How Fishers Count

Engaging with fishers’ knowledge in fisheries science and management

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Abstract

Engaging with fishers' knowledge (FK) is increasingly valued in fisheries management (a) for FK's utility for science and management, and (b) to improve the legitimacy of fisheries governance. Referring to both perspectives, this thesis examines: the nature and types of FK; FK's relationship to scientific knowledge; and 'extractive' and 'participative' approaches taken to engage with FK.

Chapters 3 and 4 compare fishers' reports of catch rates with official landings data and underwater visual census (UVC). In Seychelles, contemporary reported catch rates and landings were consistent; but FK, landings and UVC perceived different trends over time. Over five western-Indian-Ocean countries, reported catch rates had no detectable relationship with UVC-measured fish biomass, despite a six-fold range in biomass. Such disparities between fishers' and scientists' perceptions provide opportunities to broaden the information base for monitoring; but challenge the legitimacy of science-based management in the eyes of resource users.

Chapters 5 and 6 examine extractive approaches to engage FK. An interview-based stock assessment in Seychelles indicated that stocks were overexploited in contradiction to the qualitative perceptions of interviewed fishers. The extractive approach did not take account of fishers' mental models which diverged from scientific assumptions about fish population dynamics and catch rates. In the North Sea, a postal questionnaire collected FK on stock trends, but had limited potential to influence scientific advice and satisfy fishers' expectations, due to its limited scope

and the lack of frameworks to utilise FK. Both cases illustrate the limitations of extractive methods, and the importance of engaging with more complex types of FK.

Disagreements with science seem likelier, and more difficult to resolve for abstract types of FK. Extractive approaches can engage large numbers of fishers, but are less reliable and fail to improve governance. Participatory approaches, including collaborative research have greater promise for improving fisheries science and management.

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Contents

List of Acronyms

AIC	Aikike's Information Criterion
ACFM	Advisory Committee for Fisheries Management at the International Council for the Exploration of the Seas
B	Biomass
B_{inf}	Maximum biomass with no fishing
B_{msy}	Biomass when maximum sustainable yield is achieved
BIC	Bayesian Information Criterion
C	Catch
CAS	Artisanal Catch Assessment Survey of Seychelles Fishing Authority
CBC	Community-based conservation
CBM	Community-based management
CFP	Common Fisheries Policy of the European Union
CPR	Common-pool resources
CPUE	Catch per unit of fishing effort
$CPUE_{inf}$	Catch per unit of fishing effort in a virgin fishery with no previous fishing pressure
EBM	Ecosystem-based fisheries management
EU	European Union
f	Fishing effort
FAO	Food and Agriculture Organisation of the United Nations
FK	Fishers' knowledge
FO	Fishermen's organisation
GAM	Generalised additive model
ICES	International Council for the Exploration of the Seas
IUU	Illegal unregulated and unreported fisheries
M	Natural mortality

MEY	Maximum Economic Yield
MSY	Maximum Sustainable Yield
NFFO	National Federation of Fishermen's Organisations
NSCFP	North Sea Commission Fisheries Partnership
NSRAC	North Sea Regional Advisory Council
NSSS	North Sea Stocks Survey
PSAI	ParFish stock assessment interview
PRAC	Pelagic Regional Advisory Council
q	Catchability coefficient
RACs	Regional Advisory Councils
SES	Social-ecological system
SFA	Seychelles Fishing Authority
SFF	Scottish Fishermen's Federation
SK	Conventional scientific knowledge
TAC	Total allowable catch
UVC	Underwater visual census
VPA	Virtual population analysis
WGNSSK	ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak
WG	Working group (of ICES)
WIO	Western Indian Ocean

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Prologue

"Los biologos? No tienen ni puta idea!"

In April 2002, I was on 'The Tail' in the Northwest Atlantic Ocean, one of the two slivers of the Grand Banks of Newfoundland that remains outside the Canadian exclusive economic zone, and thus is still accessible to European (mostly Spanish and Portuguese) fishing boats. I worked as a fisheries observer, an employment opportunity resulting from the political fallout of the 'Halibut Wars' of the early 1990s, and, as with every European vessel fishing within the regulatory area of the Northwest Atlantic Fisheries Organisation, the small Spanish trawler, was required to carry me so I could monitor and report on their activities as they aimed to fill their freezer-hold with Greenland halibut. Professionally, my job was to scrutinize the vessels catches and logbooks and record, for later reporting, any evidence of catch misreporting or other infringements of regulations. Personally however I had a good relationship with the warm Galician crew and captain Javier.

Spending two months at sea allowed me ample time in the small bridge to debate with the captain on the nature of fisheries and various related fields from politics and biology to pollution and the nature of scientists. One conversation had a deep impression on me because of the animated and intriguing critiques Javier made of the conventional fisheries science I had been trained in, and the arrogance of scientists he had interacted with.

If you wanted to know how many people there were in Galicia, there's no point in trawling on the beaches during the night. Even in the summer, with the tourist population, you'd only catch the odd amorous couple at night on the beach and assume no-one was there. You'd need to trawl in the bars and streets to sample people. Likewise, if you trawled on the beach in the winter when the tourists had gone back to Madrid, you would mistakenly conclude that there were no people in Galicia. Why then do scientists ignore all the subtleties of tides, moon and habitat when they conduct their surveys and fish with the wrong gear in the wrong places? Like trying to survey yellowtail flounder during the day, when any trawl skipper could tell you they are caught in much greater proportions during the night. Scientists have a pitiful understanding of fishing ('*no tienen ni puta idea'*) and assume wrongly that one plus one is two, when reality is more complicated than that.

I returned to my cabin on that evening with a notably altered perception. The conversation had not led me to discard or disbelieve what I had previously learned, but three things struck me: 1) there was so much richness and scope to learn from his points 2) my education up to this point had left me not only seeing a partial picture, but also poorly equipped to appreciate and learn from influences which challenged my accepted wisdoms 3) conventional fisheries science and management completely failed to benefit from such rich information. This thesis is a partly a result of that moment (although many influences before and since have helped shape my interests in this subject). That conversation and its immediate reflection contributed more than any other single moment to me finding myself on the path that led to this thesis. Without the privilege of bridge-discussions with Javier I may never have got here.

Chapter 1. Introduction

1.1 Rationale for this thesis

Harvesting fish is a vital use of our oceans for many people. It directly employs at least 38 million people (FAO 2005), is the basis of an international trade worth over US$ 70 billion (FAO 2007) and provides one fifth of animal protein in developing countries (and up to 90% in some of those) (Thorpe 2004). The tremendous growth of capture fisheries in the 20th century reached a plateau by the 1980s (FAO 2007) and now numerous examples of overexploitation, stock collapses and alteration of marine ecosystems have led many to perceive a global fisheries crisis (Buckworth 1998), and call for a reinvention of the science and management systems which appear to have failed to sustain fisheries (Pitcher et al. 1998; Pauly et al. 2002). One aspect of this reinvention is an interest in fishers' knowledge (FK) and the participation of fishers in management.

There are two main perspectives behind this interest: One, which I call the '***FK-utility perspective***' combines an awareness of the extent of local and indigenous knowledge and a recognition of the limitations of scientific knowledge to contend that FK is needed to understand and manage fisheries (e.g. Johannes and Neis 2007).

The other, which I call the '***governance perspective***', calls for more legitimate, participatory fisheries governance in which fishers (and their knowledge) are involved in management decisions (Jentoft et al. 1998; Gray 2005). The benefits for management according to this perspective include improved legitimacy and compliance (Jentoft 2000), greater trust between stakeholders and managers (McCay et al. 2006), institutions which fit the multi-scale dynamics of fisheries (Berkes 2006), identification and resolution of cognitive conflicts (Adams et al. 2003) and adherence to ethical principles of democratic rights (Dryzek 1990).

These two perspectives have been accompanied by a wide range of attempts to collect FK and to establish participatory research and 'co-management' arrangements. Unlike the population biology focus of conventional fisheries science, many fields have important contributions to make to understand the knowledge aspect of these new relationships. Ecology, psychology, sociology, political science, natural resource management, political economy, political ecology and philosophy all contribute to understanding the contesting perspectives, aims and visions, which more than ever before constitute the field of knowledge underlying fisheries management (Hoefnagel et al. 2006). Thus it is timely to take an interdisciplinary look at FK within the general knowledge context of fisheries, both with mindfulness of the contingent nature of knowledge and with disciplinary flexibility to draw on the many different fields as each becomes relevant. This thesis aims to take such a look by the study of FK-cases from a range of situations using a range of disciplinary perspectives.

1.2 Outline of this chapter

This chapter starts by explaining the title of this thesis. It then introduces literature from a range of fields that have influenced this thesis, including fisheries science and management, resilience, common-pool resources, science and society, local ecological knowledge and psychology. Finally, the research themes of the thesis are defined and subsequent chapters are described.

1.3 The title of this thesis

The title of this thesis makes ambiguous use of the words ‘count’ and ‘engaging’. An ambiguous title is somewhat appropriate for a field which brings together different perspectives from natural and social scientists, fishers, fisheries managers and other stakeholders. In a contested and interdisciplinary field, words have different meanings to different people, who may have quite different reasons behind their interest in FK.

1.3.1 How fishers ‘count’

‘How fishers count,’ has two possible meanings, reflecting two main perspectives for why FK is of interest. It can be taken either as how fishers perceive the abundance of fish (i.e. how they go about counting fish), or as the role of fishers and their knowledge within fisheries governance (i.e. how and why fishers themselves are important for management). The FK-utility perspective is interested to know whether fishermen can reliably perceive, recall and report fish abundances, and thus whether FK is reliable enough to be used by scientists and managers. The governance perspective, on the other hand, emphasises the roles fishers play in the processes of resource management. This thesis engages with both of these perspectives by looking at the nature of FK, and implications for its role in fisheries management.

1.3.2 ‘Engaging’ with fishers’ knowledge

‘Engaging with FK’ was not part of the original title of this research project, which instead referred to the ‘use of FK for fisheries management and science’. However, I came to believe that ‘use’ suggests only the FK-utility perspective whereas this thesis expanded to address the governance perspective, and to investigate alternative perceptions of the nature of fisheries. ‘Use’ also suggests an extractive engagement with FK in which fishers are seen merely as the vessels which hold useful FK, which (as explained in Chapter 2) is only one approach to FK.

The chosen verb for the thesis title, ‘to engage,’ captures more of the range of approaches to FK. It has several meanings in the Oxford English Dictionary (Karlsen 1998), three of which are particularly appropriate in the context of this thesis. The first, “To hire, secure the services of,” relates to the *use* of FK in terms of it being a resource to be used for fisheries management and science. It is akin to the sentiments behind the title for the 2001 conference, "Putting Fishers' Knowledge Back to Work," (Haggan et al. 2003) in which FK is personified as an agent who can be seconded and employed for the goals of fisheries management. A second definition is, “To enter into combat (with),” which hints at the way FK and other perspectives may engage in conflicts of validity on the metaphorical battlefield of fisheries-management decision making. This thesis examines how FK interacts with conventional scientific knowledge and data, whether it disagrees or agrees with other bodies of knowledge, and how it can be reconciled with them.

Finally, in a participatory governance sense, the definition of engage as, “To pledge oneself; to enter into a covenant or undertaking,” suggests that ‘engaging with FK’ refers to the devolution of power to resource users, recognising the relevance and legitimacy of their knowledge. In this sense, the word engage suggests authorities committing to listen to fishers, and establishing participative institutions that recognise FK when forming policy regardless of the ‘usefulness’ of FK.

1.4 Crisis and reinvention of fisheries management

1.4.1 Fisheries and their science and management

Fisheries are found on nearly all the coasts, oceans and inland waters around the world and include a huge diversity of systems in terms of scale, species, gears, vessels, technology, markets, fishers, management arrangements and political contexts (Berkes et al. 2001; Jennings et al. 2001). A useful generalisation highlighted by Thompson (1988) and emphasised by Pauly (2006) is between large and small-scale fisheries. Some of their characteristics relevant to issues of FK are drawn out in Table 1.1. Baelde (2007) contrasts the management context of small-scale fisheries in developing countries, with indigenous links to the resource and little formal science or management; and large-scale, developed-country, modern fisheries, with extensive management systems, and which are embedded in more technologically advanced and capitalist societies.

Table 1.1. Some generalised differences between large and small-scale fisheries (after Berkes et al. 2001; Baelde 2007)

Characteristic	Large-scale, industrial fisheries	Small scale, artisanal fisheries
Found in	Mostly developed countries	Mostly developing countries
Investment	High	Low
Vessels and equipment	Mechanised, advanced technology	Manual, simple technology
Employment	Low per catch	High per catch
Catches per man hour	High	Low
Fishers	Full-time, professional	Full and part time
Status of fishers	Politically powerful and organised	Often poor and marginalised
Fishers relationship to resource	Often recent and mediated through high-tech exploitation	Often traditional and/or indigenous resource use
Complexity of fishery	Low, fewer fishing units, similar gears, few species	High, more fishing units and diverse gears, many species
Scientific development	Extensive, well funded	Poorly funded or non-existent
Management capacity	High, large management bureaucracies	Low, fishing communities remote from government

Most modern fisheries science and management concepts have evolved in industrialised fisheries and may be inappropriate for many small scale fisheries (Berkes et al. 2001). Despite these differences, there are common principles which apply to many fisheries, including the basic behaviour of exploited populations and many of the challenges faced by managers (Jennings et al. 2001).

Conventional fisheries science has basically focussed on assessing fish stocks by modelling their population biology based on inputs and outputs from the stock as first simplified by Russell (1931) and illustrated in Figure 1.1. Recruitment is the addition of new individuals to the stock biomass and can be measured as the number of fish reaching a certain point in their life history, for example when young fish settle into adult habitats or when fish become large enough to be caught by fishing gears. Thus recruitment is a function of both reproduction and early survival. This simple model captures the dynamics of biomass but has no spatial element, direct consideration of ecological interactions, or accounting for the age structure of populations.

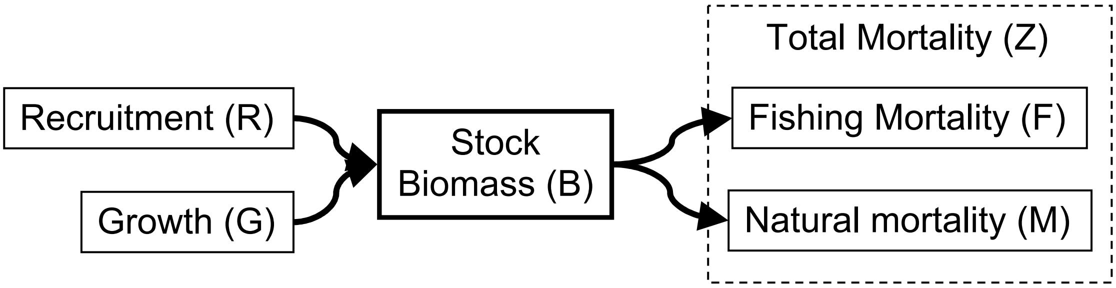

Figure 1.1. Fish stock biomass modelled as a result of inputs and outputs according to Russel's axiom (Russell 1931)

Basic assessment techniques can be done using only data on catch and effort to model how biomass responds to fishing effort[1]. More complex virtual population analysis (VPA) based on the work of Beverton and Holt (1957) models the growth and mortality of different age classes of the stock. This requires estimates of parameters for individual growth, mortality rates due to natural processes and fishing; and recruitment. Modern stock assessment involves complex statistical techniques for these estimations but most assessment of industrialised commercial fisheries, for example European fisheries, is still based on these basic parameters and assumptions (Kelly and Codling 2006).

[1] These are surplus production models explained in more detail in chapter 5

Management based on scientific assessments aims to limit fishing mortality (F, the proportion of the total adult fish population killed by fishing each year) by one, or a combination, of various controls on fishing. 'Input controls' affect the way in which fishing effort is applied and include licensing, limited days at sea, gear regulations and closed areas. 'Output controls' do not directly control fishers' behaviour but stipulate what can be landed. They include minimum landing sizes or total allowable catches (TACs) of individual species, which may be divided into quotas and allocated to individual fishing operations.

The aim of science-based management in the mid 20th century was an optimal level of fishing to generate maximum biological or economic yields (maximum sustainable yield, MSY and maximum economic yield, MEY). More modern approaches, recognising the difficulty of achieving MSY and the risk of overfishing when aiming for MSY, focus on maintaining spawning stock biomass and F within precautionary reference points (Beddington et al. 2007).

1.4.2 The 'fisheries crisis'

The failure to exploit fisheries sustainably has been increasingly discussed in the scientific and popular media. Some perceive a global crisis (Buckworth 1998) and have extrapolated from past failures to make dire predictions about future stocks under a business-as-usual model (Worm et al. 2006). Although the most extreme of these assessments is disputed by more measured literature (Beddington et al. 2007), there is a consensus that fisheries management has not in general been very successful. Many stocks have been, and are, at risk of being overexploited (Hilborn et al. 2003). Statistics from the United Nations Food and Agriculture Organisation (FAO) support this view, reporting that marine fisheries production peaked in the

1980s and that over recent years approximately half of fisheries have been exploited to their maximum capacity, one quarter overexploited, collapsed or in decline, and only one quarter have had potential for increased production (FAO 2007). High profile collapses of Peruvian anchoveta (*Engraulis ringens*) stocks, the NW Atlantic cod (*Gadus morhua*) and the decline of cod and other groundfish stocks in the North Sea (Daw and Gray 2005) are emblematic cases of management failure despite scientific research. In addition to stock collapses, overfishing in general has costs in lost revenue, economic inefficiencies, increased variability, reduced resilience of stocks and catches (Hsieh et al. 2006), and ecological impacts.

Global overfishing has led to a generalised trend of 'fishing down the food web' as fish from higher trophic levels decline causing fishers to target lower levels (Pauly et al. 1998). Overfishing of target species can eventually lead to extinction even of fish species with high reproductive outputs (Sadovy and Cheung 2003), while impacts on incidentally caught species and habitats also constitute a loss of marine biodiversity (Worm et al. 2006) and can impact ecological processes like predation (Myers et al. 2007), bioerosion (Bellwood et al. 2003) and provision of food to seabirds (Jahncke et al. 2004). By introducing a new and dominant selection pressure, fishing probably also affects the genetic character of fish stocks (Hutchings 2000).

Many industrialised fisheries suffer from overinvestment and surplus fishing capacity (Hilborn et al. 2003) making it economically and politically difficult to scale back fishing to match biological productivity (Ludwig et al. 1993). Meanwhile small scale fisheries, responsible for 50% of the catch and 90% of fisheries employment (FAO 2005a) are trapped in cycles of poverty, marginalisation and overexploitation (Bene

2003), leading in some cases to destructive practices which further undermine the productivity of the system (Pauly 1994a).

1.4.3 **Indicators of resource abundance**

Indications of fish abundance can be ‘fisheries dependent’, deriving from fishers’ catches. By collecting data on catch alongside a standardised measurement of fishing effort, for example, number of trap-days, or trawl-hours, an indicator of the catch rate, or catch-per-unit-effort (CPUE) is obtained, which is often assumed to reflect fish abundance (Russell 1931). The concept of CPUE is important for the discussion of FK as it is equivalent to the catch rates experienced by fishers through which they may perceive the resource abundance (although see Chapter 5 for an example where fishers’ perceptions of abundance are based on other observations). Mathematically, a catchability coefficient (q) is used to express the proportion of the total stock caught for each unit of effort applied (Equation 1.1).

$$C = B \times f \times q \qquad \textbf{Equation 1.1}$$

Where C is total catch, B is the biomass of fish, f is fishing effort and q is the catchability coefficient. If catchability is assumed to remain constant then CPUE is proportional to biomass (Equation 1.2).

$$CPUE = B \times q \qquad \textbf{Equation 1.2}$$

However, in most cases CPUE is not proportional to biomass. Depending on the characteristics of the fishery, CPUE can be insensitive to declines in biomass (known as ‘CPUE hyperstability’) or CPUE can decline faster than biomass (known as 'hyperdepletion' (Hilborn and Walters 1992)). Fish behaviour, handling time and spatial distribution of fishers and stocks can all affect the relationship between CPUE and biomass (Hilborn and Walters 1992; Walters 2003). For example, fishers fishing for cod in the NW Atlantic experienced high CPUE almost up until the point that the stock collapsed as aggregations of the remaining fish maintained their catchability (Hutchings 1996). Increases in fishing efficiency, expansion of fishing areas or increases in effort that are not detected by the unit of effort measurement used can also limit the extent to which CPUE indicates stock trends. For example, if effort is measured in man days and fishers spend more time at sea each day, this allows fishers to maintain their CPUE (in terms of catch/day) even if stocks and catch rates decline. Hyperdepletion can be caused by fish behaviour (Pierce and Tomcko 2003), artefacts of the spatial distribution of fishing effort and interference of fishing operations at high densities of fishers (Walters 2003). Given the widespread use of CPUE as an indicator of biomass, and its potentially complex relation to biomass, FK about factors affecting their efficiency and catch rates is therefore a potentially valuable resource for scientists trying to interpret CPUE (Neis et al. 1999; Baelde 2007).

Because of the vagaries of commercial CPUE series, scientific assessments often use fisheries-independent indicators of abundance, which may come from surveys conducted with standardised gears by scientific vessels; tag and recapture studies and direct observation (for example, underwater survey of coral reef species or camera surveys of burrows of *Nephrops norvegicus*). Compared to fishery-dependent data these are expensive and inevitably have limited coverage in space and time. Fishers may also doubt their reliability if they contradict their own experience (pers obs. from interviews with Seychelles sea cucumber fishers and North Sea trawler skippers).

1.4.4 Limitations of fisheries science

Widespread failures to sustainably manage fisheries have highlighted the limitations of conventional data-intensive approaches to fisheries science and management. This has given strength to claims that FK is needed to complement scientific knowledge (Johannes and Neis 2007).

1.4.4.1 Uncertainty

Despite about a century of development, fisheries science still suffers from inherently high levels of uncertainty. For example, stock assessments often have error margins of up to 50% (Walters 1998). Such uncertainty is caused by stochastic fluctuations, for example in recruitment; uncertainty in estimating the state of nature (e.g. stock size) and the correct magnitude of model parameters (e.g. M, Natural mortality); and 'structural uncertainty' about the whether the models used are appropriate to describe the system (Charles 1998).

Further uncertainty is suggested by some research that has characterised marine ecosystems as complex systems with non-linear, or even chaotic dynamics (Acheson et al. 1998) that may 'flip' between different 'regimes' with different behaviours in response to change in forcing variables, and positive feedbacks which inhibit recovery following a regime shift (Scheffer et al. 2001; Collie et al. 2004).

The uncertainty inherent in fisheries science is compounded by difficulties of collecting representative and reliable data. By their very nature, fisheries resources are expensive and difficult to observe. In small-scale, multi-species and multi-gear fisheries there is frequently no time-series to contextualise contemporary data or even no data available whatsoever, while the costs of scientifically assessing each stock would outweigh the total value of each fishery (Johannes 1998; Freire and Garcia-Allut 2000) making conventional scientific study and assessment a practical impossibility. In a rapidly globalising world, fisheries may develop and become critically in need of management before any conventional scientific data can be collected (Berkes et al. 2006). Even in well-established, valuable, industrialised fisheries where substantial resources are available for fisheries research, illegal, unregulated and unreported (IUU) landings and discards create unknown errors in estimates of fishing mortality (Daw and Gray 2005). Output controls can exacerbate this problem by providing incentives to misreport catches, leading to the corruption of fishery dependent data. In North Sea cod assessments, for example, the fishery-dependent data on cod was so unreliable that recent assessments have been based only on the sparse data available from fisheries-independent scientific surveys (ICES 2006a).

The collection and analysis of data for scientific stock assessments also requires time and money. Assessment of stocks in EU waters is estimated to cost € 60 million (Kelly and Codling 2006) while the time taken to process data and run complex models means that final scientific advice can be based on data which is two years old (C. Needle, pers. comm.).

The failure to take such scientific uncertainty into account in top-down management systems has led in the past to overexploitation (Ludwig et al. 1993) and there is now more appreciation of the need for robust management that does not rely on accurate assessments (Walters 1998). ‘Adaptive management’ allows continuous learning from the behaviour of the fishery by treating management as an experiment, while the ‘precautionary approach’ dictates that decisions are made erring on the side of caution in the event of any uncertainty. Several fisheries scientists advocate simpler and less scientifically ambitious approaches to management (Johannes 1998; Kelly and

Codling 2006) claiming they would be more cost-effective and allow more timely advice.

1.4.4.2 Limited scope

Fisheries are complex systems in which biological stocks interact with ecology, oceanography and are fished by social fishermen affected by economics, technology, culture and politics. The biological focus of fisheries management science has left it ill-equipped to grapple with the dynamics of so many domains.

Fisheries science has largely evolved as a population biology discipline, separate from marine ecology. This has been criticised by those who call for an ecosystem-based management (EBM) of fisheries that takes account of ecological interactions rather than viewing each species as independently interacting with fishing pressure (Browman et al. 2004). For example, the survival of cod eggs and larvae is affected by the abundance of predators and competitors (Bundy and Fanning 2005). However, models of interacting species are even more data-hungry and complex than single species models, so in practice the ecosystem approach has thus far largely constituted the application of multiple single-species models (Beddington et al. 2007). EBM is also called for by conservationists concerned about the impact of fisheries on habitats and non-target organisms, which remain outside the scope of conventional fisheries science. There is also little doubt that large scale oceanographic factors can affect the productivity of fisheries (e.g. Stige et al. 2006), while the recruitment of coral reef fish appears to have been affected by climate mediated coral-bleaching in Seychelles (Graham et al. 2007). Combining the perceived crisis in fisheries and the incomplete and uncertain nature of fisheries science, it becomes clear why some see FK as additional information essential for understanding ecological aspects of fisheries dynamics and managing them sustainably (Johannes and Neis 2007).

While ecological factors have often fallen outside the scope of most fisheries management science, the human aspects of fisheries have been even more neglected. Fishers have largely been considered ‘downstream’ in the science and management process. Once the biology has been worked out, managers are left to implement the findings in measures to restrict fishers’ behaviour. Recently there has been more awareness of the critical nature of understanding fishers’ behaviour (Salas and Gaertner 2004) and that sustainable fisheries relies on creating the right incentives for fishers rather than finding the right top-down rules to impose on them (Hilborn et al. 2005). Given the dearth of information about the human side of fisheries, FK may be a valuable source of information on the social, technical, political and economic dynamics of fisheries. For example, Wilen (2004), in discussing simulation of fishers’ spatial behaviour, accepts the need to "actually ask fishermen how they form expectations". Political aspects of fisheries management, including issues of power, values and competing interests are increasingly recognised, reinforcing the role of social science for their understanding, leading several scientists to argue “that the “hegemony of the natural sciences should be replaced by a multi- or, ideally, inter-disciplinary approach” (Jentoft 2006, p672).

1.4.4.3 Issues of ‘regulatory science’

Fisheries science is a form of ‘regulatory science’ producing a standard end result for fisheries managers (Weeks 1995). As a result, fisheries science often occurs within highly political environments with the potential for political interference. ‘Political devaluation’ of science can occur in several ways. When politicians, subject to economic or electoral pressures, apparently act in contradiction to scientific advice, this can lead to apathy among scientists and encourage them to focus on esoteric questions rather than generating the most appropriate scientific advice (Corten 1996), or even to increase the precaution of their advice in anticipation of it being watered down.

Fisheries science can also become a ‘political football’, used and oversimplified by politicians keen to give legitimacy to their own positions. For example, reporting on the political processes around scientific assessments which led to the collapse of the Northern cod in Eastern Canada, Finlayson (1994, p138-139) notes that, “all the caveats that the scientists routinely attached to their projections and advice were routinely stripped away and discarded by the consumers of scientific knowledge”. Finally, it is possible that the political environment may affect the content and results of regulatory science. Finlayson’s analysis suggests the political appetite for finding cod stocks recovering appeared to feed into the scientists overestimates of biomass, while Hutchings (1997) notes several examples of direct political interference with and suppression of scientific reporting and debate. Finlayson (1994) quotes the former head of the Groundfish Division of the Canadian Department of Fisheries and Oceans: “I, and no other scientist in the Department that I know of, have never been asked to lie. But we certainly have been discouraged from revealing the whole truth. Every government has to do that to its civil servants.”

As natural scientists, working from a realist epistemology that views fisheries research as the objective elucidation of the nature of fisheries, fisheries scientists are perhaps poorly equipped to be reflexive about biases resulting from their personal worldview or background that may affect their research and advice. Pauly (1994b) alludes to this problem by suggesting that the gender of scientists may influence how they theorise about the sex of fish, but he does not go on to explore the problematic issue of whether the typically natural science background of most fisheries scientists could influence their recommendations when these involve value-laden trade-offs between conservation and economic opportunities.

Political dimensions to fisheries science feed the suspicions of fishers, and fuel science versus FK disputes over the situation of fisheries and the need for controls. A representative of a Scottish fishermen's organisation, for example, wrote in response to European proposed conservation measures that, "draconian measures now being imposed have nothing whatever to do with conservation. They are part of a European 'federalist' agenda to hand over the bulk of European fishing to Spain. The Commission has exploited and will continue to exploit scientific recommendations to close down the British whitefish sector" (Fishing News 17/1/03, p. 4). Similarly, in Seychelles, many sea cucumber harvesters dismissed stock assessments and quota restrictions as a ploy to close down an industry which the Seychelles government found hard to control and tax, and which elevated underprivileged groups to new economic power (Pers Obs., Interviews in Seychelles with sea-cucumber divers).

The relationship between fishers and fisheries science is not helped in those cases where science is removed from fishers. Not only does remote science fail to benefit from FK, but fishers have been shown to be more accepting of scientific results and management when they are more closely involved (Varjopuro and Salmi 1999; Stanley and Rice 2007), while non-compliance by fishers is exacerbated in situations where they have no faith in the relevance or ability of regulations to improve stock status (Acheson et al. 1998) and have been excluded from decision-making processes (Hilborn et al. 2003).

1.4.5 **From fisheries 'management' to 'governance'**

With increasing awareness of political aspects of fisheries, 'the fisheries problem' is being reframed as one of institutional arrangements rather than biological know-how (Hoefnagel et al. 2006). This transfers the focus from fisheries 'management', the actions taken to achieve sustainable use of fisheries; to 'governance', which encompasses power sharing and decision-making structures and processes (Vallega 2001; Folke et al. 2005). While some blame the fisheries crisis on inappropriate and partial fisheries science, others blame the lack of appropriate governance (Browman et al. 2004).

FK is even more relevant in a discussion of fisheries governance than fisheries management. In the field of fisheries management, FK is a source of information to guide understanding and management actions, whereas the broader field of fisheries *governance* is about who, and whose knowledge and perspectives contribute to management decisions.

1.4.6 **Co-management and community-based management of fisheries**

Co-management (Jentoft 1989) is the sharing of management responsibility between government and resource users. Co-management is thought to improve legitimacy and compliance (Jentoft 2000) and can involve sharing of responsibility for various tasks of fisheries management (Sen and Nielson 1996), for example, enforcement, deciding harvest rules and understanding the nature and status of the fishery. The latter is of particular relevance to questions of FK and may or may not be included in co-management arrangements. However, although accessing FK is one of the widely cited benefits, in many co-management arrangements there is as yet no systematic use made of FK for management decisions (Hoefnagel et al. 2006).

Berkes (2006) points out the multi-scale conundrum of natural resource management issues. Local-level management cannot account for ecological processes occurring at larger scales (e.g. trans-national fish stocks), but centralised management misses sensitive local monitoring and knowledge about the resource. He sees co-management as a way to cope with the multi-scale nature of resource management by matching multiple scales of resource management institutions with the scales of the ecosystem. Berkes (2002) claims that the range of institutional arrangements which can link across scales are more diverse than suggested by the term co-management. Many co-management arrangements are in fact interactions across a complex network of different actors leading Carlsson and Berkes (2005) to conclude that co-management could as well be classed as governance, and to emphasise the importance of seeing networks of governance as dynamic rather than just fixed in formal co-management arrangements. The emergence of ‘network governance’ is also driven by globalisation of markets, development of communication and information technologies, and the increasing number of actors who are informed of, and involved in, decision-making (Gibbs 2008).

In co-management, government maintains some responsibility for management and may provide input of elite scientific knowledge, but community-based management must be based solely on local knowledge within the community. This implies another important rationale for the study of FK: within both co-management and community-based management, FK will contribute information about stocks on which to base management decisions. Many examples exist of local systems of monitoring and controlling fishing activity which have successfully sustained resources over time, but it is debatable whether this is due to intentional resource conservation (see review in Cinner and Aswani 2007). In an increasingly globalised world, it is also questionable whether purely traditional knowledge and management systems are sufficient to sustain resources in the face of cultural erosion, technological innovation and new globalised markets (e.g. Berkes et al. 2006; Cinner and Aswani 2007).

1.5 Participation and societal change

Interest in co-management and participatory governance of fisheries has developed in the context of wider societal interest in governance and participation. In development and agriculture over the last three decades, Chambers (1983) and others have promoted tools such as participatory rural assessment (PRA), to support a move towards a development paradigm which involves local people as participants rather than subjects and recipients, recognising their local knowledge and perspectives (Blaikie et al. 1997). Meanwhile ideas of 'new conservation' suggested that conservation objectives could be met more successfully by addressing development concerns of local communities alongside conservation rather than seeing their interests as being in conflict.

Principles of 'good governance' promoted by international bodies and incorporated into the FAO code of conduct for responsible fisheries (FAO 1995) also include notions of representation and participation. This was taken up in the European

Union's reform of the Common Fisheries Policy (CFP), with reference to principles of good governance including "broad involvement of stakeholders at all stages of the policy from conception to implementation" (CEC 2002, p61).

The development of greater public participation in policy and science has been facilitated in Western societies by social changes. Nowotny et al. (2001) describe how science has become less elitist and the knowledge generation process has become more open, diffuse and accessible on account of increased education and communication, and the changing nature of scientific research, which is increasingly answerable to the priorities of society. This is called a move from Mode 1, in which processes of science are clearly demarcated from society, to Mode 2 in which science is contextualised by interaction with society and people are actively involved in research rather than passively being objects of research.

Participation is itself the subject of a substantial literature. A key paper by Pretty (1995) presents a typology of participation, from 'manipulation' to 'self-mobilisation' and argues that higher forms of participation with genuine input from stakeholders is superior and lower forms should perhaps not even be called participation. Meanwhile Jentoft and McCay (1995) draw attention to the importance of the institutional design of participation arrangements.

Several published experiences of participation have highlighted how participatory processes need to formally feed into decision-making forums or they risk being viewed as irrelevant (Fraser et al. 2006). A vicious cycle can result, in which disingenuous 'participation' leads to stakeholder apathy and undermines subsequent participatory processes (Glaesel and Simonitsch 2003). In a fisheries context, fishers can become cynical about participation so the sources of useful knowledge 'go quiet' (Maurstad 2002). Thus it appears important to understand and manage the perceptions and expectations of fishers within participatory mechanisms.

