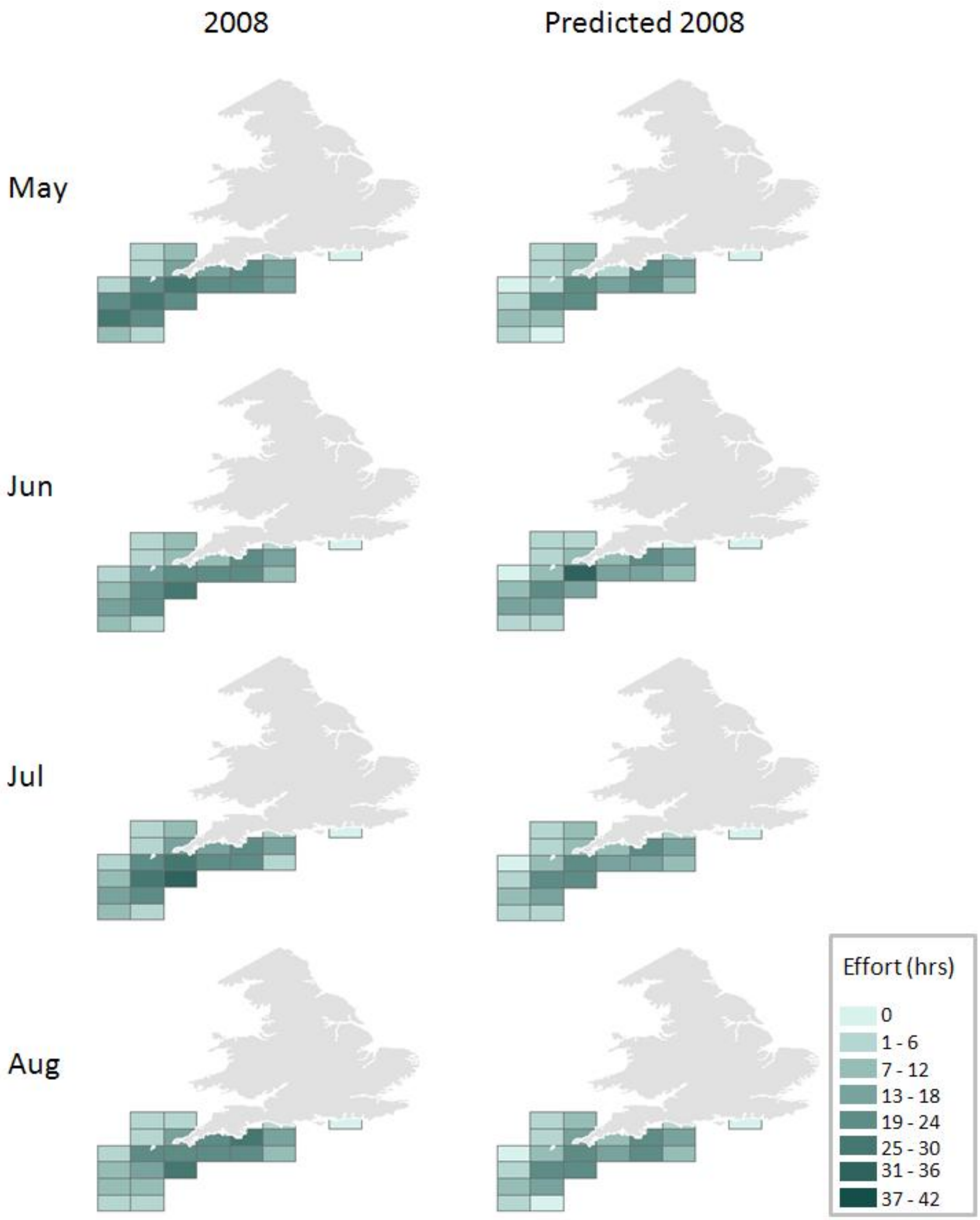

Figure 8b. Actual 2008 fishing effort (hours) data compared to Predicted 2008 fishing effort data, May to August.

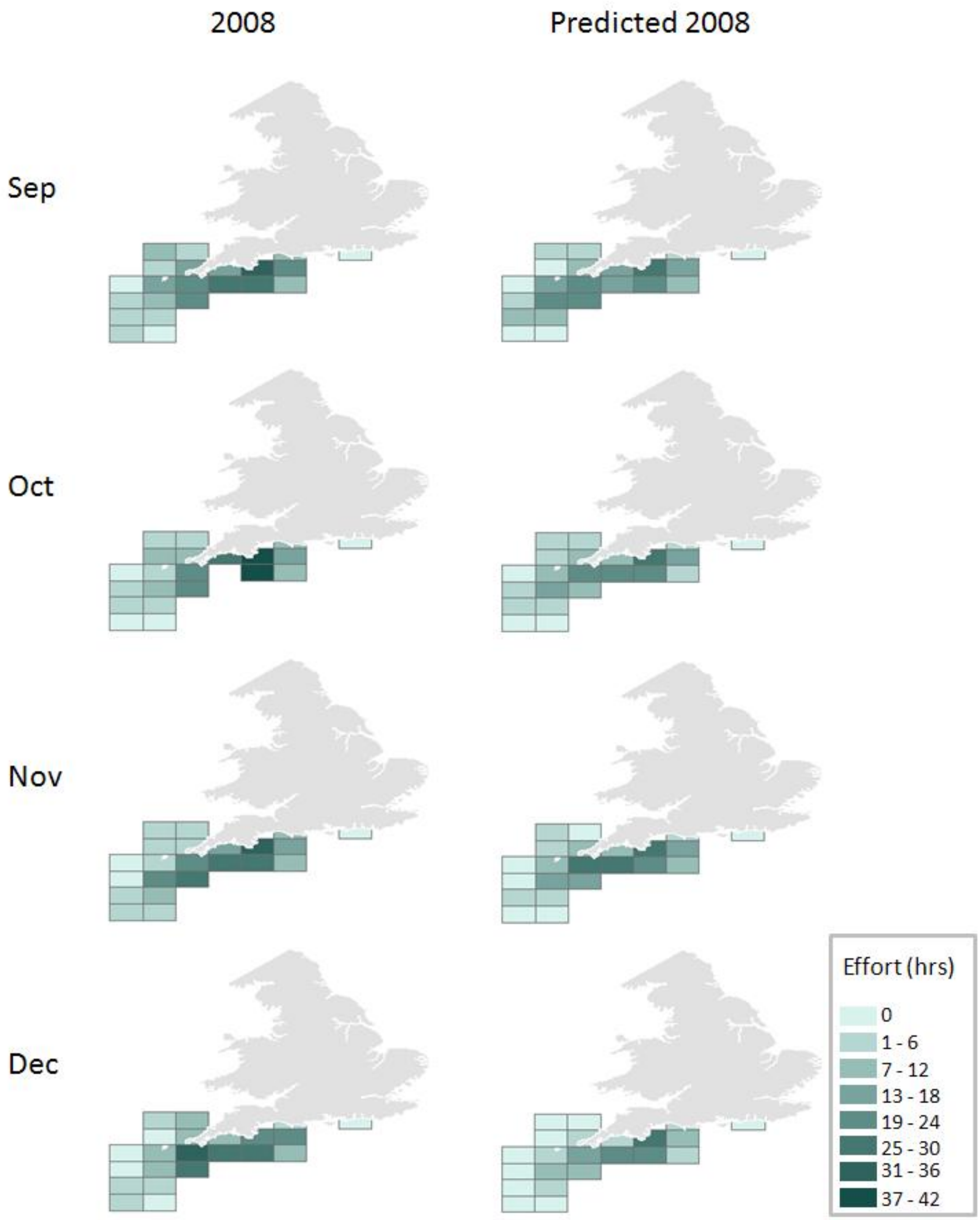

Figure 8c. Actual 2008 fishing effort (hours) data compared to Predicted 2008 fishing effort data, September to December.

The ability of the model to predict fishing effort does not seem to have a discernable monthly pattern when examined visually on the maps. However, for each month the maps show that the predictive model tends to predict less effort than actually occurred in 2008. Breaking down the correctly predicted percentage of fishing and no fishing observations by month, shows that there is some variation between months, with some months predicting fishing observations better than others (Table 4.). In all months, the model correctly predicted vessels not fishing in a rectangle between 96 and 99% of the time. It correctly predicts vessels fishing in a rectangle between 46% (January) and 68% (March) depending on month.

Table 4. Percentage of correctly predicted fishing observations, no fishing observations, and total observations for each month in 2008.

Month (2008)	**% Fishing observations correctly predicted**	**% No fishing observations correctly predicted**	**% Total observations correctly predicted**
January	48	98	90
February	52	97	90
March	68	97	92
April	58	96	88
May	46	96	88
June	65	97	92
July	51	96	89
August	60	96	91
September	60	96	91
October	48	97	90
November	61	97	92
December	51	99	93

5. Discussion

The results of the RUM show that beam trawl vessels in SW England in 2005 to 2007, make location choices based on recent economic returns and the economic returns in the previous year in the same month. Vessels also make decisions based on the economic returns of the entire fleet; choosing locations based on higher economic returns of the fleet relative to other locations which is suggestive of transfer of knowledge of what others in the fleet are catching and where. However, SW beam trawlers also appear to trade off economic returns with risk- aversion tactics, preferring to fish locations closer to their homeport, and at locations with less variance in the value of catch per unit effort at a location. Vessels prefer locations with less variance in VPUE even if the economic returns could be high. Vessels also prefer locations where the water is deeper, particularly the larger vessels of the fleet.

Hutton *et al.* (2004) is most relevant to this study because they modelled the location choice of European vessels (North Sea) that use the same gear (beam trawl), used the same spatial resolution (ICES rectangle) and also used the conditional logit model. The main point of difference is that Hutton *et al.* (2004) used vessel trip level variables and aggregated the data to year, where I used vessel monthly data. I extended the Hutton model in this study to include vessel specific characteristics such as vessel age, size, as well as distance from port. In addition, variation of VPUE in a rectangle was included which proved to be an important predictor of location choice. While Hutton *et al.* (2004) found that greater number of trips, greater average trip length, and greater average effort (hours fishing) in a rectangle suggested a greater probability of returned activity, they also found that higher previous value of catch for the fleet impacted negatively on location choice which is in contrast with other studies (including this study) using similar methodology (Holland and Sutinen, 1999, Holland and Sutinen, 2000). In line with this study and others, Hutton *et al.* (2004) found that the previous VPUE of vessels added likelihood of a choice being made (Campbell and Hand, 1999, Anderson and Christensen, 2006, Prellezo *et al.*, 2009). This comparison suggests that beam trawler location choices may be motivated by similar decision frameworks related to previous economic returns, but it also proved important to incorporate variables that examine risk taking behaviour (distance from home port and variance of returns) of vessels.

The model overall successfully predicted where vessels did not fish 97% of the time, but only predicted where vessels did fish 56% of the time. The ability of the model to predict where vessels fish varied by month, and ICES rectangle. The model fails on more occasions to predict location choice the further away the rectangle is from the English coastline. 2008 may have been an unusual year for location choice behaviour. Interview-based fieldwork undertaken in 2008 uncovered skipper behavioural differences in the SW as a result of rapid fuel price rises in 2008, such as vessels fishing closer to homeport than in 2007 (Abernethy *et al.*, 2010).

The power of the RUM used in this study to predict location choice in 2008 could be improved by the inclusion of species-specific catch variables, ecological variables, individual skipper characteristics, or a more complex approach to the modelling structure. Depth proved to be an important variable for predicting location choice and the reasons for this could be found by incorporating catch data that relate to target species. Interviews with skippers in the SW revealed that beam trawlers either targeted megrim and monkfish in the deep water (80- 120 nautical miles from port), or a mix of species closer to port (up to 60 nautical miles from port). Therefore beam trawlers may use one of two strategies for location choice dependant on target species preference. One option would be to not model the entire beam trawl fleet, but base the RUM on métiers - vessels doing similar activities under similar conditions. Typologies for metiers have been used to analyse fisheries, and have been created from gear type, mesh size, fishing grounds, and *a priori* target species (Tingley *et al.*, 2003, Marchal, 2008). However, this approach does not account for fishers' ability to switch gear type or target species.

The model also lacks ecological data related to habitats and other biological information. Interviews with beam trawlers in the SW revealed they search for fish based on different types of sea bed substrate depending on the species they want to target (e.g., sand, stony ground, banks). Skippers determine the substrate by using technology such as echo sounders and ground discrimination software, which suggests that they make decisions based on fish habitat. Unfortunately these habitat data were not available for use in this model. The lack of forward predictability of the 2008 model may also be due to inter-annual variation. I found that there was a significant year effect with vessels less likely to fish in 2006 than 2007 in a rectangle. This may also be due to a lack of ecology in the model, and knowledge of fish distributions changing from year to year. It has been shown in the North Sea that the average depth distribution of most North Sea fisheries varies substantially annually due to inter-annual variability in local and regional climate (Dulvy *et al.*, 2008). Future development of the model could include sea surface temperature as a variable to capture the distributional biology of fish stocks.

The model also does not take into account individual skipper qualities and characteristics (apart from some vessel characteristics). In their model of location choice Smith and Zhang (2007) collected interview-based data and used skipper characteristics such as the age of skipper in their model. They found that older fishers were less likely to choose profitable locations than younger skippers and suggested this was because "old habits die hard". A possible option for future research is to model the location choices of fishers for whom I have interview data, incorporating individual skipper characteristics, risk preferences[12], as well as their strategic archetype (See Chapter 3). For example, innovative and dynamic skippers ('Prospectors') may choose a wider range of locations, exploring new grounds and targeting different fisheries throughout the year, compared to skippers who focus more on improving their efficiency and improving what they have always done ('Defenders'). The difficulty with using these data with VMS and FAD derived data is making sure that the skipper has not changed on each vessel over the whole time period to be modelled.

The model type itself may explain the lack of predictive power of the model and the method I used to evaluate the predictability of 2008 data may also be limited. The model type itself could be improved: the conditional logit model used here is relatively simple, but I deliberately chose the conditional model for two reasons. First, it provided a direct comparison of the North Sea beam trawl fleet modelled by Hutton et al. (2004). If a different model type was used, it could not have been clearly determined if differences between this study and Hutton *et al.* (2004) were due to the different beam trawl fleets or to the model type. Secondly, by starting with the simple model, I now have the opportunity to develop and improve the model further, and examine the effects of using different model types. The main assumption (and limitation) of the conditional logit model is that it does not account for independence of irrelevant alternatives (IIA) - each choice is assumed to be completely independent and the probability of a choice is not affected by the other choices available. However, for spatial analysis, this assumption is likely to be invalidated because of spatial autocorrelation (e.g., a vessel may be more likely to choose a location close to its current location, rather than locations further away) which can have implications for the application of the model to policy analysis. The nested logit model is often used to overcome problems of spatial autocorrelation because although it is basically the same model (but with a hierarchical structure: a choice set within a choice set), it does not impose the independence of irrelevant alternatives to

[12] I also conducted experimental games with SW skippers to determine their risk preferences, publication forthcoming.

the same degree (Curtis and Hicks, 2000, Greene, 2003, Anderson and Christensen, 2006). An alternative to the nested approach is the mixed logit model, which similarly does not impose the independence of irrelevant alternatives but can be difficult to estimate for more than three or four hierarchical levels (Mistiaen and Strand, 2000, Train, 2003, Smith, 2005), or a multinomial model which allows for more than two alternative choices. However, all of these models use a static RUM framework. It may be possible to determine a fully dynamic model which can include forward-looking behaviour (e.g., the location choice made on the first day of a fishing trip can influence subsequent location choices), which conceptually is the most realistic of all the RUMs. However, this is very computationally intensive and there is currently only one published paper that has applied a dynamic RUM to fishing location choice (Hicks and Schnier, 2006).

In the predictive analysis, I simply reported the “hits and misses” – the ability of the model to predict the absence or presence of fishing. It must be borne in mind this is a blunt tool. For example, if the model predicted the vessel goes to the adjacent rectangle instead of the rectangle in question, this was scored as a “miss”. Mapping the modelled outcomes was slightly more forgiving than the results presented in Table 3, and showed that the model was better at predicting 2008 closer to the English coastline. More sophisticated predictive modelling may be possible but was beyond the scope of this study.

6. Conclusion

The practical purpose of developing random utility models of location choice is to accurately predict fisher responses to management actions. When any catch or effort control, or technical measure intended to modify fishing pressure is introduced, vessels will respond to this management action. There are numerous examples of vessel responses to management, with perhaps the most dramatic associated with large area closures (Rijnsdorp *et al.*, 2001). To ensure that management does have the intended effect on fishing pressure, methods are required to predict responses to management actions so that management recommendations can be modified to account for these responses. For these purposes, random utility models based on the probability of choosing alternative fishing grounds based on expected net rate of return (utility) of each fishing ground were developed and can be of use (Allen and McGlade, 1986, Holland and Sutinen, 1999). Random utility models can be used to model fishing displacement due to management initiatives such as area closures (Hutton *et al.*, 2004). One issue with these models is that they rely on data collected at the scale of the rectangle size used and therefore predictions can only be made at the scale of the rectangle (in this case ICES rectangle). While this may be suitable for predicting how fishing mortality changes as a result of effort reallocation, it does not help with predictions of local habitat impacts, which need to be predicted at much finer scales (Hiddink *et al.*, 2006).

In the past decade, increased availability of spatial information, advances in remote sensing, Geographical Information Systems (GIS), spatial statistics and enhanced computational power have provided new opportunities to understand the patchiness and heterogeneity of fishing activity in the marine environment. The advent of vessel monitoring systems (VMS) which use satellites to continuously log and report vessel location provide an unprecedented overview and detail of fishing activity in near real time. Given that there have been so many technological advancements for data collection, the key task for fishery analysts is now to advance new methods of analysis incorporating spatial characteristics which will have the capacity to accurately predict responses to management initiatives (Wilen, 2000). Despite their limitations, with further development, random utility models could be incorporated in to fisheries management decisions for fisheries where these data are available and the increasing interest in spatially explicit policies of management may provide the impetus for policy makers to do so.

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Chapter 5

Fuelling the decline in UK fishing communities?

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1. Abstract

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, while 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.

2. 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 subsidised 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 Food and Agricultural Organisation, 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 (International Energy Agency, 2008). This does not account for any price increases that may be associated with measures to decarbonise 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, 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, 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 prior to 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, 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 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, 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 jeopardise 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"* (Commission of the European Communities, 2008). The importance of creating a stable future for both the industry itself and for the communities that depend upon it was recently emphasised 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, I 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, I 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. This 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, I 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, I examined the effect of the increase in fuel price on different gear types and vessel ownership structures to determine who is being affected. I then examined the effect of vessel characteristics on fuel consumption of different vessels to determine why different vessels are affected. I also carried out an analysis to investigate how fishers were being affected, i.e. how it was affecting their business and fisher behaviour. Third, I investigated the community impacts of rising fuel prices and the concerns that it has further increased the vulnerability of the fishing community.

3. Methods

The study was undertaken in a southwest (SW) English fishing community. The field site has been anonymised and is referred to throughout the chapter as a 'SW fishing community'. With the decline of North Sea stocks, the fishery in the southwest of England now harbours most of the remaining English fleet. The three largest ports and markets in England are Newlyn, Brixham and Plymouth (Barratt and Irwin, 2008). In 2007, 18% of the >10 m fleet were registered in the SW fishing community, 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 southwest 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.

3.1. 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 ten years were obtained through the records of a supplier of fuel to vessels in the SW fishing community. 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 per litre.) 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 (available at http://www.intrafish.no/fn/). Data for the four main species caught in the SW fishing community were recorded: monkfish (*Lophius piscatorius*), sole (*Solea solea*), hake (*Merluccius merluccius*), and megrim (*Lepidorhombus whiffiagonis*).

I also interviewed 34 skippers from the larger (>10 m) vessels. This represents 68% of the larger vessels registered in the SW fishing community in 2008. This percentage of vessels is approximate because although vessels are registered in the SW fishing community, their actual home port may be elsewhere and vice versa. It may also be an underestimation because there are several large vessels registered in the community 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 randomised respondent selection was neither feasible nor possible. However, I 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 were 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; Marine and Fisheries Agency statistics fishing vessel lists, UK, available at http://www.mfa.gov.uk/statistics/vessellists.htm, and 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 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 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. Interview guide

Quantitative and qualitative (marked *) **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 *

The 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. In order 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, I 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 organisation (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.

3.2. Analyses

3.2.1. Trends in fuel and fish prices over time

I 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 I estimated the annual trend while accounting for daily and monthly effects.

3.2.2. Who is affected by increased fuel prices?

Using interview data I 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 fishers, the fuel cost as a percentage of a trip gross in July 2008 was compared with that in July 2007 for different gear types.

3.2.3. Why are different vessels affected by increased fuel prices?

I 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 VCU), 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 I 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.

3.3.4. 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.

4. Results

4.1. Trends in fuel prices and fish prices over time

Fuel prices for fishers in the SW fishing community 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 per litre, then dipped and subsequently rose near the end of 2000. Since 2003, prices have increased by £0.05 per litre annually ($F_{1,4}$ = 39.2, p = 0.003). Average fuel prices increased by 45% from mid-2007 to mid-2008, from £0.31 per litre in 2007 to £0.45 per litre by the end of May 2008. By mid-2008, they had reached £0.57 per litre, 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.).