1.6 Social-ecological systems and knowledge

1.6.1 Social-ecological systems and resilience

The study of linked social-ecological systems (SES) and the related school of resilience have become influential in natural resource management within the last decade. Gallopín (1991) defines an SES as a "system that includes societal (human) and ecological (biophysical) subsystems in mutual interaction". The SES approach views distinctions between society and ecology as arbitrary and unhelpful because of the many feedbacks which lead to social and ecological systems co-evolving over time (Berkes and Folke 1998). Such an approach focuses on the linkages between ecology and society and is thus strongly interdisciplinary. In a fisheries SES, resource users' knowledge determines how communities interact with the marine ecosystem. Perceptions of the state and dynamics of the ecosystem are a feedback between communities and ecosystems, and affect how communities interact with, and adapt to the behaviour of the ecosystem (Figure 1.2).

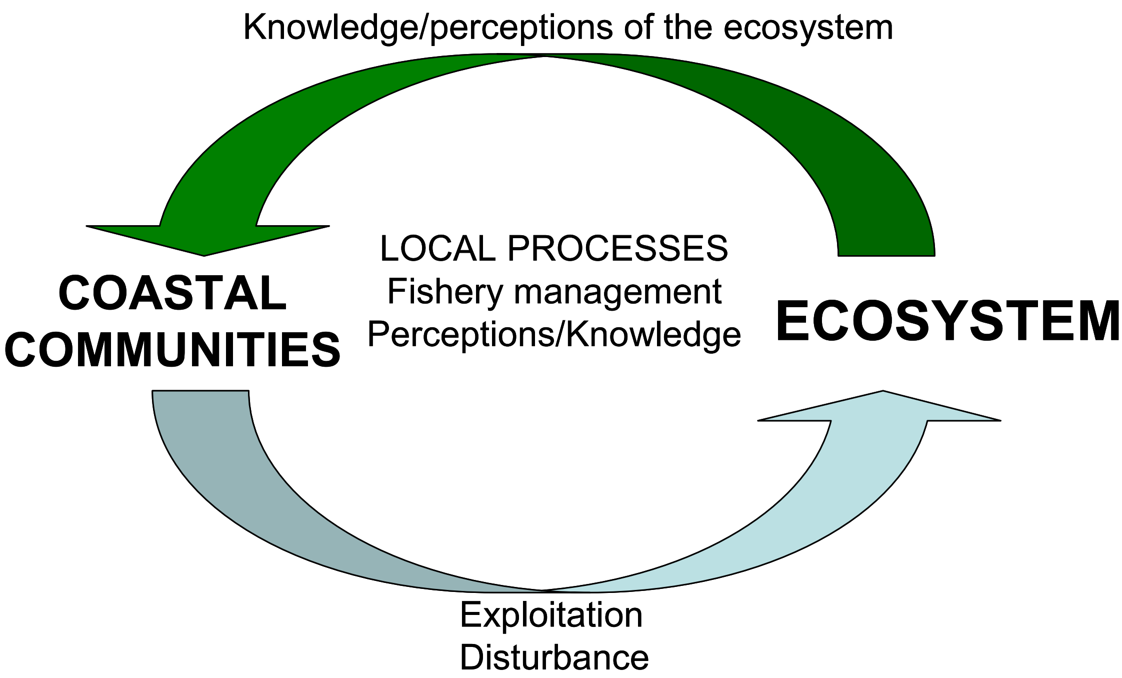

Figure 1.2. The role of knowledge and perceptions as feedback within a social-ecological systems conception of a fishery.

The study of social-ecological systems has been closely associated with the resilience school of environmental research, which emphasises the importance of disturbance, reorganisation and renewal and the possibility of systems to be pushed into alternative behaviours (Folke 2006). Accordingly, resilience is seen as the capacity of a system to absorb disturbance while maintaining its basic functions, to self-organise and to build capacity for learning. The complexity, density of feedbacks and hierarchical organisation of SES make them capable of undergoing unpredictable shifts to different behaviours. They are not amenable to management that aims to optimise outputs based on linear models and reductionist science (Berkes et al. 2003). The resilience perspective focuses on change and disturbance rather than ‘equilibrium perspectives’, and supports calls for adaptive management that recognises the limitations of scientific prediction and aims to improve understanding by continually learning from the results of management. The resilience perspective also emphasises the need to draw on diverse knowledge rather than limited horizons of elite knowledge systems (Berkes 2002). Olsson et al. (2004) combine concepts of adaptive management and co-management to propose 'adaptive co-management' for enhancing the resilience of SES. They go on to identify important social factors which can facilitate the evolution of adaptive co-management including, leadership, trust between stakeholders, social networks which facilitate information flow, capacity for monitoring environmental feedback, the combination of various sources of knowledge and 'arenas for collaborative learning'. All these factors relate to knowledge and the social context in which it is created, communicated and applied and thus inform an interest in the way in which FK may contribute to the resilience of fisheries.

1.7 Fisheries as common pool resources

Fisheries are a classic common-pool resource (CPR) in which exclusion of other users is particularly difficult and use of the resource by one user affects its availability for others (Berkes 2006). Hardin's (1968) influential paper describing 'the tragedy of the commons' suggested that natural resources not under private or government ownership would ultimately be degraded by individuals acting in their own rational self-interest. Indeed many fisheries have succumbed to the tragedy as individual fishers (or nations) saw no incentive to limit their exploitation for long-term sustainability when other fishers (or nations) would reap the benefits and eliminate any positive effects. This model has influenced fisheries management policies as reflected in the prevalence of top-down government control (e.g. European fisheries) or privatisation of access rights (e.g. individual transferable catch quotas). Subsequent research, however, has strongly critiqued Hardin for failing to recognise the possibility of communal ownership, highlighting how in many cases societies have evolved local institutions to sustainably use common-pool resources (Ostrom 1990). In fact, top-down-government and private property rights regimes can fail to sustainably manage natural resources as readily as communal ownership (Acheson 2006). Ostrom and colleagues go on to suggest the conditions which seem to facilitate sustainable management of CPR (Dietz et al. 2003). Importantly for this thesis, these conditions include a common understanding of the system amongst resource users. Adams et al. (2003) go further to suggest that many CPR problems are not due to conflicts in the material interests of resource users, but ‘cognitive conflicts’ and suggest that "Where cognitive conflict is important, policy dialogue needs to be structured so that differences in knowledge, understanding, ideas and beliefs in the public arena are recognised" (p 1916). They propose that alternative perceptions should be explicitly researched to highlight and focus on cognitive conflicts, suggesting that making different stakeholders’ positions explicit can facilitate meaningful negotiations to resolve CPR problems. These writings provide a theoretical framing and rationale for co-management as well as the explicit study of FK to highlight cognitive conflicts with other, including scientific, perceptions.

1.8 Fishers’ knowledge research

1.8.1 The nature of knowledge

Blaikie et al. (1997) define the nature of knowledge as concerning "the way people understand the world, the ways in which they interpret and apply meaning to their experiences". In terms of what is actually constituted by ‘knowledge’, Gadgil et al. (1993) suggest a blend of “knowledge, practice and belief”, which captures a range of forms in which knowledge can be conceived.

Research on FK is part of a wide range of literature on ‘non-scientific’ knowledge including such categories as local ecological knowledge, traditional ecological knowledge, indigenous knowledge and others (Sillitoe 1998). Throughout this thesis, I write about FK, meaning the perceptions, knowledge, practices and beliefs of fishers, which may or may not be local, ecological, indigenous or traditional. The literature on these various forms of non-scientific knowledge' (termed '*** knowledge' by Stanley and Rice 2007) and natural resource use has many insights and conceptual points relevant to this thesis.

FK is embedded within, and dependent on, its social, cultural and ecological context (Murray et al. 2006), including such factors as how fishers are positioned within social networks (Crona and Bodin 2006), the age of fishers (Saenz-Arroyo et al. 2005) and the nature of their fishery. For example, Johannes (1981) and Neis (1997) both highlight how the fishing technology in use affects FK. Paluan spear-fishers had acquired specific knowledge due to their direct observation of their target fish, while inshore trap and hand-line fishers were more aware of the reduced range of shrinking cod stocks than were highly mobile trawl fishers. Similarly, spear fishers in Brazil had greater knowledge of goliath grouper ecology than long-liners had, even though spear fishing was a less traditional activity (Gerhardinger et al. 2006).

FK is not static but continually updated. Research in industrialised fisheries in Norway and Canada highlight how rapid changes in technology can change the place-based and ecologically-focussed nature of FK in industrialised fisheries to more universal harvesting knowledge (Karlsen 1998; Murray et al. 2006).

1.8.2 Fishers' and fisheries scientists' knowledge

Various authors have characterised the differences between systematic, abstract and universal scientific knowledge (SK), and anecdotal, empirical, intuitive FK (or other 'non-scientific' knowledge) rooted in local cultures (see Table 1.2). Others have warned against such a simple dichotomous understanding of different knowledge systems, both of which are diverse categories with overlapping characteristics (Agrawal 1995). For example, Staley and Rice (2007) highlight the scientific skills of fishers for theorising and experimenting, while Finlayson (1994) points out that SK is a social, technological and product at least as much as is FK. Having made his own allusions to the differences between FK and science, Pálsson (1998) counters these distinctions by pointing out that biologists use practical and intuitive understandings, and fishers use abstract reasoning to explain the functioning of fisheries. Wilson (2003) finds that disputes in bluefish management in the US were driven by institutional problems rather than clashes between two 'knowledge cultures'. The divide between FK and SK seems likely to be less tangible where fishers become acquainted with fisheries science as a result of participatory management, and as fishing industry bodies increasingly employ scientists (Hoefnagel et al. 2006).

While taking heed of Agrawal's warning not to fall into rigid stereotypes of FK and SK, and recognising that both are products of their cultural, technical, social and ecological context (Pinkerton 2003), distinctions between the two are so frequently cited that some generalised differences can be drawn out. These seem particularly likely given the stark difference between the experience, background and context of fishers and scientists[2]. Table 1.2 highlights some of the key distinctions relevant to this thesis.

[2] Although this is not in all cases. In Iceland fisheries biologists often themselves hail from fishing communities (E. Hjorleifsson, Pers Comm, October 2007)

Table 1.2. Generalised contrasts between fishers' knowledge and fisheries science knowledge. Summarised from (Neis 1997; Pálsson 1998; Sillitoe 1998; Berkes et al. 2000; Gray 2002; Moller et al. 2004; Hoefnagel et al. 2006; Ames 2007)

Fishers'/Non-Scientific knowledge	Fisheries/Western scientific knowledge
Tacit, Intuitive	Discursive
Long historical perspective	Short time horizons
Qualitative	Quantitative
Holistic	Reductionist
Inductive, providing hypotheses	Deductive, testing hypotheses
Human-centred, subjective	Objective, insensitive to human concerns
Empirical, experience-based	Model-based
Oral	Written
Anecdotal, opportunistic data	Systematic data
Fine spatial scale, Locally relevant	Large-scale, Universal
Concerned with detail and complexity	Concerned with averaging and reducing complexity to facilitate models
Focus on extreme events	Focus on stable and average conditions
Sceptical of predictability of nature	Aims to model and predict nature
Embedded in cultural traditions	Rooted in scientific method
Tested through unclear processes	Explicitly tested

Differences between SK and FK present challenges for integration, as well as opportunities for complementarily. Unlike conventional SK, FK is often tacit and intuitive (Pálsson 1998). That is, it is difficult to communicate and is learned by experience and imitation. SK is based on systematic data, collected according to a proscribed strategy while FK is largely based on anecdotal, incidental observations, which weakens it when it is brought to a co-management forum (Hoefnagel et al. 2006). For example, Neis (1997) describes how the local, anecdotal character of FK from inshore Newfoundland fishers, disqualified it from consideration by stock assessment scientists in the 1980s, and suggests that its complexity and integration of many factors makes it difficult for scientists to handle or integrate into their reductionist frameworks.

One solution is to formalise qualitative FK into a common systematic format along with SK to allow integration between the two and give FK a structure more accessible for scientists and policy makers. Such an approach has been attempted with geographical information systems, fuzzy logic, Bayesian statistics (see Chapter 5) and artificial intelligence (Mackinson and Noettestad 1998; Anuchiracheeva et al. 2003; Garcia-Allut et al. 2003). Mackinson and Noettestad (1998) suggest that the exercise of formalising FK should foment mutual respect between fishers and scientists and facilitate co-management. However, Holm (2003a) has criticised this approach as it 'de-contextualises' FK, making the process of knowledge-production *more* remote from the resource users' society (contrary to the ideals of contextualised Mode 2). Meanwhile, Maurstad (2000) suggests that the incorporation of FK into SK in this way could increase scientific arrogance and the domination of SK.

For Johannes (2000) the different characteristics of FK from SK offers opportunities for it to fill shortfalls in scientific understandings of fisheries, while Moller et al. (2004) see local and scientific knowledge as having opposite and complementary strengths. What is missing from conventional Western science, an holistic and complex perspective, long time horizons and considerations of social and human contexts, is exactly the nature of local knowledge systems. Having critiqued the reductionist, linear thinking which has failed to grapple with environmental problems of our time, Berkes et al. (2000) suggest that indigenous knowledge and management systems offer perspectives and frameworks for more successful adaptive management.

1.8.3 Conformity and discrepancies between FK and science

Some studies of FK directly look for agreement with SK and experimental results. This could be viewed in three ways, depending on the primacy given to science. First FK can be tested against an assumed-to-be-correct SK (e.g. Costa-Neto 2000; Olsson and Folke 2001). Second, FK can be used as a source of hypotheses to be tested by further scientific investigation (e.g. Hamilton and Walter 1999). Third the comparison between FK and SK can be seen as identifying discrepancies between two equally valid sets of perceptions (e.g. Moller et al. 2004). Where a disagreement exists, it may be due to errors in either knowledge system, or that each looks at different dimensions of the same problem (Moller et al. 2004). For example, Christie (2005) reports differences between ecological data and the perceptions of local communities on an Indonesian protected area, and suggests that local perceptions may be focussed on more general and large-scale conditions than ecological surveys.

Johannes and Neis (2007) suggest that focussing on disagreements can lead to revision of scientific ideas. For example, Australian aboriginals correctly observed that barramundi enter rivers to spawn when scientists (based on research in Papua New Guinea) believed they did the opposite, swimming downstream to spawn in the sea. Further research showed the fishers to be correct and the different behaviour to be due to local salinity patterns (Johannes and Neis 2007). Likewise, Huntington (2000) describes how Alaskan Eskimos' knowledge of alternative migration routes of bowhead whales led to almost a trebling of scientists' estimates of their numbers. Such an approach to validating FK and integrating FK to improve science is informed by the FK-utility perspective. The governance perspective also leads to an interest in the level of accordance between FK and science as such discrepancies represent challenges to the governance based on a common understanding.

1.8.4 Limitations of FK accuracy

Sillitoe (1998) raises the difficult question that indigenous knowledge might be factually wrong and warns against romanticising knowledge and practices that might not be adequate in modern and rapidly changing times. Some researchers are sceptical of the utility of FK for management. For example, Karlsen (1998) doubts that the local knowledge of Fjord fishers in Norway, which tells them when and where to catch fish, has the ecological and theoretical underpinning needed to inform resource management strategies. It is also debated whether traditional management practices which appear to sustain resources are, in fact designed to achieve resource conservation (Neis 1997; Cinner et al. 2006; Cinner and Aswani 2007). Evidence suggests that many societies overexploited their fisheries resources even before modern times (Jackson et al. 2001; Pauly et al. 2002) and some theories of resource management suggest that societies have to experience resource crises before they evolve a 'conservation ethic' (Berkes and Turner 2006). For traditional institutions that do facilitate resource conservation (McClanahan et al. 2006), it is arguably inconsequential whether or not conservation is intentional because it can be impossible to unravel ecological management strategies from the traditions and rituals in which they may be encoded (Sillitoe 1998). Moreover many cases suggest that such systems are under threat from forces of globalisation. For example, McClanahan et al. (2006) found that traditional closed areas in Indonesia and Papua New Guinea were only successful in those communities more geographically and economically isolated from the globalised, modern world.

There are also a number of considerations which might limit the ability of fishers to perceive changes in fish stocks. The 'shifting baseline syndrome of fisheries' (Pauly 1995) describes how declines in fish abundances can go relatively unnoticed by society as each new generation of scientists perceives current abundances relative to their own experience and do not appreciate declines since previous generations' times. In the original description of the shifting baseline, Pauly suggested that anecdotes from older fishers could serve as an antidote for scientists working on short time-series of data. However, similar risks exist for FK (Pinkerton 2003), and studies in Mexico and Rodrigues have detected a shifting baseline syndrome in which younger fishers had less perception of the extent of resource decline (Saenz-Arroyo et al. 2005; Bunce et al. 2007).

Trends in stocks can also be difficult for fishers to perceive because of natural variability in CPUE that makes it a noisy signal. Van Densen (2001) has shown for a wide range of fisheries how fishers' statistical power to perceive trends in catches over time depends on the variability (noise), the length of the time window and the steepness of a trend. Thus in highly variable fisheries like those for shoaling pelagic species, individual fishers struggle to perceive trends in catch rates over time or space (Oostenbrugge et al. 2001). Authorities, with access to data from across the fishery, can reduce the effect of this variability by aggregating CPUE trends from a large number of fishers, giving them greater power to perceive stock trends than individual fishers. This 'administrative gain' can lead to contrasting perceptions between individual fishers and authorities, and creates governance issues whereby fishers do not perceive the need for management interventions (van Densen 2001).

Another factor that may conceal stock trends from individual fishers is the gradual increase in fishing efficiency (catchability) due to continually developing technology, increased investment and better information. Neis et al. (1999) and Gendron et al. (2000) describe a wide range of developments of the Newfoundland gill net and trap fisheries which effected increases in fishing efficiency including vessel, engine, navigation and gear improvements. They describe how efficiency increased throughout the careers of the interviewed fishers. Against this background of "technological creep," it would be hard for any fisher to distinguish actual abundance trends. This effect is not limited to hi-tech or industrial fisheries. Tropical artisanal fishers are also quick to adopt new catching technologies as can be seen in the progression from hand-thrust spears to rubber-powered spearguns in Palau (Johannes 1981).

1.8.5 The 'You-would-say-that-wouldn't-you' problem and incentives to bias information

A major barrier to engaging with FK is the suspicion with which it is viewed by scientists and managers as being biased in favour of fishers' material interests (Hall-Arber 2003), especially regarding questions which may affect fishers' livelihoods. Scientists, managers and other stakeholders may dismiss FK on such issues by saying "You would say that wouldn't you".

However, Johnnes and Neis (2007) suggest that such suspicions can be overplayed, and provide several examples in which fishers' 'excuses' for declines in catches turned out to be important scientific insights. This explanation, while demonstrably true in some cases, is somewhat naïve about the struggles of vested interests which are inherent in fisheries governance. Fishers may in fact have rational reasons for promoting an optimistic view of the status of their fishery, especially if this results in greater catching opportunities.

Why would resource users overstate the abundance of stocks and call for less controls when this would harm the long term sustainability of their livelihoods? Property rights approaches to governing fisheries are based on the assumption that fishers will not rationally promote overexploitation. However, the efficacy of this principle is disputed (Bromley 2005) and even totally private property has not prevented unsustainable harvest of natural resources (Acheson 2006). Several incentives exist for fishers to argue for increased catching opportunities. These include lack of resource security, discounting, impacts on non-target species, disinterest, and disbelief in the need for controls.

If there is uncertainty about management or future access to resources, for example in the North Sea where new regulations and technical measures are agreed every year, or in the case of the Seychelles sea cucumber fishery, where divers fear that the government may close the fishery (pers. obs.), there is no incentive for individual fishers, or fleets to sacrifice their economic gain for long term sustainability.

Discount rates may make short term overexploitation of a resource the most rational resource-use strategy (Clark 1990). Time horizons can also be shortened in the face of extreme poverty (as in the case of 'Malthusian' overfishing, Pauly 1988) vulnerability to various threats (FAO 2005b) or in the face of economic pressures (Acheson 2006). A Scottish industry representative emphasised this by pointing out that “It’s hard to be green when you’re in the red” (Mike Park, Pers. comm.).

Where the ecological impacts of a fisher do not directly affect the productivity of their own fishery, but some other part of the ecosystem there is no economic self-interest to limit impacts. Examples would include bycatches of cetaceans in gillnets or bycatches of juvenile commercial fishes in Nephrops trawls.

Fishers may be able to maintain incomes by moving to new areas or new species. For example, a North Sea fisher suggested, "*It's a little bit over dramatised, the cod thing [concern and management actions over declines in cod biomass] from a fisherman's point of view because, we know there'll be something else to catch*." Meanwhile capital driving overexploitation can be reinvested into entirely new fisheries as observed in internationally mobile, 'roving bandit' fisheries for high value species like sea urchins (Berkes et al. 2006).

Fishers may not believe that stocks are in decline or in the need for regulation or reduction of fishing. Individual fishers may not be able to discern long-term stock declines due to short term variance (van Densen 2001) or CPUE hyperstability (Hilborn and Walters 1992)..

Finally, fishers may also not believe that fisheries have a major impact on stocks or the marine ecosystem. For example, a Scottish fishers' representative in a North Sea Regional Advisory Council (NSRAC) meeting suggested scientists should re-examine their models rather than looking to point a finger for the 'missing mortality' at a fishery (pers obs).

All these factors may create incentives for fishers to consciously or unconsciously (see next section) favour information which presents an optimistic picture of the state of stocks and suggest that the you-would-say-that-wouldn't-you problem may constitute more than just prejudice of scientists. Whether imagined by scientists and managers or not, the you-would-say-that-wouldn't-you problem is a serious impediment to FK engagement that is rarely explicitly discussed in the existing FK literature.

1.9 Psychological research relevant to this study

Knowledge is created and modified by cognitive processes including processes of memory and recall (particularly in the case of FK which tends to be oral). This is not a psychology thesis, but psychological theories about how to represent mental processes, are enlightening in understanding knowledge, perceptions, and attempts to engage with FK. A similar point is observed by Nicholls (1999) who reviews the insights psychological research offer for climate prediction.

1.9.1 **Heuristics and biases**

The human mind uses a variety of 'rules of thumb', called heuristics, to process information from the outside world. These are mental shortcuts that, given the typical nature of our world, allow us to make maximum use of the time and data available to us to make sound judgements (Kahneman et al. 1982). Often these involve qualitative judgements about quantitative phenomena allowing faster processing than arithmetic operations (Tversky and Kahneman 1974). Psychologists have uncovered some of these heuristics and in doing so identified situations in which our generally reliable heuristics are not applicable, creating biases or errors. One example particularly relevant to memory (and thus to perceived historical experience and changes over time) is the 'availability heuristic' in which the ease with which memories or scenarios are brought to mind is used to indicate frequency or probability (Tversky and Kahneman 1973). In fisheries this may result in more memorable occasions (e.g. exceptionally large fish catches) being seen as more frequent in the past than they actually were.

1.9.2 **Factors affecting memory**

Other research has shown the complex nature of memory, which is not a simple store of facts and episodes but an actively managed store of information encoded and then reconstructed during recall (Bradburn et al. 1987). Aspects of the coding and recall environment can affect the accuracy of memories. Events associated with positive emotions are more strongly remembered, and our minds can even reconstruct 'memories' of episodes which did not actually happen (Matlin 2004). Such cognitive phenomena are subconscious and although they may introduce bias to anecdotal and remembered knowledge, the biases are quite different to conscious tactical or politically motivated biasing of information by fishers as sometimes suspected in the you-would-say-that-wouldn't-you problem. Psychological research can demonstrate that such biases can occur, but cannot yet conclude whether their magnitude, in real world situations of FK-engagement, is great enough to meaningfully bias responses.

Psychological theory which highlights potential biases in FK is obviously relevant from the FK-utility perspective when evaluating whether FK can reliably contribute to science. From the governance perspective, it is enlightening to know about ways in which the different contexts in which scientific and fishers' perceptions are built up might lead to differences and 'cognitive conflicts'.

1.9.3 Mental models

Fazey et al. (2006) use a simplified model of cognitive processes whereby a 'mental model', based on past experience is maintained within the mind of an individual, determining how they interpret experiences and what questions they ask (Figure 1.3). This concept is useful for understanding how FK is accumulated, and also how fishers and scientists may interpret the same information differently depending on how their background and previous experience 'frames' the information (Miller 2000).

Özesmi and Özesmi (2004) have used formalised cognitive mapping approaches to map the mental models that stakeholders have about causal linkages within environmental issues. They showed that different stakeholder groups had different cognitive maps which contributed to resource conflicts, in agreement with the 'cognitive conflict' thesis of Adams et al. (2003).

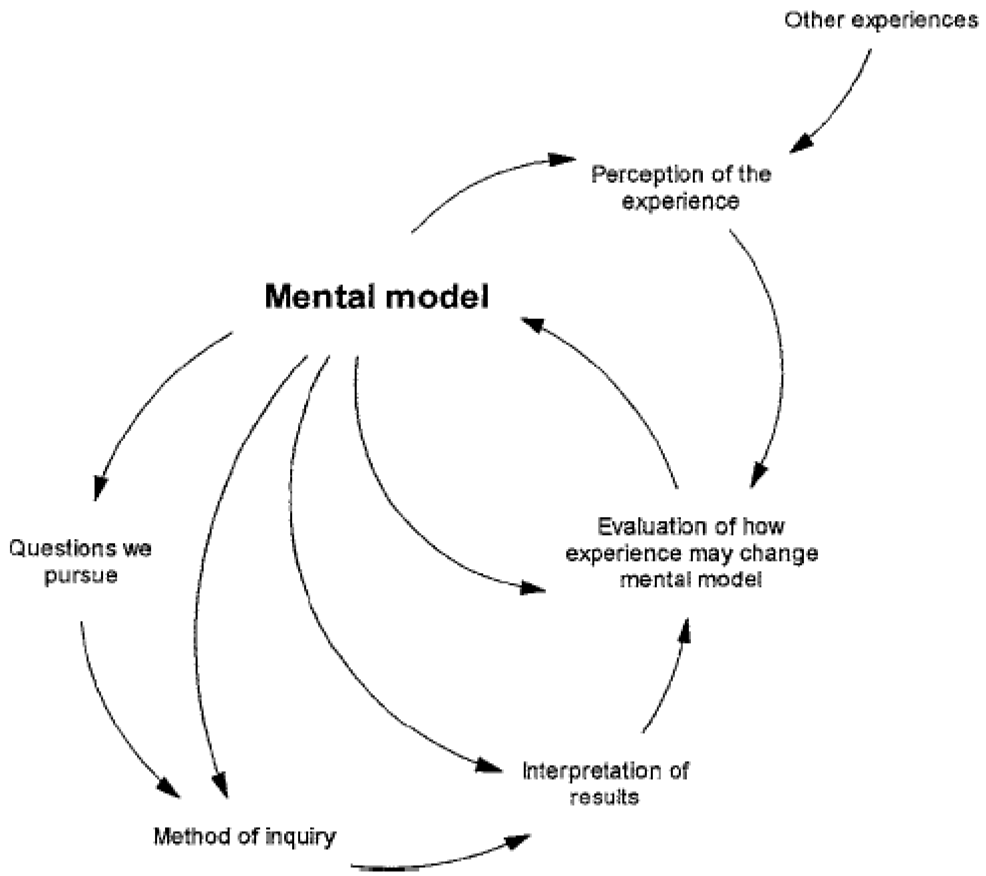

Figure 1.3. The role of a mental model for the perception and understanding of experience. Reproduced from (Fazey et al. 2006)

1.9.4 **Cognitive dissonance**

'Cognitive dissonance' describes the negative experience of holding contrary opinions or by behaving in a way which is contrary to an opinion held. The theory states that people will minimise cognitive dissonance. For example, if a person is induced to do or say something which is contrary to his private opinion, there will be a tendency for him to change his opinion so that it is less dissonant with his words or deed (Festinger and Carlsmith 1959). This theory can be applied to fishers' views on processes which control fish abundance. It suggests that if a fisher's actions were contributing to overfishing and the degradation of the resource, he would tend to minimise cognitive dissonance by adopting the opinion that stocks were in decline due to the actions of users of other gears, or environmental events.

1.9.5 **Belief persistence**

People are conservative about their beliefs (Nicholls 1999), so that if they are presented with information or events which is contrary to their mental model they are likely to seek to try to explain those events within the framework of their mental model rather than challenge and adjust that model (Tversky and Kahneman 1982). People also deal more effectively with emotionally positive information (good news) than emotionally negative information (bad news) (Matlin 2004, p26). Thus fishers who believe resources are in good condition are likely to place less significance on evidence of resource declines. One English fisher's reflections on his colleagues seem to capture the combined effect of these belief persistence biases: "some fishermen, they don't want to get involved, stick their heads in the sand and nothing will happen" (Interview transcript).

This also has direct relevance to illustrate the challenge for two parties holding opposing views of the world (e.g. fishers and scientists) to develop a shared understanding.

1.10 Summary

Fisheries science has highlighted knowledge gaps which could be filled by FK. At the same time, common property theory (e.g. the work of Ostrom and colleagues) illustrates the need for a common understanding to successfully avoid Hardin's tragedy of common resources. FK research is therefore important both to improve the knowledge base of management and to understand and harmonise the differences between FK and the perceptions of scientists and managers. Finally, there is a general move towards participatory governance of natural resources in which resource users are incorporated into management decisions.

In developing countries, FK is seen as an important source of information where scientific resources are limited, and as part of a growing discourse of participation within the development literature. In developed regions, where fisheries management has become a politically charged issue, failures of management and the discontent and distance felt by fishing communities who suffer from the outcomes of remote decision-making structures has led to recognition of the need for, and virtues of, engaging with fishers. Thus in all parts of the world, FK and co-management of fisheries are highly topical issues.

The accuracy of FK may be limited by fishers' ability to perceive trends, by psychological processes or, (within political arenas) personal interests. But FK may also disagree with science and still be correct, either because of mistaken scientific assumptions or because it is based on a different cultural context and worldview that prioritises questions in a different way. Even when science turns out to be a more accurate representation of reality than FK, understanding FK is essential for management as it gives an insight into the perspectives, incentives and cognitive background for fishers' behaviour and their engagement in management debates. If FK and science disagree, the cognitive conflict and lack of legitimacy for science-based resource management will disrupt management attempts, whether or not science turns out to ultimately be correct.

1.11 Research Themes

This thesis aims to look specifically at FK about fish abundance and its engagement SK based on the following four research themes.

1.11.1 Theme 1 – Categories of fishers' knowledge

General findings and statements are often made about FK, but there is obviously great diversity in FK. The cases in this thesis are largely concerned with FK about fish abundance but this is also very diverse. To attempt to make sense of this diversity, Chapter 2 presents a typology of 5 categories of resource-abundance FK, and Chapter 7 discusses each of these categories in the light of the preceding chapters to ask what the characteristics are of these different categories of FK and how they relate to one another.

1.11.2 Theme 2 - Congruence between FK and conventional 'scientific' knowledge

The similarities and differences between FK and SK have important implications for validity, compatibility, complementarities, and the effect of cognitive conflicts on sustainable fisheries governance. Throughout the thesis comparisons are made between FK and SK to ask whether they are in agreement, what the implications are of disagreement and whether some types of knowledge are more in agreement than others.

1.11.3 Theme 3 - The range of approaches to engagement with fishers' knowledge

Engagement with FK can be approached in different ways. In Chapter 2, I describe a conceptual arrangement of cases from extractive to participative approaches.

Extractive approaches studied in Chapters 5 and 6 inform discussion in Chapter 7 about the strengths and weaknesses of extractive versus participative approaches.

1.11.4 Theme 4 - Two perspectives on the importance of fishers' knowledge

As described at the beginning of this chapter the interest in FK for science and management derives from (a) the FK-utility perspective, aiming to obtain information for management, and (b) the governance perspective, aiming to improve governance through the participation of fishers. The conceptual framework of these two perspectives is used throughout the thesis to interpret and discuss the findings. I highlight the implications of my results from both perspectives and in Chapter 7 discuss how complementary they are.

1.12 Outline of chapters

Chapter 2 presents the theoretical framework and methodology on which the thesis is based. It also presents a review of cases of FK-engagement in order to identify methods that have been used to engage with FK, and develop the concepts of extractive and participative engagement with FK.

Chapter 3 compares two types of Seychellois FK with two conventional scientific datasets. Discrepancies between these highlight the importance of diverse sources of knowledge for monitoring fisheries, and inform discussion of the sources of such discrepancies.

Chapter 4 compares FK and SK spatially over the Western Indian Ocean. I investigate the absence of a relationship between fishers' reported catches and UVC estimates of fish biomass and discuss implications for the utility of FK for scientific monitoring the relevance of conventional ecology from the perspective of local fishers.

Chapters 5 and 6 examine cases of applying extractive methods designed to collect FK for stock assessment in Seychelles and the North Sea. They focus on the types of FK collected and the potential for the collected FK to integrate into and improve scientific assessments.

Chapter 7 revisits the four themes of the thesis to draw out general patterns. Issues surrounding the engagement with FK are highlighted with some recommendations. Finally, the relative merits of extractive and participative approaches are examined from the FK-utility and governance perspectives.

The four research themes underlie all of the work within this thesis, but some chapters explicitly address some themes more than others as shown in Table 1.3

Table 1.3. Research themes addressed directly by the chapters in this thesis

	Chapter						
Theme	1	2	3	4	5	6	7
1. Types of FK (State of nature to worldviews)		✓	✓		✓	✓	✓
2. Congruence between FK and science (Do FK and science agree?)	✓		✓	✓	✓	✓	✓
3. Range of engagements with FK (extractive to participative)		✓			✓	✓	✓
4. Two perspectives on FK importance (FK-utility & governance)	✓		✓	✓	✓	✓	✓

Appendices 1-4 present survey and questionnaire guidelines used in this research and Appendix 5 (Daw 2006b) is a report submitted to ICES on the North Sea Stocks Survey which formed the basis of Chapter 6.

To date, three published papers also relate to the material in this thesis. Daw and Gray (2005) draw much material from this literature review and describe the ineffectiveness of fisheries science which is remote from fishers, specifically within the European Union. Stead et al. (2007) use a version of the knowledge typology of Chapter 2 to characterise attempts to use FK in the North Sea and contrasts extractive and participative approaches. Finally, Graham et al. (2007) use the processing of underwater visual census data presented in Chapter 3 to analyse impacts of coral bleaching on reef fisheries.

Chapter 2. Theoretical Framework and Methodology

This chapter outlines the interdisciplinary framework and methodology which I adopted to address the research themes outlined in chapter 1. A review of example cases of engagement with fishers' knowledge (Table 2.2) helped to formulate concepts and typologies which are used as a conceptual framework to inform the subsequent chapters.

2.1 Epistemology and Fishers' Knowledge

Epistemology is the philosophical study of knowledge and how it is created. This thesis is concerned with different, and sometimes competing, forms of knowledge and so concerned with questions of validity and subjectivity that are encompassed by epistemology. Also, like any piece of research, this thesis draws upon its own epistemology. Ontology is a related concept which is about philosophical beliefs about the nature of the world. A particular ontology describes the way that things are and an epistemology how one can go about knowing them.

2.1.1 **Epistemology of this thesis**

As a marine biologist student I was trained in the natural science tradition (and not in the philosophy of science) and conformed to an epistemology which could be described as 'crude realism' (Jones et al. 1999). That is, I believed in reality as a fixed entity that existed outside human experience, and in science as an objective process that progressively described it. The objectivity of science, guaranteed by statistical hypothesis testing of quantitative empirical data, meant that scientific knowledge was a direct reflection of reality. This could also be described as a positivist epistemology. This realism was 'crude' in the sense that I was largely uncritical to the truth claims of science and un-reflexive about the impact that social context might have on such knowledge (Jones et al. 1999). Such a position presupposes that scientific research is the only valid way to describe the 'truth' about biophysical reality.

Social constructivism challenges this epistemological superiority of science and sees all knowledge (including scientific research) as a social construct, that is a product of the social context, history, and personal background of the knower (Basset 1999). Even though an external reality may exist, acts of describing it in words or scientific theories is a social process, and produces a social construction which cannot be said to mirror reality. These views have influenced the epistemology of most social scientists but natural sciences tend to continue within a realist framework (Jones et al. 1999).

Studying the interaction of different knowledge systems and engaging with the relevant natural and social science literature required me to draw on both realist and constructivist accounts of knowledge in fisheries. Thus, I have tried to move beyond a positivist framework, to avoid a rather sterile and non-informative comparison of FK against the 'truth' of natural science. The uncertainty and fallibility of scientific fisheries knowledge, and the politicised context of much fisheries research, as discussed in Chapter 1 and illustrated by Finlayson's constructivist analysis of cod stock assessments (Finlayson 1994), suggests that natural fisheries science is to a certain extent socially constructed.

However, I do not take the position of radical constructivism, in which reality is irrelevant, leaving all knowledge as entirely subjective, and therefore equally privileged (Carolan 2005). I would agree with Bhaskar and Lawson when they state (quoted in Carolan 2005) "...the intelligibility of experiments presupposes that reality is constituted, not only by experiences ... but also by structures, powers, mechanisms and tendencies". In a similar way, the ability to conduct fisheries science, to develop and refine stock assessments and to diagnose and agree on the reality of major changes in marine ecosystems, like stock collapse, demonstrates the existence of a real (but practically unknowable) number of fish in the sea which is determined by underlying biophysical processes and can, to a certain extent be learned about through scientific investigations.

Fisheries management aims to influence and respond to this ‘real’ fish stock but cannot be based on reality itself, only knowledge of it (including fisheries science), which is both subjective and objective. That is to say, the knowledge in some way reflects the biophysical reality (e.g. the abundance of fish) but is also affected by the context in which it is produced, and is subject to great uncertainty. It also follows that some knowledge may be more objective than others and some may be closer to reality than others. Such an epistemological position is akin to the 'critical realist' philosophy of Bhaskar. (Carolan 2005). This finds more of a ‘middle ground’ between the extremes of a radical social constructivist view of all knowledge as relative, and a naïve realist view of science as a mirror to the truth of reality. I will now describe why I find such a middle ground useful in understanding knowledge and fisheries science.

Chapter 1 has described both the uncertainties apparent in even the most sophisticated fisheries science and the social and political aspects of fisheries management, comprising competing values and interests. Both aspects illustrate the need for more than scientific absolutes to understand the role of knowledge in fisheries, and justify a move from crude realism to critical realism, which learns something from, but does not surrender to, the relativism inferred by social constructivism.

Although this thesis makes use of methods typical of conventional realist science (e.g. quantitative data collection and statistical modelling) and makes comparisons between FK and scientific knowledge, I view both types of knowledge as constructs of reality rather than true depictions of reality per se. The interesting question is whether and why they are divergent and what the practical consequences are for management, policy and governance (see specifically Chapters 3 and 4). The challenge for scientists, fishers and managers is not to find out what the truth is, but to reach an 'inter-subjective' truth[3], a representation of reality which is broadly agreed and bears enough resemblance to reality to usefully inform management decisions.

Divergence between different knowledge systems, 'cognitive conflicts', may inhibit communities from finding collective action solutions to common pool resource management, but identifying such conflicts can stimulate interaction, dialogue and development of the shared understandings needed for management of common resources (Adams et al. 2003). This corresponds to the 'discourse ethics' of Habermas, which emphasises rational discussion and the force of the better argument as mechanisms for deliberation between and integration of different knowledge, but contrasts with a Foucault's view of communication as the application of discourses to enforce or challenge power structures (Flyvbjerg 1998). In collapsing the concepts of knowledge and power into, 'power/knowledge', Foucault (1995) draws attention to

[3] An 'inter-subjective truth' is not objectively true in the sense of representing reality, but is a commonly held view of reality shared by a number of subjects.

the importance of power within discourses about knowledge. Certainly much debate around fisheries and knowledge is no doubt related to the competing power and material interests of different stakeholders. This is particularly evident in the case of small-scale fishers in developing countries who may be politically marginalised in various ways and struggle to have their views (and FK) taken into account by management in the face of powerful discourses of industrialisation, free market economics or marine conservation promoted by external actors and agencies.

This thesis focuses on analysing discrepancies in knowledge between different actors but does not go so far as to explicitly analyse the power structures in place between the holders of those different knowledge systems that will, at least in part, determine the resolution of cognitive conflicts. In this way I follow Adams et al. (2003) in implicitly adopting a Habermasian perspective, which suggests discourse ethics are a feasible way to integrate different knowledge. However I accept that this approach is somewhat naïve to power structures, and that a Foucaldian, political ecology perspective seeking to understand discourses within fisheries management and governance through the lens of power would offer much to extend and interpret the findings and inferences of this thesis. Adams et al. (2003) also make the notable concession that dialogue to resolve conflicts will be ineffective where they are driven by the unilateral will or economic power of particular stakeholders.

2.1.2 Interdisciplinarity in Fisheries Research

Brewer (1999) defines interdisciplinarity as “the appropriate combination of knowledge from many different specialities - especially as a means to shed new light on an actual problem”. Thus interdisciplinarity is seen as the result of problem-oriented enquiry, an essential development away from specialist disciplinary perspectives in response to complex problems, like environmental issues (Nissani 1997).

It has been widely argued that the fisheries science which has informed much of fisheries management has been too narrowly conceived and that interdisciplinary science is needed to understand linkages between social and ecological systems (Berkes et al. 2003). For example, Jentoft (2006) states: "The separation of the sciences has been allowed to prevail for too long, leading to fragmentation and incoherence, not only in research but also in the advice that politicians receive from fisheries scientists." Thus problem-oriented research, which aims to contribute to the interdisciplinary problem of fisheries management, must also be interdisciplinary. Purely specialist perspectives can suffer from tunnel vision and lead to recommendations which lack awareness of social or moral impacts (Nissani 1997).

Brewer (1999) supplements his definition with the observation that effective interdisciplinarity, "adds value: the total is more interesting than the sum of the individual contributions or parts". Interdisciplinarity is more than several disciplines working alongside one another on the same problem (Bauer 1990), which could be better described as multi-disciplinarity. It requires researchers to work across disciplinary divides in order to find that added value. Bauer points out that disciplines have different cultures, with the implication that it is impossible to move effortlessly between disciplines. An effective analogy is made with languages. One cannot master a new language simply by learning the vocabulary. Syntax and grammar form formidable barriers to crossing languages in the same way that intellectual barriers such as differing epistemologies make interdisciplinary research difficult.

Having now trained in both natural and social science disciplines, I could be considered an interdisciplinary student as I have spent time in both natural and social science departments during the past 4 years and had to internalise and learn the culture of each. Whether or not this thesis is classed as truly interdisciplinary or multidisciplinary is a matter for debate and dependent on which criteria are used. I believe that this thesis contributes to the interdisciplinary project of working at the boundary of natural and social sciences, as I use data and methods from both disciplines at various points in the thesis and attempt to integrate them. Chapters 3, 4 & 5 are interdisciplinary as they integrate social and natural science data and theory to answer a single research question and provide a more complete understanding of the relationship between FK and science than would be possible with only one perspective. Chapter 6 utilises social science methodologies within the context of a problem which has historically been conceived as the realm of the natural scientist. In this case, although the methods and data were principally drawn from social sciences, being an interdisciplinary student was advantageous to enable me to interpret the implications for the natural-science process of stock assessment.

2.2 Methodology

2.2.1 **Multiple methods**

Many theses apply a single methodology to multiple cases, while others may apply multiple methodologies to understand different aspects of a single case study. This thesis is unusual in that the subsequent chapters apply a range of methodologies to different cases. For example, Chapters 3, 4 and 5 are based on quantitative questionnaires, statistical analysis and deductive reasoning to test for relationships between variables. Chapter 6, in a different context, is based on qualitative interviews and observation of scientific meetings. Interdisciplinarity and problem-focussed research demands a pluralistic methodology[4] and an open mind to other research cultures so that researchers can move between and utilise the strengths of different disciplines (Brewer 1999). No single methodology can be said to offer more insight than others for understanding issues around knowledge and fisheries management. The most enlightening perspective and appropriate method depends on the individual case and the amount and types of research already conducted. For example, the qualitative interviews used in Chapter 6 were most appropriate to provide an insight into their subjective experiences and motivations as they participated in an existing FK survey, whereas in Chapter 3, quantitative interviews were appropriate to allow quantitative comparison of fishers' perceptions of stock with the existing quantitative landings data.

A pluralistic approach to methodology is an appropriate and natural development from my own problem-oriented perspective on fisheries research. My interest in moving from pure natural science into social sciences was driven by the belief that by itself, natural science was capable of making only limited further contributions to natural resource management and that other methodologies were needed to understand critical linkages in fisheries systems. Thus, my aim is to develop new understanding about individual aspects of fisheries management and governance, given the opportunities available. In each chapter I examine a different aspect of the nature of engaging with fishers' knowledge and have selected from a range of methods in order

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[4] That is, recognising value in alternative approaches

to answer the most pertinent question in each case given the opportunities of data, time and language available to me. Thus the approach is not only pluralistic, in terms of choosing different methodologies appropriate to each question, but pragmatic in making use of the data available to me. For example, the opportunity to collect perceptions of catches with a standard methodology on the regional scale of the Western Indian Ocean, where there was matching ecological data, led to the investigation reported in Chapter 4. Chapter 6 resulted from the opportunity to conduct in-depth interviews in my own language with fishers who were already participating in a FK-engagement project. This plurality of methods has also given me a stronger interdisciplinary training by allowing me to practise a diversity of methods.

2.2.2 Case and site selection

This thesis has two geographical areas of focus, the North Sea and the Western Indian Ocean (WIO), particularly Seychelles. These sites were selected to give a wide range of conditions, including artisanal and industrial fisheries, within developed and developing countries and based on tropical coral reef and temperate shelf ecosystems. Ultimately, sites, and fisheries were selected because of potential access to fishers and managers, the existence of some attempts to engage with FK by scientists or managers, and the presence of a parallel scientific knowledge base.

Groundfish fisheries in the North Sea are managed under the Common Fisheries Policy (CFP) of the European Union. This is widely accepted to have failed to meet biological and socioeconomic objectives for sustainable fisheries despite elaborate scientific assessment and advice systems (Daw and Gray 2005). Establishing the status of fish stocks and deciding management measures are highly politicised and fishers' have objected to the research and findings of conventional fisheries scientists.

The CFP was reformed at the end of 2002 including the commitment to “broad involvement of stakeholders at all stages of the policy from conception to implementation” and the provision for the establishment of Regional Advisory Councils (RACs) with stakeholder members to support and advise on fisheries policy (CEC 2002, p61). In addition, some projects were already underway in an attempt to engage with FK and integrate it with scientific research and advice including the North Sea Stocks Survey, which is the subject of Chapter 6, and the North Sea Commission Fisheries Partnership, which held meetings between fishers and scientists to promote cooperation between the two groups in the monitoring and management of North Sea fish stocks (Hawkins 2002).

The WIO and specifically Seychelles were chosen as a study site in response to the opportunity to contribute to an international project to collect socioeconomic data in coastal communities alongside ecological research on the impacts of coral bleaching on fish stocks (Graham et al. 2006). This was suitable as a basis for the second geographical focus of the thesis because of the opportunity to a) collect standardised perceptions of fishers in Seychelles and have access to equivalent data from Kenya, Madagascar, Mauritius and Tanzania, b) collect fishers’ perceptions alongside ecological research and a long time-series of landings data held by Seychelles Fishing Authority (SFA) and c) to collaborate with an international and multidisciplinary team, helping me to learn methodologies and participate in attempts to conduct interdisciplinary science. In addition, SFA had an interest in developing participatory management for artisanal fisheries and experimenting with methodologies to engage with FK. Seychelles artisanal fisheries are unusual for tropical small-scale fisheries in the level of scientific monitoring and research conducted (although this is still considerably less than in North Sea Fisheries). Other sites in the WIO have much less or no scientific fisheries data available, typical for many tropical small-scale fisheries (Johannes 1998).

These study sites are obviously very different in terms of environment, fisheries and governance (including the extent to which science and management engage with FK) and range from tropical to temperate and small-scale to industrial. The validity of looking for generalised findings across a diverse range of situations is justified in the light of interest in FK as a general topic in its own right (Neis and Felt 2000; Haggan et al. 2007). Additionally, early reviews of previous research confirmed that similar issues were raised in cases of engaging with FK from a wide range of contexts (section 2.3). However, this thesis is not a comparative study. The different methods, focus and coverage of each chapter clearly preclude direct comparison across the cases. The intention is rather to make inferences about each local context, which illustrate the general findings related to the four research themes detailed in chapter 1.

2.2.3 **Methods**

The data collection and analysis methods used for Chapters 3-6 are described in detail in those chapters. Here I give an overview of the methods used throughout the thesis. An interdisciplinary study of knowledge and fisheries requires an engagement with a range of methods including both quantitative methods, favoured by natural scientists and positivist social scientists, and qualitative methods, favoured by more constructivist epistemologies (Bryman 2004).

2.2.3.1 Quantitative model fitting

Scientific assessment of fish populations is based on statistical analysis of quantitative data collected from random and representative sampling. I did not conduct any original ecological data-collection but I make use of several natural-science datasets. In Chapter 3, I analyse quantitative landings data and quantitative ecology data on fish abundance by fitting statistical models to determine trends in fish abundance based on the available data. The fitted models are only indications of reality based on the available data and in some cases there are several candidate models. In these cases information criteria (e.g. Aikike's Information Criterion, AIC) give an objective indication how well alternative models fit the data while not being too over-parameterised (Burnham and Anderson 2002). Chapter 4 is also based on fitting regression models to both ecological and social science data to explore relationships between the different variables.

2.2.3.2 Quantitative interviews

Quantitative social science methods are based on a similar approach to that used in the natural sciences. Large, representative sample sizes allow statistical analysis which can allow general trends to be observed despite individual variability (Bryman 2004). Quantitative approaches fail to capture the subtleties of each particular individual but overcome this by taking a large enough sample for trends to become visible as contextual variation starts to average out. Surveys with closed questions (some of which were included in semi-structured interviews) with fishermen and door-to-door household surveys allowed me to collect quantitative and categorical data, which were amenable to statistical analysis and quantitative comparison with natural science data in Chapters 3, 4 and 5, (Bunce et al. 2000).

2.2.3.3 Qualitative interviews

Qualitative research allows the researcher to understand people's subjective experiences and explain their actions as conscious actors (Devine 1995). Semi-structured interviews allowed the collection of qualitative data, allowing follow-up probing questions to elicit clarifications or further details. Qualitative data collection and analysis was conducted in Seychelles and UK/Europe (specifically for Chapters 5 and 6 respectively). Qualitative data collection in Seychelles was more challenging due to language issues and the difficulty of being seen as politically independent from authorities.

Some Seychellois interviewees spoke fluent English while others only Seychellois Kreol (and French in some cases). This necessitated translation of both the questionnaire into Kreol and the resultant qualitative data into English for analysis and writing up. I studied Kreol informally during my time in Seychelles but also relied on an interpreter for all of the initial interviews. Some interviews in the last two weeks of my fieldwork time were conducted without an interpreter, as I had acquired sufficient Kreol language skills specific to the topic of my interview to pose and understand straightforward questions. These interviews were improved by the less intrusive nature of being alone, but my language skills inevitably limited the richness of explanation of questions and probes and understanding subtleties of responses and tones in answers. The use of interpreters for the interviews presented difficulties in terms of clarity in questioning and interpreting responses and I was entirely reliant on the skills and goodwill of the interpreter who I had available on that day. Some of the difficulties are illustrated by these quotes from my field notes on individual interviews. :

[interviewee] was animated and would give long lively responses rich in examples and sometimes straying off subject and it was particularly difficult to steer him through a translator and I was quite tired

In early parts of the interview I became very frustrated with [Interviewer] as I didn't feel like he was concentrating, trying or translating enough for me. I think he was pretty tired and it's actually an effort for him to speak English

This meant that the limited Kreol language skills I had in the early survey were very useful even when I was using an interpreter:

[Translator]'s attention wanders a bit or he summarises answers a bit more than I'd like. Perhaps due to fact that his English isn't good enough to easily and directly translate answers, so I have to listen carefully and get what I can from the Kreol answers to check I'm getting the full picture.

Given these limitations, and depending on the success of interpretation on each interview, sometimes it seemed preferable to conduct interviews in English if the interviewee was comfortable with this. In this case the presence of a Kreol speaking interpreter perversely actually inhibited the interview:

[Interviewee]'s English was a bit halting and some questions took a while to explain but we seemed to get there in the end and he was fairly relaxed and patient.

Turned out that [Interviewee] actually spoke fairly good English so I opted to encourage him to speak English rather than have [Translator] translate which takes longer and loses information. Frustratingly, [Translator] would chip in in Kreol, perhaps rephrasing a question into Kreol, which would cause [Interviewee] to switch to Kreol and I'd be reliant on translation. Got the feeling that a far more reliable take on [Interviewee]'s views was obtained by him talking directly in English than him to expressing himself in Kreol and relying on translation.

Interpreters were used for the study arranged through the Seychelles Fishing Authority (SFA). One of these was an actual SFA fieldworker who had the advantage of familiarity with the fishery and many of the fishers. However, his status as an employee of SFA likely compromised the candour with which interviewees were willing to speak about fisheries management. It may also have led to fishers using my interviews to portray views or requests to SFA. Even when I was not conducting work with the SFA fieldworker, and despite the fact that I emphasised my independence from SFA to each respondent at the inception of the interview, it was apparent from informal conversations that many fishers did associate me with SFA. This is unsurprising and in many ways correct as I arranged much of my work with SFA, and had daily contact with a range of the organisation's staff.

These limitations (translation requirements and association with SFA) along with the research questions of Chapter 5 informed my decision to limit the richness and depth of data collection and analysis of routinely collected qualitative data from Seychelles. Thus qualitative questions in Seychelles were in the form of short, open-ended questions allowing respondents to answer questions based on their own views, not constrained by the suggested format of closed questions. These answers were converted to categorical data after the survey by reviewing and coding answers (Bryman 2004). Extra information and notes from participant observation, and informal conversations were recorded as field notes and used as anecdotal data to support the more structured data.

In the case of interviews with North Sea fishers and scientists, a richer qualitative analysis was both required by the research question (Chapter 6), and possible when working entirely in my native language. These interviews were fully transcribed and analysed thematically using qualitative data analysis software (NVivo 7). Such qualitative methods provided an insight into worldviews (Chapter 7) that would have been difficult from quantitative or categorical analysis of survey data. Evidence of differing worldviews between fishers and scientists in Seychelles was necessarily more anecdotal and less rigorous. This balance reflects my opportunities and research questions in each case and in no way indicates that subtle political feelings, motivations and complex understandings are less important in Seychelles. Rigorous research of such factors in Seychelles would require greater investment in language skills, time, and relationships with fishers than was possible in this study.

I found the quantitative and qualitative methods complementary, providing statistical rigor and generalisations on one hand, with a more sensitive understanding of context and important issues that may be missing from the questions in quantitative surveys, on the other. However, qualitative data collection, with the requirement for accurate transcriptions, thick description and appreciation of contextual information was difficult to combine with quantitative approaches requiring large sample sizes. It was difficult to mix quantitative and qualitative data collection within the same method as the sample sizes ideally needed for quantitative research were hard to achieve when investing time in each interview for qualitative research.

Literature on FK has emphasised the need to target knowledgeable individuals for FK research (Davis and Wagner 2003). However, the objective of this thesis is not to collect FK, but to conduct a meta-study of the nature of FK and science and the process of engaging with FK. Therefore, I aimed for representative samples of fishers in order to discover typical perceptions, rather than only 'expert fishers' who may not represent the views of the fishing community.

Table 2.1. Data collection methods used for this thesis.

Method	n	Chapters
Semi-structured (quant. & qualitative) interviews		
Seychelles trap fishers	40	3, 4, 5
Seychelles sea cucumber fishers	27	*
North Sea fishers	23	6
Qualitative key-informant interviews		
North Sea stock assessment scientists	10	6
North Sea fishers' representatives	5	6
European Commission representative	1	6
FK researchers	3	2
Household questionnaires		
Seychelles	243	4
Kenya, Madagascar, Tanzania, Mauritius[1]	1321	4
Non-participant observation of meetings		
North Sea Commission Fisheries Partnership (NSCFP)	2	*
ICES Advisory Committee for Fisheries Management (ACFM)	1	6
ACFM/NSCFP consultation meeting	1	*
NSCFP/ICES WG on industry information in stock assessments	1	2, 6
North Sea Regional Advisory Council (NSRAC)	2	
NSRAC Demersal Working Group	2	6
Pelagic Regional Advisory Council (PRAC)	1	*
Participant observation		
Seychelles trap fishing	2	3, 5
Collaborative lobster assessment in Seychelles	1	5
Collection of ParFish data from Seychelles trap and sea cucumber* fishers	67	5
Collection of FK on spawning aggregations in E. Malaysia	78	*
Secondary data		
North Sea Stocks Survey[1]		6
Seychelles Fishing Authority, Catch Assessment Survey[1]		3
Underwater visual census of reef fish in Seychelles[1]		3, 4

* These data are not reported and analysed in this thesis but are incorporated into overall discussions on FK-engagement

[1] these data were not collected by me but made available through collaborations with the individuals and organisations that collected them

2.2.3.4 Participant and non-participant observation

Observation of and participation in fishing activities, collaborative research, scientific meetings, stakeholder meetings and FK-collection projects were used to understand the knowledge producing contexts of fishers' and scientific knowledge and how they interact. These observations are listed in Table 2.1.

2.3 Existing cases of FK-engagement

Initial investigations included qualitative interviews with practitioners, attendance at meetings and reviews of published accounts of 30 cases of engagement with FK (Table 2.2). Cases were compiled in a database with descriptions of each case including categories for methods, sampling strategies and types of knowledge engaged with. This is not a systematic or exhaustive account of the growing literature, but a review of these cases, supported by theoretical literature, helped me to elaborate the concepts and categories described in the following sections and used throughout the thesis.

Most cases stated scientific aims, but this may have been due to the use of scientific literature as the main source of cases. A wide range of FK was engaged with relating to the biology of individual species or groups; ecology, describing relationships between species and with their environment; technical, describing aspects of fishing gears and behaviour; relating to the role of economic forces or social phenomena in fisheries; or political, relating to the effects of power, institutions and structures

Table 2.2. Examples of researchers engaging with fishers' knowledge (categories explained in the text)

	Aim				Role of fishers							Method to engage FK					Topic of FK						
Case	Cultural	Democratic	Management	Enhance science	Data sources	Res. assistants	Data collectors	Consulted experts	Stakeholders	Clients	Researchers	Interaction	Interview	Logbook	Mapping	Res. participation	Biological	Ecological	Economic	Political	Social	Technical	Extractive/Particip.
Reef fish aggregation survey in Malaysia (Daw 2004)	✓			✓									✓		✓		✓	✓				✓	E
Mapping fishing grounds in Thames Estuary, UK (des Clers et al. 2001)	✓				✓								✓					✓		✓		✓	P
Assessment of goliath grouper recovery, Caribbean (Porch et al. 2003)				✓	✓								✓				✓						E
Research on seals in the Clyde Estuary, UK (Moore 2002; Moore 2003)				✓	✓				✓	✓			✓					✓	✓				P
Mapping Essential Fish Habitats in Irish Sea (Bergmannn et al. 2004)				✓	✓								✓		✓		✓	✓					E
Fish and habitats in Galicia, Spain (Garcia-Allut et al. 2003)				✓	✓								✓					✓			✓		E
Bumphead Parrotfish surveys in Fiji (Dulvy and Polunin 2004)				✓	✓								✓				✓						E
Fisher Surveys in Bahia Brazil (Costa-Neto 2000)	✓				✓								✓				✓	✓			✓		E
Fisheries/Science Partnership on Sandeel bycatch in the North Sea (Bell et al. 2004)				✓		✓										✓						✓	P
Carangid behaviour in the Solomon Islands (Hamilton and Walter 1999)	✓				✓							✓	✓					✓			✓	✓	E

	Aim				Role of fishers							Method to engage FK					Topic of FK						
Case	Cultural	Democratic	Management	Enhance science	Data sources	Res. assistants	Data collectors	Consulted experts	Stakeholders	Clients	Researchers	Interaction	Interview	Logbook	Mapping	Res. participation	Biological	Ecological	Economic	Political	Social	Technical	Extractive/Particip.
Bumphead parrotfish in Solomon Islands (Aswani and Hamilton 2004)				✓	✓							✓	✓				✓	✓				✓	E
Recreational fishers survey, Baja California (Martinez-Delgado et al. 2004)				✓	✓								✓				✓	✓				✓	E
Bluefish ecology in Brazil and E.Australia (Silvano and Begossi 2005)	✓				✓								✓				✓	✓				✓	E
Mapping fishing in Bang Saphan Bay, Thailand (Anuchiracheeva et al. 2003)	✓				✓								✓		✓		✓	✓		✓		✓	P
N. Cod stock assessment, Canada (Neis et al. 1999)				✓	✓								✓		✓		✓	✓			✓	✓	E
Herring shoaling behaviour, Canada (Mackinson 2001)				✓	✓								✓				✓						E
Participatory stock assessment of reef fish, Zanzibar (P. Medley, S. Walsmley, pers comm.)			✓		✓	✓			✓				✓			✓		✓	✓		✓	✓	E
Parfish in TCI (Medley and Taylor 2003)			✓		✓				✓				✓				✓	✓	✓		✓	✓	E
Assessment of Chinese Bahaba stock status (Sadovy and Cheung 2003)				✓	✓								✓				✓		✓			✓	E
Widow rockfish acoustic survey, Canada (Stanley and Rice 2003)				✓							✓					✓		✓				✓	P

Case	Aim				Role of fishers							Method to engage FK					Topic of FK						
	Cultural	Democratic	Management	Enhance science	Data sources	Res. assistants	Data collectors	Consulted experts	Stakeholders	Clients	Researchers	Interaction	Interview	Logbook	Mapping	Res. participation	Biological	Ecological	Economic	Political	Social	Technical	Extractive/Particip.
Catch and effort data from Dutch beam trawlers (Quirijns et al. 2004, Pers comm)				✓			✓							✓		✓	✓					✓	E
Cetacean surveys, North Sea (Stockhill 2005, Pers comm)				✓	✓								✓					✓				✓	E
Cultural work with fishers, Northumberland, UK (Porteous 2005)	✓				✓							✓	✓		✓						✓	✓	P
Research on commercial goose barnacles, British Columbia, Canada (Lessard et al. 2003)			✓	✓	✓	✓	✓	✓					✓		✓	✓		✓	✓			✓	E
Spiny lobster stock monitoring, Seychelles (pers. obs.)			✓	✓			✓	✓				✓				✓		✓				✓	E
Efficiency of the tuna purse seiners, Spain (Gaertner and Pallares 2002, pers. comm.)			✓	✓	✓								✓									✓	E
Spawning Aggregation Research, Seychelles, (J. Robinson pers. comm.)				✓	✓								✓				✓	✓	✓	✓		✓	E
Ecology of Goliath groupers, Brazil (Gerhardinger et al. 2006)				✓	✓								✓				✓	✓	✓			✓	E
North Sea Stocks Survey (Marrs et al. 2004; Daw 2006b; Laurenson 2006, S. Marrs pers. comm.)		✓	✓	✓	✓								✓				✓		✓			✓	E
Cod spawning grounds, Maine, USA (Ames 2007)				✓	✓					✓			✓		✓		✓						E

A variety of methods were used to collect FK in these cases. The most common was some form of structured questioning, especially semi-structured interviews, but also postal questionnaires, focus-group interviews and map-based interviews and questionnaires to capture spatial aspects of FK. Other cases engaged FK by interaction between researchers and fishers and the participation of fishers directly in research.

The data collected from FK was often formalised in some way by entering it into a database, geographical information system (GIS), or compiling frequency tables of responses. Other studies used various techniques to 'translate' FK into more scientific formats, for example using Bayesian statistics, decision analysis tools or artificial intelligence languages. Many cases also showed evidence for simply assimilating FK into scientific understandings or practises through interaction between fishers and scientists, or fishers' involvement in research.

Most cases used an inclusive sampling strategy in which no active selection of fishers was made, but some studies selected individuals based on their reputations as experts.

2.3.1 **Ethics and aims for engaging with FK**

Examples of engagement with FK vary in their aims, methodologies and underlying philosophy, as individuals engaging with FK come to it from different perspectives and with different aims (Neis 2003). Ethical reasons for engaging with FK could be divided into *idealist* or *pragmatic* aims. Where aims are idealist, the use of FK is seen as a worthy aim in itself. Where aims are pragmatic, the use of FK is a practical means to a desired end. This distinction is similar to that between deontological and consequentialist ethical theory in that both deontological ethics and idealist aims for engaging with FK are focussed on the 'right' way to do things (Peach 1997), in this case fisheries governance. They are based on the application of *moral values* (i.e. respect for individuals and cultures) and *rights* (i.e. that of fishers' to contribute to decisions which affect them). In contrast, both consequentialist ethics and pragmatic aims for engaging with FK are concerned less with what is the 'right' and 'wrong' way to behave, and more with the ultimate 'good' which will result from different actions, or in this case fisheries governance structures .

2.3.1.1 Idealist aims – engagement as an end in itself

An example of an idealist aim is to promote FK so that it is respected, appreciated and preserved, because it is being disregarded and is in danger of being eroded and lost, along with the unique culture of fisheries-dependent communities. In order to pursue this 'cultural' aim, actors may collect FK to show the breadth and depth of knowledge possessed by fishers, validate FK by testing or comparing it with conventionally produced scientific knowledge, or illustrate the uniqueness of FK by demonstrating a particular application of FK to provide knowledge new to conventional science. Such an aim is based on the perspective that increased respect for FK is, in itself, a desirable outcome, because it exemplifies the values of the community in which fishers live and find their identity.

A different idealist aim of engaging with FK would be to give expression to the right of fishers to engage in fisheries governance and decision-making. By feeding FK into the science and management processes, the views and knowledge of the primary stakeholders (the fishers) most affected by management, are taken into account thus conforming to the ideals of democratic accountability and good governance (Dryzek 1990).

2.3.1.2 Pragmatic aims – engagement as a means to other ends

Many calls to engage with FK are based on the belief that fisheries management will be more effective under more participatory governance. Allowing fishers to contribute knowledge to management decision-making is thought to increase the legitimacy of management instruments (Jentoft 2000). The process of choosing and implementing management measures is expected to be easier when dialogue between FK and other knowledge allows a common understanding to develop. This is a general finding and conclusion from common-pool resource management theory (Ostrom et al. 1999; Adams et al. 2003) and may be borne out in fisheries governance practice. For example, Rice (2005) notes that where the fishing industry is excluded from the stock-assessment process, they attempt to exert influence in a highly politicised and adversarial way elsewhere in the management/policy process.

Engaging with FK may also be seen as a means to improve the scientific understanding of fisheries (usually marine ecology) by accessing extra information which is unavailable to science due to constraints on scientific resources. This scientific aim only exists where there is a perceived shortfall of scientific data or understanding, whereas engagement with FK would be desirable according to 'idealist' and 'governance' aims even if infinite resources were available for scientific research. Scientists may be attracted to engage with FK with the expectation of cost effective data collection (Ticheler et al. 1998); the realisation of the impossibility of conventional assessment of diverse and extensive fisheries (Johannes 1998); the need to complement temporal, spatial or taxonomic gaps in conventional scientific knowledge (Moller et al. 2004); or the desire to derive novel insights or hypotheses (e.g. Hamilton and Walter 1999). Johannes (1981), for example, commented on his time learning from fishing communities in Palau, "I gained more new (to marine science) information during sixteen months of fieldwork using this approach than I had during the previous fifteen years".

How does this definition of aims relate to the dual perspectives on the importance of FK introduced in Chapter 1? The FK-utility perspective is by definition a pragmatic aim as the use of the FK is the end which is justified with the means of engaging with fishers. On the other hand, the governance perspective spans both idealist and pragmatic aims (Figure 2.1) and the ethical position of this perspective is not always clear. Cultural preservation aims fall outside both of these perspectives and are not referred to further in this thesis.

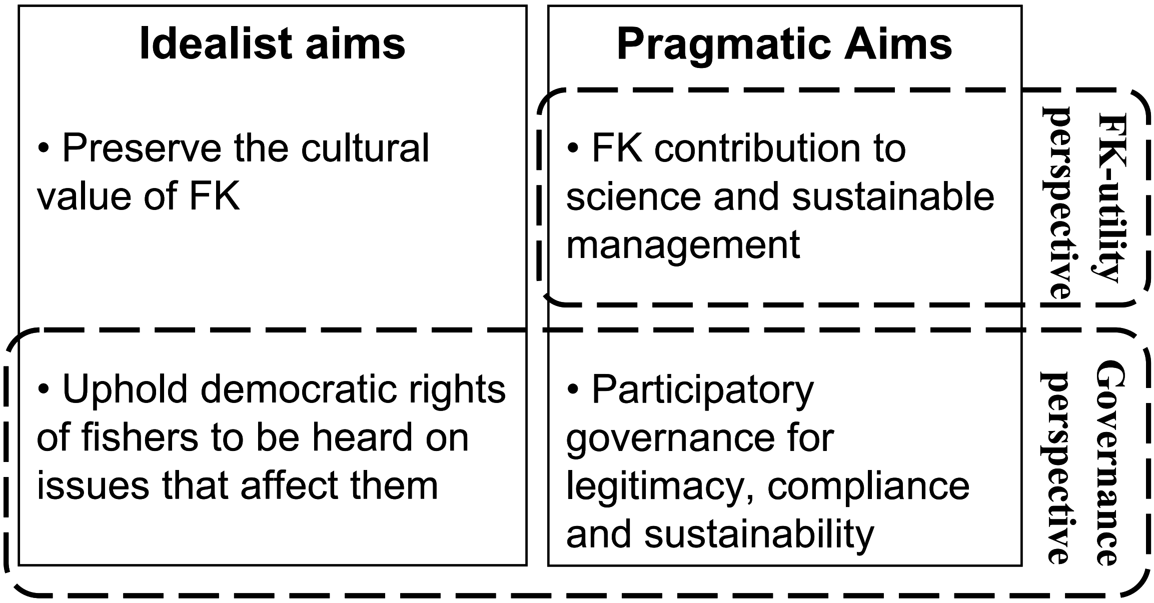


Figure 2.1. The relationship between ethical aims for engaging with FK and two perspectives frequently alluded to in the literature

Literature reporting engagement with FK often makes reference to several of these aims and both perspectives. For example, the scientific merits of FK may be invoked to help justify a desired move towards more participatory governance. Likewise, natural scientists wishing to access and use FK may justify research by reference to participatory governance ideals. Different participants in any individual FK engagement may have different aims in supporting the venture. Fishers may contribute knowledge in expectation of claiming more power in management, while natural scientists may wish merely to extend and pursue esoteric research. Such combinations of underlying aims may all be served by the same type of FK-engagement. However, mixed aims may become problematic, for example if information collected from fishers did not contribute to management as expected by participants. For example, Pinkerton (2003) relates examples of fishers sabotaging FK science in protest to their aims not being met.