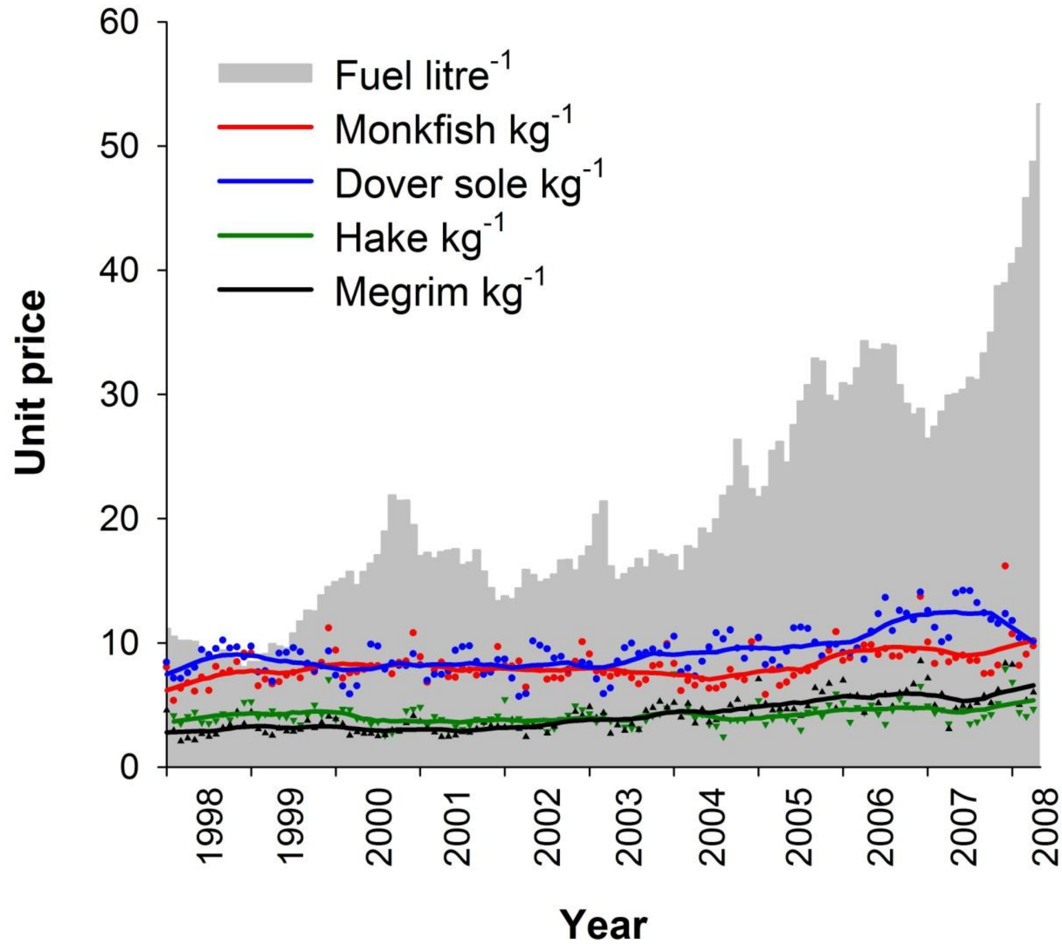

Figure 1. The price of fuel (excluding tax duty) in UK pence (£0.01) per litre paid by vessels in the SW fishing community from January 1998 to July 2008, and the average monthly price of the four main species of fish in UK pounds sterling per kg landed at the market, for the period January–July 2008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

4.2. 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 that 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 realised 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 static gears, they were more seriously affected by the rise in fuel costs.

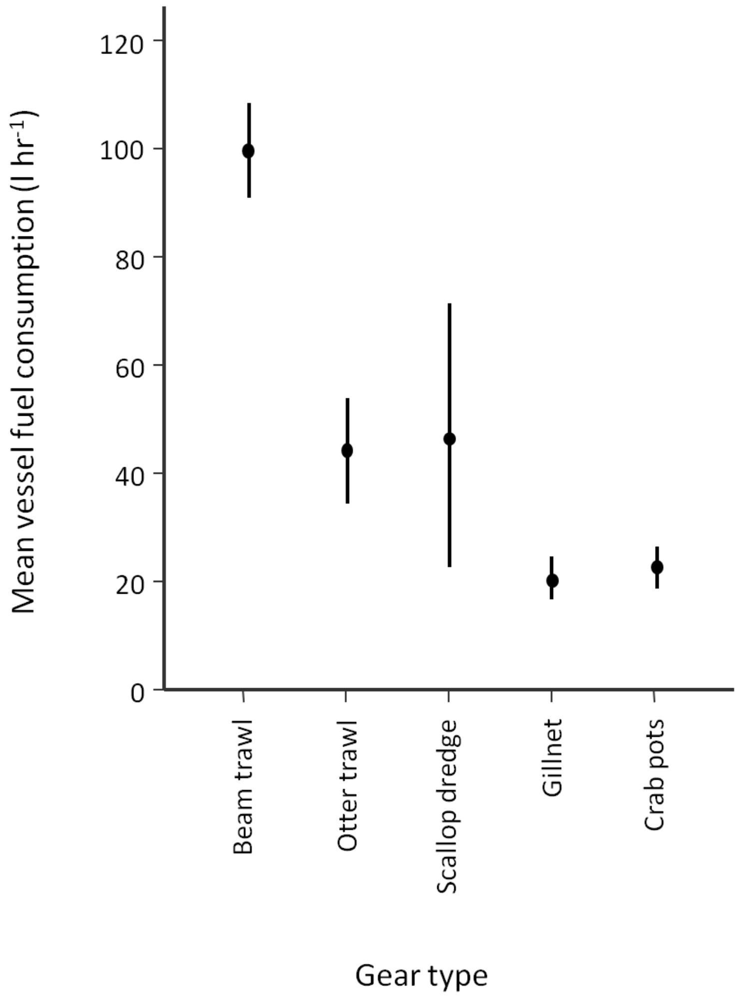

Figure 2. Average fuel consumption for five different gear types. Values are the means ± 2 s.e.

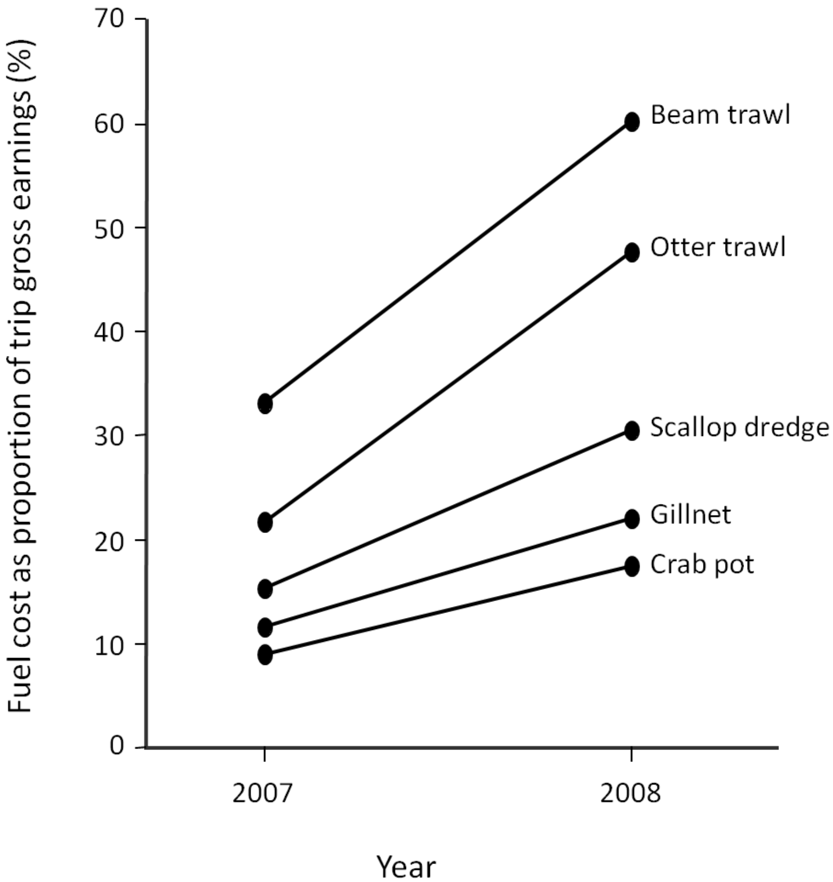

Figure 3. Comparison of fuel consumption as a percentage of fishing trip gross earnings between July 2007 and July 2008 for five different gear types.

4.3. Why are different vessels affected by increased fuel prices?

To examine the link between fuel use and 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 ($\chi^2(1) = 2.07$; $p = 0.1499$); despite this, to make results comparable with the regression used later, I 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 ownership of towed geared 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.

Coefficient	**Fuel consumption (l h^{-1})**	
	(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 (vessel capacity units VCU)	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 < 0.01, * p < 0.1

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).

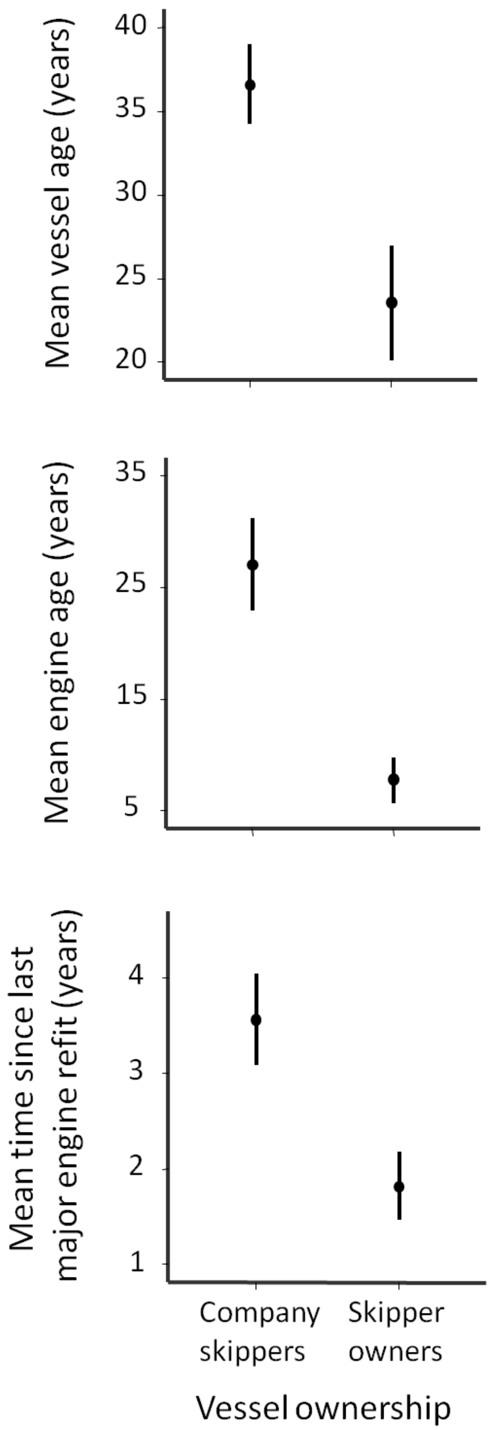

Figure 4. Comparison of average vessel age (t_{32} = –3.1, p = 0.004), engine age (t_{32} = –3.9, p < 0.001), and time since last major engine refit (t_{32} = –2.8, p = 0.009) for skipper- and company-owned fishing vessels.

4.4. 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 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. 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 in the community 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).

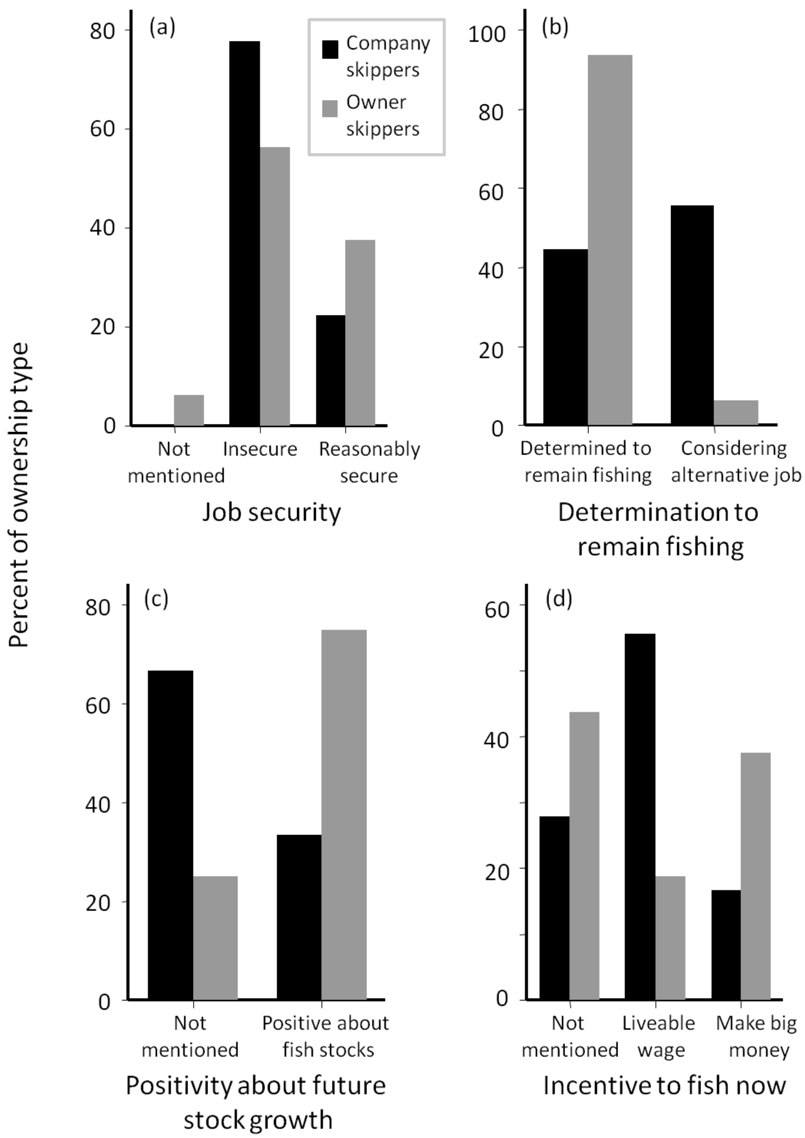

Figure 5. The percentage of skipper owners (grey) and non-owner skippers (black) that (a) had concerns about the security of their job, (b) were determined to remain in fishing, (c) felt positive about the future of fishing with respect to the fish stocks and, (d) felt their incentive to fish had diminished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

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. 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 were also reduced for the same reason. *"There is no incentive any more to try out different gears"*. It is not known whether the aggregate effect of these changes in behaviour is positive or negative for fish stock status.

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**	**% 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 in order 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 in order 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 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 in order 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

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 [the SW fishing community] going", "what will people do and what will happen to [the SW fishing community without the fishing industry?" "In this neck of the woods where we are, possibilities are limited. It's a downward spiral".*

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	% of responses
Skipper expressed uncertainty about the future of the fishing industry in their community	32	94.1
Skipper believes there will be a significant reduction in fishing fleet as a result of increasing fuel prices, pushing fishers out of business	34	100
Skipper mentioned a likely loss of jobs ashore (engineering, processing, harbour working, etc)	24	70.6
Skipper 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
Skipper 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

5. 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; (European Commission, 2008b, Lockley, 2008, MacDonald, 2008). This research 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 that 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 prior to 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 (International Energy Agency, 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 this SW fishing community. 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 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 this SW fishing community and with potential knock-on effects for the European fish supply chain. The rapid change in 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, such as some onshore businesses, the fish market, fish merchants, and processors may disperse. The concern with such a situation in this SW fishing community 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. This 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 of 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 this SW fishing community have remained stagnant for the past ten 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 ten 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 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 the SW fishing community, most vessels land and sell their fish at the local market, where buyers bid in person each morning. Approximately 80% of all fish landed are then sold to buyers in continental Europe, mostly Spain and France, with the rest sold on the domestic market (personal communication, southwest fish merchant, 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 in order 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 (IUU) 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 Food and Agricultural Organisation, 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 Food and Agricultural Organisation, 2008). Despite subsidies being widely considered to have harmful long-term effects on fish stocks (World Bank and Food and Agricultural Organisation, 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 Food and Agricultural Organisation, 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 Food and Agricultural Organisation, 2008).

This 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 in order to weather increasing and uncertain costs. However, I 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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Chapter 6

Are fishers ‘price takers’ or ‘price makers’? The factors influencing cost pass-through for fishers in southwest England

1. Abstract

This chapter investigates profitability in the fisheries of a southwest fishing community, in England, examining the relationship between fuel costs (which make up the majority of variable fishing costs) and the prices fishers received at the fish market from 1998 to 2008. A time series analysis indicates that fish prices do not significantly respond to fuel price increases implying limited cost pass-through in this fishery. In fact when there is a correlation, it is likely to be negative. With increasing fuel prices, the fisheries of southwest England therefore experience higher costs, stagnant output prices and diminishing profitability, even before any decline in catch-rates has been factored in. An interview based analysis uncovers strong market constraints to fishers' ability to influence fish prices at first point of sale. The interactions between the institutional set-up of the seafood market, the lack of competition at the fish market, and globalisation of fish markets mean that fishermen lack the price-setting power to effectively pass on their escalating costs through improving prices at first sale. Rising costs have resulted in reduced profitability for fishers which may have negative consequences for the sustainability and resilience of coastal fishing communities. As long as fishing effort is not increased, it is suggested that policies and investment that give room for producers to remain profitable by increasing the price-setting power of fishers may contribute to the health of UK fisheries.

2. Introduction

The state of global fisheries is told as a story of doom and gloom. Marine fish catches are in decline (Pauly *et al.*, 2002, Pauly *et al.*, 2005, FAO, 2008b), the biomass of higher trophic-level species (i.e. the fish humans prefer to eat) in the sea is diminishing (Christensen *et al.*, 2003), and several fish populations may be threatened with ecological and/or commercial collapse (Cook *et al.*, 1997, Dulvy *et al.*, 2006, FAO, 2006). These stories of fisheries decline are primarily due to either fisheries management failing to achieve its goals or lack of regulation, leading to overcapacity within fleets and overexploitation of marine resources. Overcapacity has also been attributed to the 'race for fish' which can develop in open access or shared resource fisheries, where users have no rights over the resource and thus there is little incentive to conserve for their future (Gordon, 1954). Technological creep and subsidised costs have also allowed vessels to successfully exploit new fishing grounds further from shore and in deeper waters (Morato *et al*., 2006, World Bank and Food and Agricultural Organisation, 2008). Dwindling fish stocks and collapsing fisheries have economic and social consequences for communities particularly for those with few employment opportunities other than fishing (FAO, 2008b).

Despite the grim picture that is painted, the future of global fisheries is not necessarily doomed. There are increasing efforts to restore marine ecosystems and rebuild fisheries (Worm *et al.*, 2009). State-designed management practices which have tended to employ a command and control approach through imposing restrictions on catch and effort, informed solely by science and reliant on enforcement, have clearly not been broadly successful. In response there is a growing demand for development of new, more holistic management paradigms to rebuild ecosystems (Pitcher, 2001, Pauly *et al.*, 2002). The political commitments to an Ecosystem Approach to Fisheries management (EAF) - an adaptive integrated management system that aims to promote both biodiversity conservation and sustainable resource use by managing the ecosystem and the people that use it as a whole – are increasing (FAO, 2003). There are successful fisheries from which management lessons can be learned and applied (Cunningham and Bostock, 2005). It appears evident that good governance, enforcement, and compliance forms the basis for conservation and rebuilding efforts (Worm *et al.*, 2009). Designing management with appropriate incentives, encompassing participation and transparency in design along with good science is also important (Defeo and Castilla, 2005, Hilborn, 2007, Costello *et al.*, 2008, Mora *et al.*, 2009). However the transition towards new methods of managing fisheries has been slow, despite the fact these new management measures appear to be a win-win situation for fisheries and marine resource conservation. There are many reasons for this but in fisheries systems even where there is capacity for change (i.e. developed world commercial fisheries with high enforcement) there seems to be two major deficiencies. Firstly there is a marked difference between broad policy acceptance and the will to actually implement corrective measures (Mora *et al.*, 2009). Secondly, while the tools for successful management have been identified, the socioeconomic drivers that have enabled particular regions or fisheries to prevent or reduce over fishing while others remain overexploited have not been identified (Worm *et al.*, 2009). In other words, the incentive structures which are necessary for new management approaches to work are not understood.

While 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). Diminishing profitability may jeopardise the underlying infrastructure of the fishery, which can then result in the degradation of a fishing community and the community as a whole (Rossiter and Stead, 2003, Stead, 2005, Abernethy *et al.*, 2010). Unprofitability is often attributed to declines in fish stocks but is also due to rising costs of fishing. A recent example of this was the impact of high fuel prices in 2008 on the highly regulated fisheries of the European Union. 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). Research presented in the previous chapter showed that the consequence of this recent fuel price shock reduced fishers' profitability and their ability to cope and adapt with the changing conditions, causing job losses, economic hardship, and deep uncertainty about the future (Abernethy *et al.*, 2010). One of the direct environmental consequences of the fuel price shock was that innovation and engagement within the industry toward sustainable practices was reduced due to fishers' financial constraints. The key barrier to fishers in the face of unstable and rising fuel prices was that they were unable to offset increased costs because ex-vessel market fish prices have remained stagnant for at least a decade. This reflects the same trend in market fish prices across European fishing nations. Consequently, fishers, like farmers, 'have been unable to benefit from reduced supply and rising retail prices' throughout Europe and have been unable to pass on their increased costs (cost pass-through) to the supply chain (Joe Borg EC Fisheries Commissioner, European Commission, 2008b). The divergence of trends for fuel and fish prices, and the evident inability of fishers to pass cost increases up through the value chain to buyers, retailers and consumers, prompted further empirical investigation in the southwest, on the market structures and processes that constrained fishers' ability to set prices to offset their rising costs.

For fishers, cost pass-through is the ability to pass on increased costs of production to the buyers of the goods. Thus, cost pass-through is directly related to the method of price formation at the first point of sale of fish. The fish market and price formation has a long tradition in economic literature particularly in investigations of exchanges for similar goods (Mill, 1869, Thornton, 1869). If the fish market is competitive, then the price of fish is determined by the free interaction of supply and demand. However, empirical studies tend to show that prices are determined by the market structure (such as the type of auction system) (Guillotreau, 2008), the characteristics of the traded good (Graddy, 2006), and the social interactions between different actors, which may include collusion (Acheson, 1985, Etienne and Vignes, 2008, Genesove, 2008). This paper investigates which of these factors play a part in determining the price received by fishers at a southwest fish market.

First I document the degree of cost pass-through for fishers and identify the factors constraining cost pass-through and determine market price. Fuel prices comprise the largest proportion of the variable costs of fishing in this case, and it was this cost that changed the most over the time period under investigation. I use econometric time series analyses to quantify the relationship between fuel prices and ex-vessel fish prices and thus determine the degree of cost pass-through for fishers. I use co-integration techniques to model the long-run and short-run correlations between fuel price and fish price, and autoregressive integrated moving average models (ARIMA) to explore lagged effects. I found there is very low cost pass through for fishers and therefore I undertook a complimentary interview-based analysis exploring the reasons for fish price suppression at the first point of sale. I examine factors relating to the nature of the product sold, the method of sale, the factors influencing supply and demand, and the factors influencing the competitive nature of the market.

3. Methods

3.1. The study location

The study was undertaken in a fishing community, in the southwest of England. The field site has been anonymised and is referred to throughout the chapter as a 'SW fishing community'. The fish market in the SW fishing community is based on the quayside and operates Monday to Friday.

Fish is landed from vessels (any time from afternoon to late at night) and is sold on the market the next morning. Prior to opening for sale, market workers use a grading machine to sort the main species of fish into weight-based size classes (1 to 5). Other species of fish are graded by hand by market workers. Damaged fish are removed from the grading system and are sold separately. The fish sale starts at 6.30am, and continues until all the fish is sold, which on average takes two hours. All fish on the market is sold every day. Two auctions operate simultaneously: One auction is for the large vessels with large quantities of fish (the large beam trawlers, otter trawlers and gill netters) and the other auction is for the small day boats with small quantities of mixed species. The fish are sold by vessel in the order they sailed into port and landed their fish. The market is an open ascending price auction, or 'shout auction'. The auctioneer opens the bidding at a starting price (per kilo of fish) and then accepts increasingly higher bids from the floor where the merchants are standing around boxes of fish. The highest uncontested bid wins the fish. Fish is sold by the box or 'stack' (between 2-4 boxes high), species by species. The winning bidder of the stack then has the option to buy the entire catch of that particular species caught by that particular vessel at the bidding price. Approximately 80% of all fish landed at the market are then sold to continental Europe, mostly Spain and France (mainly sold to wholesalers in Europe), with the rest sold directly on the domestic market.

3.2. Cost pass-through: econometric analysis

I examine the relationship between fuel price and fish price to quantify the cost pass-through for fishers using time series analyses. Fuel price data and fuel duty data for ten years (January 1998 to July 2008) were obtained through the records of a fuel supplier to vessels in the SW fishing community. 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 per litre.) Fish price data were obtained for the same period from the 'Fishing News', a UK weekly fishing industry newspaper that reports fish prices by port and by species (Fishing News [Online], Available at: http://www.intrafish.no/fn/). Data for the four main species caught in the SW fishing community were recorded: monkfish *(Lophius piscatorius)*, Dover sole *(Solea solea)*, hake *(Merluccius merluccius)* and megrim *(Lepidorhombus whiffiagonis)*. Each one of these species are categorised into three sizes: large, medium and small. To decide at what level of aggregation the analysis should be done – either on only fish-type level or fish-type-size level – pair-wise t-tests comparing mean prices of different sizes were conducted; the tests indicated that mean price of fish is significantly different by size. Hence, each species and size was taken as distinct giving a total of twelve products (four species x three sizes). In all cases except for Dover sole, larger size fetches a higher price. In the case of Dover sole, the medium size is the most expensive. Dover sole is a popular restaurant dish and medium size is the perfect size for a plate, therefore it is in more demand than the other sizes. With twelve products and 124 months between January 1998 and April 2008, the data contain 1488 observations of monthly fish and corresponding fuel prices.

For the analyses, first descriptive graphs and statistics were run to examine the trends in fish and fuel prices over time including computing the average monthly growth rates. Second, a time series econometric analysis was undertaken to test and quantify the correlation between fuel and fish prices in the short- and long-run. The descriptive results indicated that most likely the fuel and fish price series are non-stationary which means that the mean and variance of price changes over time. Therefore, a simple regression between fish price and fuel price will likely be spurious. Augmented Dickey-Fuller (ADF) tests were conducted as formal tests for non-stationarity (Dickey and Fuller, 1979). Three versions of the ADF tests were conducted; random walk without a drift (here current price (P_t) is last period price (P_{t-1}) plus pure random element (μ_t), i.e., $P_t = P_{t-1} + \mu_t$), random walk with a drift (the price series drifts either upwards or downward depending on a positive or negative constant drift parameter (δ) $P_t = \delta + P_{t-1} + \mu_t$)) and random walk with time trend ($P_t = \beta t + P_{t-1} + \mu_t$ where t represents time). Generally, the ADF tests indicated that the two price series are non-stationary. Therefore a regression between fuel and fish prices can only be meaningful if the two are co-integrated (i.e., if two time series are non-stationary, but the linear combination of them are stationary). Johansen tests were run to test for co-integration.

A co-integration analysis was then performed to examine both the long- and short-run correlations between fish and fuel prices, using co-integration equations to capture the long-run correlation between fuel and fish prices and vector error correction models to capture the short-run dynamics. A one month lag was used for this analysis. To further examine the short-run dynamics between fuel and fish prices, autoregressive integrated moving average models (ARIMA) were used which help to control for autoregressive disturbances and also further examines lagged effects.

3.3. Cost pass-through: qualitative analysis

To understand the factors that influence fish prices, qualitative data and analyses were undertaken. Three types of qualitative data were collected in October 2009: Interviews were conducted with (1) key informants within the fishing industry in the SW fishing community, (2) fish merchants present at the fish market, and (3) daily observations of the fish market were undertaken over a two week period (See Appendix 1 for interview respondent codes and details).

A key informant approach was used because it gathers the kind of qualitative and descriptive data that are difficult and time consuming to unearth through structured surveys and direct observation. I spent six months in the fishing community in 2008 and had developed a rapport with the significant actors in the fishing community, hence key informants could be selected with confidence that data collected would be both reliable and precise. Potential candidates were considered based on Tremblay's (1957) selection criteria for key informants: (1) The informant's role in the community should expose him/her continuously to the information sought by the researcher, (2) the informant should have direct access to the information in a meaningful way, (3) the informant should willingly communicate knowledge with the researcher, (4) the informant should be able to communicate the knowledge in a clear and intelligible manner to the researcher, and (5) the informant should be impartial but if there are biases these should be clear to the researcher. Given that only criterion (1) can be a certainty before interviewing begins, a preliminary list of eight informants was drawn up, determined by the nature of the information sought. These included interviews with market workers, locally based government officials, fishing industry liaison officers and fisheries observers. Lack of knowledge over the time period specified (10 years), bias, and lack of responsive communication between informant and researcher eliminated two informants. The six informants that remained were well-qualified to respond and interviews were highly productive. Qualitative interviews were conducted using open ended questions (Bernard, 1994). In order to get the maximum detail of their knowledge, key informants were interviewed several times, with three of the six informants accompanying the researcher to observe the fish market on one or more occasions.

A common guide of subjects to be discussed and specific questions were used for all respondents, allowing for both specific responses and the drawing out of broad themes and interpretations. To generate information about the forces that have influenced fish price at the market over the past ten years, the general subjects discussed with informants were (1) the nature of the product being sold, (2) the method used to sell the product, (3) the factors influencing supply and demand, (4) the factors influencing competition, and (5) any events in the past ten years that may have influenced supply and demand, and/or competition. All except one informant were very familiar with me and the field of research before the interview began. The one informant who wasn't familiar was given a full explanation of the research being conducted. While informants were given considerable leeway with respect to the content of answers and were encouraged to follow from one thought to another with freedom, I constantly directed the informant to the focus of the interview, interjecting with comments and questions but without leading the interview.

Interviews with merchants were conducted alongside key informant interviews. I was interested to understand what merchants believed to be the factors constraining fish prices from their business perspective. Interviews were undertaken with seven merchants. The number of merchants changes at the market daily, and ranges from 20 to 30 merchants present each day. Six merchants interviewed were mid-sized merchants, buying and selling between 5-20 tonnes of fish per week. There are approximately 12-15 merchants of this size buying at the fish market. The other merchant was one of three large merchants, buying and selling more than 100 tonnes of fish per week. Small merchants buying to sell fish at local markets, from shops, fish vans, and food outlets were excluded from this study as I wanted to understand what was affecting buying and selling of larger quantities of fish. It is the medium and large merchant businesses that buy the bulk of the fish at the market. Interviews were semi-structured and followed the same protocol described above for key informant interviews in terms of technique, except these interviews were conducted only once. Interviewees were asked questions about (1) the size of their business and who they sold fish to, (2) the factors influencing supply and demand, (3) the factors influencing competition between merchants, and (4) merchant costs and their ability to pass their costs through to their customers. For each subject I asked how these factors have changed over the past ten years and how these factors may influence fish price at the market.

For key informant and merchant interviews, detailed notes were taken during each interview, and an in-depth report was written after each interview on the day of the interview. Reports were systematically coded using qualitative analysis software, (NVivo 7) according to each variable of interest to ensure that data were not used selectively. Using key informants as a qualitative technique requires the data to be judged for reliability. I used agreement among informants as the criterion of reliability (Tremblay, 1957, Romney *et al.*, 1986, Bernard, 1994). Given that key informants are most likely to provide accurate answers about things that are publically observable, I am confident in the responses presented in this analysis (Poggie, 1972). The difference between key informant interviews and merchant interviews was that key informant interviews were analysed on the basis of consensus, where as for merchants I wanted to understand if there was a diversity of views. Given that interviews with merchants were more subject to unreliable responses (because they are not unbiased participants in the market), triangulation of responses was very important to increase confidence in the accuracy of data collected. 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). Market observation and discussion with key informants about merchant practices formed the basis for triangulation.

Daily observations at the fish market were conducted over a two week period. Detailed notes were taken on (1) how the market is run from the point of fish landing to fish sale, including observations of the auction itself (2) how and why fish prices vary, (3) who the merchants are, what they do at the market and how they interact with each other. These observations were undertaken to independently understand how the market works and also to increase confidence in the accuracy of data collected through key informant and merchant interviews. Observations were recorded and detailed notes were written down each day.

4. Results

4.1. Cost pass-through: econometric analysis

4.1.1. Descriptive statistics

Fuel prices rose much faster than fish prices during the study period 1998 to 2008 (See Appendix 2 for average annual fish and fuel prices, and Appendix 3A and 3B for fish and fuel prices 1998-2008). For example, while fuel price increased by 185% in the study period, the highest increase for fish price was 117% (for large sole). At its maximum, fuel price increased by 437% compared to that of January 1998 while the highest fish price increase was 268% (for large monkfish). This pattern is clearly illustrated in Figure 1. Each fish price was plotted against fuel price but both were computed as a proportion of the respective initial price with January 1998 given a value of one. In all cases the plots for fuel and fish prices diverge. Compared to January 1998 monthly fuel prices increased much faster than fish prices.

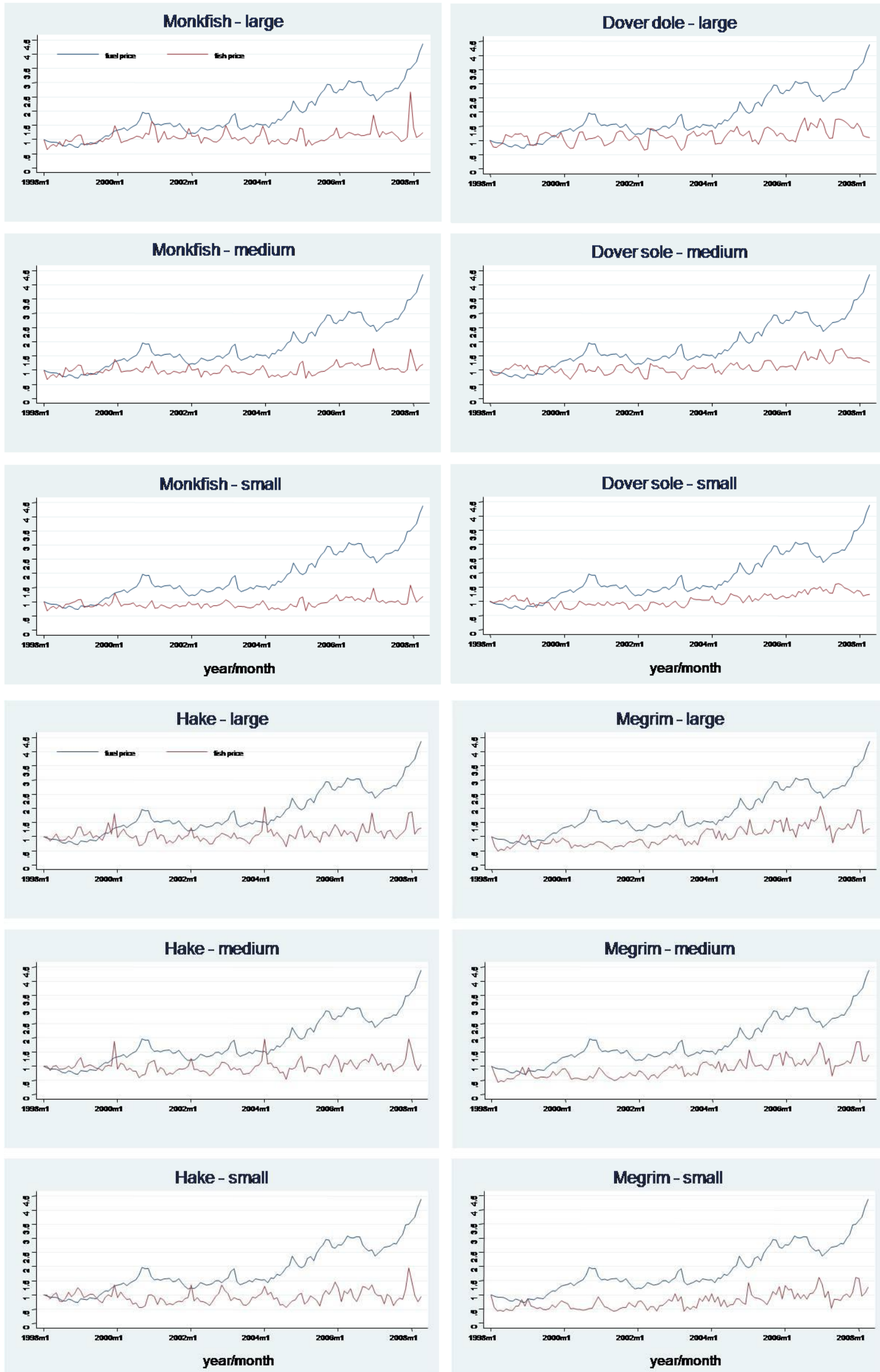

Figure 1. Fuel (blue line) and fish prices (red line) 1998 to 2008 for four main fish species at the market: monkfish, Dover sole, hake and megrim (January (m1) as reference = 1).

To further illustrate differences in price changes and get a quantitative measure, average monthly growth rates were computed by regressing logarithms of prices on time (year-month); the coefficients on the time variable measure the average monthly growth rates (Table 1). While fuel price increased on the average by 1.1% per month, the highest growth for fish price was 0.72% for medium megrim and the lowest 0.10% for small hake.

Table 1. Estimated monthly growth rates of fish and fuel prices (%) from 1998 to 2008.

Fish type	Growth rates	SE
Monkfish		
- Large	0.20***	0.04
- Medium	0.16***	0.04
- Small	0.16***	0.04
Sole		
- Large	0.29***	0.05
- Medium	0.33***	0.04
- Small	0.38***	0.04
Hake		
- Large	0.16***	0.05
- Medium	0.13**	0.05
- Small	0.10*	0.06
Megrim		
- Large	0.71***	0.05
- Medium	0.72***	0.05
- Small	0.67***	0.06
Fuel	1.11***	0.00

*** p<0.01, ** p<0.05, * p<0.1

The above descriptive results all indicate that fuel price was increasing at a much higher rate than all fish prices. This is indicative that fishers were not able to pass-through the increased cost of fuel to selling prices. Further examining how the two prices are related, through time-series analysis, can help quantify how much of the increased cost is passed-through and whether or not there is a relationship between the two prices.

4.1.2. Time series analysis: Tests for non-stationarity and co-integration

Augmented Dickey-Fuller (ADF) tests were conducted as formal tests for non-stationarity (Dickey and Fuller, 1979). For fuel prices, the null hypothesis of unit root[13] is accepted in all cases thus the

[13] The null hypothesis of unit root is that the time series is non-stationary, i.e. the mean and variance change through time. If the null hypothesis is accepted for both fuel price and fish price, then a regression between them will lead to spurious results.

fuel time series is non-stationary (Table 2). For fish prices the null hypothesis of unit root is accepted only for the case of random walk without drift. This means that if fish prices are assumed to have a constant mean, the variation changes through time, and the fish price time series is non-stationary. The same ADF tests were conducted on the first differences of price for fish and fuel prices (the change Δ in price between t_X and t_{X+1}) and the results indicate that the null hypotheses of unit root are strongly rejected in all cases (Table 2). This indicates that the two are difference stationary[14]. Overall, the ADF tests indicate that the two price series are non-stationary at first difference [15].

The Johansen tests for co-integration involve calculating Eigen values, trace statistics and comparisons with critical values. The tests indicated that the two price series are co-integrated with rank one in eleven out of the twelve cases (which means the long term relationship can be represented by one equation); the only case with a maximum rank of zero was for small sole and fuel prices.

[14] Difference stationary means that the time series for fish prices and fuel prices are stationary if one considered the first difference in prices (the monthly change in price), not the absolute values.
[15] The fact that the series are difference stationary will be used to undertake further analysis to explore the effect of lags in Section 4.1.4.

Table 2. Augmented Dickey-Fuller (ADF) unit root tests for (a) fish and fuel prices and (b) for first differences of fish and fuel prices (1998-2008). Three ADF tests conducted were random walk without drift, random walk with drift and random walk with trend.

Fish type	(a) Fish and fuel prices			(b) First differences of fish and fuel prices		
	Without drift	With drift	With trend	Without drift	With drift	With trend
Monkfish						
-Large	-0.06	-6.59***	-7.31***	-14.33***	-14.27***	-14.22***
-Medium	-0.02	-5.99***	-6.57***	-14.98***	-14.93***	-14.86***
-Small	-0.02	-5.86***	-6.85***	-15.70***	-15.65***	-15.58***
Sole						
-Large	-0.08	-4.53***	-5.20***	-9.10***	-9.96***	-9.93***
-Medium	0.05	-3.81***	-4.97	-10.98***	-10.93***	-10.89***
-Small	0.09	-3.04***	-4.54***	-12.79***	-12.74***	-12.69***
Hake						
-Large	-0.07	-7.02***	-7.48***	-15.89***	-15.82***	-15.76***
-Medium	-0.17	-6.52***	-6.75***	-15.15***	-15.08***	-15.02***
-Small	-0.24	-5.84***	-5.93***	-13.20***	-13.15***	-13.09***
Megrim						
-Large	-0.05	-3.38***	-6.64***	-16.00***	-15.95***	-15.88***
-Medium	-0.05	-3.50***	-6.82***	-14.96***	-14.90***	-14.85***
-Small	-0.16	-4.41***	-7.58***	-17.25***	-17.19***	-17.13***
Fuel	1.97	0.12	-2.10	-9.26***	-9.51***	-9.51***

*** $p<0.01$

4.1.3. Time series analysis: Co-integration analysis

First I discuss the co-integration regression equation results which captured the long-run correlation between fuel and fish prices. Small sole, small hake and medium hake are not significantly correlated with fuel prices in the long run at 1% and 5% levels (Table 3, P_p(log)); the significant increase in costs due to higher fuel prices did not seem to pass-through to these fish prices at all. Over all species and size classes, the long-term pass-through was relatively low, as reflected by the coefficients on fuel prices in the co-integration equations (Table 3, P_p(log)). Since the prices are in logs, the coefficients give elasticities. For example, a 1% increase in fuel price was associated at most with a 0.60% rise in fish price (medium sized megrim). For hake, monkfish and Dover sole the elasticities dropped below 0.16%, 0.20% and 0.27% respectively. The elasticities are higher than 0.50% only for megrim. It is difficult to tease apart why there is variation between species, but megrims may have a higher elasticity because there is a high demand for megrims from Spain. The SW fishing community is known as the main port in the southwest of England for selling megrims caught by their beam trawl fleet. The beam trawl fleet has contracted in the ten year study period as beam trawling has become less profitable; one of the reasons being beam trawlers are high fuel consumers. Therefore with high demand and reduced supply, megrims may be more responsive to fuel price increases over time. In summary, these co-integration equations indicate that there is a significant long-run correlation between fuel and fish prices (with the exception of small sole, small hake and medium hake) but the elasticity of fish price with respect to fuel price is relatively low.

Next I discuss the vector error correction models which captured the short-run correlation between fuel and fish prices and provide some striking results (Table 3). First, the short-term response of fish prices to changes in fuel prices is very weak (almost non-existent); this is captured by the coefficients on lagged changes of fuel prices ($dP_p(t-1)$). From the twelve coefficients only small sole is significant ($p<0.05$). Interestingly, for small sole, the correlation is also negative; the fish price moves in the opposite direction to fuel price changes in the short run. Given other factors, this indicates that the profit of producers dependent on these types of fish were likely squeezed from both sides – higher costs as well as falling product prices.

The error correction coefficients (EC) are highly significant and in most cases show rapid adjustment to equilibrium conditions. The EC captures what proportion of a deviation from the long term relationship, as captured by the co-integration equations, is 'corrected' in one month. In eight out of 12 cases, the coefficients are higher than 0.40, implying that more than 40% of the deviation from equilibrium relationship between fuel and fish prices is 'corrected' within one month.

Overall, the co-integration results indicate that there is a long-term relationship between fuel and fish prices but the magnitude is small; a 1% increase in fuel price brought about a much lower percentage increase in fish prices in the study period, with megrim as the exception. In the short run, generally there is no correlation between changes in fuel and fish prices; in the case where there is correlation, it is negative, meaning higher fuel prices are correlated to lower fish prices.