2.3.2 **Role of fishers**

Fishers may fulfil different roles for science and management when their knowledge is engaged: sources of data, research assistants, data collectors, consultants with relevant auxiliary information, stakeholders, clients of research or researchers in their own right. They may have input into the initial planning of research or even initiate it, be consulted as a research project develops, or simply be approached by researchers at the point where their knowledge is required (as highlighted in Pretty's (1995) typology of participation). Any single research project may enlist fishers in any one, or several of these roles. The types of roles are likely to be affected by the underlying aim of the research and affect the types of information which is collected. For example, the majority of cases in Table 2.2 stating scientific aims involved fishers as information sources. Such engagements may access discursive FK, but be less able to utilise tacit FK than would a democratically-aimed project which involves fishers in the planning and execution of research.

2.3.3 **Extractive and participative approaches to fishers' knowledge**

Based on the review of FK-engagement cases (Table 2.2), I now present a conceptual distinction between 'extractive' and 'participative' approaches to engaging with FK. Extractive approaches see fishers as vessels of knowledge. This can be collected and then stored, processed and utilised separately from fishers. Participative approaches, in contrast, involve fishers themselves in science and management so that they bring their knowledge along with them. This could include participatory governance structures, if participating fishers contribute their knowledge to management decisions. Extractive approaches involve *ex-situ* use of FK, that is, removal of FK from its context of a body of knowledge within the minds and communities of fishers. *Ex-situ* approaches to conserving indigenous knowledge have been criticised by Agrawal (1995), who contends that indigenous knowledge is defined by its culturally embedded and dynamic nature and so needs to be conserved *in-situ* by supporting the rights and autonomy of indigenous groups who hold such knowledge.

This is related to the distinction of Nowotny (2001) as applied to approaches to FK research by Holm (2003a) between Mode 1 science as exclusive and de-contextualised from society, and Mode 2 science, which is open to, and responsive to a wider section of society.

2.3.4 **Types of fishers' knowledge**

Although FK on a wide variety of topics may make extensive contributions to science and management (Table 2.2), subsequent chapters of this thesis narrow the focus to

FK about the abundance of target fish stocks. Within this particular domain of FK, I make the following distinctions between different types of FK.

Some initiatives simply collect data from fishers in their raw form (e.g. landings data), while others collect perceptions (e.g. thoughts about the status of a fish stock). Raw data are collected or observed by fishers and passed on with no interpretation by the fishers. Fishers' perceptions, on the other hand, are accumulated through time from experience and information networks, and are the result of fishers' mental processing of data, informed by their own prior knowledge, theories and instincts. Much of the former category of data is collected from fishers (e.g. from official EU logbooks), but in subsequent chapters I use the term 'FK' to refer to latter body of fishers' perceptions.

The cases reviewed in Table 2.2, suggest a typology of five different categories of FK: state-of-nature; trends; processes; worldviews; and management perceptions. First, FK may be about individual states of nature, such as abundance of a particular fish species. Second, fishers may place the current state of nature in the context of other time periods and derive FK of trends. Third, FK may describe processes leading to fisheries' dynamics, such as causal links between parts of the marine ecosystem (e.g. the impact of a predator on a fish stock). Fourth, FK can be conceptualised to include worldviews, including normative positions on such issues as equity, rights and responsibilities to nature. Fifth, FK may include views on appropriate management of fisheries (e.g. whether decommissioning of fishing vessels is an appropriate response to declines in cod abundance). These management perceptions can reflect 'state-of-nature', 'trends', 'process' and 'worldview' FK but may also be affected by material interests. These categories are discussed in more detail in Chapter 7.

In these definitions, I use the word 'knowledge' when it could be argued that my thesis is entirely about perceptions. This is deliberate and has three justifications. First, as scientific perceptions are commonly labelled scientific '*knowledge*', to speak of fishers' '*perceptions*' implicitly devalues FK by suggesting it is more subjective and less valid than scientific knowledge. As discussed in section 2.1, neither the 'true' number of fish in the sea; nor the exact trend; nor what has driven it, can be definitively known by anyone. Thus all types of 'knowledge' are in some way perceptions. Second, I use the term 'knowledge' to link to the existing literature and tradition on fishers', local, indigenous and traditional *knowledge*. Finally, one cannot distinguish between knowledge, perceptions and views without making an impossible judgement on validity or correctness. Within a critical realist epistemology, in which all knowledge claims are seen as social constructs which may be more or less close to reality, there is no qualitative difference between a fisher stating that quota management is causing a decline in stocks, or that whiting eat young cod, or that he caught 10 packets of fish in 2000, even though our confidence in these statements may be very different. Correctness or reliability is not an absolute quality. All claims to knowledge are viewed as the same type of entitity and thus given the same label, 'knowledge', even though some are closer to the reality of nature than others. By using the same term throughout, I also aim to avoid discussion of semantics, and the issue of whether or not FK is correct; and focus instead on identifying FK and scientific knowledge: investigating how they interact: and suggesting the implications for natural resource management.

Having established the conceptual framework, scope and themes of the thesis, I turn, in the following four chapters, to the task of using empirical data to examine the relationship between FK and science in particular cases.

Chapter 3. Fishers' and scientific perspectives of fish abundance in Seychelles trap fisheries

3.1 Introduction

There is often a lack of, or limitation to, formal data with which to make management decisions. For example, Johannes (1998) points out the impossibility of collecting conventional scientific data for large areas of the Pacific. He and others have suggested that fishers themselves can be an important source of information which can help to manage fisheries in such data-poor situations (Haggan and Neis 2007). Even within more intensively studied fisheries, for example in the North Sea, there has been a growing acceptance that stakeholder knowledge should be incorporated into management from a participatory governance perspective (Jentoft et al. 1998), but also that such knowledge may have a higher spatial resolution and be more up to date than formal scientific knowledge as well as having a longer historical perspective (Dulvy and Polunin 2004; Ames 2007). It also has a broader scope including information on the ecological, social, technical and economic aspects of fisheries that have historically been neglected by conventional fisheries science (Moller et al. 2004).

One major barrier for scientists to the use of FK is the difficulty of appraising its reliability (Hall-Arber 2003). Information collected from fishermen is subject to various and often unknown sources of error or bias, making it difficult to use within a formal decision making setting (see Chapter 1). Perceptions can be distorted through psychology or vested interest of individuals, and findings of FK-research can be affected by methodological aspects of the research and the context within which knowledge is accessed.

Whether or not fishers' perceptions accurately represent trends in catches, understanding them has important implications for governance. Authorities with access to larger and more long-term datasets may have more statistical power to discern trends than individual fishers, leading to disagreements and conflicts over the status of the fishery and the most appropriate actions (van Densen 2001). Such cognitive conflicts can be the main difficulty in managing common pool natural resources (Adams et al. 2003), preventing the common understanding needed to develop collective management actions (Ostrom et al. 1999). Quantifying the conflict between the perceptions of fishers, and formal data normally used by management agencies, highlights the extent and importance of cognitive conflicts.

This chapter contributes to both of these lines of enquiry, evaluating both the potential utility of fishers' perceptions for monitoring stocks and the degree of consensus between fishers' perceptions and two common forms of scientific fisheries data.

3.2 Methods

3.2.1 **Study sites**

Artisanal trap fisheries of the Seychelles were chosen for the study due to the availability of three sources of data on fish abundance: interview-based reports of catches and effort: officially collected landings records; and underwater visual census (UVC) data of fish biomass by coral reef ecologists using SCUBA diving.

The trap fishery of the Seychelles is conducted from small boats with outboard engines of 15-40 hp, and uses three different types of traditional bamboo traps. *Kasye peze* and *Kasye dormi* are both sturdily constructed and left in place for up to 3 days. Kasye peze, are unbaited and wedged amongst corals on the shallow reef flats, while Kasye dormi are set outside the reef crest in depths of up to, and sometimes exceeding 60m and may be baited. *Kasye lavol* have a lighter construction and are placed in a variety of depths for a soak time of only several hours. Siganids and Scarids are the most important fish caught in traps generally but *kasye dormi* also catch large quantities of Mullids, Lethrinids and Lutjanids. Octopus, Labrids, Acanthurids, Serranids, Haemulids, Balistids, Muraenids and Pomacanthids are also fished while Chaetodontids and Scorpaenids are frequently caught but generally discarded. Kasye lavol are used to target known spawning aggregations of *Siganus sutor* in which case they catch this species almost exclusively (pers obs and qualitative interview data).

Trap-caught fish are used for local consumption within the Seychelles and are typically sold fresh in 'packets' by the side of the road by the fishers themselves. The packets constitute several fish threaded onto a palm-frond fibre. The price of packets tends to be constant but their weight and species composition can vary according to catches (pers obs, qualitative interview data).

Three areas of Seychelles were chosen (Figure 3.1) for this study, and the dominant trap type and season were selected in each to maximise the relationship between the datasets (Table 3.1).

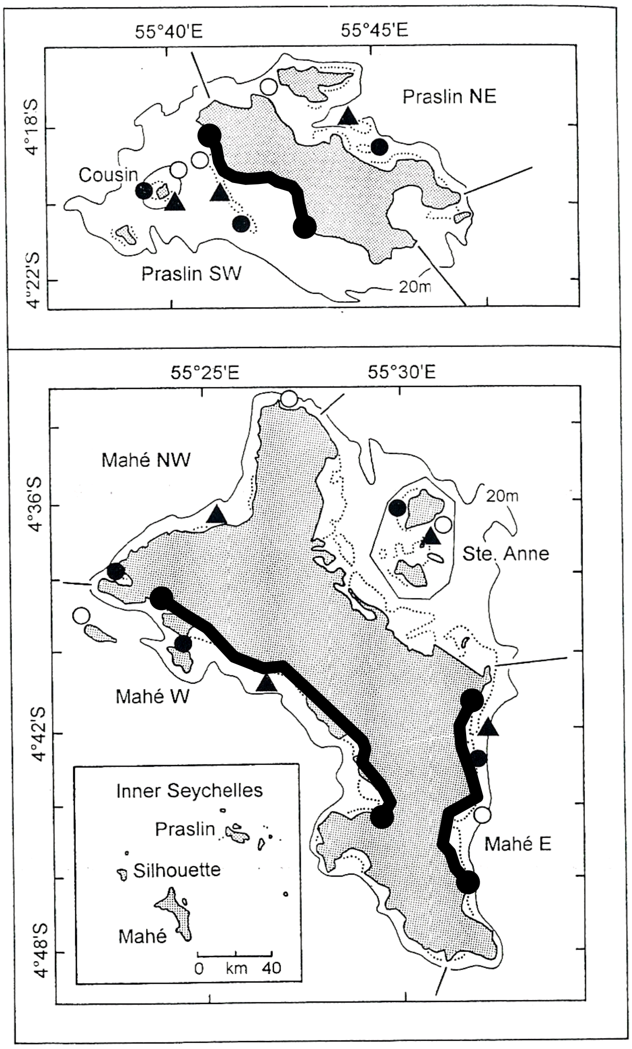


Figure 3.1. Seychelles study locations. Dark lines indicate the 3 areas of coastline where interviews were conducted, and shapes indicate underwater visual census sites in 3 sites of different habitats (coral=filled circles, granite=open circles, patch reefs=triangles). Adapted from Jennings et al. (1995)

Table 3.1. The area and trap type distinctions used to define the 3 fisheries selected for this study with the total number of fishers identified, interviewed and who refused to be interviewed.

Area	Gear	Fishers identified	Interviews	Refusals	Valid area/gear[1]	Valid trends[2]
E Mahe	Kasye peze (June-September)	35	23	5	15	11
W Mahe	Kasye dormi	10	8	0	7	5
SW Praslin	Kasye lavol	16	9	4	6	2

[1] Fishers who fished with the specified gears within the area of the UVC surveys and landings data
[2] Fishers with ≥8 years of continuous gear use.

3.2.2 **Data collection**

3.2.2.1 Perceptions of fishers

Interviews were conducted from 7th and 15th October 2005, within the areas shown on Figure 3.1, with as many of the trap fishermen operating in each area as could be contacted by speaking to local residents, fishers and SFA staff, and seeking fishers at landing sites. Interviews were focussed on three 'fisheries' which were defined by trap-type and area (Table 3.1) and based on the survey form in Appendix 1. Individual trap fishers were asked about their typical catch and effort on a good, bad and normal day and their perception of whether catches had increased or declined over the past 10 years (or since the start of their career if less than 10 years). Catches were generally reported in packets while effort was described by numbers of traps hauled or (for active traps, *kasye lavol*) number of traps and number of hauls per day. Fishers who answered questions on other gears or spent a lot of time outside the area were excluded from the analysis. Participant observation of hauling and setting *kasye lavol* and *kasye dormi* and informal conversations with fishers provided a familiarity with local trap-fishing methods.

3.2.2.2 Catch assessment survey data

Landings data were extracted from the Seychelles Fishing Authority (SFA) artisanal fisheries catch assessment survey (CAS), a stratified catch and effort monitoring system that has been in place since 1985. The trap fisheries of interest in this paper come under the small-boat survey which monitors fishing effort by foot, wooden pirogue (<15 hp engines), fibreglass boat with outboard engine (>15 hp) and decked fibreglass or wooden boats with inboard engines (SFA No Date).

Fieldworkers record fishing activities per day at 63 different landing sites around the three main inhabited islands. Fieldworker effort is randomly distributed around the sites in proportion to the number of boats known to be active at each site. Numbers and types of vessels fishing, number of gears used, and sample weights of catches are recorded and fed into the CAS database and used to raise estimates of total catch and effort for all artisanal fish catches in Seychelles.

The CAS distinguishes catches of active traps (kasye lavol) but not between different types of fixed traps (kasye peze and kasye dormi). Interviews with trap fishermen in E Mahe indicated that there is typically a seasonal pattern in the use of fixed traps, with kasye dormi being used in the calmer NW monsoon and kasye peze used inside the reef during the SE monsoon. Of 20 fishers who may be fishing in the SE monsoon according to interviews, 75% would be fishing only with kasye peze and a further 15% would be fishing kasye peze perhaps in addition to kasye dormi. This suggested that the majority of trap fishers fishing in E Mahe during the SE monsoon are using kasye peze. Thus to maximise the overlap between interview data on kasye peze only, landings from fixed traps during the SE monsoon (June-September) were selected, with the assumption that they are largely composed of kasye peze catches. Records for W Mahe and SW Praslin were taken from all months. Only records from vessels with outboard engines were selected as all interviewees used outboard engines.

3.2.2.3 Underwater visual census

Fisheries independent indications of trends in fish biomass were obtained from UVC conducted in 1994 and 2005 (Jennings et al. 1995; Graham et al. 2006). At each of 3 areas, 16 replicate point count surveys were conducted at 3 sites located in three different habitats: a carbonate reef, a granitic reef and an area of patch reefs interspersed with sand (Figure 3.1).

3.2.3 **Data Analysis**

3.2.3.1 Catches as reported by fishers

Catch rates from fisher interviews were converted to kg to allow comparison with landings data. Most trap fishermen in Seychelles reported their catch rates in terms of numbers of packets.

Individual packet weights collected by SFA fieldworkers during the CAS are not part of the output of the CAS database. A sample of 239 original SFA fieldworker datasheets detailing trap catches (including weights of individual packets) from July to December 1996 and from July 2004 until June 2005 was analysed to derive an appropriate conversion from packets to kg and identify trends. The average weight of packets in 2004/5 was 3.63 kg, but packets in July-December 1996 were 19.1% lighter than during the same months in 2004. Estimates of current catches from fisher interviews were therefore converted from packets by multiplying by 3.63 and estimates of catches 10 years ago were multiplied by 2.94 kg.

3.2.3.2 Landings data and estimates of current catches and CPUE

To compare fisher-reported catch levels with landings data, a subset of landings data was taken from a three-year period prior to the interviews. Three years was chosen as a compromise between looking at contemporary catches and including enough records to indicate the frequency distribution and central tendency of catches. Some records included the sampling of more than one boat, giving a mean catch from several trips.

Inclusion of these points would reduce the apparent spread of data as the effect of individual large catches would be mediated by averaging them with other catches from that site and day. Only records representing an individual catch were therefore included, to capture the variability of individual catches.

CPUE in kg/trap was calculated by dividing catch by the NO_GEARS field in the CAS database and the frequency distributions of catch and CPUE were plotted for each fishery. Due to the positively skewed nature of the landings data (which is typical for fisheries catches) and the existence of outliers, the median rather than the mean catch and CPUE were used to compare with fishers' perception of a 'normal' days catch and CPUE.

For each fisher interviewed, the difference between the median catch and CPUE of the landings data for that fishery and their estimate of a normal day's catch was calculated (δcatch and δCPUE). This difference was expressed as a proportion of the median landings per person (Equation 3.1).

Proportional catch difference ($\%\delta catch_{fa}$) = $100 * (NC_{fa} - M_a)/M_a$ **Equation 3.1**

NC_f is a normal day's catch in fishery a according to fisher f

M_a is the median catch from landings data in fishery a

For each fishery the distribution of δcatch was tested for significant differences from 0 (Wilcoxon signed ranks non-parametric test). If δcatch was significantly different from 0, it was concluded that reports of normal catches by fishers as a population was different than median catches according to landings data.

3.2.3.3 Time trends as perceived by fishers

Proportions of fishers who perceived a decline, no change or an increase were used at each site to assess fishers' general perception of trends. Quantitative indicators of trends were calculated as the difference between reported contemporary catches and catches 10 years ago or at the start of their trap fishing activities (whichever was longest). Only data from fishers with eight or more years experience were used for quantitative trends. Six different trend indices were calculated as a result of comparing 'normal' or 'good' days with former conditions; and comparing total daily catch, CPUE in the units reported by fishermen (usually packets), or CPUE in kg as calculated by the packet conversion weights described in the previous section.

3.2.3.4 Time trends as perceived by catch assessment survey

For analysis of trends in landings data, records from the CAS database (including records which included data from more than one boat) were selected between January 1995 and July 2005. Two variables were analysed for trends: average catch per boat-day (total catch/number of boats sampled) and average CPUE (total catch/number of gears).

Some outliers for CPUE were apparent in which the number of gears had been recorded as one. These were deemed to be unreliable records in which the number of gears had been mistakenly entered as one, inflating the estimates of CPUE (Figure

3.2). Records in which gear number was recorded as one were therefore removed from the sample before analysis of CPUE trends.

Data were visually assessed with lattice plots produced in R for evidence of different trends at different landing sites within each area. Clearly, different trends were apparent between the 3 main landings sites on Praslin so only data from Grande Anse, where the majority of interviews were conducted, was included and trend perceptions from fishermen from other landings sites were not included for trend comparisons.

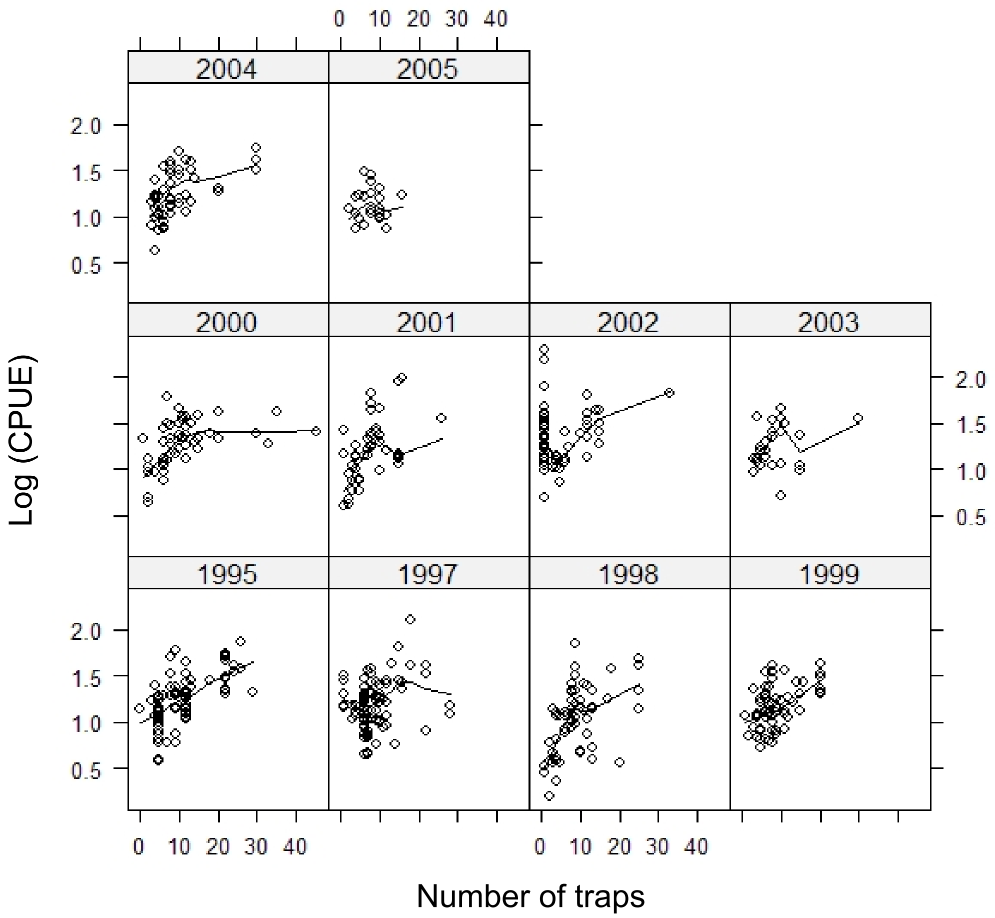


Figure 3.2. Relationship between gear number and CPUE for CAS records in each year. Note the outlying values of CPUE where Number of traps=1 in 1997 and 2001.

The presence of a linear or nonlinear trend in catches over the 10 years was assessed by comparing the suitability of four statistical models given the data according to the

Aikike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). AIC and BIC provide an objective means to compare alternative statistical models based on to what extent they explain the variance within a given dataset. Models that explain greater proportions of the variance in the data receive more favourable (lower) AIC and BIC values. Models with additional terms will always increase the proportion of variance explained whether or not the additional terms have a relationship with the dependent variable, so AIC and BIC scores include penalties for the number of parameters in the model, favouring less parameterised models. The best fitting model is taken as the one with the lowest AIC or BIC. Differences in AIC of more than 2 are taken to indicate a difference in the models, otherwise the simplest model is assumed to be the best fitting (Burnham and Anderson 2002). The absolute value of the criteria is unimportant, so it is common practice to convert scores to ΔAIC and ΔBIC showing the difference between each model's score and the minimum (most favoured) model in the set of candidate models. There has been considerable debate on which of the two criteria is superior for model selection, with some simulations showing that the superiority of one or the other measure depends on the nature of the system under study (Burnham and Anderson 2004) both AIC and BIC are therefore calculated in this study.

To infer whether a trend in catch and CPUE had occurred between 1995 and 2005, four models were compared using AIC_c (AIC with an adjustment for small sample sizes, Burnham and Anderson 2002) and BIC. Three linear mixed-effects models were fitted to the catch and CPUE time series for each of the three fisheries using the nmle package in the statistical software R: (1) a model with no effect of year, (2) a model with a linear effect of year, and (3) a model with a linear effect of year which varied in slope for different months (Table 3.2). Given the seasonality of conditions in Seychelles resulting from the monsoons (MRAG 1995) and the observed seasonality in catches, a random effect on catch or CPUE between months was included *a priori* in all linear models. As sample size varied for each year/month combination and variance was unlikely to be consistent between months due to the seasonality in the fishery, the month effect was modelled as a random factor using mixed modelling. This allows differing variance and error structures between different months (Zuur et al. 2007).

Finally, a generalised additive model (GAM) was fitted to the data using the mgcv library within R. GAMs allow the visualisation of non-linear relationships between dependent and multiple explanatory variables (Zuur et al. 2007). In this case, the GAM smoother term shows the relationship between catch or CPUE and year once the seasonal effects of month are accounted for in the month term.

Table 3.2. Four candidate models fitted to the 10year time series of landings data in each fishery

Model	Model Terms	Hypothesis
M0	lme (y ~ 1, random = ~1|month)	Seasonal variation, no linear trend over years
M1	lme (y ~ year, random = ~1|month)	Seasonal variation, linear trend over years
M2	lme (y ~ year, random = ~year|month)	Seasonal variation, linear trend over years which is different in different seasons
M3	gam (y ~ s(year) + month)	Seasonal variation, non-linear trend over years

For each model fitted to each dataset, ΔAIC_c and ΔBIC values were calculated, residual plots were examined and graphical outputs of the GAM smoother term were examined.

Catches in one year are likely to be related to those in adjacent years (temporal auto-correlation). As no account was taken of this temporal autocorrelation, AIC and BICs for the GAMs assume the independence of each year and over-estimate the degree of fit. Although AIC and BIC values for the GAMs are presented as an indication of how well GAMs fit relative to linear models in each of the datasets, a GAM having the lowest AIC or BIC does not necessarily indicate that it would be the best fit if autocorrelation was accounted for.

Where AIC and BIC scores indicated that a year-effect model was more suitable (where M1 was favoured over M0), the predicted change from 1995-2005 was calculated from the linear model and represented as a percentage of the modelled 2000 catch. Where patterns in the residuals of linear models indicated non-linear relationships, and information criterion scores suggested that GAMs provided the best fit for the data, the modelled fluctuation in catch (averaged over all months for each year) was calculated as a proportion of the long-term mean to give an indication of the extent of the fluctuation shown by the GAM. In addition, the slope of the GAM between the last 2 years was calculated as a % of the long term mean to give an indication of recent trends.

3.2.3.5 Time trends as perceived by underwater visual census

Each UVC count was treated as a replicate of each area to test for trends in the biomass of fishes available to trap fishermen. Analysis was conducted both on total fish biomass and on biomass of target species and sizes. For the latter, the UVC data was filtered for targeted species and to exclude fish too small to be caught by the inshore trap fishery. There is a strong relationship between body depth of retained fish and the maximum width of trap meshes (Munro et al. 2003). In Seychelles, minimum legal trap hexagonal mesh diameter is 4cm, but fishers often use trap meshes larger than this size (field interviews) and fish are able to squeeze through meshes smaller than their specific body depth (Robichaud et al. 1999). Body depth of commercially trap-caught fish was calculated from length frequency sampling of 5651 trap-caught fish between January 1992 and June 1994 (SFA unpublished data). Ninety five percent of fish in the sample had a body depth of over 6.0 cm (Figure 3.3).

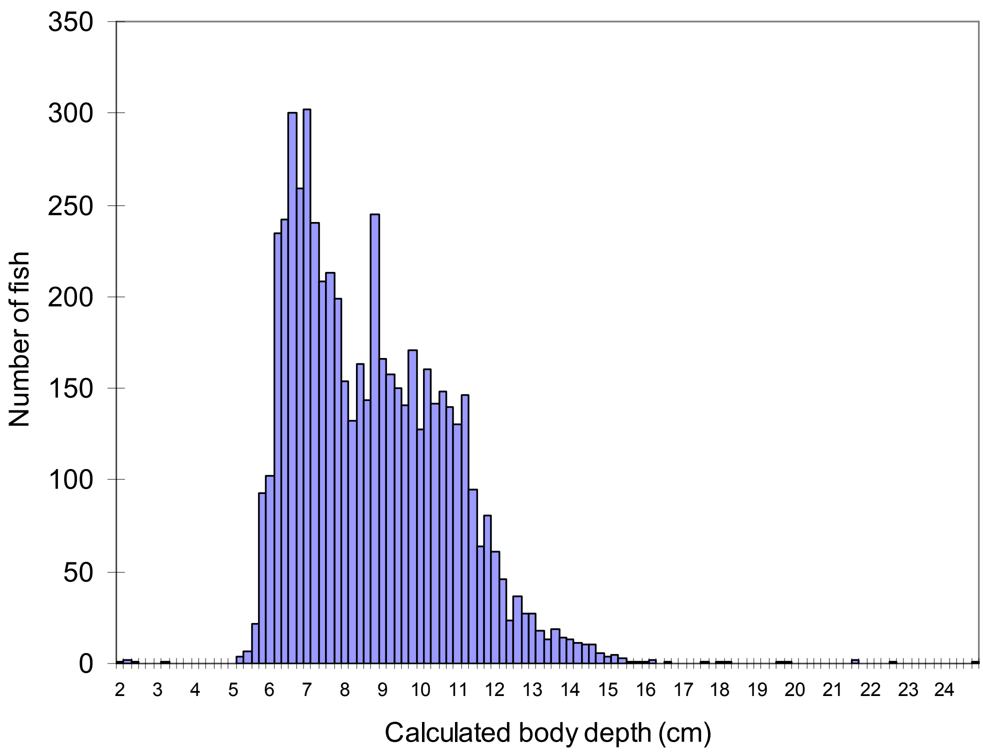


Figure 3.3. Body depth frequency of fish sampled from commercial trap catches in Seychelles between 1992 and 1994 (SFA unpub. data)

A list of 35 main trap target species was compiled from the literature (Grandcourt 1999); market surveys (SFA unpublished data); interviews with key informant fishers; and observations of trap catches (pers. obs, Table 3.3). The total biomass of individuals of these 35 species that were over 6cm body depth was used as an indication of the biomass of fish available to trap fishers.

Table 3.3. Species selected as trap target species and the cut-off length for inclusion as 'trap fish'

Family	Species	Depth/Fork Length	Fork length at 6cm body depth (cm)
Haemulidae	*Diagramma pictum*	0.33	18.3
Haemulidae	*Plectorhinchus orientalis*	0.29	20.8
Labridae	*Cheilinus fasciatus*	0.32	19
Lethrinidae	*Lethrinus lentjan*	0.36	16.7
Lethrinidae	*Lethrinus mahsena*	0.38	15.9
Lethrinidae	*Lethrinus nebulosus*	0.35	17.2
Lethrinidae	*Lethrinus obsoletus*	0.33	18.3
Lethrinidae	*Lethrinus olivaceus*	0.29	20.8
Lethrinidae	*Lethrinus rubrioperculatus*	0.26	23.3
Lutjanidae	*Aprion virescens*	0.24	25.5
Lutjanidae	*Lutjanus bohar*	0.32	18.9
Lutjanidae	*Lutjanus fulviflamma*	0.3	20.2
Lutjanidae	*Lutjanus gibbus*	0.37	16.2
Lutjanidae	*Lutjanus kasmira*	0.32	18.5
Mullidae	*Parupeneus barberinus*	0.27	21.9
Mullidae	*Parupeneus bifasciatus*	0.29	20.9
Nemipteridae	*Scolopsis frenatus*	0.29	20.7
Pomacanthidae	*Apolemichthys trimaculatus*	0.55	10.9
Pomacanthidae	*Pomacanthus imperator*	0.5	12.1
Scaridae	*Cetoscarus bicolour*	0.35	17.3
Scaridae	*Chlorurus atrilunula*	0.33	18.4
Scaridae	*Chlorurus sordidus*	0.31	19.2
Scaridae	*Scarus falcipinnis*	0.35	17.4
Scaridae	*Scarus ghobban*	0.36	16.7
Scaridae	*Scarus rubroviolaceus*	0.32	18.7
Serranidae	*Aethaloperca rogaa*	0.35	17.3
Serranidae	*Anyperodon leucogramma*	0.25	24.2
Serranidae	*Cephalopholis argus*	0.29	20.9
Serranidae	*Cephalopholis leopardus*	0.3	20.1
Serranidae	*Cephalopholis miniata*	0.28	21.4
Serranidae	*Epinephelus fasciatus*	0.27	22.3
Serranidae	*Epinephelus spilotoceps*	0.25	24.2
Siganidae	*Siganus argenteus*	0.33	18.1
Siganidae	*Siganus puelloides*	0.37	16.4
Siganidae	*Siganus sutor*	0.39	15.4

Total biomass and biomass of trap fish was analysed by fitting a linear model with year, site and site*year interaction as nominal factors to square-root-transformed biomass in each area. Models were selected for each area by AIC-based stepwise removal of terms and F-tests on nested modes (Zuur et al. 2007). Where unequal variances between years were detected, Welch's t-tests, which do not assume equal variance, were applied between the two years if site was not selected in the linear model. If site*year interactions were retained in the model selection (selecting a different trend at each site) but variances were unequal between the years, Welch's t-tests were applied to each site in turn. Where a year effect was evident, the difference between the estimates of the mean for each year was back-transformed to absolute biomass levels and expressed as a percentage of the mean biomass level between the two years.

Figure 3.4 illustrates the data sources, assumptions and analysis used to compare official landings data (CAS), fisher interviews and underwater visual census. To facilitate comparison of trends indicated by the different methods and data sets, all detected trends were converted into reported change per year as either a percentage of mean or year 2000 (in the case of linear trends) levels.

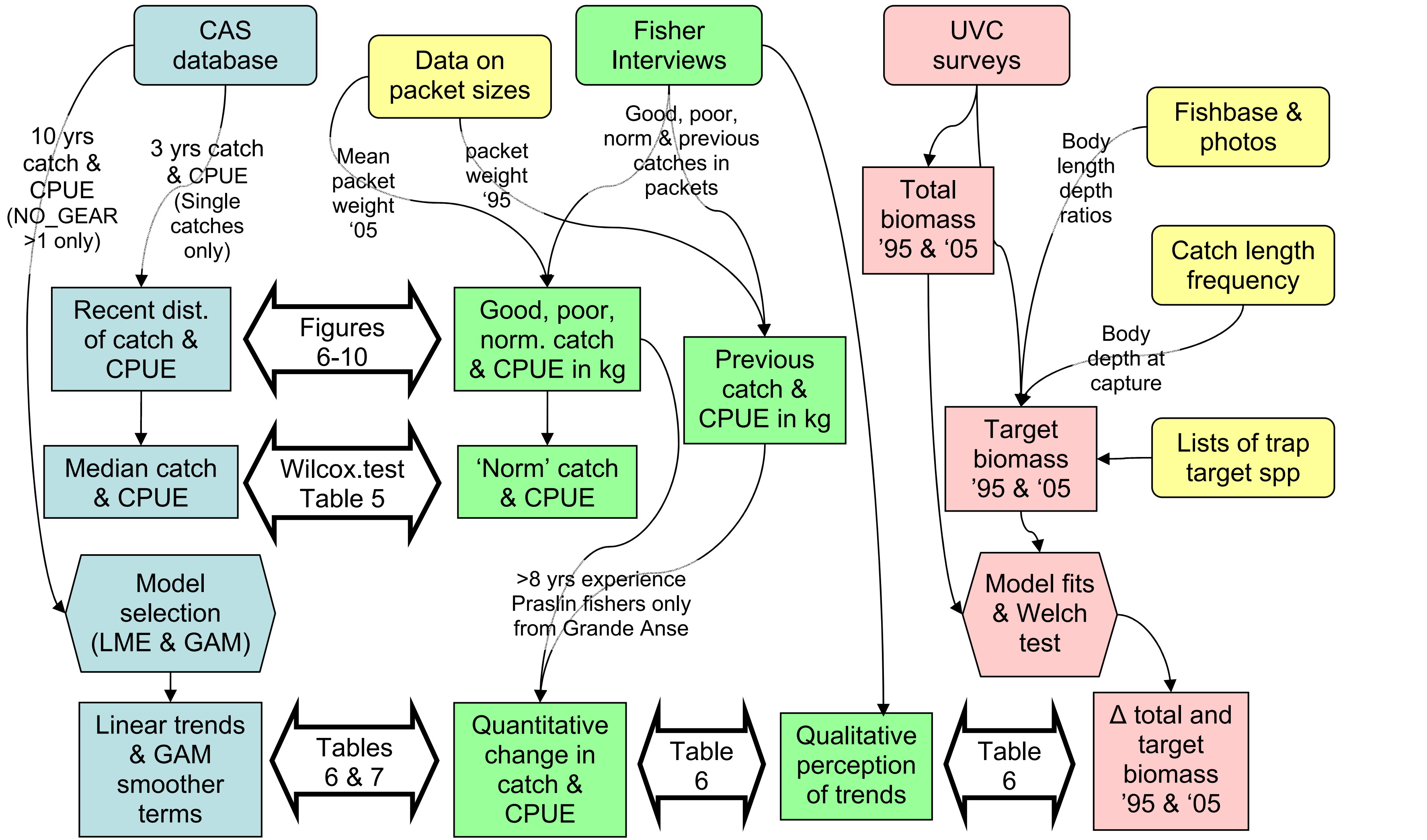


Figure 3.4. Data sources (rounded boxes), analysis (hexagons) and comparisons (block arrows) made in this chapter to compare official landings (blue), fisher interviews (green) and underwater visual census (pink) data. Additional sources of information that inform analysis are coloured yellow.

3.3 Results

3.3.1 **Perceptions of current catches from interviews and landings**

All three fisheries in the Seychelles showed a positively-skewed distribution of catch with outliers at the higher end of the range and most of the data clustered within the lower half of the range (Figure 3.5-7). The skewed distribution is also apparent from univariate statistics in Table 3.4, including median values below mean values and skewness statistics greater than one. This skewed distribution was most prominent in the E Mahe kasye peze fishery due to the presence of extreme outliers (Figure 3.5). SW Praslin kasye lavol catches are the least skewed apart from two extreme outliers.

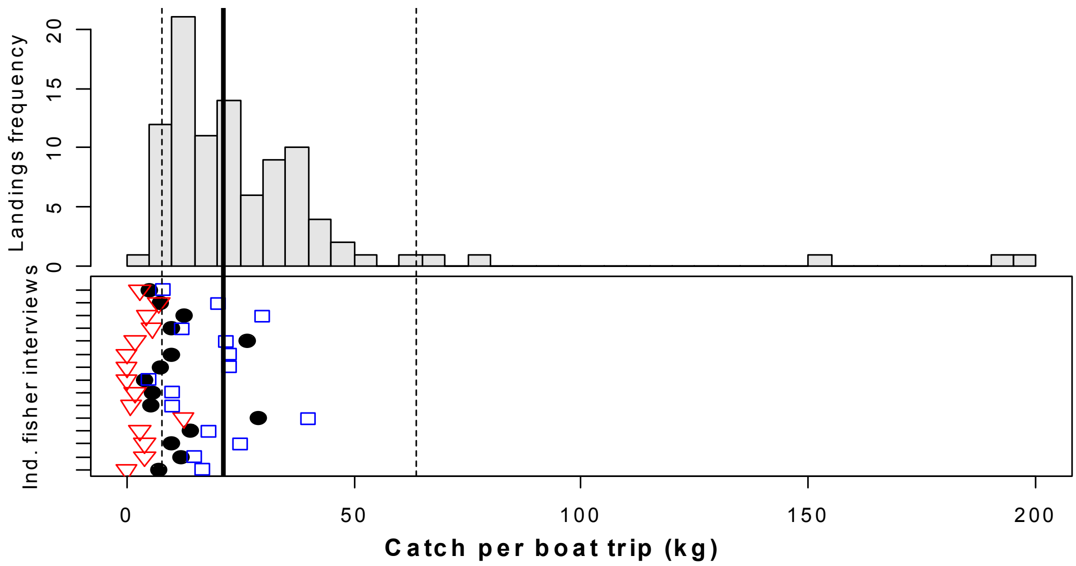


Figure 3.5. Distribution of daily catches by Seychelles fishermen using *kasye peze* in E Mahe from landings data (upper panel) and fisher interviews (lower panel, filled circles=catch on a 'normal' day, triangles=catch on a poor day, squares=catch on a good day. Thick vertical line indicates median and dotted vertical lines indicate 5 and 95% quantiles from landings data.

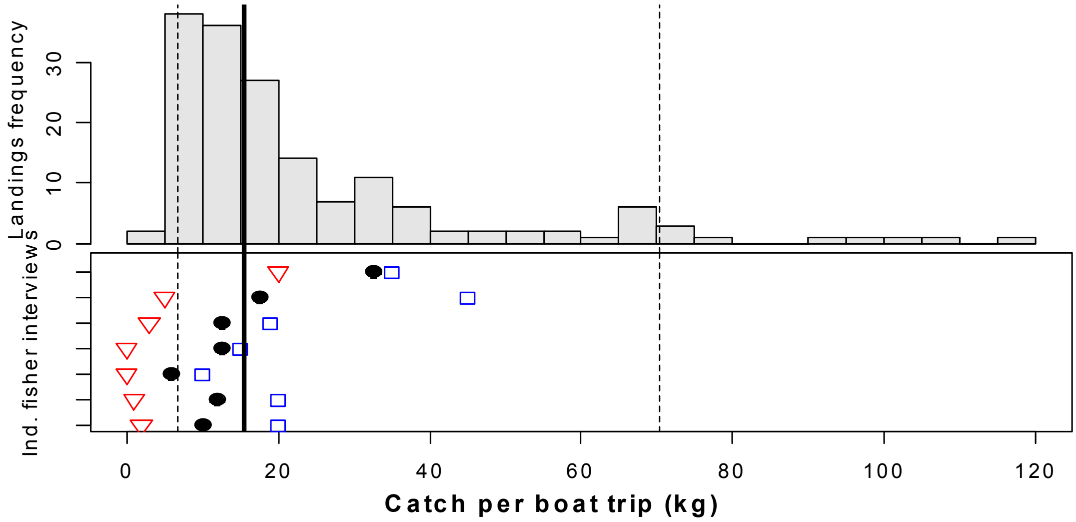


Figure 3.6. As Figure 4 but for *kasye dormi* in W Mahe

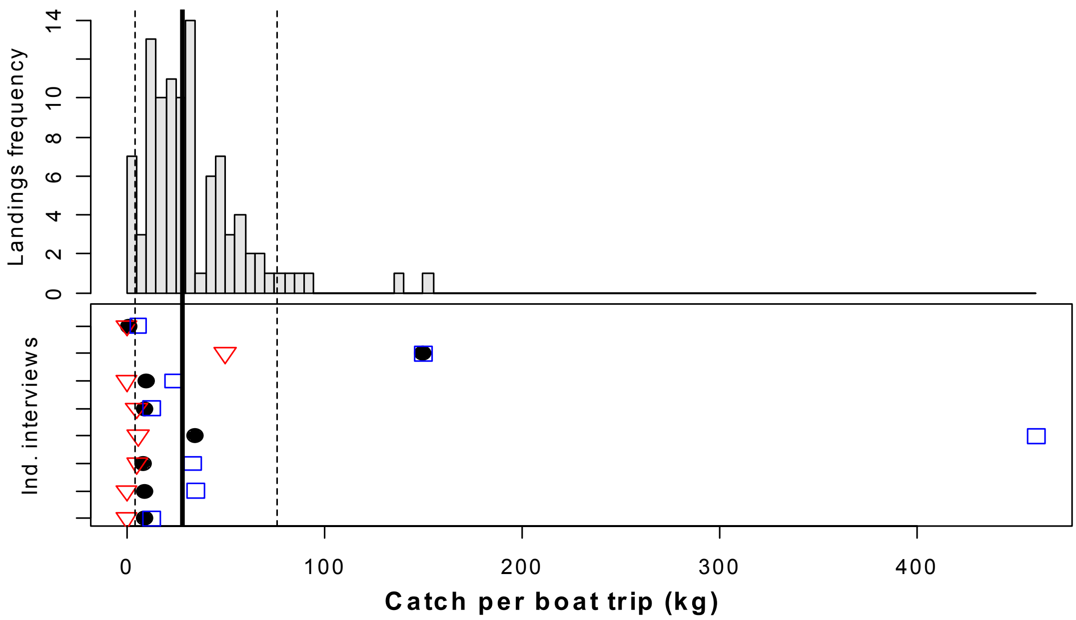


Figure 3.7. As Figure 4 but for *kasye lavol* in SW Praslin

Table 3.4. Statistics for records of landings by trap fishers in 3 strata in Seychelles

	Fishery	n	Mean	Median	Min.	Max.	Skewness	Kurtosis
Catch (kg)	E Mahe *kasye peze*	97	28.46	21.40	3.20	199.40	4.04	18.71
	W Mahe *kasye dormi*	179	24.12	15.60	2.80	116.52	2.06	4.22
	SW Praslin *kasye lavol*	102	33.39	28.45	0.00	155.00	2.02	6.41
CPUE (kg/trap)	E Mahe *kasye peze*	97	13.40	3.09	0.80	199.40	4.60	22.24
	W Mahe *kasye dormi*	179	6.26	4.20	0.68	67.72	5.54	35.92
	SW Praslin *kasye lavol*	102	7.01	4.55	0.00	41.00	2.27	6.83

When converted to kg, fishers' reports of catches were generally lower than landings records. Reports of a 'normal' catch was usually less than the median value of landings data, which was better estimated by fishers' reports of 'good' catch (Figure 3.5-7). In all but one case, estimates of 'good' catches fell within the 95th percentile of the landings data and 'poor' catches in E & W Mahe tended to be lower than the 5% quantile. One third of reported 'poor' catches were zeros but only 2 of the 362 landings records reported zero catches, both in Praslin.

Two outliers which appear in the Praslin landings data at ~150kg are on par with an outlier in the interview data. This interviewee did not distinguish good and normal catches and reported a 'poor' catch which was higher than all other reported catches (Figure 3.7). An even more extreme outlier in the interview data is over twice as large as the largest landings figure, although 'normal' catch of this interviewee is similar to the median landings figure.

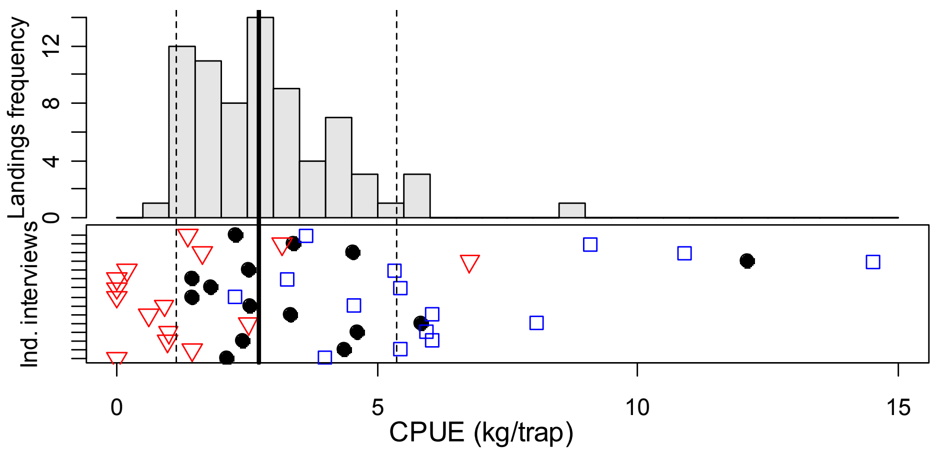


Figure 3.8. Distribution of CPUE by fishers using *kasye peze.* Landings data (upper panel) and fisher interviews (lower panel), filled circles='normal', triangles='poor' catch, squares= 'good' catch. Thick vertical line indicates median and dotted lines indicate 5 and 95% quantiles from landings data.

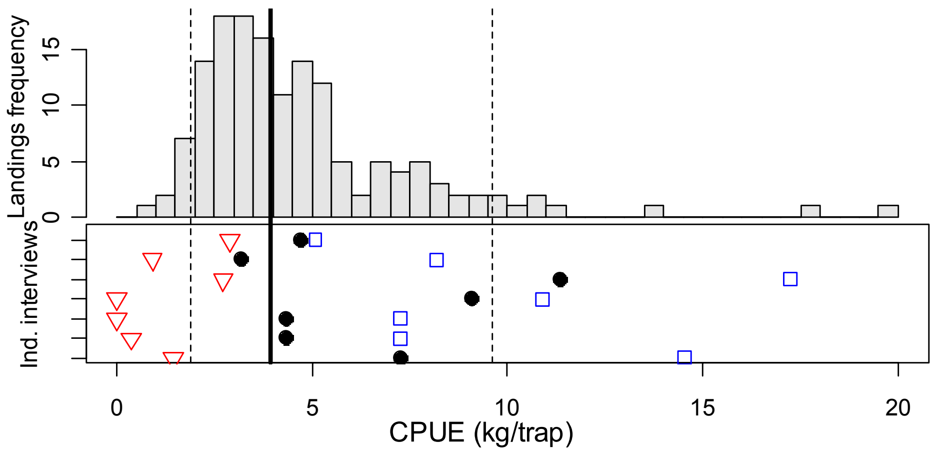


Figure 3.9. As figure 7 but for *kasye dormi* in W Mahe

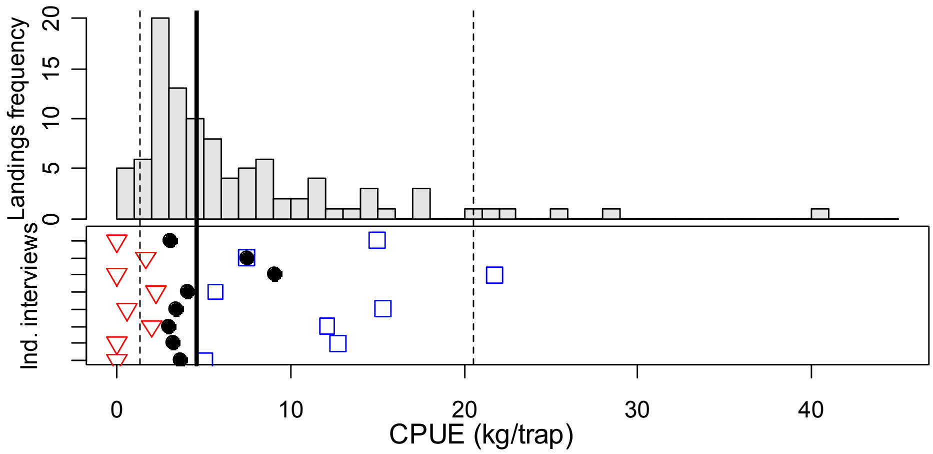


Figure 3.10. As figure 7 but for *kasye lavol* in SW Praslin

Landings and interview data are more similar in terms of CPUE than in terms of catch per trip, as shown in Figure 3.5-7 compared to Figure 3.8-10. At all sites, the spread of 'normal' CPUE is closer to and straddling the median. 'Good' CPUEs from interviews are more in line with the positive tail of the distribution, roughly straddling the 95% quantile for E Mahe kasye peze and W Mahe kasye dormi fisheries. Extreme outliers in the interview data for SW Praslin (Figure 3.7) are not outlying for CPUE because they are associated with a large number of trap hauls (10 traps hauled twice and three times per day; Figure 3.10). Outliers in the landings data on catch come from different records than the outliers in the CPUE dataset. The catch outliers are associated with high (8 and 9) numbers of traps while outlying CPUE values of 25-40 kg/trap are in fact from other data points with only two traps (Figure 3.11).

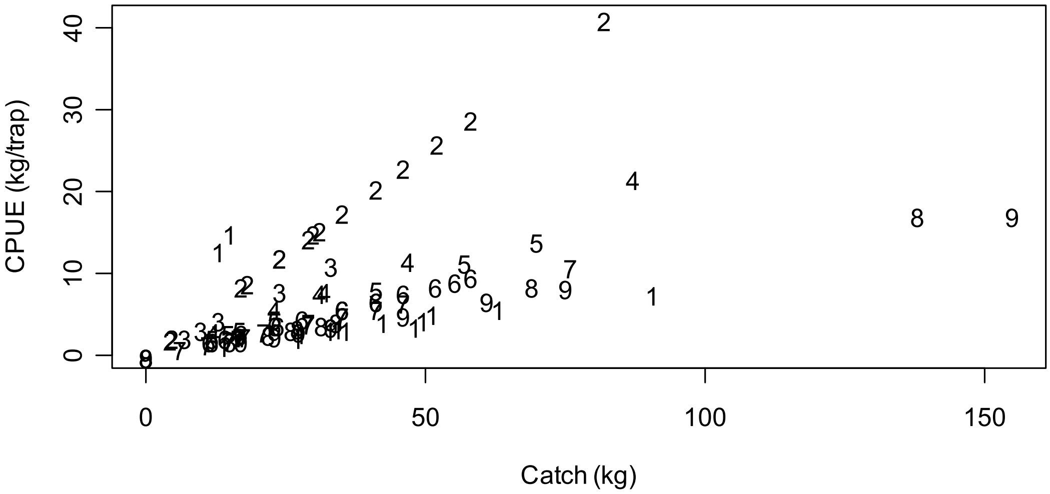


Figure 3.11. Catch plotted against CPUE for landings data from SW Praslin *kasye lavol*, with number of gears shown at each point. ('1's near the bottom of the figure are truncated larger numbers of gear (e.g. 14)). Outlying CPUE values come from different records than outlying catch values.

Non-parametric tests indicated significant differences between reported normal catches and median catches from the landings data at all three sites, but no significant difference between the reported normal CPUE and median CPUE from landings data (Table 3.5).

Table 3.5. Results of Wilcoxon Signed rank tests of differences between quoted 'normal' and median recorded catch and CPUE for trap fishers in Seychelles

Fishery	N	Norm-Median Catch		Norm-Median CPUE	
		Z	**P**	**Z**	**p**
E Mahe *kasye peze*	14	-2.546	0.011*	-0.220	0.826
W Mahe *kasye dormi*	8	-2.533	0.011*	-0.420	0.674
SW Praslin *kasye lavol*	7	-2.371	0.018*	-1.693	0.09•

3.3.2 **Time trends according to fishers' perceptions**

Most fishermen (82%, n=28) in all areas perceived that catches had declined (Table 3.7, column 1), but quantitative indexes of trends gave different conclusions depending on which index was used (Figure 3.12). Comparing 'good' catches to previous catches suggested less of a decline than if 'normal' catches are compared. In terms of the different variables, daily catch suggested less of a decline than CPUE and CPUE in kg indicated less severe declines than CPUE in the fishers' own units, due to the different packet conversion for current and former times. 'Good' versus previous catch in kg (Figure 3.12, top right), indicates no decline on average; the same number of fishermen claim to catch more now as catch less now, while, 'normal' versus former CPUE in packets/trap (Figure 3.12, lower left) suggests the most pessimistic picture, in which only 1 fisher (from E Mahe) perceived an increase in catches and 13 perceived a decrease of 0-17%.

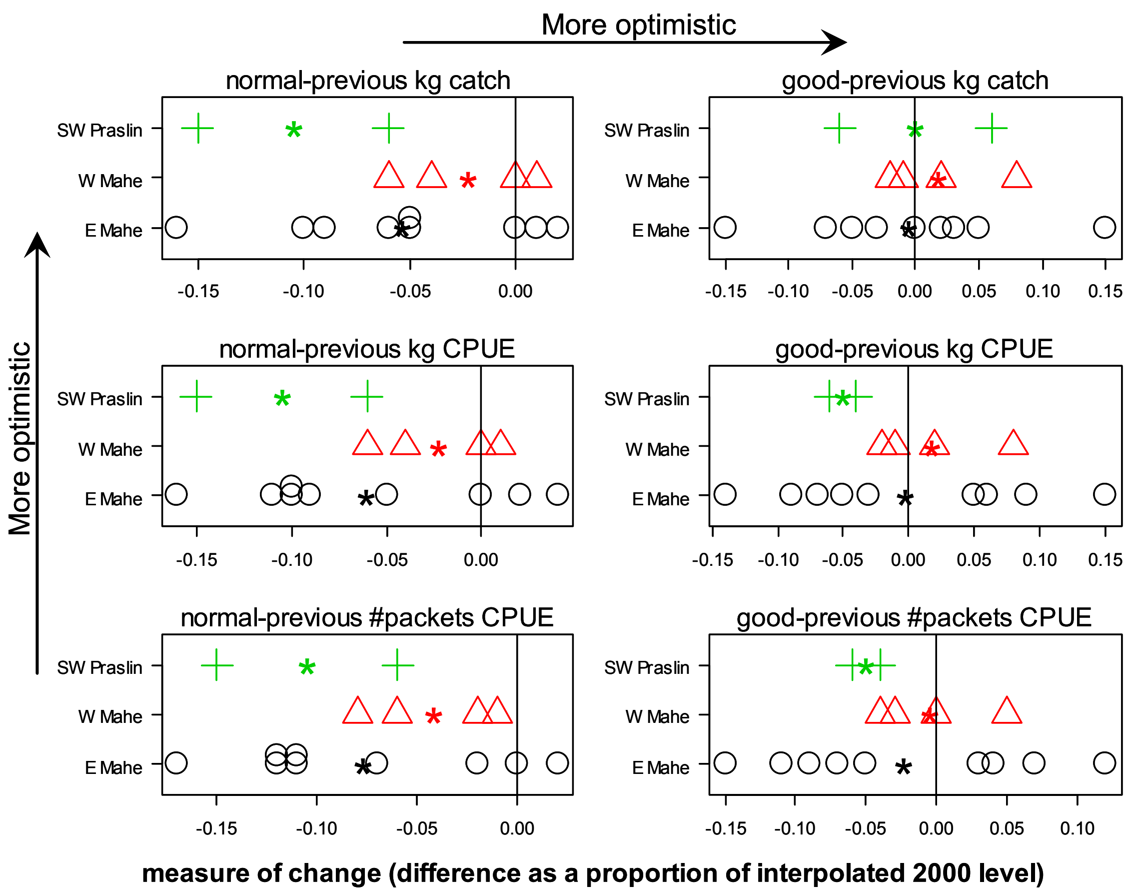


Figure 3.12. Different quantitative measures changes in catch from trap fishers in 3 areas of Seychelles stars indicate mean values.

3.3.3 Time trends according to catch assessment survey

Model selection indicated different trends in the 3 fisheries and in the case of E Mahe, between catch and CPUE (Table 3.6). AIC-based selection between the three linear models suggested a year effect for E Mahe CPUE and all W Mahe data. No models with a year*month interaction term were selected. All detected linear trends were positive, and equivalent to 3-15% of mean levels per year. SW Praslin showed little evidence of any long term time trend.

The GAMs were selected by AIC_c and BIC in nearly all cases except CPUE in SW Praslin and by BIC for CPUE in E Mahe. The graphical representations of the GAM smoother terms give an indication of the underlying trend in catches by year when seasonal trends are accounted for by the month term in the models (Table 3.6). All sites show a similar general pattern of increases from the late 1990s until the early 2000s, with declines within the last 2 years. A particularly steep decline in CPUE in E Mahe is indicated - 39% of mean levels within the last year.

3.3.4 Time trends according to UVC data

Difference in total fish biomass between 1994 and 2005 were detected at E Mahe (Welch $t=2.05$, $p=0.04$). There was found to be a significant site*year interaction at W Mahe so the three sites were tested for differences separately. Significant differences between the two years were detected at the patch reef site (Welch $t=4.87$, $p<0.001$), but not at the other sites.

Table 3.6. Selection of candidate models for catch and CPUE of each fishery and indicators of trends where present. Shaded cells indicate the lowest (i.e. best) information criterion scores between the linear models.

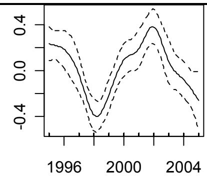
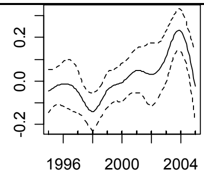
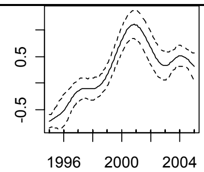
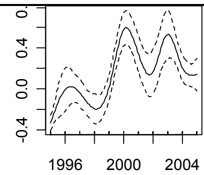
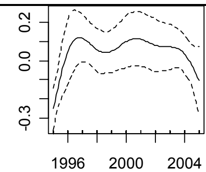
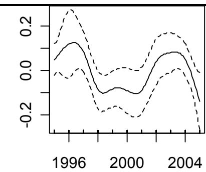
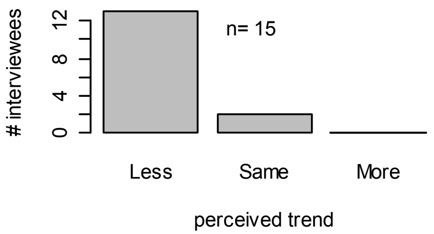
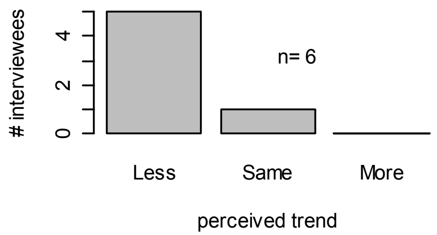
Fishery		E Mahe Kasye Peze				W Mahe Kasye Dormi				*SWP Kasye Lavol*			
Variable		Catch		CPUE		Catch		CPUE		Catch		*CPUE*	
Number of records		447		401		329		312		723		*719*	
Model selection	Criterion	ΔAICc	ΔBIC	ΔAICc	ΔBIC	ΔAICc	ΔBIC	ΔAICc	ΔBIC	ΔAICc	ΔBIC	ΔAICc	*ΔBIC*
	M0: month only	61.9	31.0	23.0	1.3	150.4	123.2	104.5	73.6	28.1	2.6	**0.0**	***0.0***
	M1: Year + month	71.2	44.3	17.7	**0.0**	57.6	34.2	52.6	25.4	32.5	11.6	10.3	*14.9*
	M2: Year*month	75.2	56.5	21.9	12.0	61.6	45.7	56.8	36.9	36.6	24.7	14.4	*28.0*
	M3: GAM s(year) + month	**0.0**	**0.0**	**0.0**	6.6	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	7.3	*37.8*
10 yr Linear trend	Linear effect indicated?	N		Y		Y		Y		N		N	
	Modelled change (/10yrs)			+ 0.93 kg		+ 25.58 kg		+ 2.67 kg					
	Slope (% of 2000 catch/yr)			+ 3.6%		+ 14.7%		+ 7.9%					
GAM	Deviations from mean (% of mean)	+45% to -36%		+34% to -20%		+12% to -69%		+65% to -49%		+9% to -27%			
	'04-'05 slope (% of mean)	-16%		-39%		-22%		-10%		-14%		*23%*	
	Smooth term (log scale on y axis)												

Table 3.7. Perceptions of trends from UVC and fisher interviews in each fishery

Fishery		E Mahe Kasye Peze		W Mahe Kasye Dormi		*SWP Kasye Lavol*	
UVC	**UVC biomass of**	**All fish**	**Trap fish**	**All fish**	**Trap fish**	**All fish**	***Trap fish***
	Trend detected (% of mean/yr)	- 1.6%	No trend	No trend (coral and granite sites) - 6.3% (patch reef site)	- 1.6% overall (- 7.4% at patch reef site)	No trend	*No trend*
Fishers' Perceptions	**Perceived trends**						
	No quant. estimates	9		4		*2*	
	Change from previous to 'normal' CPUE (% of year 2000/yr)	- 6.1 % (SD=6.7%)		- 2.3 % (SD = 3.3%)		*- 10.5 % (SD = 6.3%)*	
	Change from previous to 'good' catch (% of year 2000/yr)	*- 0.3 % (SD=9.5%)*		*+ 1.7 % (SD = 4.5%)*		*- 0.5 % (SD = 1.4%)*	

Biomass of 'trap fish' (target species greater than 6cm body depth) was not significantly different in the two years at E Mahe or SW Praslin. In W Mahe, the year and site*year interaction were both significant, showing a significant difference with year (F=4.98, p=0.028), and a very significant difference between the two years at the patch reef site (Welch t=3.60, p=0.001).

Comparisons of trend perceptions in the datasets

Overall comparison of the perception of trends from interviews, landings and UVC do not show any clear agreement. The site that shows the greatest evidence for a decline in UVC-measured fish biomass (W Mahe) actually shows evidence of an increase in catches and the most positive quantitative trend estimates from interviewees (Figure 3.12). No distinction can be made between the sites based on the proportion of fishermen perceiving a trend. Fishermen tended to perceive declines at all sites, while any long term linear trends in the CAS data (in E and W Mahe) were increases.

3.4 Discussion

3.4.1 Current catch distributions

The frequency distributions of catch per boat trip recorded by the CAS in the three years before the interviews, tended to indicate higher catches than the fishers' stated poor, normal and good catches. Fishers' reports of 'normal' catches were consistently lower than median recorded landings. However, CPUE from CAS and interview data was closely in agreement both in terms of the central tendency of the data (median and 'normal' CPUE) and the range of the data indicated by the frequency distributions and the fishers' citations of 'poor' and 'good' catches. This is encouraging for situations in which time and resources are not available to initiate a structured landings recording programme. In these three cases, it seems that a reasonable account of both the magnitude and the variability of catch rates could have been obtained by simple and highly cost-effective interviews with fishers (e.g. Lunn and Dearden 2006).

The differences between normal, poor and good CPUEs give an indication of the variability of catches, which is important because high variability reduces fishers' statistical power to perceive spatial or temporal trends in catches (Oostenbrugge et al. 2001; Pet-Soede et al. 2001a; van Densen 2001). Recent literature has emphasised increased variance itself as an indicator of loss of fish stock resilience and predictor of ecological regime-shifts (Carpenter and Brock 2006; Hsieh et al. 2006). The data presented in Figure 3.8-Figure 3.10 suggest that asking fishers for good, normal and poor catches may allow a cost-effective and crude indicator of ecosystem stress in data-limited situations. Increases in this indicator may warn of the resilience of stocks being undermined in advance of a major stock collapse.

The results emphasise the importance of measurements of fishing effort (number of traps in this case) where large variations exist between different resource users. Some of the outlying points on Figure 3.7 may have raised suspicion of data errors or exaggeration by interviewees. However, when the data are presented in terms of catch per trap haul (Figure 3.10), those two individuals' answers fell comfortably within the range of the rest of the sample. The importance of measuring effort is also clear from the CAS data. Outlying catches values were within the typical range of CPUE, while records with typical catches had outlying CPUE values (Figure 3.11).

In Seychelles, CAS collects data on number of traps, but in many fisheries, aspects of effort are not recorded in monitoring schemes. Interviews with fishers have the advantage of being able to account for specific effort features, with which they are routinely familiar, either to record these or to ask about catch rate changes taking account of all effort changes exerted by fishers.

3.4.2 **Time trends**

3.4.2.1 CAS and fisher interviews

The majority of fishers in all three fisheries perceived that catches were declining whereas analysis of CAS data showed no trends or increases in catches and CPUE over the 10 year time-span. The perception of trends over time is inherently more complicated than perceiving typical contemporary catches. As well as the perception of current conditions, it requires the retrieval of former conditions and comparison between the two, taking account of variation so that the long-term trend can be separated from short-term noise (van Densen 2001). It is unsurprising therefore that there was disagreement between fishers' perceptions of trends and analysis of CAS CPUE data.

The act of retrieving estimates of past conditions is accomplished by a variety of cognitive heuristics rather than by remembering every individual fishing episode (Tversky and Kaneman, 1973). As such, more available memories, which may be more pleasant, unusual or emotive for the individual (Matlin 2004), will have a greater weight on the perception of past or average conditions. It may, therefore, be expected that particularly large or unusual catches would dominate the perception of former catches. In the left-hand panels of Figure 3.12, 'normal' catches are compared against former catches. If the previous catches being remembered were in fact 'good' catches for their day, then the trend will be perceived as more negative. It may, therefore, be more appropriate to compare perceptions of current 'good' catches with perceptions of former catches as is done in the right-hand panels of Figure 3.12. If fishers are remembering good catches from the past and comparing them with typical contemporary catches, this might explain why the majority felt catches had declined when the landings data provided no evidence for a decrease. This shows the critical impact of decisions of how FK is processed and analysed. By changing the assumption of how to interpret previous catches, the nature of the perceived trend is qualitatively changed.

The time window of 10 years may also have contributed to the difference in perception of CPUE trends from fisher interviews and CAS data. All six of the GAM smoother terms showed a decline in recent years (although caution should be taken with the interpretation of the ends of GAM smoothers, A. Zurr pers comm.) so, if there has indeed been a decline in catches and CPUE within the past two years, fishers answering questions about a 10-year time trend are likely to be influenced by the recent trends. In which case, answers based on recently perceived trends (through the process of asking about 10 years) are projected back over a longer timescale.

Figure 3.5-10 illustrate the importance of fine-scaled measures of effort. Catch per boat trip (called 'catch' throughout this chapter) gave a different and less compatible result than CPUE measured as catch per trap, because of variations in the quantity of traps used by fishers. Likewise, perception of trends may also be affected by fishers 'fishing harder', increasing effort in ways that are not incorporated into standard effort measurements. For example, fishers can increase distance travelled, trap soak-times or effort exerted in optimal positioning of traps; or they can change the design of gears in response to various socioeconomic drivers (Jennings et al. 2001), which would not be detected by CAS. In these cases, fishermen may have a more precise perception of any resource trends than crude official landings data have, because of an inherent understanding of how 'hard' they are fishing, which they can take into account while forming their opinions.

Like most artisanal fisheries in the World (Berkes et al. 2001), the Seychelles trap fishery, although small-scale, is a commercial fishery in which catches are sold for profit. Changes in the gross revenue or profits from fishing may therefore be of greater importance to the fisher, and thus better remembered, than changes in quantity of catch (Matlin 2004). Increasing costs and decreasing fish prices would provide a negative trend in fishers' fortunes. Packet prices tend to be standard in Seychelles, with fish supply and demand being reflected in the size and composition of packets rather than in price changes. Analysis of packet sizes indicated that packets were, on average, larger in 2005 than in 1995, which would equate to a decline in fish price. This, along with the economic status of Seychelles, which makes the purchase of imported equipment expensive and difficult for fishers (pers. obs), may have decreased the profits from fishing, and provide another explanation why the majority of fishers perceived a decline in the fishery.

3.4.2.2 Underwater visual census and fisher interviews

Disagreement between fishers' perceptions and the UVC is, perhaps, unsurprising considering the lack of spatial overlap between habitats and species sampled by UVC and those targeted by trap fishers who tend to fish either shallower (*kasye peze*) or deeper (*kasye dormi*) than the reef slopes targeted by the ecological surveys (Robinson and Daw 2005). This is discussed further in Chapter 4.

Filtering of the UVC data for 'trap fish' (target species over 6cm body depth) was conducted to increase the overlap with the fish community available to trap fishermen. This changed the results from an overall 'decline in biomass', to 'no detectable decline in target fish' in E Mahe, and from 'no detectable trend' to a decline in target fish in W Mahe. Trends in W Mahe were different at the different sites, with severe declines indicated at the sand site. This illustrates the complexity of comparing independent indicators of fish biomass over a complex heterogeneous seascape. If the patch-reef site is representative of areas targeting by trap fishers, they would be more expected to perceive a decline. However, if this site is atypical of fishing sites, entirely different trends may be observed.