Table 3. Co-integration and error-correction models for fish and fuel prices (1998-2008)

Fish type	**Co-integration equations**			**Vector error correction models**				
	N	**Chi-2**	**P_p (log)**	**EC**	**dP_f (t-1)**	**dP_p (t-1)**	**Cons**	**Chi-2**
Monkfish								
-Large	122	17.69***	-0.19*** (0.05)	-0.74*** (0.10)	0.12 (0.09)	-0.38* (0.21)	0.00 (0.01)	67.19***
-Medium	122	11.54***	-0.17*** (0.05)	-0.57*** (0.09)	-0.00 (0.09)	-0.25 (0.18)	0.00 (0.01)	50.90***
-Small	122	13.16***	-0.18*** (0.05)	-0.53*** (0.10)	-0.05 (0.09)	-0.22 (0.16)	0.00 (0.01)	49.81***
Sole								
-Large	122	11.67***	-0.22*** (0.06)	-0.47*** (0.07)	0.34*** (0.09)	-0.23 (0.19)	0.00 (0.01)	46.77***
-Medium	122	14.49***	-0.26*** (0.07)	-0.35*** (0.07)	0.18** (0.09)	-0.27* (0.16)	0.00 (0.01)	29.26***
-Small	122	13.08***	-0.34 (0.09)	-0.22*** (0.06)	-0.04 (0.09)	-0.43*** (0.14)	0.00 (0.01)	25.72***
Hake								
-Large	122	5.70**	-0.15** (0.06)	-0.61*** (0.10)	-0.04 (0.09)	-0.38 (0.24)	0.00 (0.02)	58.26***
-Medium	122	3.17*	-0.13* (0.07)	-0.54*** (0.10)	-0.04 (0.091)	-0.41 (0.25)	-0.00 (0.02)	48.71***
-Small	122	1.67	-0.11 (0.09)	-0.49*** (0.09)	0.06 (0.09)	-0.36 (0.27)	-0.00 (0.02)	37.38***
Megrim								
-Large	122	22.47***	-0.56*** (0.12)	-0.29*** (0.08)	-0.20** (0.09)	-0.05 (0.23)	0.00 (0.02)	32.15***
-Medium	122	30.11***	-0.60*** (0.11)	-0.35*** (0.08)	-0.12 (0.09)	-0.07 (0.26)	0.00 (0.02)	31.94***
-Small	122	29.01***	-0.59*** (0.11)	-0.42*** (0.09)	-0.21** (0.09)	-0.06 (0.30)	0.00 (0.020)	50.16***

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1 Co-integration equations: N = number of observations; Chi-2 = Chi square statistic; P_p (log) = fuel price (in log) Vector error correction models: EC= error correction; dP_f (t-1) = lagged change in fish prices; dP_p (t-1) = lagged change in fuel prices; Cons = constant.

4.1.4. Time series analysis: ARIMA

As reported above, the fuel and fish price series are generally non -stationary but are difference stationary; the Augmented Dickey Fuller tests for first differences of both price series strongly rejected the null hypothesis of unit roots. Hence, Autoregressive Integrated Moving Average (ARIMA) models are fitted using first differences of prices. The autocorrelation functions for the first differences of fish prices (given in Appendix 4) show some significant autocorrelations especially with price levels twelve months previously; many autocorrelation coefficients fall outside the 95% confidence interval. To control for autocorrelation, the ARIMA models are estimated with autoregressive function that considers twelve months lag (AR(12)); in addition a moving average component of MA(1)[16] is included. The regression results from the twelve ARIMA models are reported in Table 4. The autocorrelation functions for the error terms from the ARIMA model are given in Appendix 5; and almost all the autocorrelation coefficients are within the 95% confidence interval.

In all the ARIMA models lagged price changes of fuel prices (in logs) up to six months are included to see if some of the effect of fuel price take time to be reflected in fish prices. First, from the seventy two coefficients on lagged changes in fuel prices, only sixteen are significant even when considering 10% levels of significance. Second, from the sixteen that are significant, eleven are negative; since there were significant increases in fuel prices during the study period this negative relationship mainly captures decreases in fish prices accompanying increases in fuel prices. Both of the results from the ARIMA models reinforce the findings from the vector error correction models.

Overall, the time series analysis indicates that fish prices were not significantly responding to fuel price increases implying limited cost pass-through in the fisheries of southwest England. In fact the negative coefficients from the ARIMA model indicate if there is a correlation, it is likely to be negative. With increasing fuel prices, this implies the fisheries of southwest England are likely suffering from both higher costs and relatively sluggish output prices. In the next section, the possible underlying reasons for lack of cost pass-through are discussed using qualitative data analysis.

[16] MA models relate what happens in the current period to the random errors that occurred in the past.

Table 4. ARIMA models for fish and fuel prices from 1998 to 2008 (in first differences)

	dP_f (t-1)	dP_p (t-1)	dP_p (t-2)	dP_p (t-3)	dP_p (t-4)	dP_p (t-5)	dP_p (t-6)	AR(12)	MA(1)	Const	Sigma	Chi-2	N
Monkfish (dP_f)													
-Large	0.23***	0.03	0.09	-0.00	-0.06	0.28	-0.14	0.69***	-1.00***	-0.00	0.12***	4.79e+12***	117
	(0.09)	(0.15)	(0.18)	(0.18)	(0.24)	(0.20)	(0.12)	(0.11)	(0.00)	(0.00)	(0.01)		
-Medium	0.20	0.04	0.20	-0.11	0.10	0.13	-0.13	0.55***	-0.83***	-0.00	0.11***	126.34***	117
	(0.27)	(0.16)	(0.18)	(0.17)	(0.19)	(0.19)	(0.13)	(0.15)	(0.20)	(0.00)	(0.01)		
-Small	0.15	0.00	0.11	-0.01	0.01	0.20	-0.23*	0.15	0.00	0.00	0.12***	119.24***	117
	(0.17)	(0.18)	(0.19)	(0.18)	(0.20)	(0.18)	(0.12)	(0.17)	(0.18)	(0.00)	(0.01)		
Sole (dP_f)													
-Large	0.39***	-0.24*	0.25	-0.41**	0.43**	-0.07	-0.08	0.73***	-1.00***	0.00*	0.11***	9.72e+12***	117
	(0.14)	(0.13)	(0.18)	(0.18)	(0.19)	(0.17)	(0.12)	(0.07)	(0.00)	(0.00)	(0.01)		
-Medium	0.40***	-0.24**	0.25	-0.57***	0.71***	-0.25	0.01	0.58***	-0.91***	0.00	0.10***	567.00	117
	(0.12)	(0.12)	(0.17)	(0.18)	(0.18)	(0.19)	(0.14)	(0.08)	(0.06)	(0.00)	(0.01)		
-Small	0.45***	-0.29**	0.07	0.07	0.25	-0.19	0.07	0.25**	-0.87***	0.00	0.10***	186.55***	117
	(0.15)	(0.12)	(0.19)	(0.21)	(0.20)	(0.20)	(0.13)	(0.11)	(0.11)	(0.00)	(0.01)		
Hake (dP_f)													
-Large	0.27***	-0.41*	0.82***	-0.58*	0.27	0.04	-0.23	0.43***	-1.00***	0.00	0.16***	9.55e+10***	117
	(0.10)	(0.21)	(0.28)	(0.34)	(0.39)	(0.32)	(0.21)	(0.11)	(0.00)	(0.00)	(0.01)		
-Medium	0.31***	-0.47**	0.86***	-0.53	0.16	-0.03	-0.09	0.47***	-1.00***	0.00	0.16***	1.41e+12***	117
	(0.10)	(0.22)	(0.30)	(0.36)	(0.36)	(0.30)	(0.22)	(0.09)	(0.00)	(0.00)	(0.02)		
-Small	0.53***	-0.47**	1.12***	-0.81**	0.05	-0.06	0.14	0.46***	-1.00***	0.00	0.17***	9.31e+10***	117
	(0.07)	(0.21)	(0.29)	(0.34)	(0.38)	(0.32)	(0.21)	(0.08)	(0.00)	(0.00)	(0.01)		
Megrim (dP_f)													
-Large	0.17	0.04	-0.02	-0.19	0.31	-0.12	-0.15	0.61***	-0.89***	0.01	0.14***	546.69***	117
	(0.17)	(0.14)	(0.22)	(0.28)	(0.26)	(0.24)	(0.17)	(0.13)	(0.07)	(0.00)	(0.01)		
-Medium	0.34***	0.06	0.10	-0.23	0.12	0.15	-0.28	0.48***	-1.00***	0.01***	0.16***	1.18e+14***	117
	(0.09)	(0.18)	(0.27)	(0.37)	(0.35)	(0.32)	(0.24)	(0.12)	(0.00)	(0.00)	(0.01)		
-Small	0.24**	0.19	-0.08	-0.15	0.09	0.21	-0.23	0.52***	-1.00***	0.00***	0.19***	7.50e+12***	117
	(0.10)	(0.21)	(0.35)	(0.42)	(0.40)	(0.40)	(0.29)	(0.12)	(0.00)	(0.00)	(0.01)		

Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$. dP_f (t-1) = 1 month lagged change in fish prices; dP_p (t-1 to 6) = lagged change in fuel prices (1 to 6 month lags); AR(12) = autoregressive term; MA (1)= moving average term; Cons = constant; N = number of observations

4.2. Cost pass-through: qualitative analysis

A summary of key informant responses of the factors that influence fish prices and the direction of that influence (positive or negative) at the market is given in Table 5, categorised by the five main subjects that were discussed. Similarly, a summary is presented in Table 6 of the factors merchants thought influenced fish prices, along with the number of merchants who gave that response. The common subjects were factors that influenced the supply and demand of fish and the competitive structure of the market, so they are discussed together in this section and were used to create Figure 2.

4.2.1 Nature of the product and method of sale

The fish sold on the market is fresh and therefore a perishable product. The fresher the fish, the higher the quality, and the more desirable it is for merchants to buy it. There is no incentive, nor is there the capacity for fishers to store fish. Fishers also try to maximise their time at sea, so to the best of their ability, they come in to port to land, put their fish on the next market then, at the earliest opportunity, go back to sea again. Hence fishers are rarely present at the market. Thus, fish merchants have the advantage both in terms of the perishability of the product as well as that they can afford to wait. This strengthens their price-setting power and prices are subject to what fish merchants are prepared to pay on the day of sale.

Table 5. Summary of Key Informant responses to factors influencing prices at the market, the changes over the study period and direction of influence on fish price

	Changes 1998-2008	Influence direction	Influence on fish price
Nature of product sold			
Fresh fish is a perishable product	No change	-	Fishers do not store fish, thus are subject to the price fish merchants are prepared to pay on the day of sale.
Method used to sell product			
Open ascending price auction	No change	?	Merchants bid openly at auction & highest bid wins. Prices are subject to daily supply and demand, and amount of competition between merchants.
Factors influencing supply and demand			
Weekly fluctuations in supply due to tides	No change	-	Gillnet vessels fish on neap tides only. Thus boats tend to land fish to market at the same time, increasing supply and reducing prices.
Daily fluctuations in supply due to weather	No change	+/-	Poor weather results in less vessels fishing and landing to market, reducing supply, and increasing prices. Good weather has the opposite effect.
Export market trading days	No change	-	~80% of fish landed is exported to continental Europe. Fridays experience low prices due to low European demand.
Number of vessels at market	Decreasing number of vessels	+	Fewer vessels at the market reduces supply and should increase prices over time.
Volume of fish sold at market	Decreasing volume of fish	+	Fewer vessels reduces quantity of fish sold at the market, reducing supply and should increase prices over time.
Fish storage capacity of fish merchants	Increasing storage capacity	-	When supply on the market is low, prices remain low because of stored fish (chilled and frozen). The quality of fish landed has also improved markedly over time which can extend length of storage time.
Quotas	Variable by species	+/-	Some quota species have increased in abundance which has increased supply and reduced prices. Some quota species have decreased in abundance which has decreased supply and increased prices. Some quota species have remained the same.

Table 5 *continued*. Summary of Key Informant responses to factors influencing prices at the market, the changes over the study period and direction of influence on fish price

	Changes 1998-2008	**Influence direction**	**Influence on fish price**
Factors influencing competition			
Access to global market	Increasing access to global market	-	With increased technology (internet) and globalisation, fish landed at market is in competition with globally sourced fish, suppressing the price of fish at the market.
Access to local markets	Increasing access to local markets	-	With increased technology (mobile phones and internet) merchants have access to more local fish markets and throughout the UK, suppressing the price of fish at the market.
Number of merchants	Decreasing large merchants	-	Fewer large merchants created an oligarchy, reducing competition which suppresses the price of fish at the market
Cooperation between merchants	No change	-	There may be cooperation where merchants predetermine the fish they buy, reducing competition during bidding which suppresses prices
Events influencing fish prices			
Regulation of illegal landing and selling of fish	2002: Increased enforcement to stop illegal fishing	-	Illegal landing of fish undermined the price of fish on the market. From 2002 UK fisheries enforcement increased vigilance and prosecution of illegal landings, forcing all fish to be landed to the market. This forced merchants to compete for fish, driving price up, but also increased supply of fish on the market, driving price down.
Registration of buyers and sellers	2005: Reg. buyers & sellers	**?**	Registration of all buyers and sellers also enabled increased vigilance of illegal landings and species switching.
Regulation of fish processing	2003: Animal By-Products Regulation	-	Fish waste products required disposal increasing merchant costs & merchant motivation for lower prices.

Table 6. Summary of main merchant responses to factors influencing fish prices at the market and number of respondents

	Merchant responses	Number of respondents
Factors influencing supply and demand	A main determinate of fish prices is fluctuations in supply caused by weather (seasonal and daily) and tide	6
	Season governs prices through demand. Merchants believe there is more demand for fish in warmer seasons than colder seasons	6
	The amount of fish has decreased over the past ten years which has increased prices	6
	Merchants store fish which can alleviate supply problems to customers when fish supplies are low	6
	(a) Merchant has the same storage capacity as 10 years ago	2
	(b) Merchant has more storage capacity as 10 years ago	3
	(c) Merchant has less storage capacity as 10 years ago	1
	Demand for fish from merchants customers has changed for different species, as species have become popular or unpopular	6
	(a) Overall demand has remained the same	3
	(b) Overall demand has increased	3
Factors influencing competition	There is increasing access to fish on the global market which creates competition with locally caught fish	4
	There is increasing access to fish from other local UK markets and merchant buys more from these markets	5
	The mix of small, medium and large sized merchants has changed. There are fewer large merchants and more small merchants	6
	(a) Overall the number of merchants is the same	1
	(b) Overall the number of merchants has increased	1
	(c) Overall the number of merchants has decreased	4
	There is no communication at all between merchants because they are competing against each other for customers	5
Costs and cost pass through	Costs for merchants have risen. Common rising costs: fuel, packaging, energy costs (running premises), labour, and waste removal	5
	Merchants are able to pass costs through as they work to specified margins (% profit), and all middlemen along market chain pass on costs according to margins (one merchant mentioned lowered margins but increased volumes of fish bought to compensate)	6
	Example of cost pass through: Fuel crisis of 2008	
	(a) Staff cuts	3
	(b) Apart from staff cuts there was no noticeable difference to business practices or profits as merchants passed increased transport costs on	6

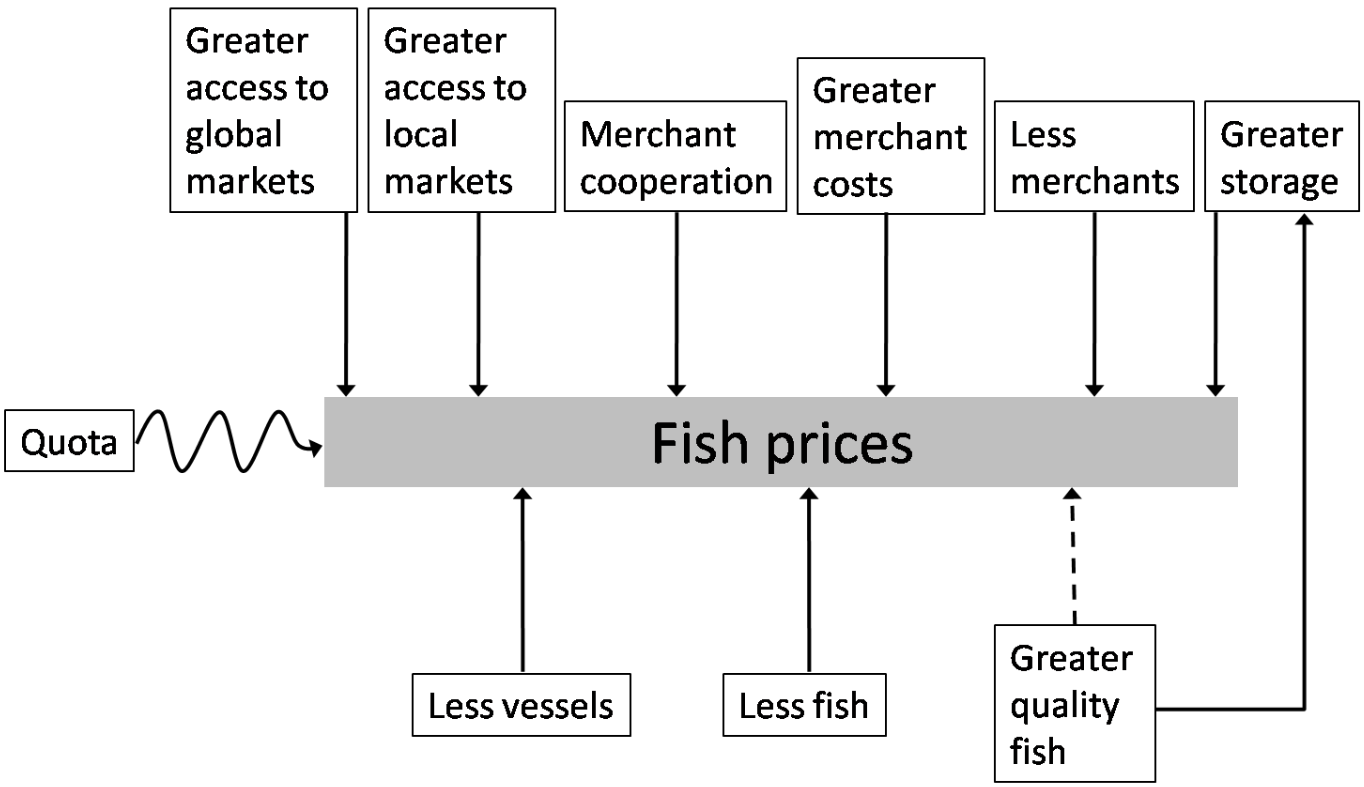

Figure 2. Factors influencing fish prices in the long term (1998-2008). Downward arrows indicate factors that suppress fish price, while upward arrows indicate factors that increase fish price. Quota variably affects fish prices, with some species experiencing higher quotas over time, increasing the supply of fish on the market (which should decrease price), and other species experiencing lower quotas over time decreasing the supply of fish on the market (which should increase price). Better fish quality should improve prices, but actually facilitates greater storage for merchants.

The auction is subject to the laws of supply and demand, and is governed by price, utility and quantity. It assumes that in a competitive market, price will function to equalise the quantity demanded and the quantity supplied, resulting in an economic equilibrium of price and quantity. Therefore, when supply is low, prices will be high, and vice versa. Given the advantage of low supply driving price up, some fishers attempt to land and sell their fish when few other vessels are doing so. Information on the number of boats predicted to land on a particular day is readily available at sea and is used by skippers. To a very limited degree, fishers can cooperate and make decisions about when to land in order to get the best price. There is no formal network or coordinated mechanism in place and communication is mostly between small groups of skippers who have social ties. Furthermore, the limitations to fishers being able to strategise and successfully 'play' the market are that uncontrollable factors such as weather override strategy and determine landing time.

4.2.2 Factors influencing supply and demand

In the short term, supply and demand are uncertain and variation is attributable to many potential factors. Both key informants and merchants said that the main short-term fluctuations in supply are caused by weather and tides, causing daily variation in price. Poor weather keeps vessels from fishing and supply of fish to the market is limited during these periods. Merchants have to compete harder for the available fish and prices at the market can be relatively high. Good weather has the opposite effect. The majority of vessels will go fishing resulting in a relatively abundant supply of fish on the market, which can reduce the price of fish. The state of the tide also has a substantial impact on fish prices at the market for the gill net fleet (approximately one third of the fleet of >10 metre vessels). Gill nets are static nets that sit like a vertical wall anchored from the bottom of the sea. The nets are most effective when the tide is weak (neap tides) and are ineffective when the tide is strong (spring tides) because the net does not sit vertically in the water. Therefore, the gill net fleet only fish on the neap tide. When the neap tide ends, the entire gill net fleet come to land at almost the same time, creating a glut of fish on the market, and can result in relatively low fish prices.

There are also short term fluctuations in demand, with high demand raising and low demand reducing the price of fish. Eighty per cent of all fish sold at the market is transported for sale to continental Western Europe. Key informant responses indicated that as a result there is low demand for fish on Fridays (and therefore relatively low prices) at the market because the timing of transport means that fish will not be ready for sale over the weekend. Merchant responses indicated there was also a trend for higher demand before public holidays. They also noted a seasonal trend in demand, where fish is in higher demand in warmer weather than colder weather, particularly when the fish is destined for the UK market. Merchants mitigate fluctuations in supply and demand by forward buying and storing fish either in refrigerated chillers or in freezers.

Short term fluctuations have a significant effect on fish price. However for this study it is important to understand the long terms drivers of fish price stagnation over the period 1998-2008. Both key informants and merchants said the supply of fish on the market had decreased substantially:

> *"There has been a huge reduction in the amount of fish on the market. When I first started at the market [ten years ago], we would still be selling fish at one pm. Now it's a rare thing to go 'til 10am. The market is turning over half what it was ten years ago. It's changed here an unbelievable amount."* (KI 6)

Key informants said the reduction in fish quantity was due to the contraction of the fleet of larger vessels but that having fewer vessels has also made daily fluctuations in price more noticeable. In addition, key informants said that the amount of fish on the market was also subject to the quota system, and has fluctuated over time depending on the species. Given that merchants said that demand for fish had either remained the same or increased over the time period and supply has been reduced, if the market is responding to the economic model of supply and demand, fish prices should have been increasing over the ten year period. However, as shown descriptively in Figure 1, this is not the case and prices have remained stagnant. Fishers have attempted to raise the prices they receive by improving quality of fish through improvements in fish handling and chilling on board the vessel but it is questionable whether this has had a true impact on the price they receive. Inadvertently, this has benefitted merchants as improvements in quality have lengthened the shelf life of the fish, increasing the storage time before selling fish on.

4.2.3 Factors influencing competition

The standard economic model of supply and demand requires a perfectly competitive market. Therefore I also looked at factors influencing competition in the fish marketing system. Key informants and merchants stated that since 1998 there had been a reduction in the number of merchants and also a redistribution of the mix of small, medium and large merchant businesses present at the market with there being a trend towards fewer large merchants and more small merchants. This seems to have created an oligopsony , with only three large merchants competing for the bulk of the fish sold each day. Improvements in communications and technology have also reduced competition for fish at the market because other local markets can be accessed simultaneously by merchants. A merchant business may have a buyer or an agent at several markets that s/he will be in constant contact with during the auction via mobile phone, along with being in constant contact with her/his customers advising them on quantities available and price trends. There has also been a shift in the UK toward electronic fish markets and auctions are conducted on the internet. One fish merchant said: *"I can talk to my buyers at Newlyn and Brixham on my mobile and buy fish online from Plymouth all from bed if I want to"* (M 4). Increased access to more markets has meant merchants can more easily search for the lowest available price for each species of fish. Both key informants and merchants also strongly suggested that increasing globalisation has meant that fish caught in the southwest of England is in competition with equivalent species sourced globally. For example, hake caught in the southwest is competing on the Spanish market with large catches of hake caught in Chile and in South Africa and Namibia, which is driving prices down. Increased access to both local and global markets has effectively increased wider supply and decreased demand for fish at the market of the SW fishing community.

Opportunities for merchant collaboration on price may be greater than ten years ago with fewer merchants on the market. All merchants said they were highly competitive with each other and don't tend to talk to each other at all. One fish merchant referred to competition with other merchants as: *"It's war!"* (M 2). However, some key informants said they feel uncomfortable about the amount of friendliness between merchants. One key informant said:

> *"There is no evidence that there is any collusion* [between merchants] *but everyone is suspicious. The friendliness between buyers makes me feel uncomfortable. The buyers from* [companies X, Y and Z] *all have dinner together and things. This is not a healthy situation. If there was a blind clock auction then the whole market would be more transparent."* (KI 4)

Over the time period spent in the SW fishing community, it was common to hear fishermen say they had received low prices unexpectedly and it happens too many times for it to be a random event. One skipper said:

> *We used to land at* [the local market] *but we were getting quite unhappy with our prices. We were getting bad prices all the time when the prices weren't so bad at other markets. It happened too many times so we landed elsewhere. We didn't intend to carry on* [landing elsewhere] *or do it as a mark of protest. The difference was between the salesmen.* [The merchants at the alternative market] *could be bothered to do something to better the prices and ones at* [the local market] *were like whatever they pay they pay. And we've never landed another fish here. Obviously it costs us more 'cause you pay landing dues twice and then you have the transport, but it works out better for us in the long run."* (beam trawler, SW fishing community)

Hostility and suspicion between fishermen and merchants is not an uncommon situation in fisheries (Acheson, 1985). However, many fishermen in the SW fishing community now refuse to sell at their local market because they strongly believe that merchants predetermine the vessel they will bid on and thus don't bid against each other. These fishermen now sell their fish at an alternative market which is an electronic market designed to favour fishermen – merchants bid anonymously and remotely so any communication between auction bidders is minimised. Fishermen who now sell at the electronic market have reported earning more money for their fish on average as a result of switching. Although there is no evidence for any cooperative behaviour between merchants, it would not be surprising given that it is more beneficial for merchants to cooperate than compete.

4.2.4 Changes in merchant costs and cost pass-through for merchants

Merchant costs have been rising over time. Common rising costs mentioned were fossil fuel related costs such as fuel for transport and energy costs to run their premises and packaging. Labour costs have also increased as skilled workers are more difficult to find and wages had gone up in the past ten years. Waste removal costs (of fish products) have also risen. However, all merchants indicated that they had passed on increased costs to their customers because they ran their businesses according to margins. In other words, they would only sell fish in order to make a specified percentage profit. One merchant mentioned that he now worked to lower margins than previously, but increased access to markets meant that he could compensate for this by increasing the volumes of fish bought and sold.

I specifically asked merchants about the impact of the fuel crisis in 2008 where diesel fuel prices paid by fishers reached a peak in mid 2008 after doubling from the start 2007 (Abernethy *et al.*, 2010). I asked this question to find a potential common example of cost pass-through for merchants. Three of the six merchants said they cut the number of staff that worked for them. However, apart from reducing labour costs, merchants said there was no discernable impact on their business, or on fish prices at the market. Two merchants had difficulty pin-pointing the period of time in question indicating it did not impact their business, whereas for fishermen, it was clearly identified as a major threat to the viability of their business (Abernethy *et al.*, 2010), further reinforcing the difference in ability to pass-through costs compared with fishers.

4.2.5 Events that may have impacted on market fish prices

I asked key informants if there had been any major events such as regulation change that may have impacted market prices in the study period. The main change mentioned by all key informants was the shift away from illegally landing fish, or 'black fishing'. Black fishing in the UK can be defined in two main ways. First, it may be fish that is landed and sold directly to a merchant without going through the market or being reported officially. Second, fish may be sold through the market but is recorded as a different species to what it actually is because the annual quota has already been reached and landing above the annual quota is illegal. Here I consider the former type of black fishing. Key informants including fisheries enforcement officers said that black landing of fish sold directly to merchants undermined the price of fish on the market. Black fish was sold at very low prices, lower than market value. Given that merchants had already bought black fish, demand for market fish was reduced and the price of market fish was suppressed.

> *"No fisherman wants to black land. It was done back then because fishermen were struggling to be profitable when the quota system came in. But the black price was lower than market price. The merchants took advantage of the situation. Then the market price also suffered because merchants had already bought the bulk of their fish through cheap black landings, so there was less competition at the market for the legal fish."* (KI 2)

In 2002, the UK government's fishing enforcement agency systematically improved vigilance, enforcement and prosecution of black landings UK wide. There were investigations and prosecutions throughout the industry including in the SW fishing community. The effect was that after 2002, the majority of fish from the >10 metre fleet is now landed through the market and as the correct species. This was further reinforced in 2005 with the compulsory registration of buyers and sellers of fish which creates a paper trail of fish from the point landed to the consumer at the end of the market chain. The reduction in black landings has had uncertain effects on the price of fish at the market in the long term. On one hand, fish merchants are forced to compete for fish using only the auction system which should drive prices up. On the other hand, the supply of fish on the market has also increased which would have the opposite effect and suppress prices.

The other main regulatory event mentioned by key informants was the introduction of regulations for fish processing and waste disposal for merchants. All merchants tend to process fish to some degree (such as filleting and packaging). Prior to 2003 when the Animal by-products regulation was imposed, merchants used to sell their waste fish. Since regulation merchants have to pay to dispose of their fish waste, increasing merchants running costs and incentive for merchants to keep prices low.

5. Discussion

Fish prices at the market do not notably respond to fuel prices in either the short term or the long term, implying limited cost pass-through in the SW fishing community. Increasing fuel prices and stagnant fish prices means that fishers suffer from both higher costs and sluggish output prices. The analyses of the market have shown that the fishers have no price setting power because of the nature of the product and the method by which it is sold. Fresh fish is a perishable product which means it has to be sold quickly. It relies on the auction market to be run according to the economic model of supply and demand with perfect competition in order to gain fair prices. However, it was found that the forces that should be driving prices up such as high demand, reduced supply and improvements in the quality of fish, are being outweighed by local and global forces that are reducing the competitiveness of the market.

On the local level the amount of fish landed has declined and merchant costs have increased, resulting in fewer large merchants bidding on the market. This has effectively created an oligopsony resulting in less competition for fish and more potential for cooperation between merchants. Although merchant costs have also been rising, unlike fishers they are able to offset and pass on costs in several ways. Fisher efforts to improve quality of the fish on the market has inadvertently allowed merchants to store fish for longer, buffering short-term variability in supply. Increased access to alternative local and electronic markets as well as improved communications has given merchants greater opportunities to search for the cheapest daily fish prices possible; but the same opportunity doesn't seem to be exploited equally by fishers. On the global level, southwest fishers are now competing internationally to sell their fish. Fish caught by the SW fishing community directly competes with fish products at low import prices from the global market, which includes large volumes of illegal, unregulated and unreported fish (European Commission, 2008a). Effectively, for southwest fishers trying to sell their product at the best price, supply has increased and therefore demand has diminished.

This study uncovered strong market constraints to fishers improving fish prices at point of first sale. The interactions between the institutional set-up of the seafood market, the lack of competition at the SW fishing community market, and globalisation of fish markets has created a barrier to fishermen effectively passing on their costs and improving prices. Rising costs, coupled with stagnating prices, result in falling profit margins for fishers, which may have negative consequences for the sustainability and resilience of coastal fishing communities (Abernethy *et al.*, 2010). The importance of creating a 'stable future for both the industry itself and for the communities that depend upon it' was recently emphasised for the UK (Prime Minister's Strategy Unit, 2004). In order to achieve healthy fisheries, fishing communities need to be encouraged to improve their ability to cope and adapt with changing conditions, alongside addressing resource conservation needs (Jentoft, 2000). Social adaptation is difficult to address because it is complex, context specific and highly dynamic and fishers often have little incentive to participate in long term resource management because of the uncertainty they face in terms of resource availability, imposed restrictions and profitability. 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 first point of sale may be an approach that has largely been overlooked by fisheries scientists and managers. As long as there is no increase in fishing effort, increased profitability may reduce the constraints fishers face and create more opportunity for adaptability and innovation within the industry toward sustainable practices, resource conservation and participatory management.

From the literature and on-going initiatives in Cornwall (southwest fisheries encompass Cornwall, Devon and Dorset) I have identified three main options to improve fish prices. These initiatives are by no means guaranteed solutions and require local and context specific initiatives. Here I discuss the advantages and disadvantages of each. The first option for improving prices is to try to add value to fish through product differentiation. This can be achieved through improving the quality of the fish at market, promoting traceability and ecolabelling. In Cornwall there has been targeted work on improving the quality of fish products since 2004. There have been improvements in on-board fish handling techniques contributing to increased quality which has critically improved the reputation of Cornish fish and has improved the value of some fish species sold (Nautilus Consultants Ltd, 2008). However, as also mentioned in the results, this has also had an unintended benefit for merchants who have been able to capitalise on improved quality because it has enhanced the shelf life of fish and its storage capacity. Traceability and ethically sourced food products are also becoming increasingly important to the consumer (Jaffry *et al*., 2004). Despite limited funding, over the past five years a non-profit organisation, Seafood Cornwall (http://www.seafoodcornwall.org.uk), has been actively promoting Cornish caught fish and have initiated a responsible-sourcing certification scheme. This has led to recognition by retailers and environmental nongovernmental organisations (Nautilus Consultants Ltd, 2008).

These types of product-differentiation can generate market-driven incentives which also support fisheries management objectives. An example of this is gear experimentation by innovative skippers which both improves fish quality and reduces environmental damage. Beam trawlers in the southwest of England experiment with square mesh codends and square mesh panels which has been shown to significantly reduce bycatch and discards, and increase catch value (Revill *et al*., 2007). However, the increase in fuel prices in 2008 reduced the experimentation of gear by the SW fishing community skippers (Abernethy *et al.*, 2010). While skippers still saw the value in continuing to modify gear, they felt they could no longer afford the fishing time (and money) lost through experimentation. The inability to offset the rise in fishing costs compromised the reputation and commitment of the fisheries to market themselves as responsible, high quality and consistent fish producers. In addition, it is unclear what the limitations are for increased prices through consumer demand for product differentiation. There is evidence to suggest that there is a gap between consumer attitudes and support of responsibly sourced fish and actual consumer behaviour. Furthermore there is uncertainty about the benefits to marine resource conservation (Jacquet and Pauly, 2007, Ward, 2008, Gulbrandsen, 2009). Consumers trade off wider environmental concerns with pragmatic factors such as price and convenience alongside a lack of awareness and knowledge of differentiated fish products (Weatherall *et al.*, 2003, Verbeke *et al.*, 2007).

The second option is to seek alternatives to the existing market structure. Merchants reported consistently high demand for southwest-caught fish over the study period. Although cheaper alternatives from the global market may be attractive to large retailers, the European seafood trade is still characterised by wide diversity of products and many southwest-caught fish species retain a cultural value to European consumers. The key may be to develop initiatives to improve competition between fish buyers. The electronic market is eighty miles from the SW fishing community. It operated very similarly to the SW fishing community market until 1999 when it converted to a modern electronic market allowing buyers to bid online, increasing the number of buyers including international buyers. Buyers have access to information on who caught the fish, when, and the gear type used. Vessel reputations have been established as a result. Since the inception of the electronic market, it has reported improved fish values as a result of improved competition, and higher volumes of fish as more vessels are attracted to land there. Some SW fishing community skippers now transport their fish to the electronic market because of the higher prices they receive. Despite this being common knowledge, many skippers have fidelity towards landing at their home market through habit, convenience and loyalty to the local fishing industry. Given that there is a marked locality effect, investments to alter the market structure and improve competition need to be directed at the local market itself rather than incentivising fishers to sell to alternative markets.

The third option is to challenge the price setting power of fish merchants through cooperative strategies. Given that fish prices at first point of sale have remained relatively stable over the past ten years and retail prices appear to have risen[17] , there may be an opportunity to integrate the market. Marketing cooperatives have been shown to be an effective tool in fisheries for reducing

[17] It is difficult to obtain specific data on trends in retail prices in Europe because most retail data are collected and commercialised by private companies (FAO, 2008a). 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 ten 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 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)

costs and increasing income (Kitts and Edwards, 2003). Associations in Cornwall such as the Southwest Handline Fishermen's Association (http://linecaught.org.uk), Cornish Tuna (http://www.cornishtuna.com), and the Cornish Sardine Management Association (http://www.cornishsardines.org.uk) comprise fishing enterprises acting as cooperatives, providing opportunities to market their differentiated product and sell directly to anyone along the supply chain, with success. Developing more cooperatives requires policy support, investment, management and determination on the part of the member fishers. Producer organisations (POs) may be the key to developing marketing cooperatives. However, with limited funding and grant opportunities, producer organisations in the UK currently focus on maximising quota entitlements and try to achieve steady supply and market prices for landings through quota regulation. Given the limitations of resources, there is little capacity for POs to get involved with direct marketing outside giving support to broader umbrella projects (e.g. Seafood Cornwall) and to facilitating communications between PO members and sales agents (Carleton *et al*., 2006).

It is often assumed that standard setting by retailers and certification schemes to encourage consumers will offer the route to sustainability. However it has been shown that the intended benefits and goals for the ecosystem and consumers are not always achieved (Jacquet and Pauly, 2007). There needs to be an incentive for the fishers to shift toward sustainable practices. This will only be possible if fishers are given the opportunity to be profitable which will enhance their ability to cope and adapt with changing conditions. I have identified three possible alternative strategies for offsetting costs through ex-vessel price improvements. Policy makers, the public, the fishing industry, and the fishing communities themselves all have a role to play: adding value through product differentiation through improvements in quality, traceability, certification schemes, all require public education and demand; improving competition at the fish market requires policy and community driven changes of the institutional set-up as well as investment; and forming fisher cooperative strategies requires organisation and collaboration between fishers themselves and potentially the producer organisations.

6. Conclusions

It is fundamental that overexploitation of fisheries needs to be addressed in order to prevent further declines. However, it is also clear that in order to succeed in managing fishery resources, initiatives rely on understanding the socio-economic incentives of fishers to change behaviour. Fishing costs have been rising for a number of years, particularly fuel costs. It is almost certain that fuel price will continue to rise in the future. However, this study has identified that it is not necessarily the fuel prices that are the constraint preventing fishers from coping and adapting to changing conditions. There are stagnant fish prices at the market and fishers are unable to pass-through increasing costs. The institutional set up of the market means that *"fishermen are price takers not price makers"* (KI 4) and this is contributing to the decline of UK fishing communities such as the SW fishing community described in this study. As long as fishing effort is not increased, policies and investment directed at improving fish prices for fishers may contribute to improved profitability and health of UK fisheries.

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8. Appendices

Appendix 1. Interview respondents

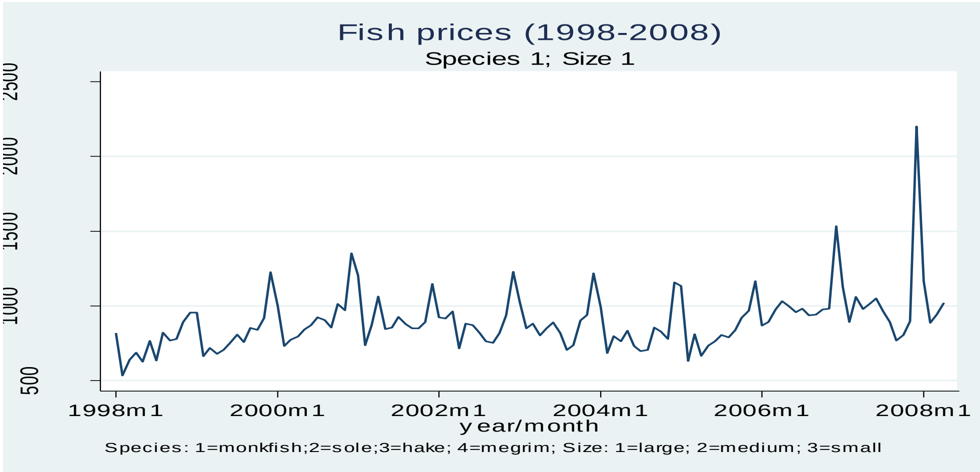
Respondent code	Respondent category	Respondent details	Interview date
KI 1	Industry liaison	Head of Cornish Fish Producers Organisation	02.10.2009
KI 2	Government official	Fisheries officer, Marine Fisheries Authority	07.10.2009
KI 3	Fisheries observer	Fish market observer and fisheries vessel scientific observer	12.10.2009
KI 4	Industry liaison	Head of Seafood Cornwall	08.10.2009
KI 5	Industry liaison	Fisheries liaison officer, Seafood Cornwall	06.10.2009
KI 6	Market worker	Market worker and auctioneer at fish market	13.10.2009
M 1	Merchant	Mid size fish merchant *(buys 5-6 tonnes fish per week)*	02.10.2009
M 2	Merchant	Mid size fish merchant *(buys 8 tonnes fish per week)*	05.10.2009
M 3	Merchant	Mid size fish merchant *(buys 2-10 tonnes fish per week)*	05.10.2009
M 4	Merchant	Mid size fish merchant *(buys 10 tonnes fish per week)*	07.10.2009
M 5	Merchant	Mid size fish merchant *(buys 10-20 tonnes fish per week)*	12.10.2009
M 6	Merchant	Mid size fish merchant *(buys 5 tonnes fish per week)*	14.10.2009
M 7	Merchant	Large size fish merchant *(buys 100 tonnes fish per week)*	16.10.2009

Appendix 2. Average annual fish and fuel prices (1998-2008). Fish prices are in UK £/kg and fuel prices UK pence/litre.

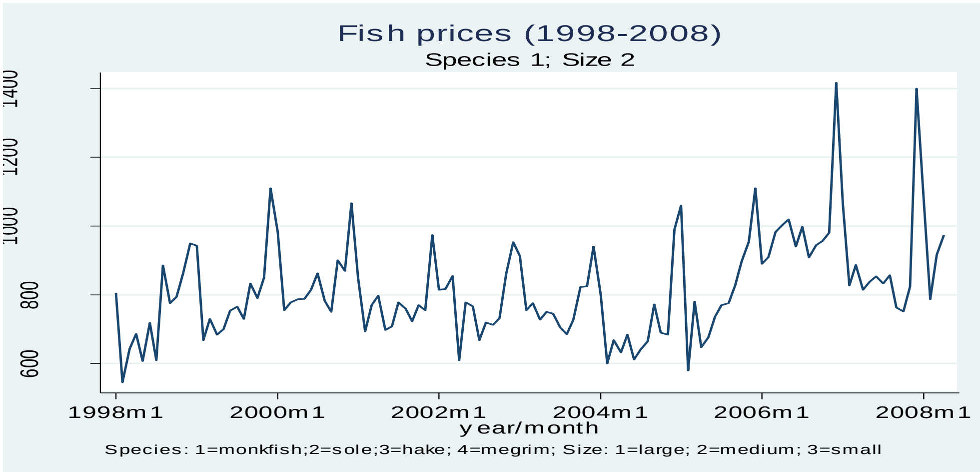
Fish type	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Monkfish											
-Large	7.44	8.23	9.20	9.27	8.83	8.85	8.19	8.52	10.07	10.54	10.05
-Medium	7.40	7.96	8.45	7.73	7.74	7.81	7.03	8.18	9.96	8.93	9.39
-Small	6.90	7.24	7.08	6.62	7.02	6.80	6.39	7.65	8.85	8.12	8.81
Sole											
-Large	8.18	8.71	8.01	8.37	8.56	8.55	9.21	9.47	10.66	11.69	9.44
-Medium	9.99	10.08	9.42	9.64	9.60	9.60	10.58	11.04	13.16	14.51	13.03
-Small	7.95	6.87	6.42	6.67	6.51	7.44	8.07	8.68	9.98	10.80	9.49
Hake											
-Large	4.85	5.72	4.92	4.74	4.76	4.82	5.50	5.46	5.92	5.77	6.77
-Medium	4.08	4.51	3.75	3.68	3.84	3.82	4.24	4.27	4.70	4.65	4.76
-Small	3.22	3.22	2.69	2.57	3.08	2.83	2.84	3.20	3.64	3.29	3.42
Megrim											
-Large	3.97	4.32	3.96	3.90	4.53	5.17	5.94	6.97	7.90	7.35	7.48
-Medium	2.77	3.02	2.81	2.76	3.25	3.87	4.23	4.98	5.50	5.11	6.05
-Small	2.29	2.41	2.35	2.25	2.60	2.92	3.04	3.88	4.44	4.02	4.88
Fuel	9.48	11.09	17.64	16.44	15.39	17.22	20.30	27.77	31.71	31.79	44.22