3.4.2.3 Conclusion: Multiple indicators for resource monitoring

All three data sources appeared to give different perceptions of trends which have occurred in the biomass of fish and catches over the previous 10 years. Each dataset has limitations, lack of precision, and/or potential biases and so none can be considered to provide the 'true' picture. This supports the contention from the resilience perspective that it is important to combine multiple information sources for monitoring and learning about system behaviour (Folke et al. 2003). Fishermen may be able to perceive trends that are masked from landings data by subtle increases in fishing effort or efficiency (Neis et al. 1999), while landings data may have more statistical power to observe large scale trends by integrating the catches of many different fishers (van Densen 2001). UVC may be able to monitor actual changes in biomass of fish without the confusion of variable catchability and fisher behaviour, but may have poor temporal, spatial or depth coverage and may have limited overlap with exploited fish populations (Robinson and Daw 2005). Consideration of several indicators increases the awareness of the contingent nature of each. This can be useful in avoiding over-confidence in only one signal. For example, in the stock assessments leading up to the collapse of the Northern cod, scientists relied too heavily on trawler CPUE and failed to detect the problem until it was too late. Had they considered more diverse indices like the experiences of inshore fishers, they may have been more discerning about the use of trawler CPUE (Finlayson 1994; Neis 1997).

Chapter 4. Regional comparisons of catch reports and UVC data

4.1 Introduction

An important question for local management of resources is whether resource users can perceive differences in stock abundance so that ecological signals can act as feedback for management actions. If fishers' and conventional data perceive such patterns differently, a 'cognitive conflict' exists which may be at once a barrier to co-management as well as an opportunity to increase the understanding of the system by combining different knowledge types. Chapter 3 compared FK and scientific perceptions of temporal patterns in resource abundance by examining perceived fish availability at the same locations at different times (now and in the past). In this chapter, I compare FK and scientific perceptions of *spatial* patterns by examining perceived fish availability at several locations at one point in time.

4.1.1 **Underwater visual census and reef fisheries**

Underwater visual census (UVC), in which fisher are counted within a standardised area of habitat, is the basis of much coral reef fisheries ecology field research (Jennings et al. 2001). The method allows researchers to describe coral-reef fish communities in terms of species richness, abundance and biomass. Fish biomass, in particular, is a metric which has been widely used to monitor the impact of fisheries on reef ecology (e.g. Polunin and Roberts 1993; Jennings et al. 1995; Pet-Soede et al. 2001b; McClanahan et al. 2006). However there has been less focus on the direct relationship between UVC-measured biomass (UVC-biomass) and fish catch, which is the primary concern and the main source of perceptions for fishing communities.

Haggarty and King (2006) found a proportional relationship between experimental hook and line CPUE and UVC-abundance where a species' habitat was adequately sampled. No relationship was found, however, for other species that were not susceptible to hook and line, or that extended beyond the depth ranges sampled.

Such controlled conditions are also unlikely to be typical of reef fisheries. For example, Jennings and Polunin (1995) reported that the annual catch of emperors (Lethrinidae) in Fiji exceeded the UVC-based estimate of the entire biomass. UVC is limited in terms of times of the day, depth, water visibility and types of fish (non-cryptic) for which it is suitable. UVC is also limited to safe depths for divers (~30m but frequently shallower) whereas many fishing gears, like hook and line or traps, can be used considerably deeper.

Catch rates experienced by fishers may be as much a function of 'catchability' as of biomass. Biological factors such as feeding behaviour, aggregations, or the nature of the habitat may affect catchability, while technical and socioeconomic factors of gears, fuel cost and availability, engines, vessels, markets, spatial distribution of effort, interference between fishers, and varying skills between individuals (the so-called 'skipper effect', Ruttan and Tyedmers 2007) seasons, weather, and grounds, can all have major impacts on catches regardless of the biomass of target species. These may be related to the wealth of individual fishers or to the level of economic development of the community, Thus, while fish catch and UVC-biomass are both related to the abundance of fish, trends in catches one may not be reflected by trends in UVC and vice versa. Biomass is the main focus of most fisheries management and stock conservation measures and it seems self evident that it should be of concern to fishers. However, if fishers may well be more concerned with other factors that are more important in determining catch rate.

UVC-biomass (in kg/ha) cannot be compared in absolute terms with catch rates (in kg/time) without scaling factors of reef area and catchability. However, relative trends can be compared to see if spatial or temporal patterns in catch rates are related to biomass. In Chapter 3, trends in time were compared. In this chapter, trends in space are compared over the spatial scale of the western Indian Ocean encompassing variations in biomass of nearly an order of magnitude. This chapter makes use of a rare international-scale dataset to compare catches and UVC-biomass for three reef fishery gears. I then investigate whether other factors (wealthy, boat type and country) from the dataset provide better explanations of the patterns in catch rate.

4.2 Materials and Methods

4.2.1 **Study Sites**

Data for this chapter is taken from ecological and social surveys at 18 sites in 5 countries (Table 4.1 and Figure 4.1) in the western Indian Ocean. These sites had been previously selected for a large-scale assessment of the impacts of coral bleaching on fish and fisheries based on the location of ecological surveys before the 1998 coral bleaching event (Graham et al. in review). At each site, coastal communities were sampled by a household survey and nearby fished coral reefs were surveyed by ecologists using underwater visual census.

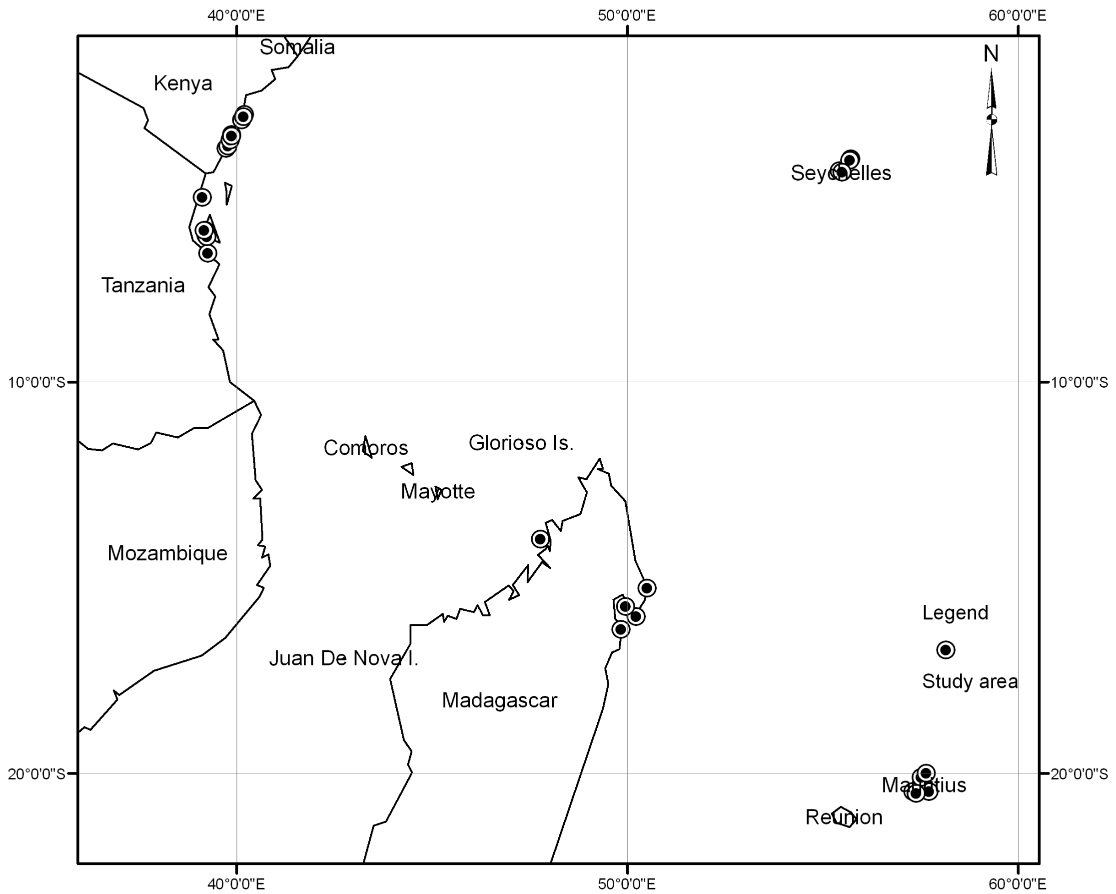


Figure 4.1. Locations of survey sites in the W Indian Ocean included in the study.

4.2.2 UVC data source

UVC-biomass was provided for each ecological site as a mean total kg of fish per ha from coral reef fish surveys conducted in each area (N. Graham, T McClanahan, unpublished data). All sites were surveyed with a belt transect as described in McClanahan & Kaunda-Arara (1996), except those in Seychelles which were surveyed using point-count measures as described in Graham et al. (2007).

UVC-biomass was provided as a total community biomass and was not disaggregated into species or size classes. In any case, catch composition, size at first capture and target species are likely to vary with gear design (e.g. mesh and hook size), local preferences, markets and locally abundant species. Detailed data on the length frequency and species composition of catches by each gear at each site were not available (unlike in Chapter three) to determine which fraction of the total fish assemblage should be considered relevant for fisheries. This meant that total biomass was used for comparison with catch rates. As fish weight increases proportionally with the cube of their length, small fish that have not recruited to the fishery and non-target species (which are typically smaller species) are expected to contribute a disproportionately small amount to biomass measures so total biomass is expected to be a reasonable proxy for biomass of fished species.

4.2.3 **Fisher interviews**

Fishers were interviewed as part of a large-scale survey of coastal communities in the region conducted between May 2005 and December 2006. A standardised questionnaire was completed with a systematic sample (Bryman 2004) of 23-143 households in each community depending on the population of the communities and the available time per site. Household surveys targeted household heads.

Household questionnaires included specific questions for fishers on the catches obtained and fishing effort expended on good, poor and normal fishing trips with their main gear (Appendix 2). Fisher interviews were either obtained where a fishing household appeared in the systematic sample or by targeted interviews with fishers if the household survey had led to few fisher interviews within a community. Reports of catches by hand line (excluding pelagic handlines e.g. trolling) gill net and fish traps were selected for this analysis, as they are typical reef fishery gears and were available for a wide range of the sites (Table 4.1).

Table 4.1. Social and ecological sites used for the comparison of reported catch rates and UVC-measured reef fish biomass with number of fisher reports of catch rate for each gear and site.

Country	Social Site	No. Comm-unities	No. catch rate reports			Ecological Site
			Hand line	Trap	Gill net	
Kenya	Vipingo	1			7	Kanamai/Vipingo
	Bamburi	1	4	1	8	RasIwatine
	Kuruwitu	1			1	Vipingo
Tanzania	Mazizini	1	17	10	1	Changuu/Chapwani
	Stone Town	1	10	12	4	
	Mtangata	3	15	4	11	Makome/Unfunguni
	Dar Es Salaam	2	14	2		Mbudya/Bongoyo
Mada-gascar	NW Madagascar	3	22		5	Sakatia/Ambaritelo
	Tanjona	5	8	5	21	Cape Est
Mauritius	Pointe des Lascars	1	5	3		Anse la Raie
	Pointe aux Piments	1	5			Balaclava 2 buffer
	St Martin	1	3			Belombre
	Blue Bay	2	2	1		Blue bay 2
	Le Morne	1	3			Le Morne
Seychelles	Grand Anse	1	3	9		SW Praslin
	Anse Volbert	1	4	1		NE Praslin
	Belombre	1	4	1		NW Mahe
	SE Mahe	2		23		E Mahe
	West Mahe	2		7		W Mahe
	Total	**31**	**119**	**79**	**58**	

Fishers were asked about their typical catch and effort on a good, bad and normal day, which were recorded in the same units used by the interviewee and converted to kg. Kenyan fishers normally reported catches in value, in which case interviewees would be asked for the price per kg. Where this was unavailable typical median fish prices for the community were used. 'Packets' of fish reported by fishers in Seychelles were assumed to be 3.63 kg (see Chapter 3) and '*toko'* in Madagascar 0.8 kg. Catches were reported either for the whole crew using a gear or as an amount which any individual fisher got (i.e. total catch divided by number of crew). Hand line and gill net catch rates were converted to kg/man hour and trap catches to kg/trap. In Seychelles the household survey dataset was supplemented with specific surveys with trap fishermen described in Chapter 3.

The questionnaire also included questions on boat type and propulsion, and the possession of 15 material assets (vehicle, electricity, television, gas or electric stove, fan, piped water, refrigerator, radio, video player, and the type of walls, roof, and floor) as an indicator of household wealth.

4.2.3.1 Data Analysis

Mean reported catch rates were plotted against mean UVC-measured fish biomass to examine if a relationship existed between the two variables. To provide an indication of the capital investment in the fishery, the boat type used by each fisher was categorised as 0-4 according to the means of propulsion (0 - no boat, 1- no engine or sail, 2 - sail, 3 - outboard engine, 4 - inboard engine).

Principal component analysis (PCA) was conducted on the material assets data and the score of each household on the first principal component (which explained 58% of the variance of the data) was taken as a univariate indicator of household wealth (Cinner and Pollnac 2004).

Individually reported 'normal' catch rates for each gear were compared graphically with country, boat type, material assets and UVC-biomass for any association. Where data were heavily skewed (for hand-lines and traps) they were natural-log transformed to give a more normal distribution. Collinearity between these four factors were assessed graphically before multiple linear regression methods were used to determine which, if any, of country, boat type and UVC-biomass, explained significant amounts of the variance in 'normal' catch rates. A stepwise selection procedure in R (function step, direction = "both") sequentially included or excluded these terms in a linear model, compared AIC (Aikike Information Criterion) as an indication of how good the model fit the data, and settled on a final model with the best (lowest) AIC (Burnham and Anderson 2002).

Because of collinearity between country and other factors (e.g. households in Seychelles tended to have the highest wealth scores), where there were significant differences between catch rates by country and a relationship with another variable (e.g. wealth score), it is not possible to know whether the catch rate-wealth relationship is due to the catch-country relationship. Thus one cannot say that wealth is driving the trend, because it could be the result of a wide range of socioeconomic, political and environmental factors which vary by country, for example, fishing traditions, underwater topography and market forces.

Therefore, where there was a significant effect of country on 'normal' catch rate, the significance of biomass, material assets and boat type in explaining additional variance in catch rate beyond that explained by country were each assessed by comparing two nested models; one containing country and the other containing country as well as each one of these additional factors successively. Significant differences between each pair of nested models were then tested with ANOVA F-tests (Zuur et al. 2007).

4.3 Results

4.3.1.1 Mean Good Poor and Normal Catches

There was no obvious relationship between mean UVC-measured fish biomass and mean reported good, poor and normal catch rates at each site (Figure 4.2). Larger ranges between good and poor catch rates were reported at sites where catches were higher, so that differences between sites were most obvious between ‘good’ catches. Generally, the lowest catch rates were reported in Mauritius, corresponding to some of the lowest fish biomass levels of around 100 kg/ha. Highest catches were reported in Seychelles with intermediate biomass of 260-240 kg/ha, but the highest biomasses found in sites in Madagascar and Tanzania (270 – 470 kg/ha) were not reflected in particularly high catch rates. For example, Bamburi in Kenya and Tanjona in Madagascar spanned the full range of biomass from 84 to 471 kg/ha respectively but had similar hand-line catch rates of about 0.8 kg/man hr, while the average normal trap catch rate reported in Bamburi was double that of Tanjona. No trend was apparent between sites within a single country. For example, biomass at sites in Tanzania had the widest range (150-442 kg/ha), but the lowest biomass was associated with the highest normal catch rates for both hand lines and traps.

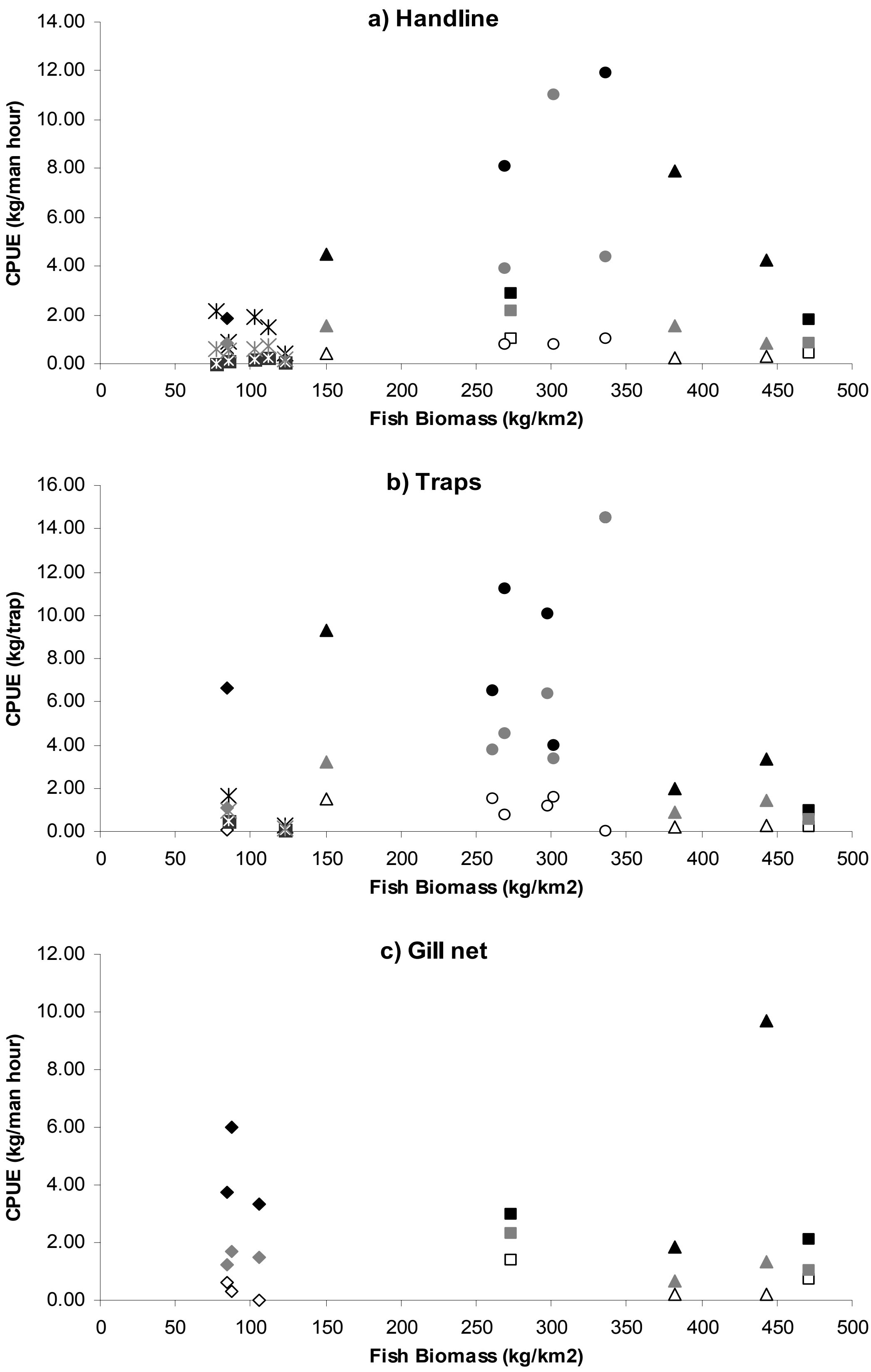


Figure 4.2. Average reports of good (filled), poor (open) and normal (grey) catch per unit effort plotted against UVC-measured biomass from fishers in Kenya (diamond), Tanzania (triangles), Seychelles (circles), Mauritius (crosses) and Madagascar (squares). One outlying value for a good handline catch rate (33.1 kg/man hr at 300 kg/km^2) in Belombre, Seychelles has been removed for plotting.

4.3.1.2 Relationship between normal catch rates and other factors

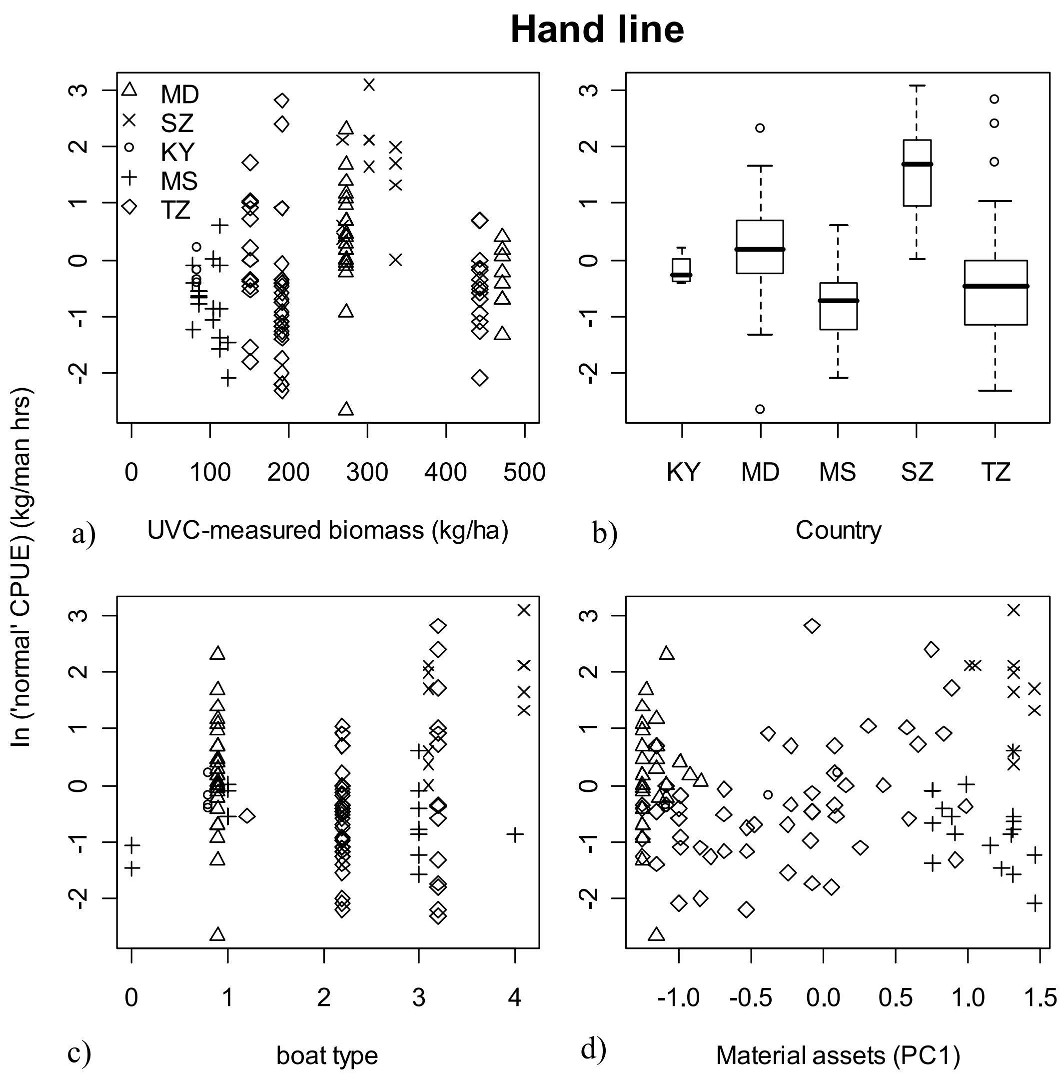


Figure 4.3. Relationship between 'normal' catch rate as reported by hand-line fishers and four independent variables: mean local UVC-biomass, country, boat and engine type and an index of household wealth. Country is indicated in scatter plots by point type. Boat types are 0 – no boat, 1 – un-powered, 2 – sail powered, 3- outboard engine, 4 – inboard engine. Countries are indicated by letters: KY – Kenya, MD – Madagascar, MS – Mauritius, SZ – Seychelles, TZ – Tanzania.

There was some evidence for a relationship between reported 'normal' catch rates and country, boat type and material assets (Figure 4.3). However, some of the differences in boat type and material assets can be seen to be related to differences in these variables between countries. Stepwise model selection chose a model in which catch rate was predicted by country and material assets. Material assets made a significant additional explanation of variance in catch rate over and above that explained by country (ANOVA with nested model, F=9.83, p=0.002), indicating that fishers from households with greater material assets reported higher normal catch rates. This is most likely driven by the clear positive relationship between assets and catch rate in Tanzania (Figure 4.3d, diamonds).

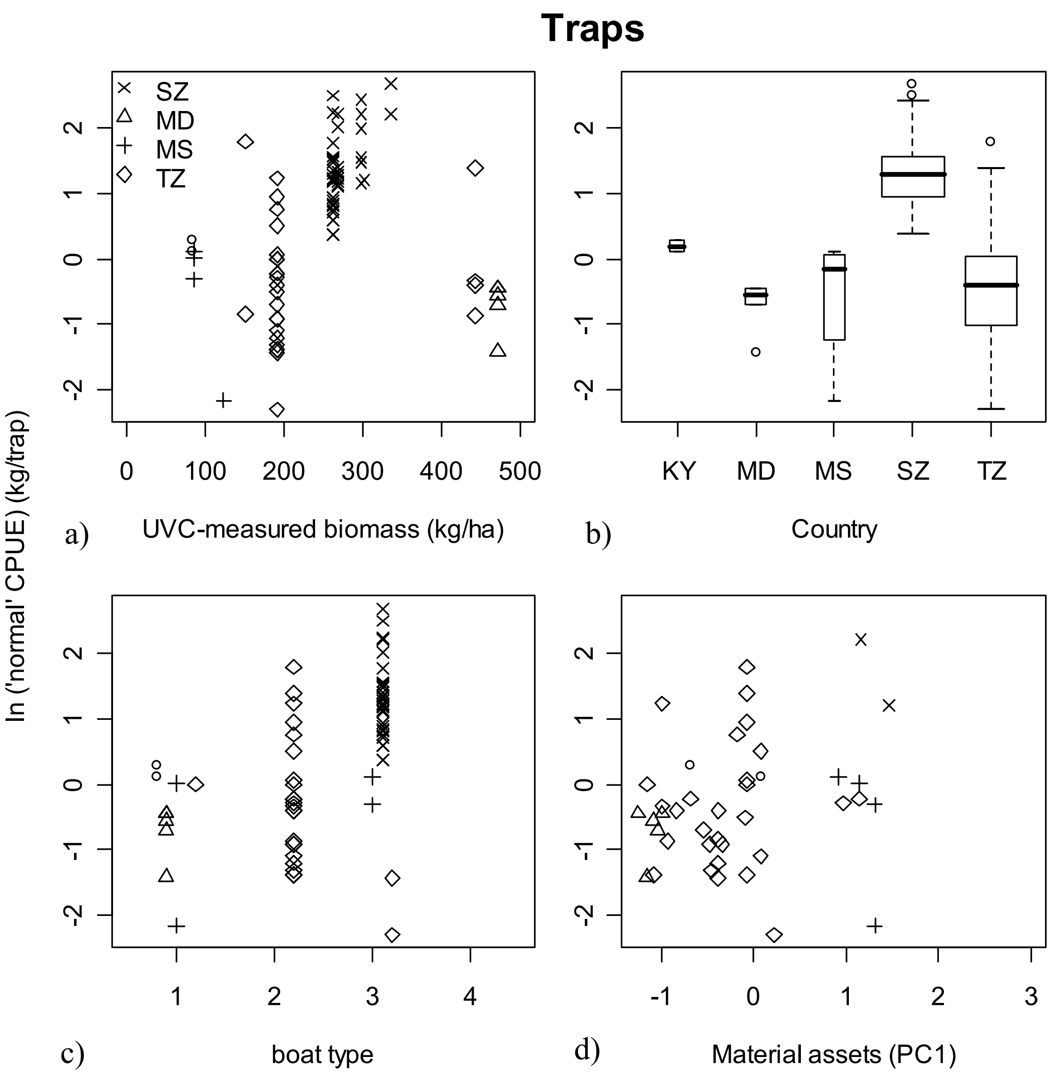


Figure 4.4. Relationship between 'normal' catch rate as reported by trap fishers and four independent variables. Boat types are 0 – no boat, 1 – un-powered, 2 – sail powered, 3- outboard engine, 4 – inboard engine. Countries are indicated by letters: KY – Kenya, MD – Madagascar, MS – Mauritius, SZ – Seychelles, TZ – Tanzania.

Trap fishers' reports of catch rate appear visually to have relationships to country, boat type and material assets (Figure 4.4). However, positive relationships between catch rate and boat type and material assets may be due to trends between countries.

Stepwise selection selected a model of catch rate as a function of country and boat type. Neither biomass, boat type nor material assets explained significant variation in catch rate beyond that explained by country at the 5% level, but boat type was almost significant (ANOVA with nested models, $F=2.66$, $p=0.0777$). However, this was driven by boat type 2 (sail-powered) which was only present in Tanzania and accounted for all but three of the Tanzanian vessels (Figure 4.4c), and so is not considered a reliable relationship. Therefore, no significant relationship could be detected between biomass, boat type and material assets and the catch rate of trap fishers, beyond the differences between countries.

No relationship was apparent between ‘normal’ catch rate reported by gill net fishers and UVC-biomass, country, boat type or material assets (Figure 4.5). Additionally, stepwise selection settled on the null model, rejecting all four of the explanatory variables as not significantly explaining variance in catch rates.

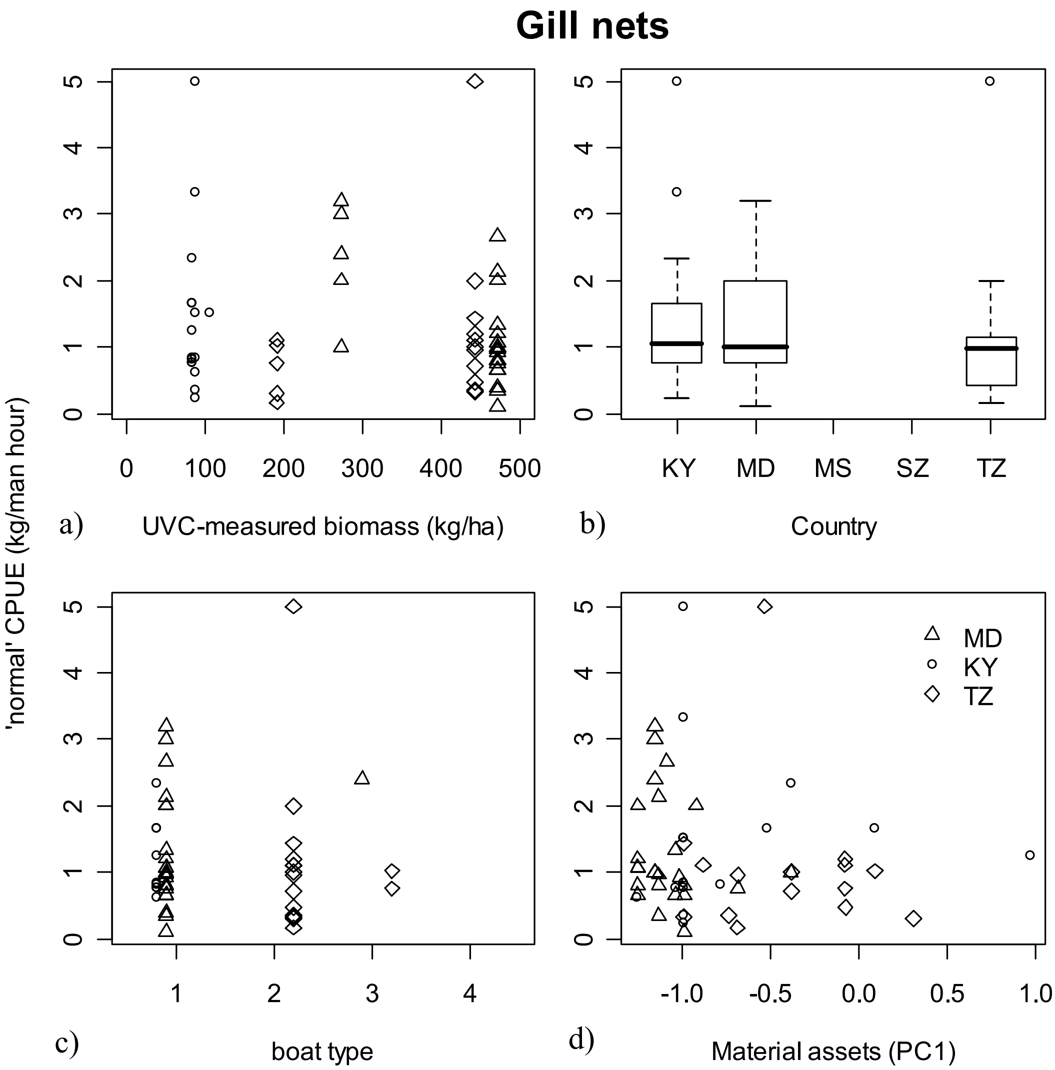


Figure 4.5. Relationship between 'normal' catch rate as reported by gill-net fishers and four independent variables. Boat types are 0 – no boat, 1 – un-powered, 2 – sail powered, 3- outboard engine, 4 – inboard engine. Countries are indicated by letters: KY – Kenya, MD – Madagascar, MS – Mauritius, SZ – Seychelles, TZ – Tanzania.

4.3.1.3 Summary of findings

A summary of the statistical relationships found between catch rates and the three explanatory variables are presented in Table 4.2. There was no relationship apparent between UVC-biomass and catch rates with any of the gears. Normal catch rates by hand line and traps were significantly different between countries. Relationships between catch rate and material assets, and between catch rate and boat type were also apparent but these were only significant over and above country differences in the case of material assets in hand line fisheries. This relationship indicated that hand line fishermen from wealthier households reported higher normal catches.

Table 4.2. Four potential explanatory variables and whether they significantly explained variance in 'normal' catch reported from 3 coral reef fishery gears. Where country was significant, other variables were tested for significant *additional* explanation of variance by ANOVA tests on nested models.

Gear	Country	Boat type	Material assets	UVC-biomass
Handline	✓	×	✓	×
Trap	✓	×	×	×
Gillnet	×	×	×	×

4.4 Discussion

This chapter compared a locally perceived indicator of reef-fish abundance (catch rate with reef gears) with an ecological scientific indicator (UVC-biomass) to see if they showed similar trends over a wide spatial scale. In theory, there should be some relationship between these variables as they are both partially dependent on the local abundance of reef fish. However as these indicators are each affected by other factors, this relationship is expected to be noisy. Importantly, both variables could form the basis for understanding trends in the ecology and deciding resource management strategies. No relationship was apparent between catch rates and UVC-biomass for any of the three gears, despite a six-fold range in biomass across the sites. Although at too large a scale to relate to local management in this case, the lack of congruence between the variables illustrates the potential conflicts between the perception of stock trends from Western scientific and local fishers' perspectives. Country, boat type and a household wealth indicator were also tested for relationships with catch rate to see if other factors can explain the variation in catches. Differences did exist in the catch rates between countries, which could have been due to a range of socioeconomic, cultural, political or environmental factors.

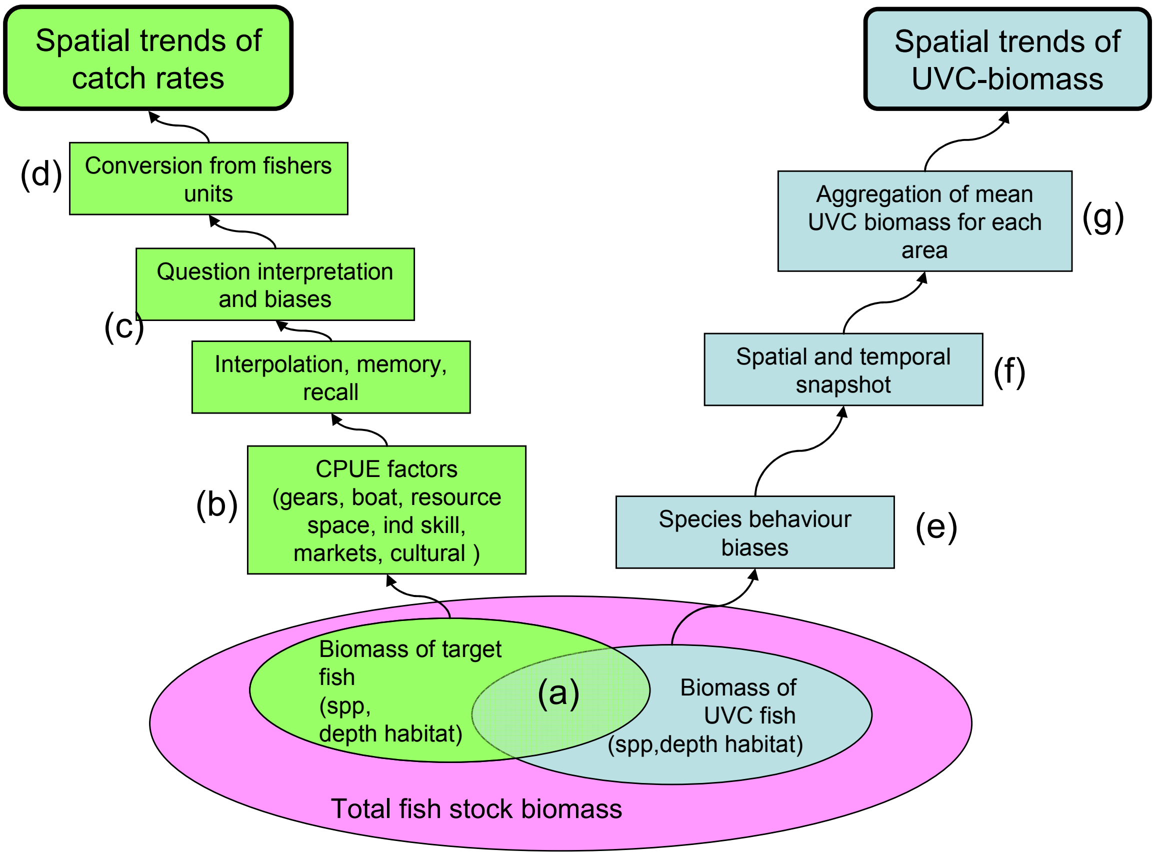


Figure 4.6. Sources of deviation between catch rate and UVC perceptions of reef fish biomass

4.4.1 The lack of a relationship between catch rate and UVC-biomass

There are a variety of possible reasons why no relationship was detected between UVC- biomass and reported fish catches, even though they both relate to local reef fish abundance (Figure 4.6). Each of the steps illustrated in Figure 4.6 is a source of variability and difference between the two signals.

UVC is practically limited by depth and habitat, while many 'reef fish' species utilise other adjacent habitats as well as reefs. Thus UVC-biomass may not coincide with the biomass of the species, depths, or habitats targeted by 'reef fisheries' (Figure 4.6a).

For example, in the WIO, *Siganus sutor* is an important commercial fish (SFA, unpublished data, McClanahan and Mangi 2004) but it tends to utilise lagoon and sea grass habitats rather than coral reef slopes where UVC is focussed (Robinson and Daw 2005).

Even if both datasets did relate to the same populations, catch rate may not be proportional to fish biomass due to CPUE hyperstability or hyperdepletion (Hilborn and Walters 1992, see Section 1.4.3), socioeconomic factors, and regional variations in habitat, fishing gear and practices (Figure 4.6b). This is supported by the observation that there was a significant country effect for hand line and trap catch rates. It is not possible to ascertain which of many potential factors that vary between nations is responsible for this effect but it is interesting to note that wealth, as indicated by household material assets, was related to hand line catch rates beyond any country-level effect. Wealthier fishers are likely to operate in a more technologically advanced fishery, operating more efficient gear, and being able to travel to fish more distant and deeper sites. Fishers in Madagascar, on the other hand, hailed from the least developed and poorest communities and may not have the capital investment which would be necessary to reflect higher fish biomass in their catch rates.

The variables would not show the same pattern if catch rate reports do not accurately reflect catches (Figure 4.6c), as suspected by Sullivan (2003). Reports may be affected by a limited ability to integrate and discern trends in catch rates, biased by the political context in which questions are asked, or affected by translation and interpretation of the concept of a ‘normal’ catch. For example, Indonesian artisanal fishers were unable to discern spatial patterns in catch rate due to high variability (Pet-Soede et al. 2001a), while small-scale Thai fishers apparently overstated both catches and effort in response to surveys (Mace 2004). Cultural factors can also lead to misleading verbal reports about fishing activities (Macintyre 2007) and political or economic biases may exist, for example to emphasise fishing skill or to give the impression of low incomes. Finally, conversions from fishers' units into kg may have introduced some further 'noise' and possibly country-specific biases (Figure 4.6d).

Although reported good, poor and normal catches were demonstrated to give a good indication of landings trends in Chapter 3, it was not possible to test reported catch against landings in this chapter due to the absence of landings data. Asking about 'normal' catches in the context of questions about 'good' and 'poor' catches was designed to reduce the variability in interpreting the question by providing some anchoring points and preventing fishers responding to the question with unusually good or poor catch rates.

In terms of UVC, biases are introduced by fish behaviour (Figure 4.6e). Some species are more cryptic in form or behaviour while others are less scared of divers or even curious and more easy to include in UVC (Edgar et al. 2004). Lethrinids, an important commercial family of reef fish appear to be one such family which is generally underrepresented in UVC (Kulbicki 1988; Jennings and Polunin 1995) which is perhaps reflected in the Swahili name 'jauja', which means cunning (I. Bryceson, pers comm.). Unlike FK which can integrate observations over a period of time, UVC surveys are necessarily a 'snapshot' view of the reef fish community while fishers' reports of CPUE may integrate catches throughout seasonal trends. This difference in temporal resolution may introduce more bias between catch rates and UVC (Figure 4.6f).

Unlike the detailed UVC records available for the analysis of Chapter 3, at this larger scale, only mean total UVC-biomass for each location was available. This prevents within-site variance in UVC-biomass being incorporated into statistical relationships (Figure 4.6g).

A straightforward relationship between biomass and catch rate is, therefore, perhaps not to be expected given the local variations in fishing methods and other complicating factors which may affect CPUE and UVC biomass. However, it is still important to note that if UVC-measured fish biomass is not related directly to perceived catch rates, fishers are unlikely to be as concerned with the results of UVC surveys or total biomass on shallow reefs as with trends in other factors which are more significant for them sustaining higher catches, for example, access to gear or markets. The results also raise questions over the suitability of UVC (especially broad indicators like total biomass) to inform policies about fishing.

However, whether or not one indicator or the other is correct, is of little interest from a governance perspective. The important finding is that these two perceptions of the same basic feature (abundance of fish) of reef ecosystems do not agree on major differences between biomass at a regional scale. They should certainly not, therefore, be expected to agree on subtle and difficult-to-detect temporal changes. If this result is indicative, divergent perspectives on resource trends between scientists and fishers in this region should be expected and need to be addressed by dialogue to avoid 'cognitive conflict', which may inhibit reaching consensus on management decisions.

It is possible that sample sizes are too sparse to detect a relationship which may be very noisy. One cannot conclude that there is no association between biomass and fish catch. But what can be concluded is that no relationship exists that is strong enough to be evident from this level of survey with over 560 fisher interviews on their catch and effort and a range of biomass spanning nearly an order of magnitude. More standardised measurements, a larger sample size and more controlled overlap between UVC and fishermen's habitats, may detect an underlying relationship, as has been achieved in previous tightly controlled studies. But at the coarse, everyday level which informs perceptions and management, the relationship remains hidden due to the complexity of the fisheries, and therefore UVC measured biomass may be of limited relevance for fishers during discussions about fisheries management.

The collinearity between country and the other variables, and the consequent need to test them for additional significance over country, limits the statistical power for relationships to be detected (increases the possibility of a type II error). This is exacerbated by the unbalanced sample in which Tanzania was the only country with a wide range of UVC-biomass. It is only possible to say that 'no relationship was detectable'.

There was a relationship between wealth and hand line catch rate. Combined with the lack of a relationship with UVC-biomass, this suggests that ecologists, poor fishers and wealthier fishers all have different experience and perceptions of the stocks. As these groups may have very different levels of power within communities, it is a challenge to ensure that their diverse knowledge does contribute to resource management.

4.4.2 Comparison with other results

The lack of a relationship between UVC-biomass and catch rates disagrees with previous controlled experiments (Kulbicki 1988; Haggarty and King 2006) but agrees with the experience of Jennings and Polunin (1995) from artisanal fishery data. Mangi and Roberts (2007) also report that over a two-fold range in fish density, no relationship was apparent between UVC measures of fish density and CPUE.

Foale (1998) has questioned whether the knowledge of local artisanal fishers is sufficient to manage local resources, and in a separate paper has highlighted the contrasting worldviews held by international eco-tourist and conservation interests and local users of coral reefs (Foale and Macintyre 2005). This chapter shows how the fact that Western ecologists and local fishers observe different indicators can exacerbate the cognitive conflicts between their perspectives. Western conservationist views informed by coral reef ecology and conservation are likely to be at odds with local understandings, perceptions and relationships with reef ecosystems. This is a governance problem if interventions are imposed based on ecological science with an expectation for them to be consonant with community perceptions.

4.4.3 Conclusion: implications

These results have several implications for management of reef fisheries. First, they support the view that reef fish biomass cannot be inferred from fishery performance, or vice versa, and thus that diverse sources of knowledge are required to understand

and manage complex social-ecological systems like reef fisheries (Olsson et al. 2004). An assessment of reef fishery condition cannot be made based purely on ecological surveys of reef fish. In the situation of very limited data that characterises most coastal areas in the developing world, any available data can become an authoritative account of the status of that ecosystem, but assessments of the ecosystem based only on UVC may incorrectly diagnose or miss issues and are likely to seem alien to local resource users' concerns. Complex systems like fisheries are not uni-dimensional and cannot be described by single variables. Therefore, to maximise understanding of the multiple ecological and social aspects of the system, there is a need for the diverse range of indicators which are monitored by different stakeholders.

Secondly, the results indicate that fishers will not easily perceive declines in fish biomass, as suggested by statistical analysis of catch trends by van Densen (2001) and the very limited agreement between reef ecology trends and perceptions of local stakeholders in Philippines and Indonesia found by Christie (2005). This finding has implications for the ability of local fishers, without additional investment or support for research and monitoring, to conduct adaptive local management which is sensitive to ecological feedbacks.

Thirdly, local resource users have at best, a weak connection to conventional ecology measurements and concepts such as UVC-measured biomass. Socioeconomic factors which have direct influence on catch rates are likely to be of more immediate concern to them. This may create divergent perceptions and governance problems if policy and management are based on reef ecology as informed by UVC, or if communities are devolved management responsibility with the expectation that they will prioritise ecological measurements as sources of information or criteria for success.

From an FK-utility perspective, this calls into question the ability of fishers to perceive trends in the overall fish biomass from their catch rates but it also emphasises the diversity of perspectives and the need for different indicators to be used to understand trends in a fishery. Neither UVC, nor catch-based data, can alone give the complete picture about spatial trends in fish abundance, and their comparison enriches our understanding of the complexity of the system. From a governance perspective, it is important for fishers and scientists to communicate about trends and resolve their divergent perceptions.

This chapter has drawn upon a very extractive process in which contact with fishers was limited to a brief questionnaire which has then been added to a regional scale database. It is difficult in analysis to take account of the details of the fishery. A more participative engagement would have involved more dialogue and feedback with the fishers which might have uncovered more information which would have explained factors driving the trends which were observed.

Chapter 5. Extracting fishers' knowledge for a stock assessment in a Seychelles trap fishery

5.1 Introduction

The merits of incorporating fishers' knowledge (FK) into fisheries management have been widely argued. It can contribute to the knowledge base needed to manage complex systems like fisheries (Berkes and Folke 1998; Johannes et al. 2000), and contributes to a move towards 'co-management' and a more participatory and legitimate form of governance (Jentoft et al. 1998; Gray 2005). However, difficulties arise when it comes to integrating FK with conventional scientific knowledge (SK), for example formal stock assessments, to make a practical contribution to fisheries management. Conventional scientific data does not easily integrate with fishers' knowledge as the two have very different characteristics (Gray 2002; Moller et al. 2004). SK is based on quantitative data, collected from random samples in a repeatable fashion to test specified hypothesis; while fishers' knowledge is based personal experience, perhaps supplemented by information networks, second-hand experience and traditional knowledge.

Extractive engagement with FK aims to formalise it into a common format along with scientific knowledge to allow integration between the two, and to give FK a systematic structure more accessible for scientists and policy makers. Such an approach has been attempted with geographical information systems, fuzzy logic and artificial intelligence (Mackinson and Noettestad 1998; Anuchiracheeva et al. 2003; Garcia-Allut et al. 2003). Holm (2003a) has criticised this approach as it de-contextualises FK, and is therefore contrary to participatory discourses, but Mackinson and Noettestad (1998) suggest that the exercise of formalising FK should foment mutual respect between fishers and scientists and facilitate co-management.

In this chapter, I examine a new example of such an approach which aims to capture FK within a framework of Bayesian statistics and allows it to be integrated with available scientific knowledge. By applying the method to artisanal fisheries in

Seychelles, this process of 'de-contextualisation' is examined to offer insights into the issues surrounding the integration of scientific and fishers' knowledge and their implications for fisheries co-management.

5.1.1 Modelling uncertainty with Bayesian statistics

In Bayesian modelling, parameters are modelled explicitly as probability distributions that describe, given existing information, the probability of each parameter across a range of possible values. Bayes' theorem (Bayes, 1763) allows probability distributions based on prior knowledge (priors) to be combined with data to give an updated probability distribution (posteriors).

Figure 5.1 shows an example of two priors that estimate the probability of different values of a parameter, that are combined to give a posterior of the updated probabilities taking account of the knowledge in both priors. Unlike conventional, statistics, probability distributions can be any shape and are not limited to specific distributions (e.g. normal). The highest point of a probability distribution is the most likely value for that parameter. The narrower the distribution, the more certainty there is over the value. Figure 5.1a shows a relatively uncertain estimate as indicated by the wide spread of the distribution while b suggests two values for the parameter that are similarly probable. The posterior provides a more certain estimate of the parameter value than either of the two priors as there is a narrow peak and a 50% probability that the parameter value lies within a narrow range.

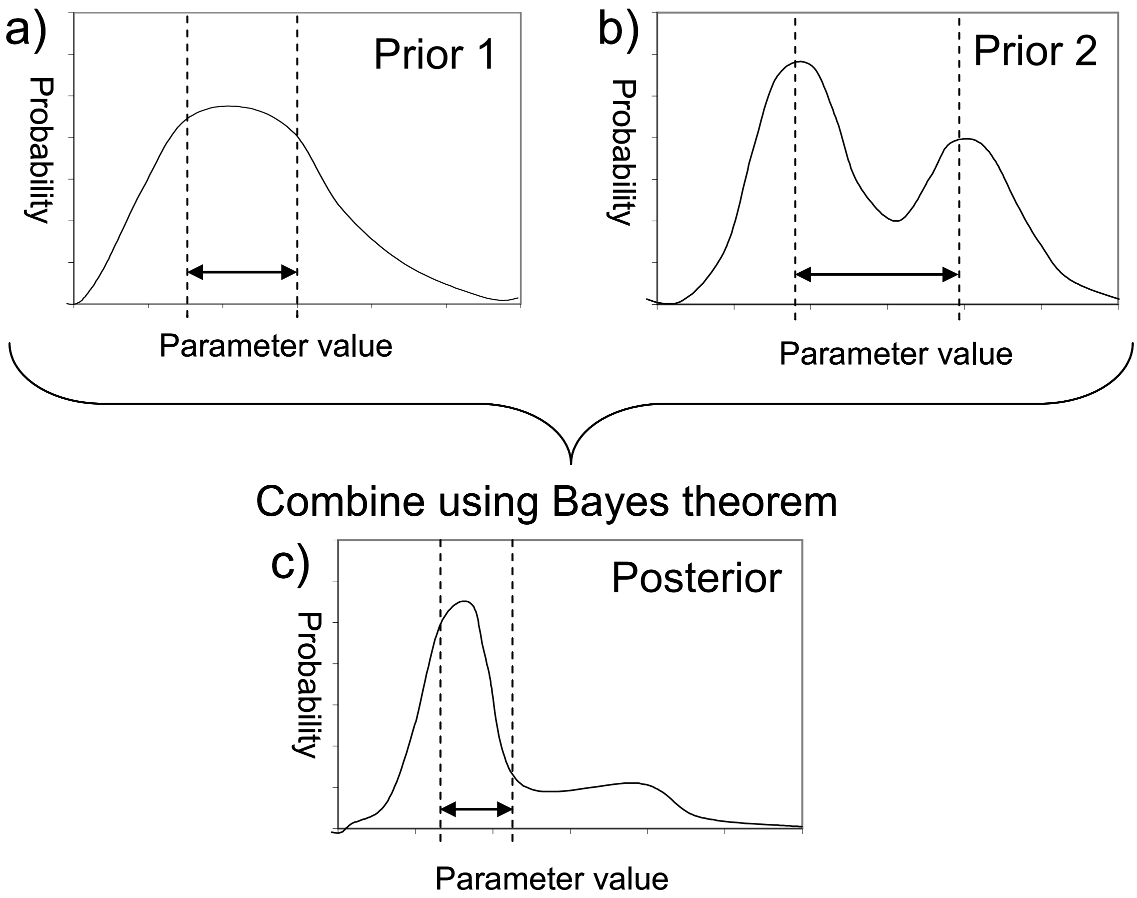


Figure 5.1. Representation of combining prior probability distributions into a posterior distribution using Bayesian methods. Dotted lines enclose 50% of the probability of the parameter value (Adapted fromWalmsley et al. 2005).

Recent improvements in computing power have increased the availability of Bayesian methods and they have become attractive to ecologists and fisheries scientists (Ellison 1996; Punt and Hilborn 1997; McAllister and Kirkwood 1998) due to their explicit treatment of uncertainty and probability. They are attractive for the task of combining different knowledge types as they provide a method for quantitatively taking account of prior beliefs and knowledge.

In this chapter, I examine the ParFish stock assessment interview (PSAI), a methodology which has been explicitly designed to collect FK in a way that allows it to be quantitatively integrated with other data sources, therefore involving fishers in participatory stock assessment and decision-making based on Bayesian statistical methods.

5.1.2 **ParFish Stock Assessment Interview**

The PSAI is part of the ParFish approach and toolkit which includes tools for measurement of stakeholder preferences, integration of scientific data, and communication with stakeholders, and is designed to be implemented as part of an iterative learning cycle. Thus the PSAI studied in this chapter is designed to be used within a participatory framework with extensive feedback and dialogue with resource users. This chapter addresses the way in which ParFish uses FK to assess the current status of the fishery. (The full ParFish toolkit, software and manuals are available at http://p15166578.pureserver.info/fmsp/r8464.htm, although since early 2007 a software problem has prevented the ParFish programme from running, I. Bryceson pers comm.)

The PSAI is designed to derive estimates of fishery model parameters from interviews with fishers. This is repeated with a sample of fishers and the frequency distribution of responses is smoothed to create an estimate of the probability distribution, as shown in Figure 5.2.

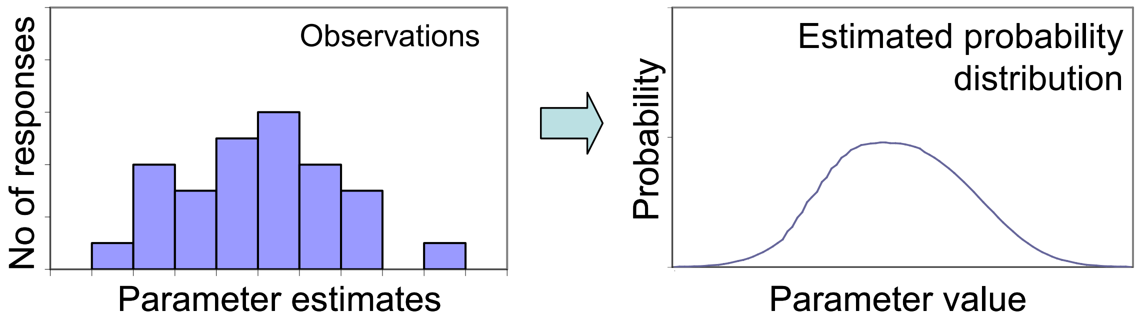


Figure 5.2. Estimating a probability distribution from the frequency distribution of answers to a stock assessment interview question. (Adapted fromWalmsley et al. 2005)

The approach could be applied to any fisheries model structure, but has initially been designed for a simple surplus production model (Graham 1935; Schaefer 1954) which assumes that the dynamics of stock population growth follows a logistic equation:

$$B_{t+1} = B_t + rB_t\left(1 - \frac{B_t}{B_{\text{inf}}}\right) - C_t \qquad \textbf{Equation 5.1}$$

Where B_{inf} is the maximum stock biomass if there was no fishing, B_t is the stock biomass during time period t, r is instantaneous population growth rate and C_t is catch in time t.

Fish catch in time period t is modelled by:

$$C_t = B_t \times f_t \times q \qquad \textbf{Equation 5.2}$$

Where C is catch, f is the units of fishing effort and q is the catchability coefficient which determines what proportion of B can be caught for each unit of effort.

The surplus production model has been misapplied in the past where fisheries have been assumed to be at equilibrium (Hilborn and Walters 1992) but it is useful as an approximation for data-limited situations as it only requires four parameters: virgin biomass (B_{inf}), the population growth rate (r), the catchability coefficient (q) and current biomass (B_{now}). Maximum sustainable yield is achieved when the fishery is at an equilibrium in which the stock is fished down so that $B_{now} = ½ B_{inf}$ (Figure 5.3).

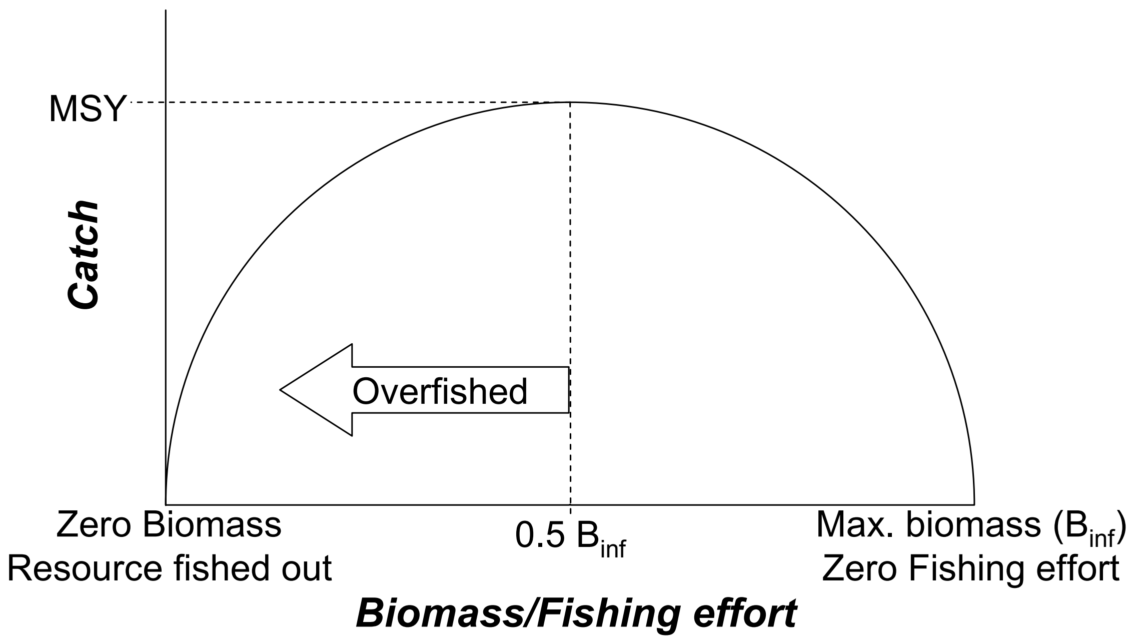


Figure 5.3. Relationship between catch, effort and biomass when the fishery is at equilibrium according to the surplus production model of Schaefer (1954).

The PSAI assumes that fishers' catch rate is proportional to the biomass of fish available, and, therefore, at the biomass for maximum sustainable yield (B_{msy}), catch rate will be half of the catch rate achieved from an unfished stock. Fishers are asked their current catch rate and to estimate what catch rate they would achieve if they fished somewhere no-one had ever fished or which had been left unfished for a very long time. The current status of the fishery is then estimated by the ratio of current and virgin catch rate. If current catch rate is less than half the virgin catch rate, then the stock is assumed to be overfished. The assumptions inherent in this model are that for any given gear and stock, catchability, growth and maximum biomass are fixed parameters. Thus the fisheries system is modelled as a simple interaction of biomass, catch and fishing effort in which biomass is solely a function of fishing, and catch rate is a function of, and proportional to, biomass.

Figure 5.4 shows a conceptual diagram of these linkages between factors which are seen as variables within the cognitive model underlying the PSAI (and most of the World's fisheries management). The thick arrows indicate the total and exclusive cause/effect relationships modelled between the factors.

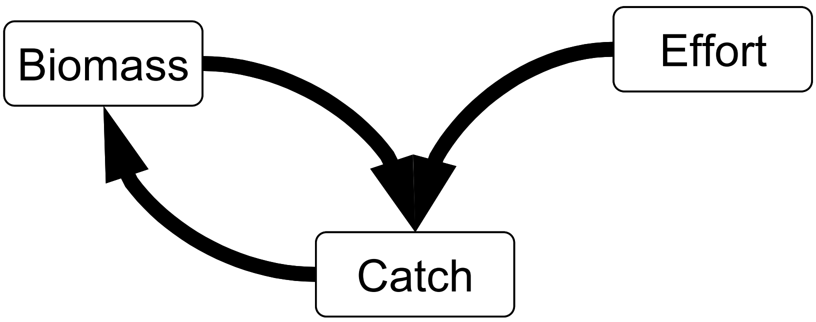


Figure 5.4. A cognitive model of causal relationships between variables as assumed by the surplus production model. Parameters (i.e. factors which are not allowed to vary within the model (e.g. catchability) are not shown.

The value of CPUE as an indicator of biomass has been critiqued in the fisheries literature. Hyperstability (depicted by the dashed, upper line in Figure 5.5) or hyperdepletion (depicted by the lower, dotted line in Figure 5.5) are more typical than proportionality between CPUE and biomass (Hilborn and Walters 1992, see Section 1.4.3).

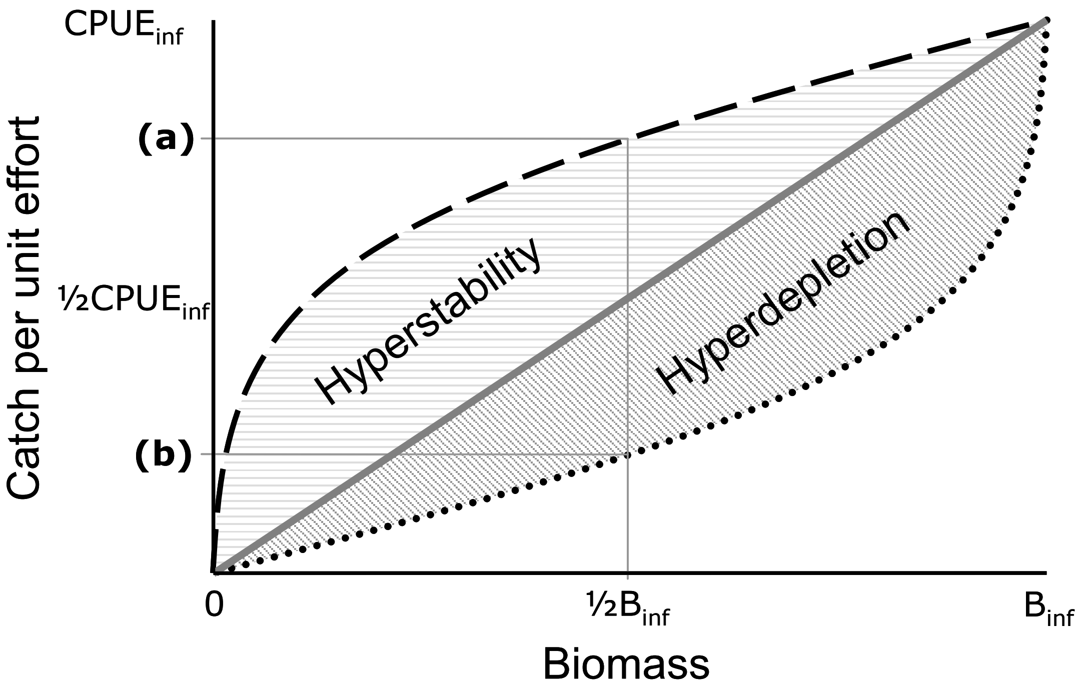


Figure 5.5. Relationships between CPUE and biomass (dashed – hyperstability, solid grey – proportionality, dotted – hyperdepletion) and how they would affect reference points for B_{msy}.

Hyperstability or hyperdepletion would contravene the assumption of the PSAI that catch rate was proportional to biomass and have implications for inference about the status of the population. The surplus production model provides a useful rule of thumb that optimal fishing pressure leads to a B_{now}/B_{inf} of 0.5. The PSAI uses an assumption that CPUE is proportional to biomass to allow the B_{now}/B_{inf} to be estimated by $CPUE_{now}/CPUE_{inf}$. However, if a fishery exhibited CPUE hyperstability, CPUE at $½B_{inf}$ would be greater than ½ $CPUE_{inf}$ (Figure 5.5a). Conversely, if CPUE hyperdepletion was occurring, then a CPUE of less than ½ $CPUE_{inf}$ would be indicative of an optimally exploited fishery (Figure 5.5b).

5.2 Methods

The PSAI was conducted with artisanal trap fishermen in Seychelles (see Chapter 3 for description of sites, fishery and sample). For this analysis, all trap fisher interviews were pooled (n=40). Not all questions were answered by all fishers, so sample sizes for individual questions were between 33-40 and are reported along with each result. The PSAI questions were asked as part of a larger questionnaire (Appendix 1) which also included questions on gears, perceived trends in the fishery during the career of the fisher or the last ten years (whichever was the shortest), whether the stock was 'healthy', the suitability of current total effort levels, and views on management regulations. To investigate how fishers perceived the impact of total effort, they were asked: (a) to estimate how many boats were using traps in their fishing grounds; (b) whether, if double that number of boats were there, it would affect their catch rate; and (c) whether they would catch more if only half that many boats were fishing.

"What factors can affect the population of trap fish?" was asked as an open-ended question. Answers were categorised into ten factors, which were established before the interviews and based on ecological theory and pilot discussions with fishers, (habitat, bleaching, tsunami, immigration, food, impact of land reclamation projects, other types of fishing and illegal gears, recruitment and reproduction and predation) or 'other', and details of the answer were noted. Fishers were then prompted for each of the factors that they had not previously mentioned, and asked if each could affect the population of trap fish. Thus, for each factor, each fisher either (a) volunteered it as a response to the question; (b) agreed that it had an effect when prompted; (c) didn't know whether it had an effect; or (d) thought that it did not affect populations of trap fish. Answers to the hypothetical question about catch rate from a virgin fishery were sometimes given as ranges, in which case the average of the range was used. After this question, fishers were asked how they estimated their response.

Relationships between categorical responses were tested using a Chi squared test in R. Due to the low expected cell counts in some cells, a p-value was simulated from Monte Carlo sampling from 500,000 replicates to give a more robust indication of significance.

5.3 Results

5.3.1 **Quantitative and qualitative perceptions of stock status**

Ninety-five percent of fishers reported current catch rates which were less than half estimated virgin catch rates, indicating (according to the assumptions of the PSAI and the surplus production model) that the fishery was overfished (Figure 5.6). The average ratio was 0.19, and only two fishers reported current catch rates that were more than half of their estimates of virgin catch rate.

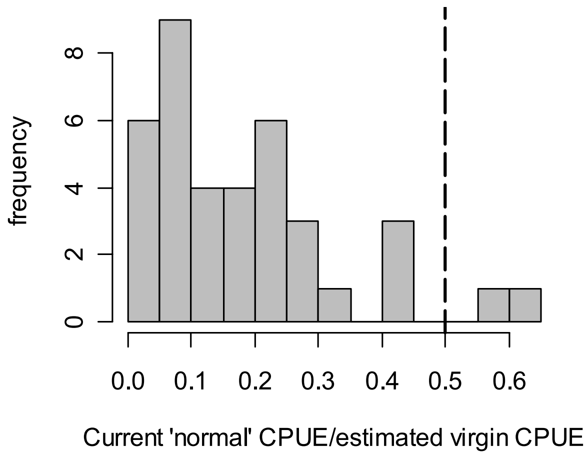


Figure 5.6. Frequency distributions of Seychelles trap fishers' reported current catch rates as a proportion of estimated catch rate from an unfished stock. (n=38). Dotted line indicates the response assumed by PSAI and surplus production model to indicate a fishery being optimally exploited.

Qualitative questions on the state of the fishery indicated that 82% of trap fishers perceived that their catches had declined, but only 37% perceived that current fishing effort was too high, and 58% thought that the condition of stocks 'OK' or 'good' rather than 'unhealthy' (Figure 5.7).

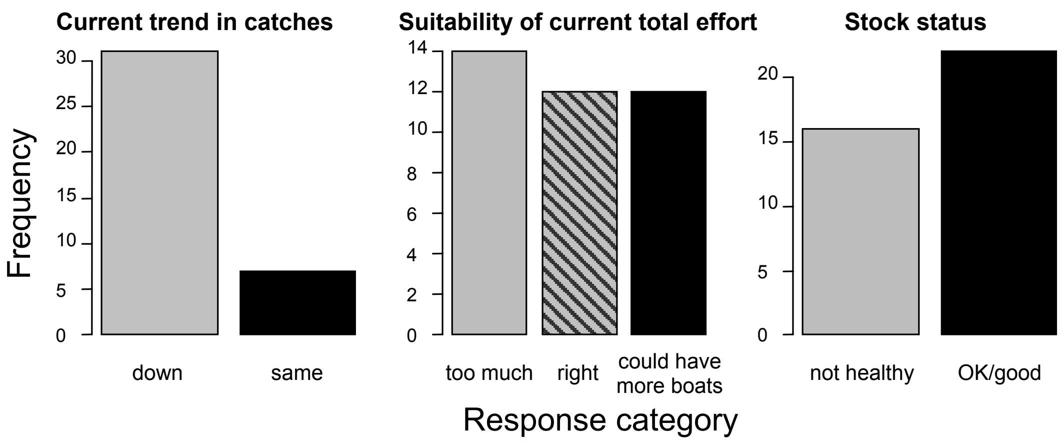


Figure 5.7. Qualitative perceptions of Seychelles trap fishers about target stocks and catches (n=38 for each question).