Appendix 3a. Fish prices (January 1998- April 2008). Prices are in pence per kg

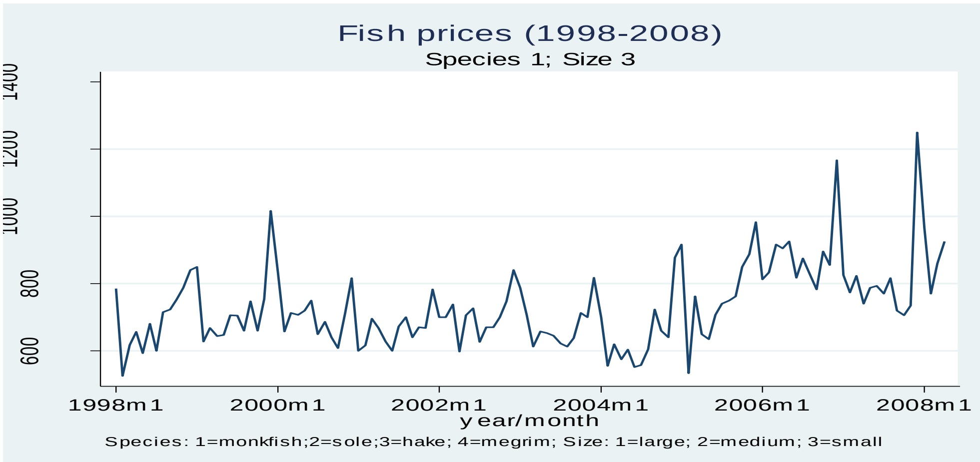
Monkfish - large



Monkfish - medium

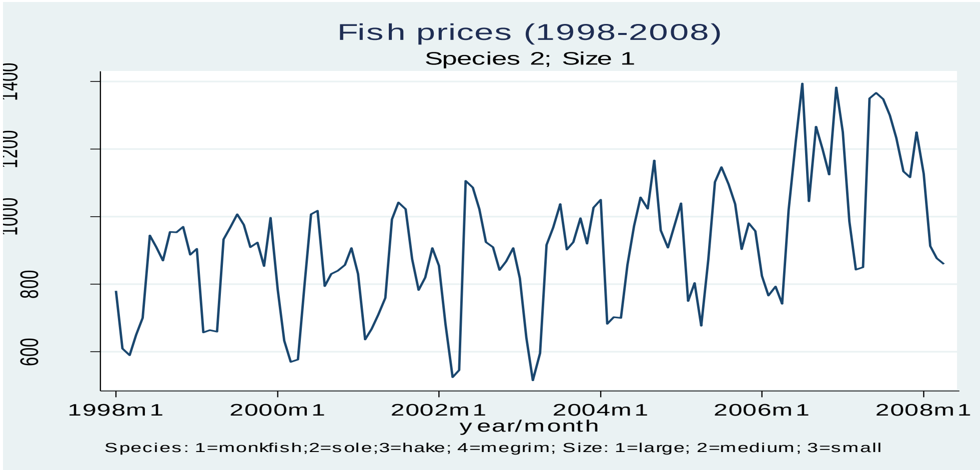


Monkfish – small

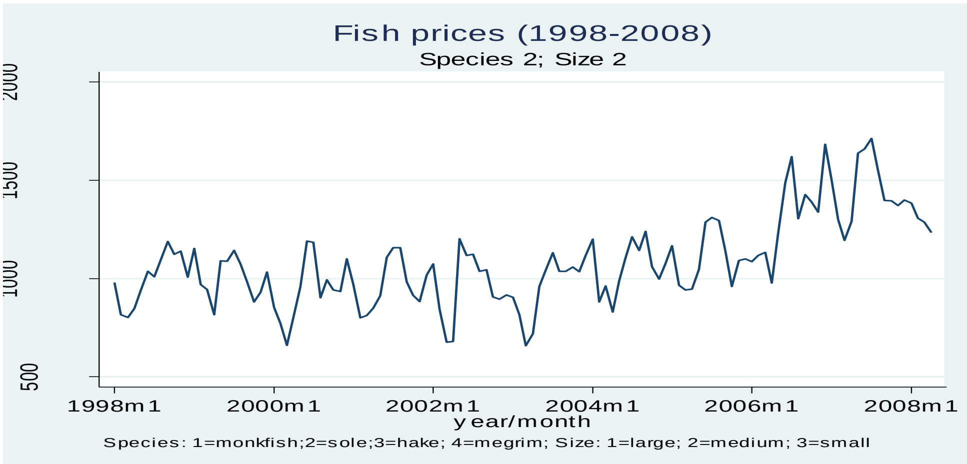


Appendix 3a. *continued.* Fish prices (January 1998- April 2008). Prices are in pence per kg

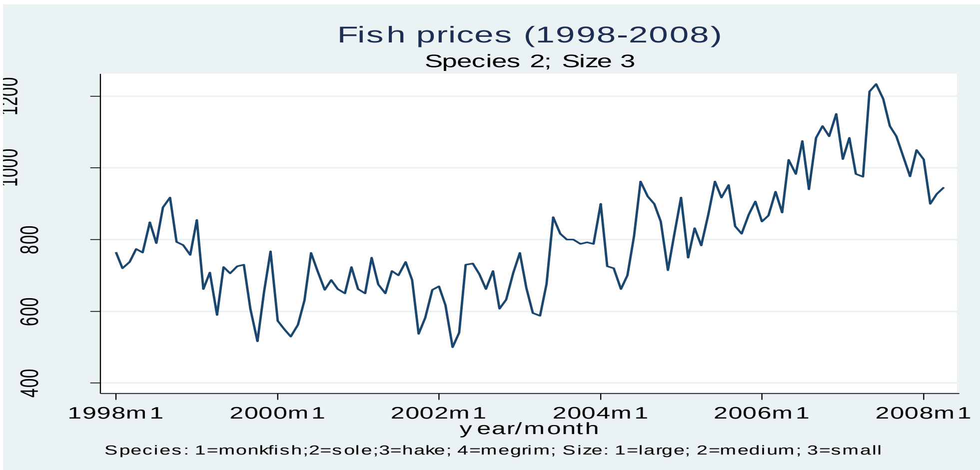
Sol e- large



Sole - medium

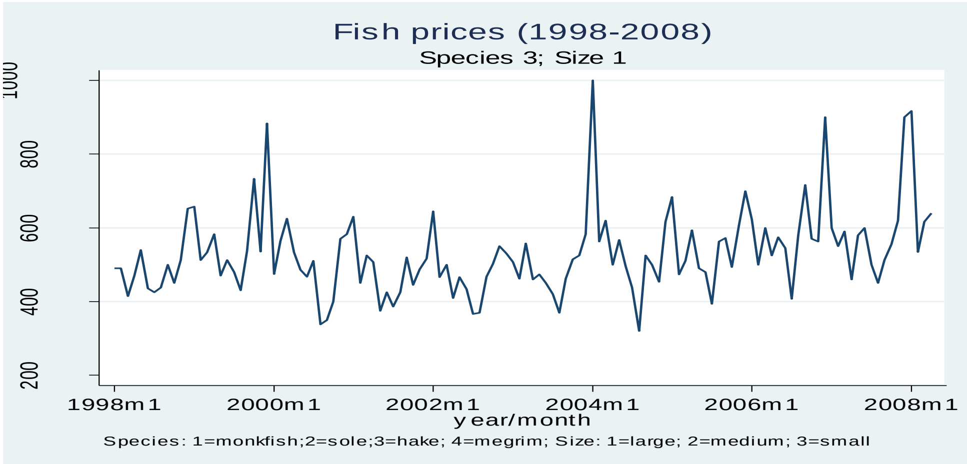


Sole – small

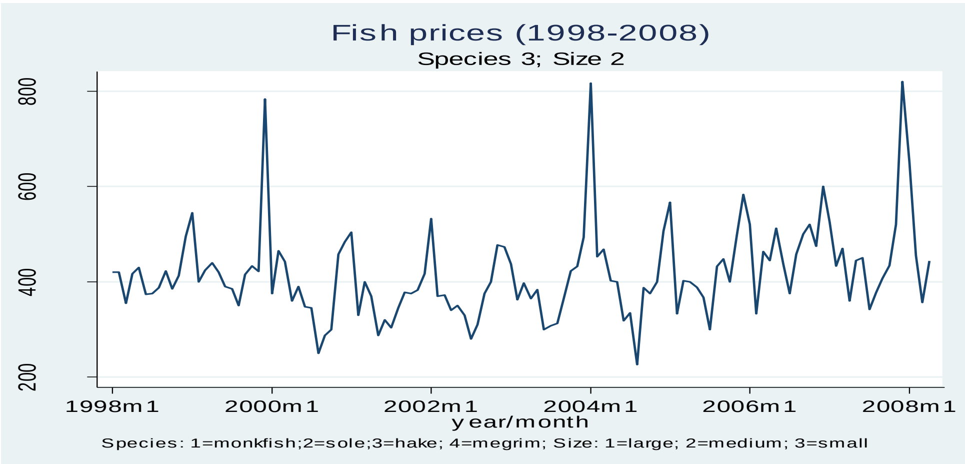


Appendix 3a. *continued.* Fish prices (January 1998- April 2008). Prices are in pence per kg

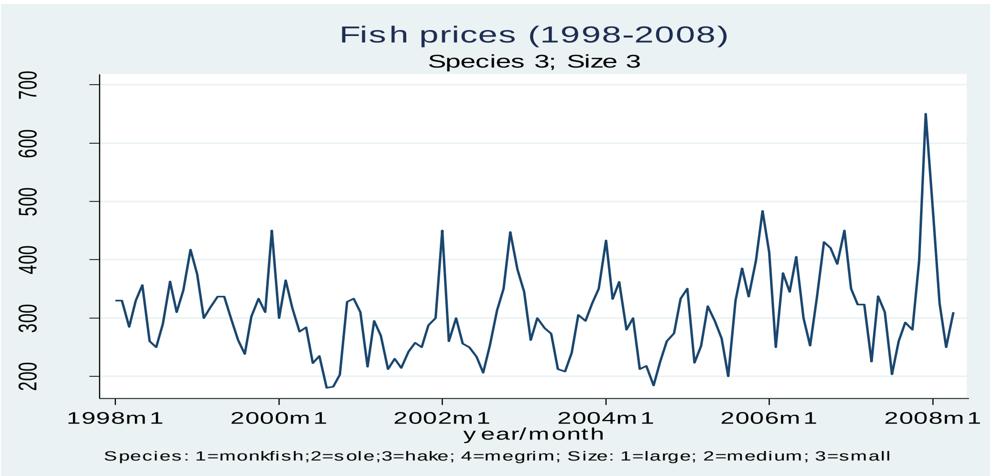
Hake- large



Hake- medium

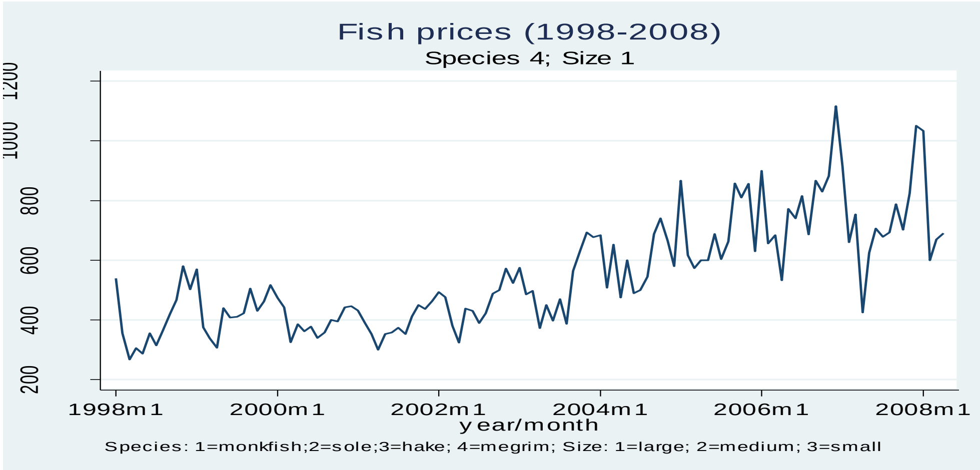


Hake- small

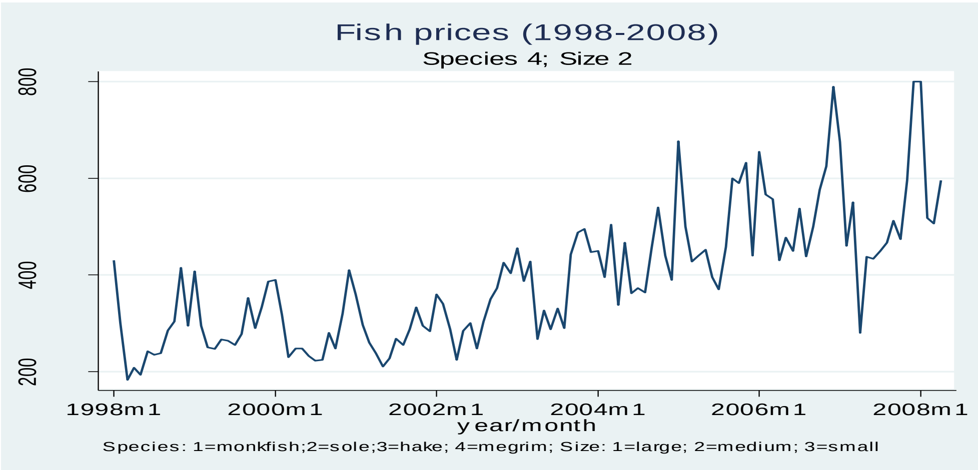


Appendix 3a. *continued.* Fish prices (January 1998- April 2008). Prices are in pence per kg

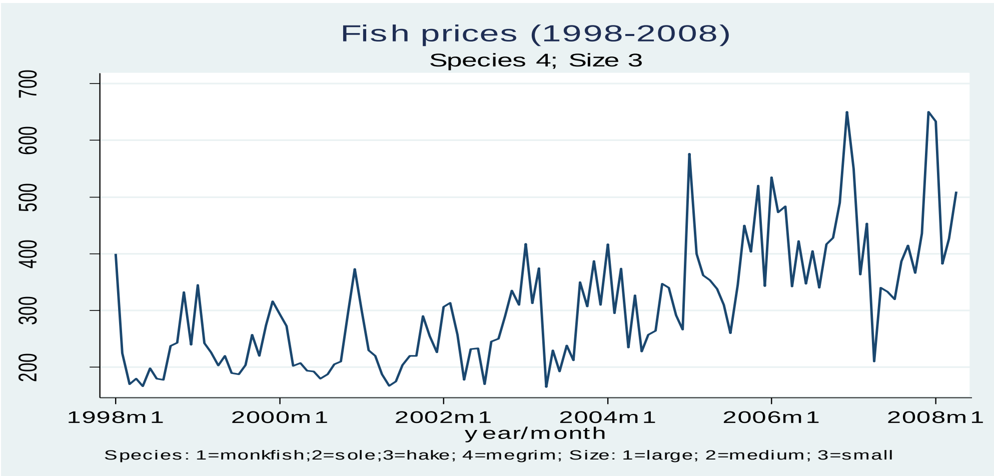
Megrim - large



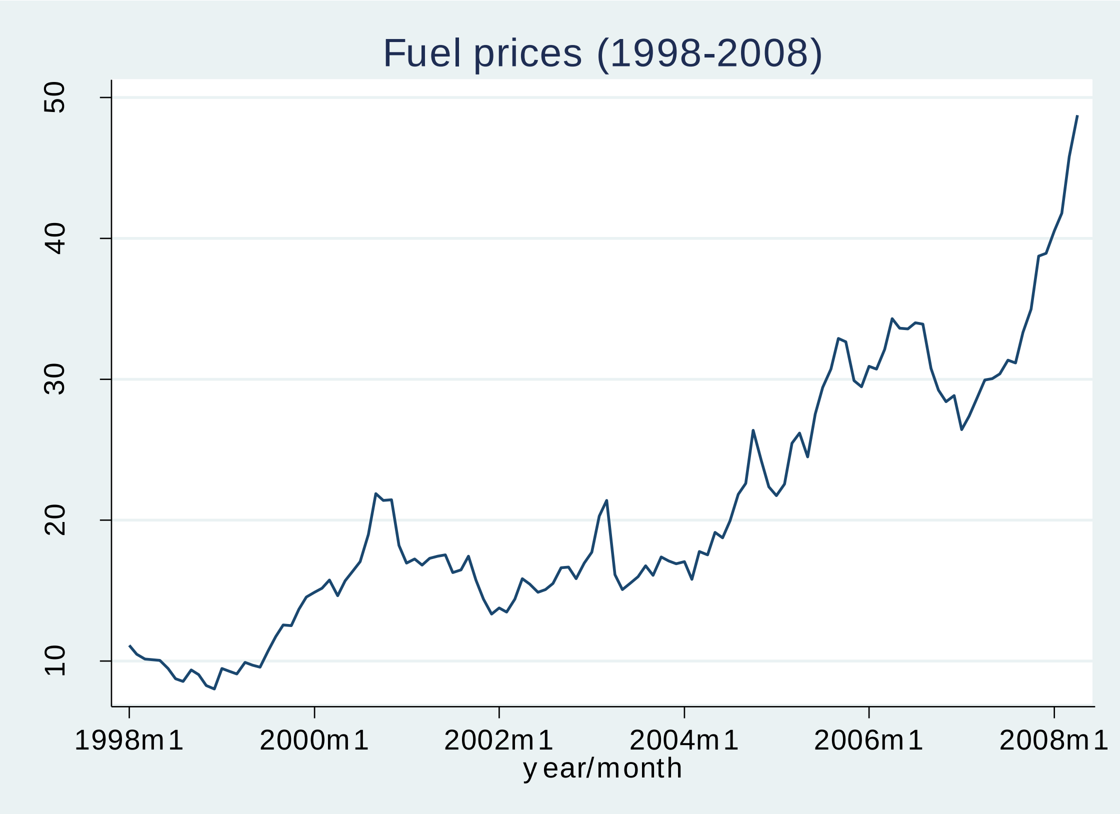
Megrim- medium



Megrim- small

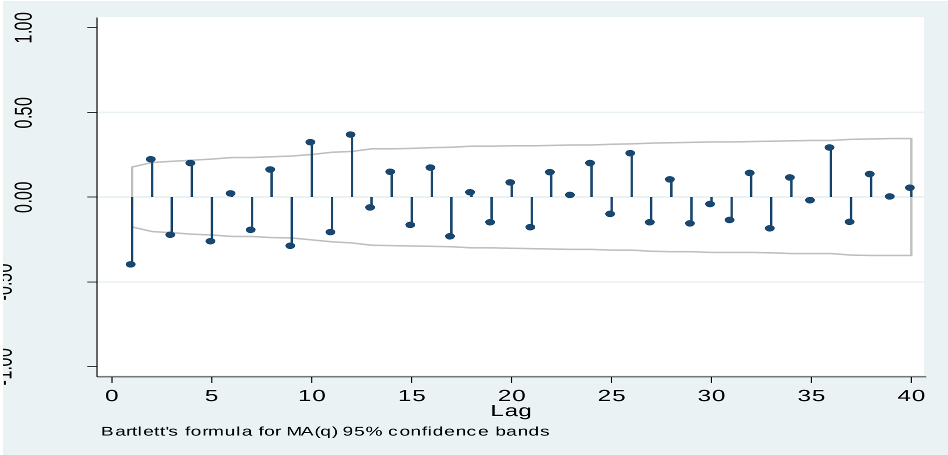


Appendix 3b. Fuel prices (January 1998- April 2008). Prices in pence per litre

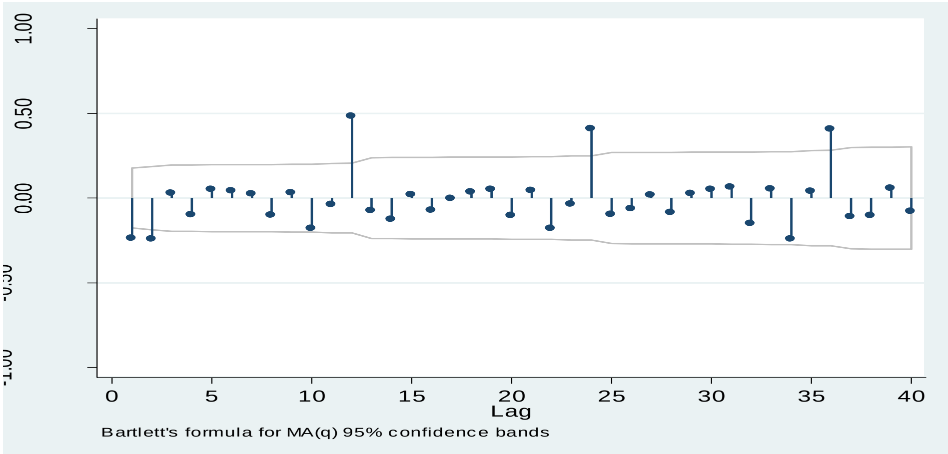


Appendix 4. Autocorrelation functions for first difference of fish prices

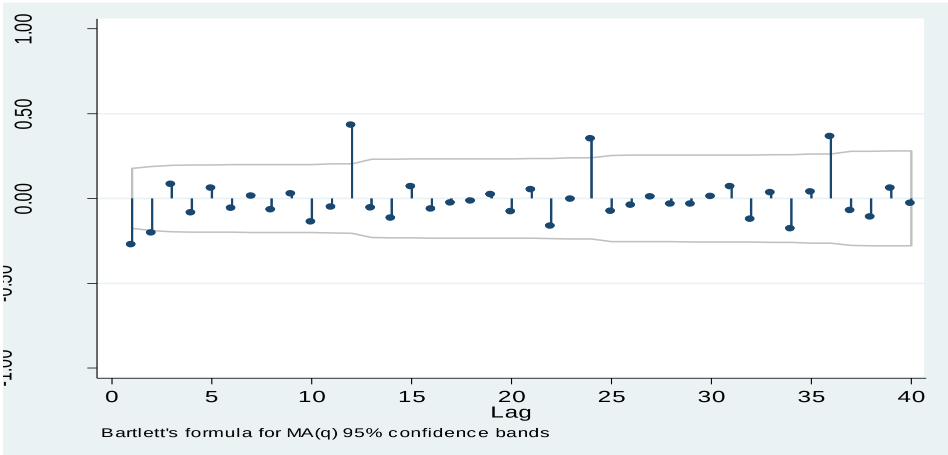
Monkfish - large



Monkfish – medium

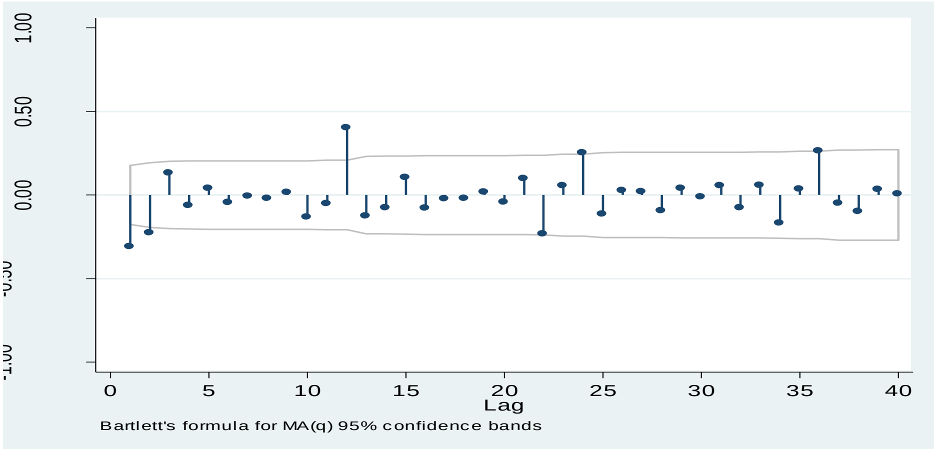


Monkfish – small

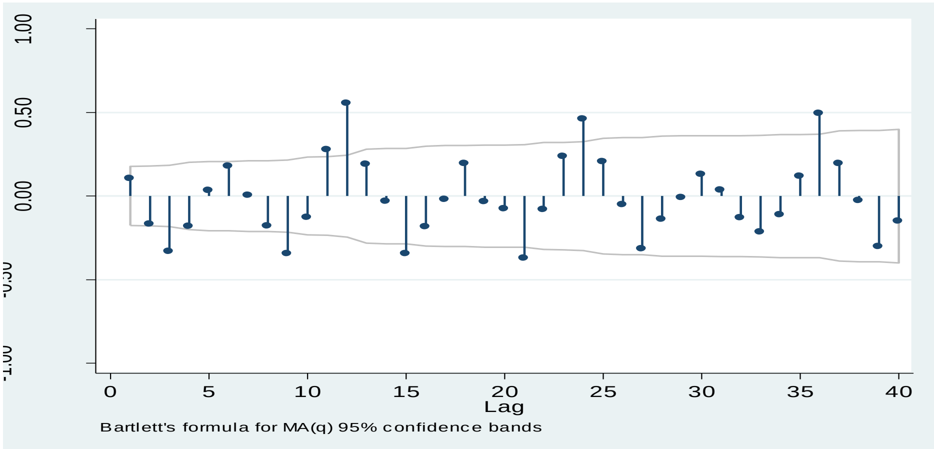


Appendix 4. *continued.* Autocorrelation functions for first difference of fish price

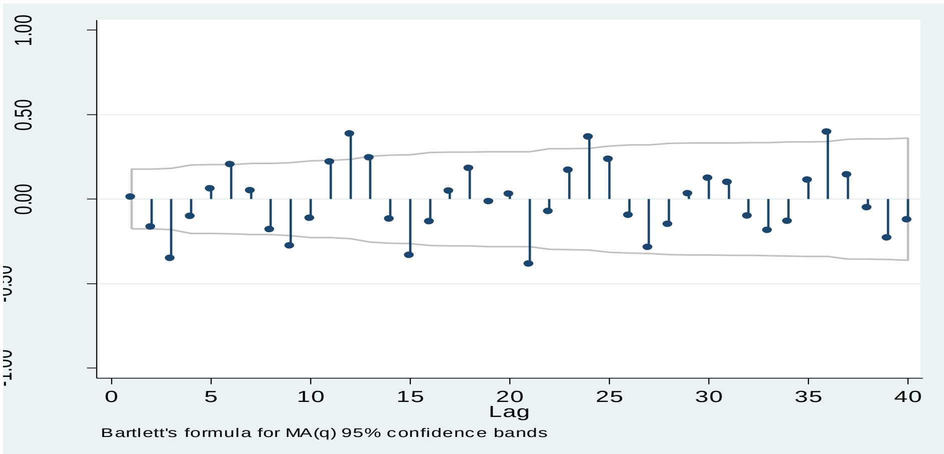
Sole – large



Sole – medium

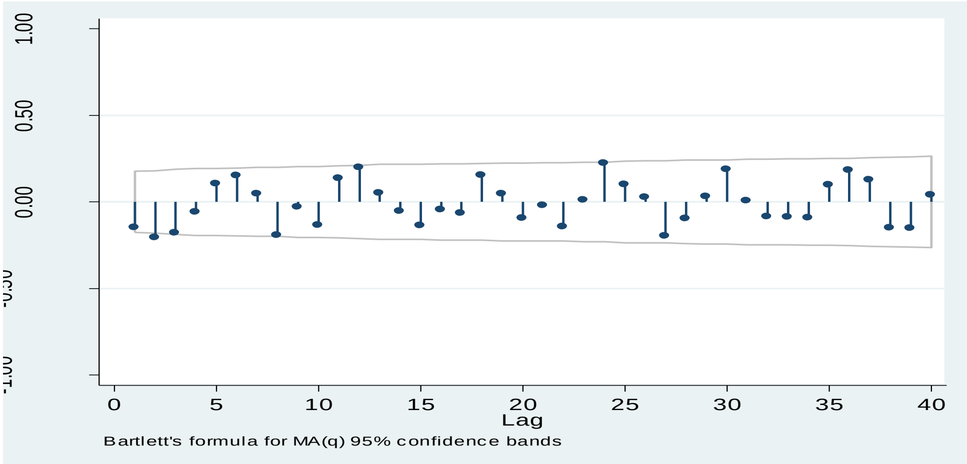


Sole – small

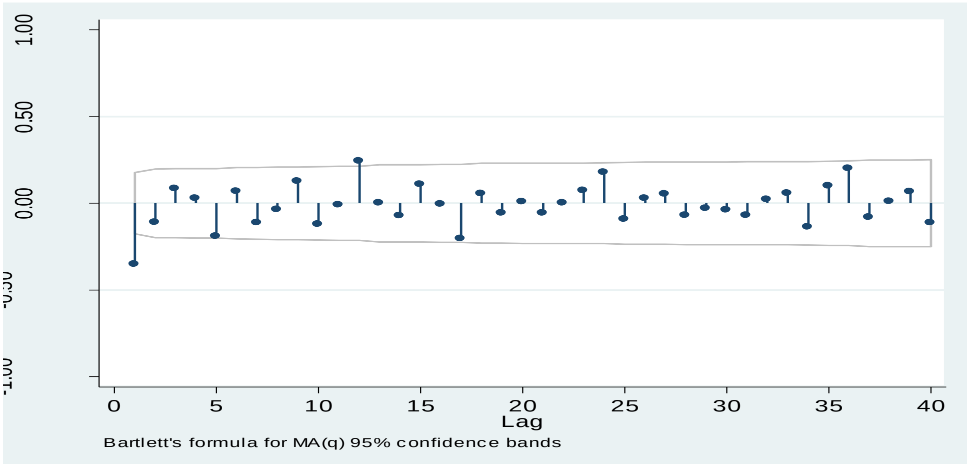


Appendix 4. *continued.* Autocorrelation functions for first difference of fish price

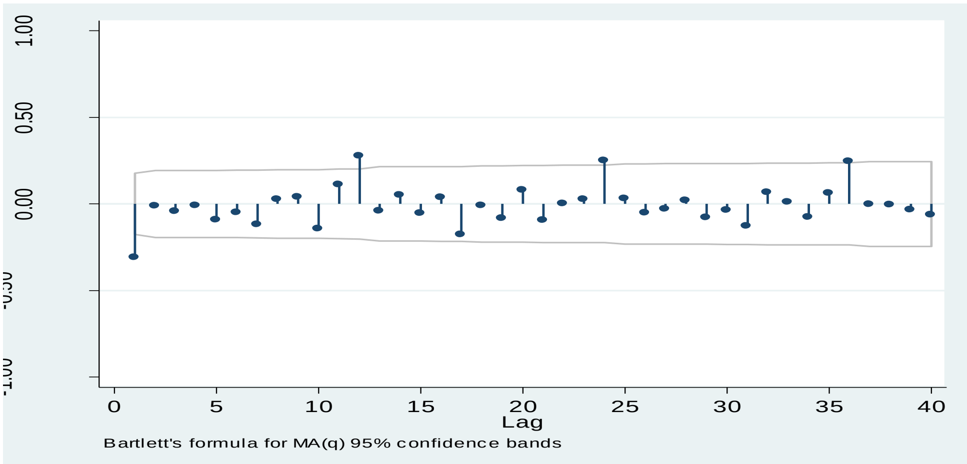
Hake - large



Hake- medium

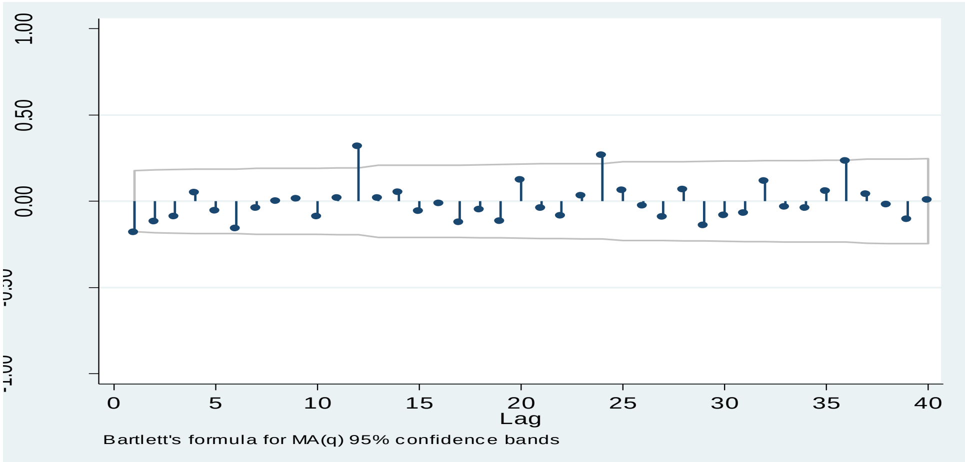


Hake- small

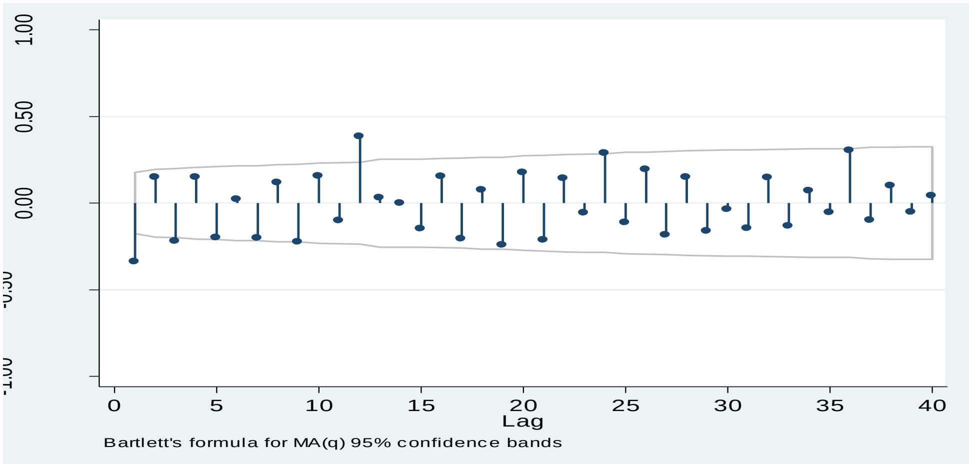


Appendix 4. *continued.* Autocorrelation functions for first difference of fish price

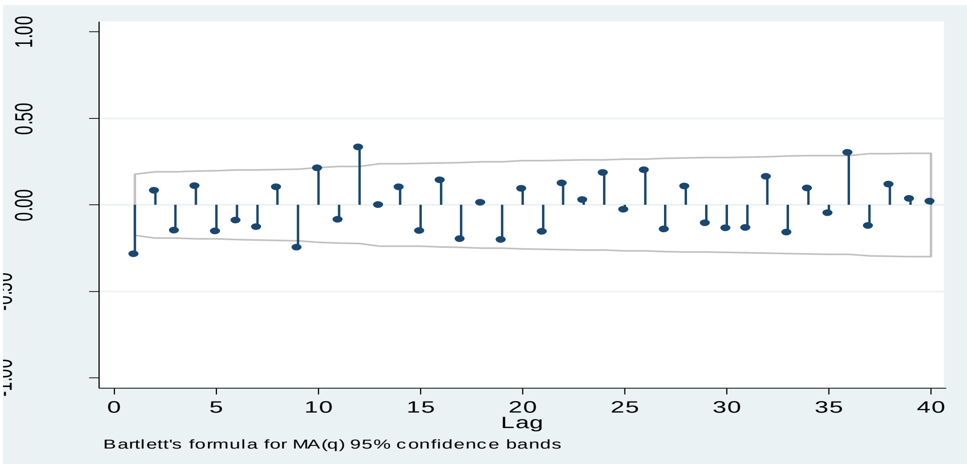
Megrim - large



Megrim- medium

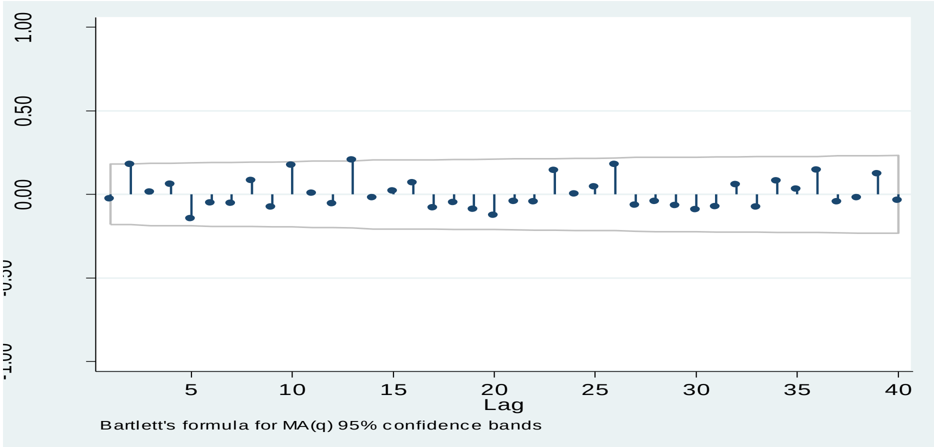


Megrim- small



Appendix 5. Autocorrelation functions for residuals from the ARIMA models

Monkfish - large



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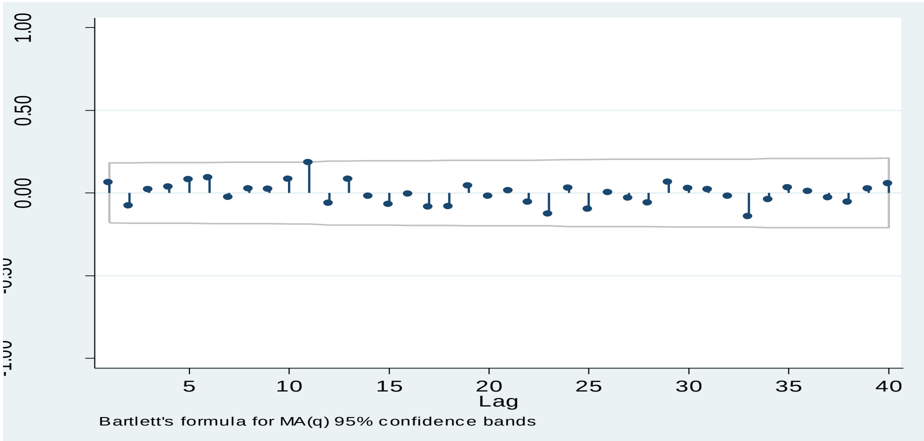
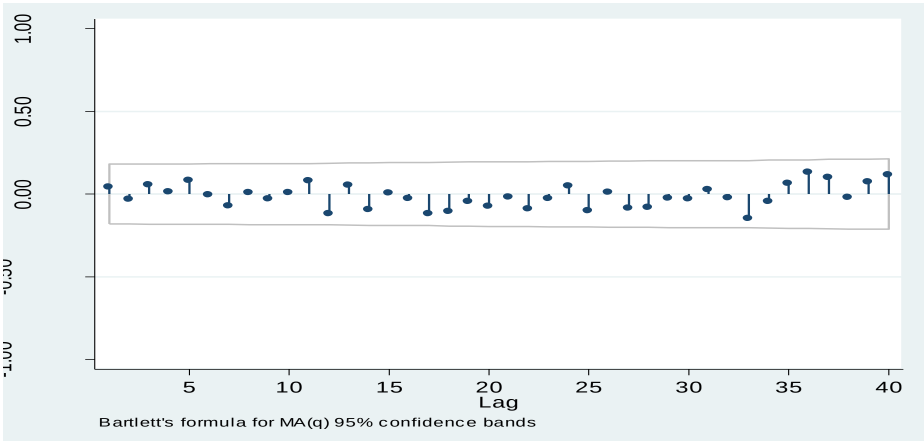
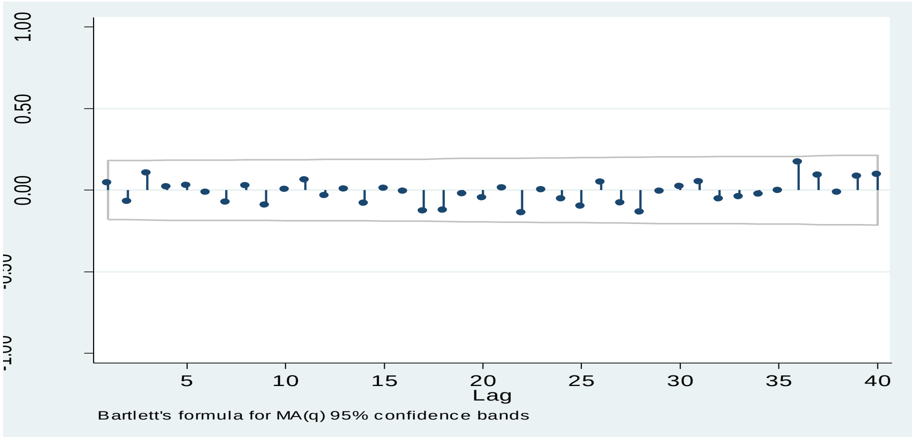


Monkfish – small



Appendix 5. *continued.* Autocorrelation functions for residuals from the ARIMA models

Sole- large



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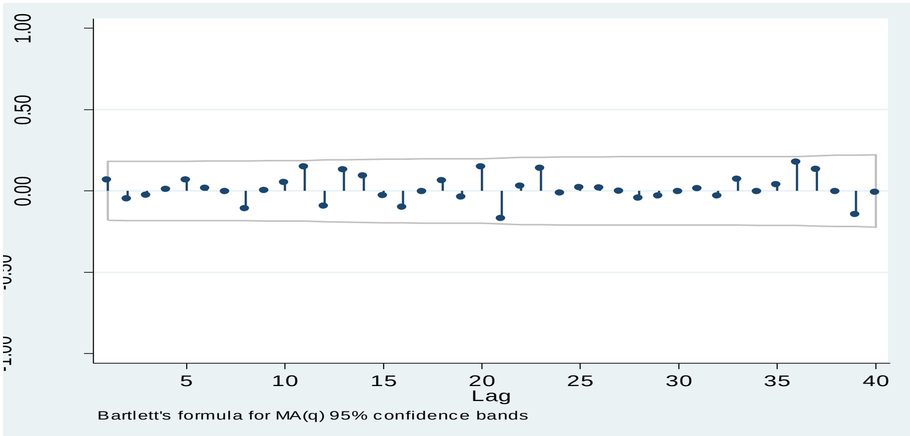

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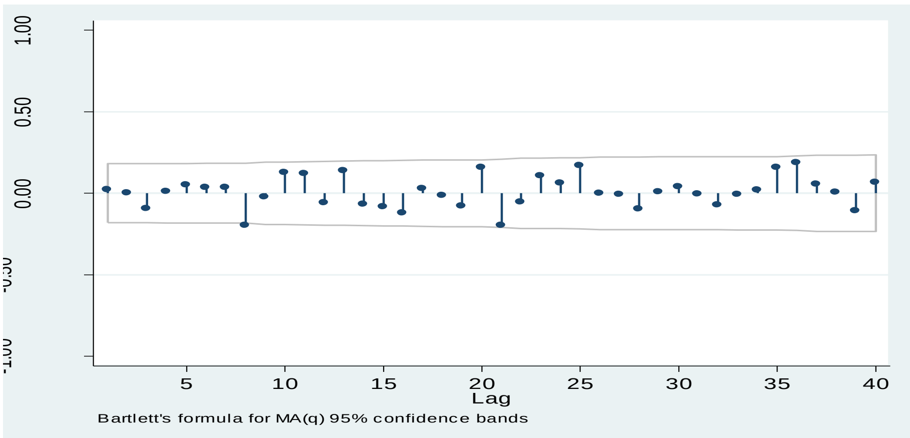
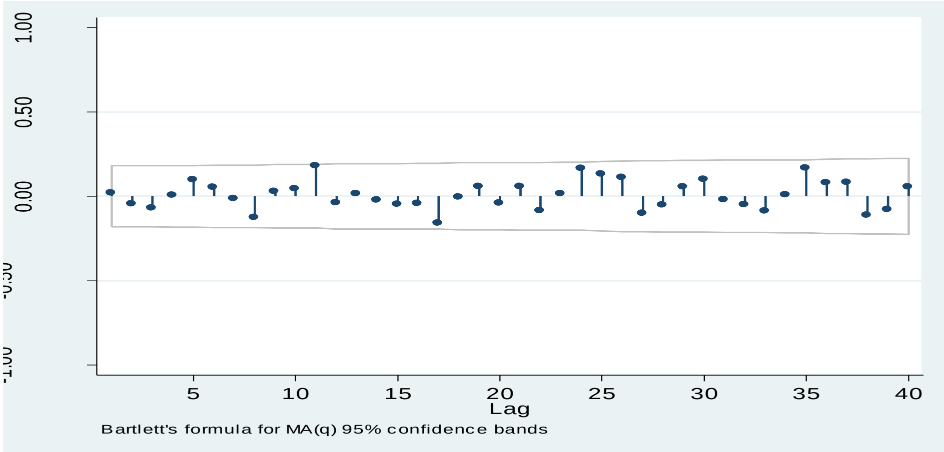
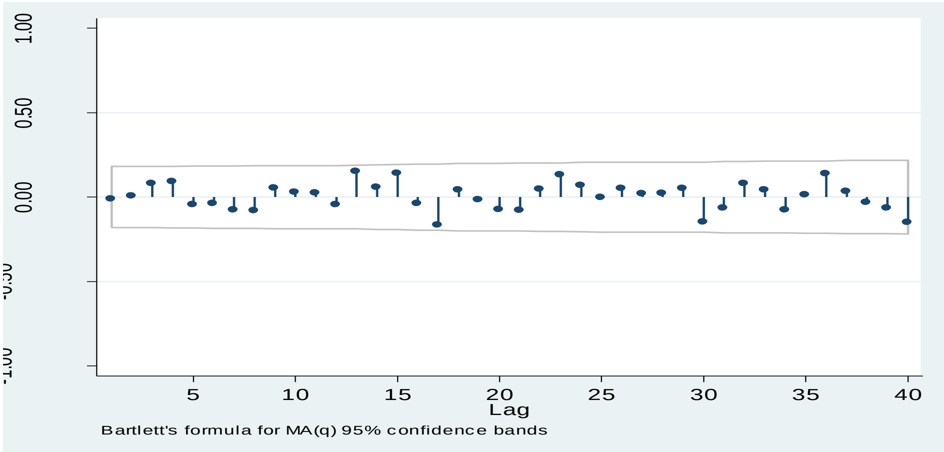


Appendix 5. *continued.* Autocorrelation functions for residuals from the ARIMA models

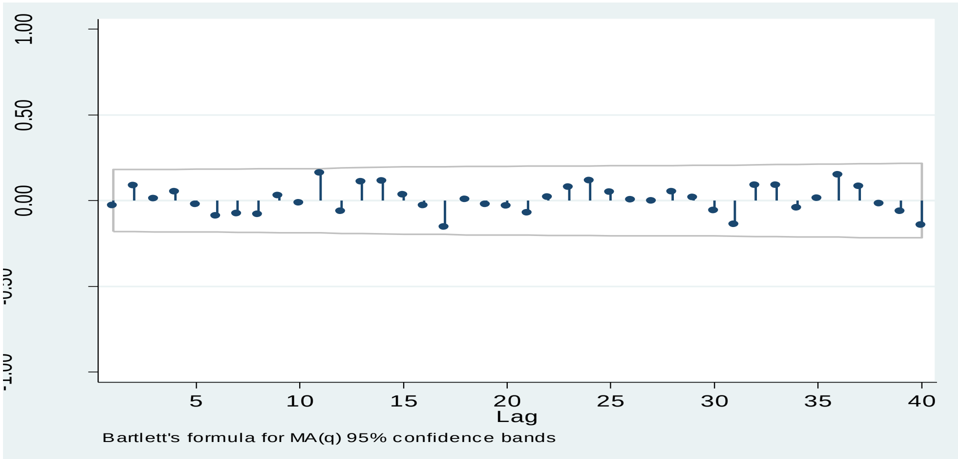
Hake - large



Hake- medium

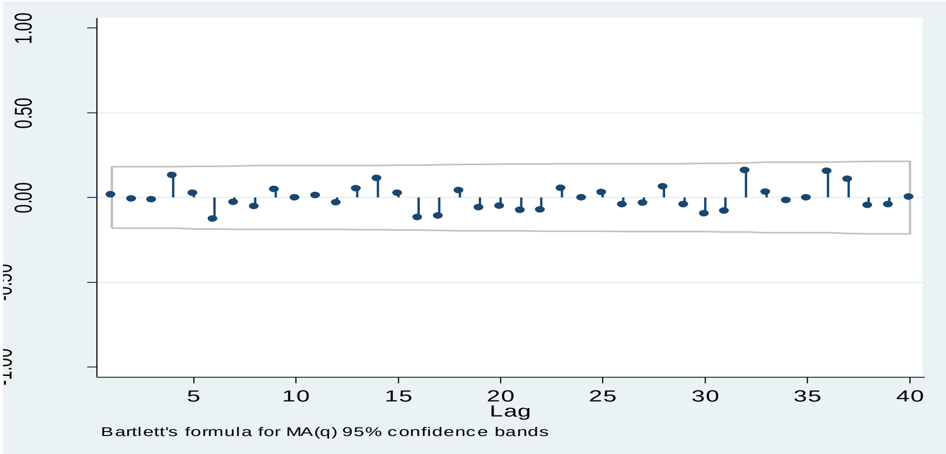


Hake- small

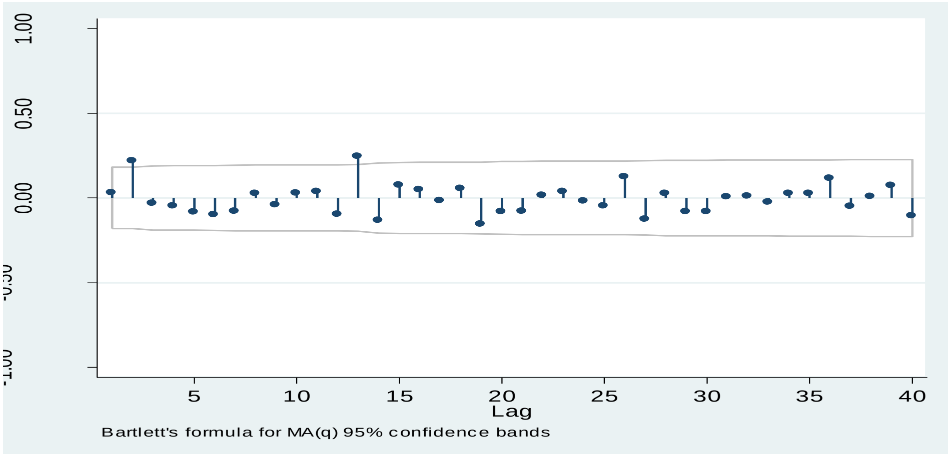


Appendix 5. *continued.* Autocorrelation functions for residuals from the ARIMA models

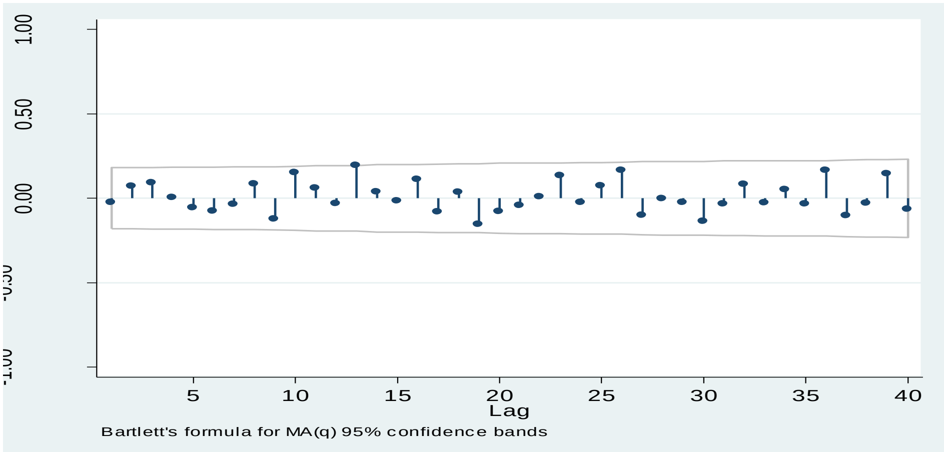
Megrim - large



Megrim- medium



Megrim- small



Chapter 7

Concluding remarks

1. Key findings

Understanding fisher behaviour is fundamental for designing fisheries policies which use appropriate incentives to promote goals of improving ecosystem functioning, efficiency and profitability of fishing enterprises, and the well being of fishing communities (Wilen, 1979, Salas and Gaertner, 2004, Branch *et al.*, 2006, Hilborn, 2007). In many fisheries, policy has failed to develop the ability to understand and anticipate fisher behaviour in advance of regulations, or learn how to shape behaviour in ways that promote management goals (Hanna, 2001). The research presented in this thesis attempted to help readdress the imbalance between understanding fisheries resources and the resource users, and adds to our understanding of individual fisher and fleet-wide decision making. I used theory from a range of disciplines within and outside fisheries research to formulate an interdisciplinary approach to uncovering the factors that influence heterogeneity of behaviour, the patterns of fisher decision making, and the implications of operating a fishing business under uncertain and changing conditions.

The research results provided an insight into the strategic behaviour of fishers and showed that there are different strategic archetypes within a fishing fleet. The analysis revealed that fishers' strategic behaviour can be classified according to the degree to which each skipper is dynamic, innovative and adaptable to changing conditions. A skipper's strategic position was 'enabled' through the degree of communication, cooperation, planning, financial and physical risk-taking they undertake and their emphasis on stability. A skipper's individual characteristics such as career time horizon, the financial pressure and responsibilities at home, their ethic towards fishing and whether they work for a company or operate independently were also important determinants of a skipper's strategy. Defining skippers strategic behaviour revealed that about half of skippers were not flexible or innovative and hence had little ability to adapt to changing conditions. The other half of skippers were able to readily adapt to changing regulatory conditions. This could result in high pressure on resources but at the same time, these skippers were more likely to adapt their practices towards goals of environmentally sustainable fisheries.

A fisher's short term tactics, such as location choice are informed by his/her strategy (Béné, 1996, Christensen and Raakjaer, 2006). Location choice behaviour was investigated in this thesis, using a logistic random utility modelling (RUM) approach. Using variables informed by the data collected through interviews with skippers and the literature, the model revealed that skippers made location choice decisions based on recent and annual economic returns. This motivation was modified by the influence of knowledge transfer within the fleet (of where the rest of the fleet were gaining high returns) and financial and/or risk aversion, with skippers preferring to fish locations closer to their home port, and choosing locations with less variance in economic returns even when alternative locations may yield higher returns.

The opportunity to examine how fisher behaviour is modified by uncertain and changing conditions arose unexpectedly when there was a fuel price 'shock' during fieldwork in 2008. Fuel prices had doubled between 2007 and 2008, peaking in mid-2008. It resulted in a significant reduction in income for fishers, a loss of job security and problems in recruiting crew. Sectors of the fleet that used towed gears, and had not invested in fuel-efficiency measures, were most impacted and less able to adapt. Fishing behaviour altered as skippers attempted to increase fuel efficiency at the cost of reduced catches, fishing closer to port, reducing exploratory fishing, and ceasing experimentation with fishing gears with lesser environmental impact. This highlighted that a threat to fishing community viability may have negative environmental effects. The key barrier to fishers in the face of unstable and rising fuel prices was that they were unable to offset increased costs because ex-vessel market fish prices have remained stagnant for at least a decade.

Strong market constraints to fishers' ability to influence fish prices at first point of sale were uncovered. The interactions between the institutional set-up of the seafood market, the lack of competition between merchants at the fish market, and globalisation of fish markets mean that fishermen lack the price-setting power to effectively pass on their escalating costs through improving prices at first sale.

2. Limitations

Overall this thesis adds weight to the argument that understanding aggregate fisher incentives can augment the design of fisheries governance systems for social-ecological sustainability and for fishing community resilience. It demonstrates that using a mixed methods approach and theories drawn from disciplines outside fisheries science (such as behavioural economics, psychology, social anthropology, management science, organisational theory, political science and economic geography) to research fisher behaviour can result in richer mechanistic understanding of the complexity of fisher behaviour and how it is modified by psychological, cultural and social determinants. The range of methods used in this thesis and the fact that research into fisher decision making is a relatively unexplored area, means there are limitations to this work in terms of direct policy relevance and the findings need to be considered as preliminary and exploratory (particularly for Chapters 3 and 4) while still useful for developing new methods for understanding fisher behaviour. Chapter 3 drew upon the strategic management research to develop a framework for categorising fishing strategies and is the first, of which I am aware, that has attempted to apply the Miles and Snow (1978) strategic typology in the fishery context. As with most research studies, many questions remain unanswered particularly those directed at informing policy choices and how defining strategies can be ethically and practically incorporated into policy. Chapter 4 developed further the RUM applied by Hutton et al. (2004) to model and predict location choice behaviour of the southwest English beam trawl fleet by including variables related to risk taking. The simple model was chosen and variables were limited by the data available. There is much scope to develop and improve the power of the RUM for southwest fisheries by the inclusion of species-specific catch variables, ecological variables, individual skipper characteristics, or using a more complex approach to the modelling structure. Chapters 5 and 6 investigated the constraints placed on southwest fishers due to rising costs and the inability of fishers to pass-through costs, and raised some important questions that were beyond the capacity of this thesis to answer, but provide scope for further research, such as: How can the adaptability of vulnerable fishing communities in southwest England be improved? Can policy supportive of market-based solutions improve the social and ecological resilience of fisheries?

The social analysis used in this thesis was based on case study research undertaken in southwest England. The case study is *'a research strategy which focuses on understanding the dynamics present in a single setting'* (Eisenhardt, 1989). Case study research has both strengths and limitations. The strengths are that it provides in-depth understanding of complex behaviour and interactions and uncovers causal relationships, it is grounded in 'lived reality', can facilitate the exploration of the unexpected, and encourages rich theoretical development. The limitations are that there is often too much data for easy analysis, and how the data is analysed and what to omit can be contentious. The complexity that is uncovered is difficult to represent simply and qualitative data does not lend itself to statistical analysis. The findings are highly context-specific and it is difficult to know the degree to which they can be generalised to other systems. There are often doubts about reliability of data, and given time limitations it cannot always answer the large number of relevant questions that are raised during the data collection process.

In order to mitigate these limitations, a rigorous approach to data collection and analysis was taken. I lived in the fishing community for a total of six months, and spent almost every day on the quayside, talking to fishermen on several occasions each. I spent a long time getting to know the fishermen and people in the community in order to gain trust. Fishermen in the southwest tend to be very wary of outsiders and researchers. They also suffer from interview fatigue from government and regulatory officials and required reassurance from me that I was not going to use the data I collected to their detriment. Going to sea on fishing trips and participating in all aspects of fishing (except for potentially dangerous aspects such as helping with gear retrieval) proved invaluable for gaining trust and acceptance beyond my status of 'the researcher' in the community. Once fishermen realised that I wanted to talk to them about what they do and not about contentious issues in the fishing community such as regulations, illegal activity or environmental impacts of fishing, fishermen tended to open up and I am confident that the data collected was accurate. No fishermen stopped the interview during the process, and only a few fishermen declined to be interviewed. I am aware that my presence did not go unnoticed - I was often the only female on the quay. I think I was a source of interest at the start of my fieldwork, but over time I believe that my sustained presence resulted in fishermen being more comfortable and open towards me.

The interview guide and questionnaires used were rigorously designed and reviewed by peers and key informants in the field prior to implementation in order to capture all relevant variables in an appropriate manner. Data were triangulated to increase confidence in the accuracy of data. In addition to repeat interviews and questionnaires, observations on the quayside and interviews with key informants were undertaken. Although based primarily at one port, I also went to several other ports in the southwest to interview fishers which allowed me to be confident in generalising my findings for the southwest region. I returned to the community on two follow-up occasions which facilitated further exploration of questions raised after initial analysis of the data collected during the main field season. Content analysis was employed to analyse qualitative data (Stone *et al.*, 1966, Krippendorff, 1980). Content analysis is a research method that uses a set of procedures to make valid inferences that can be replicated. Thus, transcripts of interviews, questionnaires and field notes were systematically coded using qualitative analysis software, (NVivo 7) according to each theme of interest, to ensure that data were not used selectively and to ensure they were analysed rigorously.

3. Policy relevance and application of findings

Although fisheries research is dominated by understanding the resource itself, interest in understanding the dynamics of resource users is increasing. There is a growing demand for development of new, more holistic management paradigms to rebuild ecosystems (Pitcher, 2001, Pauly *et al.*, 2002). The ecosystem approach to fisheries management (EAF)has been accepted as one of the key "vehicles" for developing and improving fisheries management (De Young *et al.*, 2008). The purpose of the EAF is *'to plan, develop and manage fisheries in a* *manner that addresses the multiplicity of societal needs and desires, without jeopardising the options for future generations to benefit from a full range of goods and services provided by marine ecosystems'* (FAO, 2002). Political commitments to an EAF management system are increasing (FAO, 2003). The Common Fisheries Policy (CFP) which underpins EU fisheries management explicitly refers to *'progressive implementation of an eco-system-based approach to fisheries management'* (EU, 2007). However, the EAF is still considered to be mostly in the conceptual stages of implementation (Garcia and Cochrane, 2005, Francis *et al.*, 2007, Murawski, 2007). Despite best intentions, effective implementation of the EAF has not been straightforward (Caddy and Seijo, 2005). The commitment to the concept and values of the EAF is far ahead of the research and changes in governance systems and processes required to operationalise the approach, particularly for complex organisational structures with competing interests like the European Union (EU) (Cury *et al.*, 2004, Jennings, 2005).

A key element of the EAF is the understanding of the links between ecosystem functions and fisheries. The EAF requires research which focuses on understanding how management initiatives affect fishing on target species, on other species in mixed fisheries (such as those in the EU), and on food webs and habitats. The EAF seeks to develop pressure-state-response models that link ecosystem-state indicators with pressure-state indicators from fishing effort, and design management actions to alter fishing pressure to achieve the desired values of ecosystem indicators and hence the desired status of vulnerable species, vulnerable habitats and overall health of the fish, plankton, bird and other communities. Fundamental for this research is predicting the effects of different management actions on fishing effort, before the ecosystem impacts can be assessed. Model types such as the RUM developed in this thesis could play a key role. There is growing interest in the use of spatially explicit policies for implementing the EAF, such as marine reserves and area-based property rights, as contemporary fisheries research emphasises patchiness and spatial heterogeneity of the marine ecosystem (Christie, 1992, United Nations, 2002, IUCN, 2003, Hannesson, 2004, CBD, 2006, Roberts *et al.*, 2006, Wood *et al.*, 2008). RUMs developed so far have been used to model the redistribution of fishing effort in response to marine protected areas (Hutton *et al.*, 2004). However, improved RUMs could also be used to model the effects of other regulations such as reducing capacity, fishing gear restrictions (such as mesh size) and reduced quotas for target species. It is important to make sure RUMs reflect the reality of fishing decision making as much as possible if they are to be effectively used for policy purposes. Incorporating variables based on talking to fishers and validating models through interview-based approaches (techniques used for this thesis) is of critical importance (De Young *et al.*, 2008).

While the EAF is widely considered to be the appropriate direction for fisheries management, especially to account for fishery-ecosystem interactions, it is argued by some fisheries economists that by itself, the EAF is not sufficient to address inappropriate incentives influencing fishers and the ineffective governance that frequently exists in commercial, developed fisheries (Hilborn *et al.*, 2004, Grafton *et al.*, 2006). Part of the problem has been in the definition of the EAF. Some definitions are focused on natural science ecosystem components, while others interpret the EAF more holistically, and emphasise a broader integrated and interdisciplinary social and economic approach. In response to an international call for assistance to define the ecosystem approach for fisheries, the Food and Agriculture Organisation of the United Nations (FAO) published guidelines in 2003 and defined the EAF as: *"an ecosystem approach to fisheries (EAF) strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties of biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries"* (FAO, 2003). This definition suggests that the EAF should consider the human-ecosystem interactions within the context of wider social objectives that operate regionally. However, it neglects to state that the boundaries need to be socially, economically and politically meaningful as well as ecologically meaningful.

Understanding the links between the marine ecosystem function and fisheries appears to be possible using modelling-type approaches which incorporate a sound understanding of fisher behaviour. However, a big challenge of the EAF facing policy makers lies in its implementation. Implementing the EAF is a human pursuit. On one hand, the social, economic and institutional dimensions of fisheries can be drivers, constraints, and/or supports for EAF implementation. On the other hand, there can also be social, economic and institutional impacts of EAF implementation (De Young *et al.*, 2008). Thus, it is also essential to understand the incentives and disincentives that drive human behaviour within the context of societal and community objectives, in order for fisheries management to induce desired outcomes which are compatible with societal objectives. Specifically, knowledge of institutional arrangements including governance structures that are required, what the economic drivers of fishing activity and the social and cultural values, norms and forces associated with fishing are, how incentives and penalties induce appropriate reactions, and the external influences such as global markets, natural and economic 'shocks' and political changes, and how these impact on fisheries management and are compatible with fishing communities objectives, are required for implementing a successful EAF. The work undertaken in this thesis on the fuel price 'shock' and subsequent analysis of the fish market highlighted the need for these types of contextual knowledge to be incorporated into fisheries management decision making. Although effective management 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). Reduced fleet profitability triggered by increased fishing costs or barriers to improving fish prices can put fishers out of business and jeopardise the underlying infrastructure of the fishery. It can change the incentives of fishers, changing the way they fish, reduce compliance or induce shifts away from desirable sustainable practices, and result in the degradation of fishing communities so they become a drain on society rather than a contributor. In this worst case scenario, using an EAF to mend the fisheries management inadequacies of the past may be too late.

Therefore, EAF management requires a two-tier approach to achieve its aim of an integrated and holistic system of management and it needs to be practically applied to EU fisheries urgently. First, target fish species and fishing activity within the context of the ecosystem requires appropriately designed management actions. Second, the fishery needs to be examined within the larger context of households, fishing communities and the social and economic environment (De Young *et al.*, 2008). Both of these aspects require an understanding of incentives, for which understanding the drivers of fisher behaviour is fundamental. The FAO notes that *"incentives work indirectly through affecting those factors that lead to particular individual or collective choices…"* (FAO, 2005). Although incentives are complex and multi-faceted, incorporating the human dimension of fisheries will reduce the uncertainty and improve the efficacy of EAF design and implementation for EU fisheries.

4. Future directions for research

The role of prices in fisheries development is not well understood. Constraints on market prices, under-pricing and failure to incorporate externalities into the true market cost can lead to overuse of ecosystem services and potentially a waste of these services (De Young *et al.*, 2008). Fishery input prices (e.g. fuel), directly impact on fishers' production activities. This thesis revealed that the institutional set-up of the market and rising input prices created barriers for fisheries profitability. Prices also impact resource management. If, for example, certain species yield very high prices, management action aimed at reducing effort in this fishery will prove difficult, as the incentive to cheat becomes correspondingly high. Or, if profitability is compromised, fishers' openness to sustainable fisheries practices is reduced. Although this thesis uncovered that prices and profits are not the only motivating factor driving individual decisions, they underpin much of the behaviour observed and are important enough to seek further understanding of them and their inclusion when designing an EAF management plan. EAF management actions and policy design have direct impacts on markets and trade. Markets and trade also impact on the ability to manage fisheries to achieve objectives. Therefore, this is an area of fisheries research identified in this thesis that requires much more attention.

The ideas presented and discussed in this thesis are becoming increasingly relevant in a truly holistic fisheries management context where understanding the complexities of incentives are so important. Momentum is building for implementing new approaches to fisheries management and there is clear recognition that a better understanding and incorporation of the “people side" of marine resource use is crucial.

> *“The purpose of a fishery is human use of a source of food. Fishing is carried out by human beings for human purposes. Any successful evaluation of the aims and methods of fishery regulations must necessarily involve consideration from the side of the so called social-sciences as well as the natural ones.” (Gordon, 1953, p. 442)*

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