Responses to questions about the effects of changes in the total effort applied in the fishery on individual catches indicated that 65% of fishers thought their catch rates would be negatively affected by a doubling of effort in the fishery, and 91% of fishers thought their individual catch rates would increase if there were fewer boats fishing in their area (Figure 5.8).

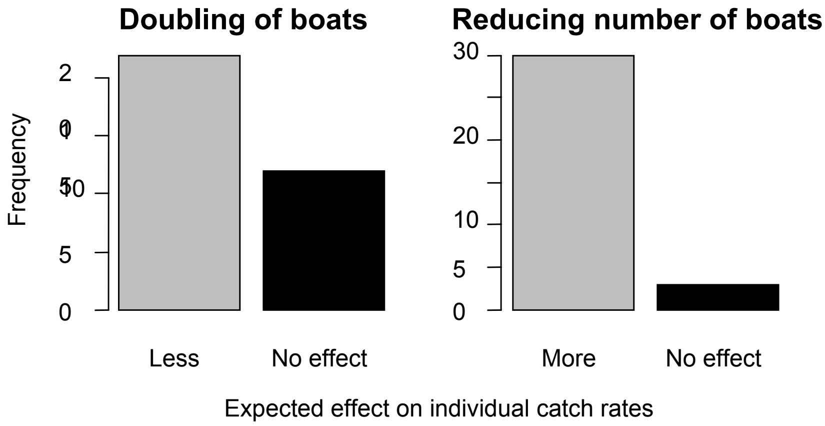


Figure 5.8. Perceived impacts on individual catch rates of changes in the total effort in the fishery (n=34 and 33 respectively)

5.3.2 **Relationships between perception variables**

Chi squared tests on fishers' qualitative perceptions confirmed that there was a relationship between three of the fishers' qualitative perceptions ('health' of the stock; whether effort was too high; and the impact of doubling the number of boats, Table 5.1). Fishers who gave a more optimistic response for one of these questions were more likely to give an optimistic response to the others. The relationship was significant in all 3 cases but only at the 10% level for stock health and whether effort was too high (Table 5.1). Chi-squared tests were not conducted on the impact of less total effort or on perceived stock trends because the counts were too unbalanced and sample sizes were too small for a valid test (minimum expected cell count of 0.5, Dytham 2003).

Table 5.1. Results of chi squared tests for the probability of independence between different qualitative perceptions of trap fish stocks. (p-values are simulated from Monte Carlo test in R with 500,000 replicates)

	Doubling boats lead to less catch?	Current total effort too much?
Stock status healthy?	$X^2 = 6.97$, **p= 0.0216***	$X^2 = 4.63$, p = 0.0707
Current total effort too much?	$X^2 = 10.8$, **p = 0.00171****	

However, there was no relationship between these qualitative perceptions and the ratio of current and virgin catch rate (Figure 5.9).

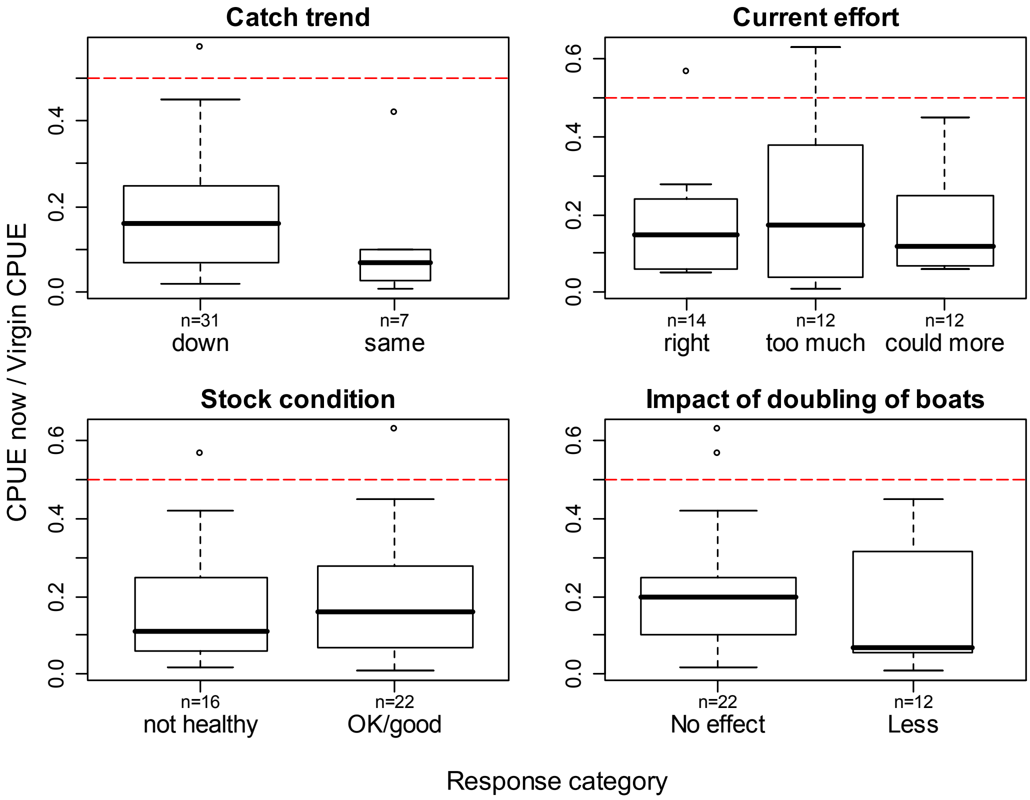


Figure 5.9. Ratio of current to estimated virgin catch rate shown as a function of fishers' qualitative perceptions of the current the state of their trap fisheries. Dotted lines at 0.5, which indicate a fish stock at MSY according to surplus production model assumptions.

5.3.3 **Perceived factors affecting fish stocks**

All of the ten different factors were identified by some fishers as affecting trap fish abundance (Figure 5.10). Nearly half of the interviewed fishermen volunteered habitat and the previous year's tsunami as factors affecting fish, while over 90% of fishermen agreed, when asked, that habitat affected fish abundance. Coral bleaching was volunteered by only 14% of fishermen, although 84% agreed when prompted that it may have an affect. The majority of fishermen also agreed that immigration of fish, food availability, impacts of land reclamation and other fishing gears had effects. The majority (56%) did not agree that trap fishing itself affected populations of trap fish, with only 21% of fishers volunteering this as a factor. A minority of fishermen mentioned supply of recruits or predation.

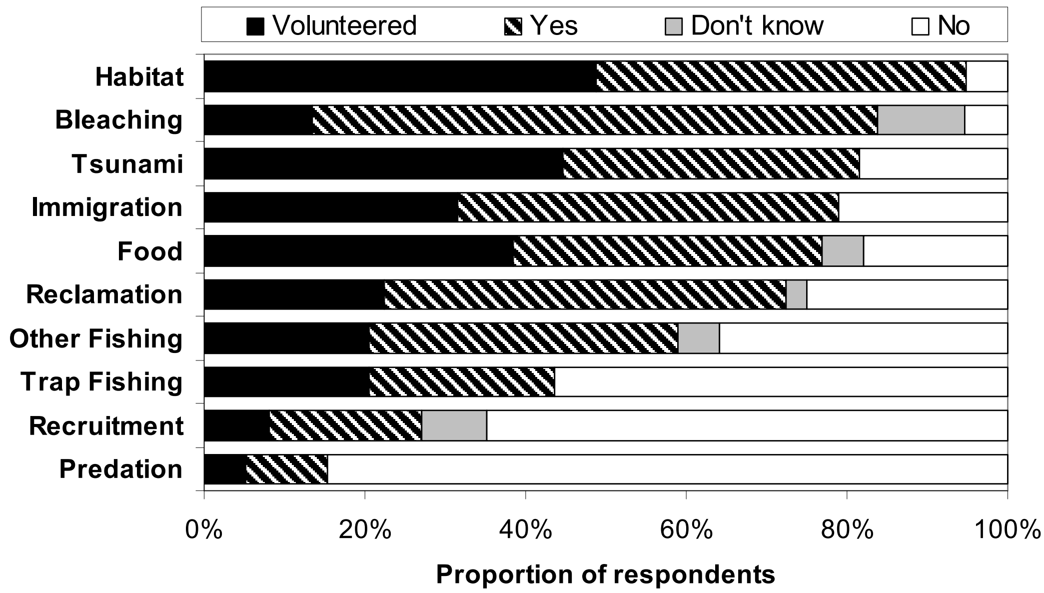


Figure 5.10. Proportion of trap fishers who suggested or agreed that certain factors could affect trap fish abundance. From a sample of 40 trap fishermen, n varied from 37-40 for individual factors.

5.3.4 Qualitative and contextual information from interviews

Many of the impacts of fishing on fish populations mentioned by fishers were related to the manner in which fishing was conducted rather than the total effort. For example, many fishers, on the evidence of mortality of fish in traps, believed that brine-frozen bonito from the commercial tuna fleet were toxic, and that their use as bait in traps had a detrimental effect on fish populations and the habitat. Likewise, fishers perceived that illegal gears (nets and small-meshed, metal traps) affected stocks but that traditional bamboo traps did not.

Seventy-five percent of fishers interviewed had experience diving or snorkelling while others used a looking glass to see under water from the side of the boat. As a result, it is possible for them to have a catch-independent perception of stock abundance. Many did not believe that the decline in catch rates was indicative of declining biomass. One trap fisher described how:

> *I can see the Kordonnyen [Siganus sutor] going around the traps but it doesn't want to go in!*

Fishers described several theories that could account for catch rates declining independently of fish populations.

1. More traps being used means that the same quantity of fish are being shared amongst more traps
2. More trap effort and leaving traps for longer soak periods has helped fish learn to avoid or escape from them
3. Movement of fish into and out of the fishing grounds (in response to food availability, disturbance etc) determines the local abundance available to traps. Hence local fluctuations in fish availability are independent from total population abundance.
4. More traps mean that bait plumes will not be as unique, clear or effective at attracting fish to traps

Figure 5.11 shows a representation of the cognitive model suggested by the trap fisher interviews. Unlike the cognitive model behind the assumptions of PSAI and the surplus production model (Figure 5.4), the relationship between biomass and catch are of limited significance; external factors have greater effect on biomass; and catchability is seen as a variable affected by the type and amount of effort.

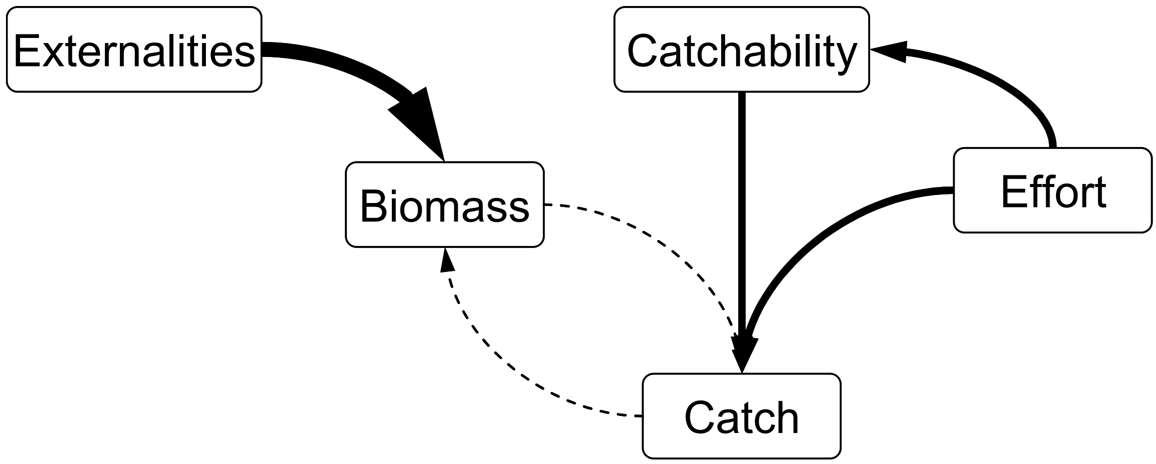


Figure 5.11. A cognitive model of casual relationships between variables based on interviews with fishers. Externalities include habitat, immigration, tsunami, food, temporal variation and coral bleaching

5.4 Discussion

5.4.1 Contradictions in the results

The majority of fishers presented an optimistic view of fisheries, in that they perceived that stocks were healthy and fishing effort was not too high. However, an overwhelming majority reported falling catch rates, and expected a reduction in overall effort to lead to higher catch rates, suggesting that existing effort levels were high enough to suppress individual catches. Two-thirds of interviewees also predicted reduced catches as a result of a doubling of the number of boats in the area. Estimates of stock status based on the ratio of current and virgin catch rates, and the assumptions of the PSAI, suggest an overexploited fishery, in which stock biomass has been fished down well below optimal levels. Thus, fishers' perceptions as indicated from their answers to various questions appeared to be contradictory. Some qualitative views of fishers supported the perception of overfishing, but others appeared to contradict this (Table 5.2).

Table 5.2. Agreement and disagreement between the majority view of fishers according to different questions. Percentages of fishers holding the views in brackets.

Supporting view of overexploitation	Refuting view of overexploitation
• *Current catch rates well below 50% of virgin rates* (mean 19%) • *Catch rates affected by total effort* (65 & 91%) • *Catch rates declining* (82%)	• *Current effort levels not seen as too much* (65%) • *Stock healthy perceived as 'OK' or 'good'* (59%)

Individual fishers' answers to qualitative questions on stock health, current effort level and impacts of increased effort, demonstrated a level of internal consistency as responses to these were related, such that more optimistic responses to one question were more likely to be followed by optimistic responses to the others. However, there was no such consistency between these answers and the questions on virgin and current catch rates, which are used by PSAI as an indicator of fishers' perceptions of the state of the fishery.

At both an individual and aggregate level therefore, answers from fishers are contradictory according to the assumptions of the PSAI (captured in the cognitive model in Figure 5.4). They indicate a perception of the fishery as overexploited and in decline according to some questions (including those used by the PSAI to assess resource state), but as healthy and not suffering from too much effort according to others. Taking account of fishers' cognitive model shown in Figure 5.11, however, can reconcile some of the apparent contradictions in the results.

5.4.2 Assumptions inherent in the PSAI and fisheries science

It was clear from interviews that two key assumptions of the PSAI/Surplus production model are not shared by fishers. First, most fishers did not think that fish biomass was controlled by trap fishing. External and environmental factors were recognised by a majority of fishers as affecting trap fish populations. In those cases where a fisheries-related impact on the stock was perceived, the impact was often due to the qualitative nature of fishing (e.g. gear or bait) rather than the quantitative abundance of effort, as measured by 'f' in scientific fisheries models. Second, fishers did not think that catch rate was proportional to population size, and there was evidence that they perceived a hyperdepletion effect. Many of their explanations about declining catches or high virgin catch rates were related to catchability, rather than biomass, of fish changing in response to fishing effort. This may explain how two-thirds of fishers thought the stock was healthy and that fishing effort was not too high, when eighty-two percent perceived a decline in catch rates.

Fish populations may decline without necessarily indicating the stock is 'unhealthy'. Fish stocks fluctuate, and so at times may quite naturally be increasing or declining in response to environmental changes. Likewise, any increases in fishing effort will cause the population to decline, but this may be within the bounds of sustainable exploitation if a stock has historically been lightly exploited. So, even if the declining catch rate is an indicator of declining biomass, this, in itself, does not necessarily mean that a stock is 'unhealthy'. Furthermore, declining CPUE may not even indicate a decline in biomass, due to hyperdepletion as described above.

There was also an apparent contradiction between the observation of declining CPUE and the impact of effort on the one hand, and, on the other hand, the belief that effort was not too high. Again, it could be argued that a decline per se does not indicate a problem, depending on the historical levels of effort. Additionally, fishers may accept that others' activities impact their own catch rates without seeking to prevent them. Coastal fisheries in Seychelles have traditionally been open to any Seychellois (Jan Robinson, pers comm), and this is reflected in the fact that about ⅔ of interviewed fishers were opposed to limited fishing licences as a management measure (additional survey data). One fisher, in response to the question on whether current effort levels were appropriate, perceived it as a political question and explained its problematic nature by saying.

> *"I choose to be a fisherman, and you choose to be a scientist. I cannot tell you that you cannot be a scientist, nor can anyone tell the fishermen that they cannot be a fisherman." [reconstructed from written interview notes]*

Thus, he did not see it as anyone's right to pass judgement on whether there should be more or less fishers.

Challenging the two key assumptions also sheds light on the contradiction between the results of the PSAI and qualitative perceptions that the stock is healthy and current effort levels are not too high. If fishing effort is not seen as controlling fish biomass, then it is nonsensical to reduce fishing effort in response to a decline in biomass.

In addition, the model assumes (based on attributing a logistic growth model to the population) that optimal exploitation occurs when fishing effort maintains biomass at half of the virgin biomass. This is a useful working model in the absence of data to parameterise more sophisticated models. It is unlikely that fishers would understand or conceive the significance of ½ B_{inf} as a target reference point and in these interviews this was not tested. Given that fishers did not believe in proportionality between catch rate and biomass, it may be interesting in future research to ask fishers how they think the *biomass* in a virgin system would compare to an optimally exploited fishery rather than catch rate as was done here.

Even if fishers accepted that ½ B_{inf} was a target, if they perceived that hyperdepletion existed, they would not conclude that the fishery was overexploited just because catch rates were less than half of those predicted in a virgin fishery (Figure 5.5). There was some evidence for this during the interviews with fishermen. Some fishers (especially those from Praslin) mentioned that fish in a virgin fishing ground would be naïve to traps and therefore very easy to catch. The implication of this is that their estimates of virgin catch-rates would take into account not only the increased abundance of an unfished stock (which the stock assessment interview is interested in) but also the higher catchability of those naïve fish, which may be the main determinant of catch rate. Thus their estimates of virgin catch rate could be very much higher than double current rates, even if they don't believe that virgin biomass would be higher than double the current biomass.

5.4.3 **Interpretations and biases of questions**

The above analysis takes all answers at face value and shows how an alternative cognitive model can reconcile several of the apparent contradictions highlighted in Table 5.2. Other biases may exist related to the material interests of fishermen to avoid rules implementation of rules which would restrict their activities, or to present an impression of poor fortunes, justifying subsidies and state aid. Although I emphasised that I was not from Seychelles Fishing Authority, the nature of my approach (structured questions by an outsider), and my links with SFA would have associated me with the Seychelles government. Resultant biases could include conscious, tactical answers or subconscious rationalisation of opinions which derive from material or political views. For example, the theory of cognitive dissonance (Festinger and Carlsmith 1959) holds that a tension results from holding contradictory views or engaging in actions which are contrary to opinions held, and that people try to reduce cognitive dissonance, for example by rationalising contradictions with further arguments or altering opinions held. Thus a trap fisher is less likely to come to the opinion that trap fishing is a problem than another opinion which is less 'dissonant' with his everyday activities. All the results presented here could be interpreted as merely the conscious or subconscious rationalisation of personal interests. Indeed, suspicion of fishers' vested interests held by scientists (the 'you-would-say-that-wouldn't-you' issue) has been a major barrier to scientists engaging with FK (Johannes et al. 2000). While accepting that interests may have affected the answers, this research demonstrates that the fishers' responses and cognitive models of the fishery were plausible and internally consistent with mental models of the dynamics of the fishery. Again, collaborative research would help to resolve this question and can be used to accommodate and test FK which may otherwise be dismissed as "you-would-say-that-wouldn't-you".

5.4.4 **Mental models of fishers and scientists**

This study examined the PSAI in isolation from the rest of the ParFish toolkit but that toolkit suggests exercises to communicate concepts of fisheries biology to fishermen and notes that depletion experiments (where fishing is concentrated for several days on a discrete area and stock parameters are calculated from the decline in catch rate) can help to convince fishermen that fishing can affect the biomass of fish. However, one might question how easy or desirable it is to displace fishers' cognitive models with that of conventional fisheries science. In discussions about depletion experiments between SFA and expert lobster fishermen, the issue of variable catchability nullified the validity of a depletion experiment in the eyes of the fishers (pers obs.). Maurstad (2000) warns against the possibility of persuading fishers to adopt flawed scientific assertions. In this case, fishers suggested various extensions of the simple cognitive model, for example, the existence of hyperdepletion, the possibility of fish learning behaviour, and the importance of habitat all of which are plausible according to formal scientific literature (Hilborn and Walters 1992; Ozbilgin and Glass 2004; Askey et al. 2006). If these factors were significant it would be disadvantageous to overrule their knowledge by persuading them to adopt the simpler cognitive model. Johannes and Neis (2007) acknowledge that fishers 'excuses' for declining catches are sometimes turn out to be right and Haggan and Neis (Haggan and Neis 2007) point out that many previously held assumptions of fisheries science have turned out to be incorrect, some identified by fishers.

Why do fisheries scientists settle for such a simple model of reality as depicted in Figure 5.4? In order to do quantitative fisheries science, those variables which are not under the control of the fishery manager (for example environmental influences) or are difficult to quantify (subtle details of the way in which different gears are used, natural mortality rates) have to be pragmatically put to one side. Quantitative models can then be used with variables which can be estimated (biomass, effort, catch), and which identify issues that are meaningful and actionable for fishery managers. Given the benefits of quantitative models (simulation, quantitative scientific advice, generation and monitoring of reference points, mathematical elegance) this approach is both sensible and necessary, but it is unsurprising if stakeholders critique the resultant simplified models as having little relevance to the real world. The habit of focussing on these measurable and manageable parameters may also lead fisheries scientists into believing the simple cognitive model, so that pragmatically chosen variables are those which spring to mind when trying to understand the dynamics of the fishery. Fishermen on the other hand, who are concerned precisely with fluctuations and subtle details of the fishery, are perhaps in a good position to remind fisheries biologists when hard-to-measure variables are in fact important.

Adams et al. (2003) suggest that identifying ‘cognitive conflicts’ is necessary for management of common pool resources. The identification of cognitive conflicts allows stakeholders to focus their discussion on specific genuine disagreements. If these cannot be resolved, there is a natural jumping-off point for collaborative research to test alternative hypotheses and develop the cognitive model used. This approach has been shown to be effective in Canadian commercial fisheries to help fishers and scientists to reach a consensus on disputed assumptions as well as improve scientific research (Stanley and Rice 2007). In Seychelles, this approach was taken in the design of a spiny lobster survey which was initially planned as a depletion experiment. The concerns of experienced lobster fishers were taken on board so that the survey took account of behavioural changes and effects of moon phase on catchability. In comparison to previous sea cucumber surveys in which fishers were not respected as equal research partners, fishers respected the results and a consensus developed around the validity of the survey (pers obs.).

I analyse the PSAI here in isolation from its intended place as part of a participatory process to illustrate some of the issues around extractive FK research. However some of the findings could be relevant for development of the ParFish approach. For example, it could be extended to include cognitive maps of fishers with alternative models to reflect the cognitive understanding of fishers which could be assessed in the light of empirical data as it becomes available. The ParFish framework of an iterative cycle of participatory research, analysis and then feedback to stakeholders, could be extended to allow cognitive models to be collected. However, this would require data to parameterise more complex models and further programming, and so would not be available as a complete and user-friendly toolkit in the way that this simple version is.

5.5 Conclusion

Perceptions of fishers as measured during this study by responses to different questions appear to be contradictory at both and individual and aggregate level. This is particularly apparent between quantitative answers which are interpreted by the PSAI as indicating the status of the resource, and qualitative assessments of stock status. However, this inconsistency can be reconciled by challenging the underlying assumptions of the model used. The method collects views of fishers in a quantitative form, and processes them through a mental model taken *a prori* from the assumptions of the surplus production model, and which is at odds with most fishers' understandings. In this regard, the PSAI as applied here, is extractive, because FK is extracted and used ex-situ within another conceptual framework. A participative approach would allow negotiation about the cognitive model used to interpret knowledge collected.

This example illustrates how fishermen (either through rationalisation of their preferred perspective or from their objective experiences or a combination of both), in contrast to most fisheries management actors, do not see catch declines necessarily as indicating stock declines due to their more complex understanding of the fishery. More participative approaches, for example collaborative research, appears to be necessary to meaningfully incorporate FK into quantitative fisheries science.

Chapter 6. Extracting fishers' knowledge of short-term trends in the North-Sea demersal fishery

6.1 Introduction

In contrast to the previous three chapters, this chapter examines engagement with FK in a developed-world, industrialised fishery. By examining the North Sea Stocks Survey (NSSS) I aim to address each of the four research themes introduced in Chapter 1: Categories of knowledge; How FK relates to science; Approaches to engaging FK; and the FK-utility and governance perspectives. The first two themes are addressed by examining the categories of knowledge that are engaged by the NSSS and whether this FK is congruent with scientific knowledge. The NSSS is an example of an extractive approach to FK-engagement, in which FK is collected and then analysed and used *ex-situ*. It therefore allows me to address the third research theme by examining the strengths and weaknesses of extractive approaches. To address the fourth theme, I will analyse the contribution of the NSSS from both the FK-utility and governance perspectives: I will ask how the NSSS contributes to the knowledge base and management of North Sea fisheries, and how it contributes to the legitimacy, trust in, and democratic credentials of fisheries stock assessment and management of North Sea fisheries. First, I briefly describe the structures and institutions responsible for the science and management of North Sea demersal fisheries, which provide the context for the NSSS.

North Sea fisheries are managed under the European Union's Common Fisheries Policy (CFP), as system which has been largely unsuccessful at maintaining either healthy stocks or economically rewarding fisheries (Daw and Gray 2005). The

International Council for the Exploration of the Seas (ICES) is responsible for stock assessments and scientific advice. Assessments are produced by the Working Group for the North Sea and Skagerrak (WGNSSK) and then critiqued and summarised into advice for the European Commission (hearafter 'the Commission') by the Advisory Committee for Fisheries Management (ACFM). The Commission then draws up management proposals which are finally negotiated by a council of European fisheries ministers ('the Council'), which meets each December.

North Sea cod (*Gadus morhua*) became the focus of North Sea fisheries management efforts in the early 2000s as it reached the lowest biomass recorded since assessments began in the 1960s (ICES 2006a), and was subject to a 'recovery plan' from 2004. This plan included catch limits, gear rules and limitations of effort (days at sea) for all demersal fisheries thought to catch cod either as a target species or as a bycatch. Despite these measures, which were painful and unpopular with the fishing industry, cod did not recovered as planned (Anonymous 2007).

Historically, there were few inputs to the management process from stakeholders, but recent reforms of the CFP have recognised a need for greater engagement with stakeholders to improve both the information base for decision-making and the legitimacy of management (CEC 2000; CEC 2002). These reforms included the establishment of stakeholder-led Regional Advisory Councils (RACs). The North Sea RAC (NSRAC) was formed in 2004 and has held regular meetings, working groups and organised a multi-stakeholder symposium on cod recovery (Anonymous 2007). Although RACs were formed with the intention of allowing stakeholder views to be voiced, they have shown an ability and desire to become involved in the creation of knowledge and are likely to promote a science which involves FK (Astorkiza et al. 2006). For example, in addition to the cod symposium, which was attended by international scientists as well as fishers, NSRAC has submitted several research proposals and commissioned their own research on the socioeconomics of fisheries.

Several initiatives associated with North Sea fishery aimed to make use of data and knowledge from the fishing industry, including discard sampling, voluntary logbook schemes, pre-assessment meetings and collaborative research on commercial vessels (ICES/NSCFP 2003; Bell et al. 2004). The NSSS was jointly initiated by scientists and fishers' organisations (FOs) in 2000 to collect fishers' perceptions of stock trends and communicate them to assessment scientists. It is unusual for being international, and for being a structured project to collect fishers' own perceptions rather than use the industry as a source of data for scientific analysis. It was developed in response to perceived disagreements between the two groups, and in recognition of uncertainties in the stock assessments. The NSSS questionnaire was distributed by FOs in Denmark, Belgium, Netherlands, Scotland and England in each national language every year up to 2006 (the year of this study). The anonymous questionnaire contained closed questions about changes in the abundance and discards of 8 species, and several economic indicators compared to the previous year on a 5-point scale (Much less, Less, Same, More, Much more). Finally a comment box allowed respondents to add any further information or views (see Appendix 3).

6.2 Methods

To assess how fishers view the NSSS, participants from the English National Federation of Fishermen's Organisations (NFFO) and the Scottish Fishermen's Federation (SFF) were contacted by distributing requests for their contact details along with the NSSS. NFFO and SFF members provided 65 of 249 returns of the 2006 survey, and 57% of these volunteered for interviews. Seventeen Scottish and 6 English fishers were interviewed, in ports from Shetland to Yorkshire, although 43% were from Northeast Scotland. Most fishers in the sample were involved with their representative organisation (91% sometimes attending meetings) and 35% actually sat on executives or attended European-level meetings. Table 6.1 shows the gear types represented by the interviewed fishers.

Table 6.1. Gear types of interviewed fishers

Main Gear	No. Interviewees
Creels	1
Fish trawl	6
Pair trawl	1
Prawn	9
Prawn/Fish	4
Seine	2

Telephone (and one face-to-face) interviews were conducted between 11th July and 20th August 2006, and lasted between 30 and 80 minutes dependent on the availability and interest of the interviewee. Interviews were based around the open-ended questions in Appendix 4 but conducted as semi-structured conversations to gain an insight into perceptions and opinions of fishers and to give them the opportunity to elaborate on topics which they felt were important (Bunce et al. 2000). Interviewees were asked their opinions on the NSSS, the status of cod, whiting and *Nephrops* stocks this year compared to 2005, 2000 and 20 years before, and the work of fisheries scientists and their interactions with fishers. Interviews were recorded, transcribed and thematically coded using Nvivo 7 software. Coding themes were allowed to emerge inductively from the data without prior assumptions about categories.

Quantitative estimates of percentage change in abundance offered during interviews were compared with individual fishers' semi-quantitative NSSS answers. To facilitate this comparison, Scottish NSSS questionnaire forms were individually numbered, and interviewees were requested the number on their form. In England, fishers' contact details were simply returned along with their completed NSSS questionnaires. Interviewees' estimates of current cod abundance as a proportion of that in the years 2000 and the 1980s were also compared with the latest scientific stock assessment (ICES 2006a).

To study the context and contribution of the NSSS, 7 scientific and stakeholder meetings were observed (Table 2.1). Qualitative interviews were also conducted with fishers' representatives (n=5) and scientists (n=11) covering their perceptions of the NSSS, the way it is used, the relationship between fishers and scientists and the utility and availability of FK for management.

6.3 Results

6.3.1 **Answer strategies of fishers**

There was variability in the way in which fishers chose their responses to the NSSS questionnaire. Only two fishers mentioned briefly consulting their records. Just over half of fishers based their answers on general perceptions while a third of interviewees spoke specifically about their memories of catches or landings (Figure 6.1):

> *Well I just thought about it, and says well this time last year we were maybe landing 1000 boxes and this time we're maybe landing 1200 so it would be 'slightly more'… it's all in my memory*

Eighty two percent of the interviewees completed the survey based only on their own experience (Figure 6.1), but notable exceptions incorporated information from other boats' catches, producer organisations (POs) and markets in order to formulate their opinions, especially if their own practices limited their ability to perceive changes in abundance:

> *I've answered different questions in different ways. I've answered the cod question based on my own fishing, I've answered the haddock question due to what the pair trawlers were landing at the start of the year and due to what my haddock buyer has been seeing and I answered the whiting question with information that I've had back from the PO*

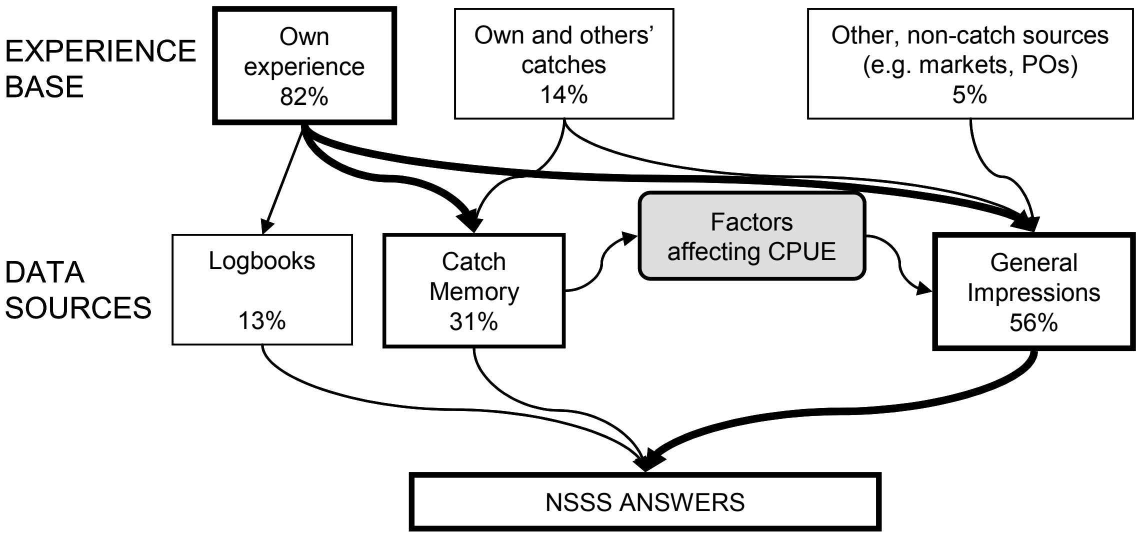


Figure 6.1. Sources of information contributing to NSSS answers. Thick arrows indicate commonest routes according to interviews. Percentages show proportions of interviewees citing each different experience base (n=21) and data source (n=16).

Although the NSSS questionnaire asked for "catches not landings" the majority of fishers answered on the basis of their general impressions (Figure 6.1) so it was not possible to discern whether answers related to landings, catch per unit effort (CPUE) including discards or their general perception of the stock size resulting from other information sources. Several fishers commented that various factors affected the relationship between stock size and catches, indicating that trends in catch rates were not thought to be indicative of stock abundance. Such factors included the new system of registration of fish buyers and sellers (which clamped down on illegal landings); increasing fuel prices; and enforcement of strict fish bycatch limits for prawn boats, all of which had reportedly had a large impact on the targeting behaviour of the fishers, and subsequently on their catch rates.

> *…it's probably not a good year to do a survey 'cause there's been so much change… [Larger] boats like our own … have been trying different things and trying to change our mode of fishing*
>
> *We haven't caught so much tonnage of prawn this year but it's not because we couldn't, it's because we've been looking for better prawns.*

6.3.2 Agreement between interview and NSSS results

Responses from individual fishers during the interviews were compared to the answers they gave on their NSSS forms. Figure 6.2 shows the percentage changes offered by skippers for cod, whiting and Nephrops during interviews plotted against the answers they gave on their NSSS forms (none of the interviewees had checked 'much less' for any of these species on their NSSS form). There was some inconsistency between the NSSS and the answers given in interview. For example, four fishers who checked 'More' and two who checked 'Less' for the NSSS, reported 0% increase during the interview; while 3 fishers who checked 'No Change' on the NSSS indicated changes during the interview (50% increase and a 0-25% and 25% decrease). NSSS responses of 'more' included two extreme outliers of 533 and 1000% increases during the interview. Both of these resulted from relating current catches of whiting and cod to extremely low levels in the previous year. Thus a very high percentage change resulted from a limited absolute change.

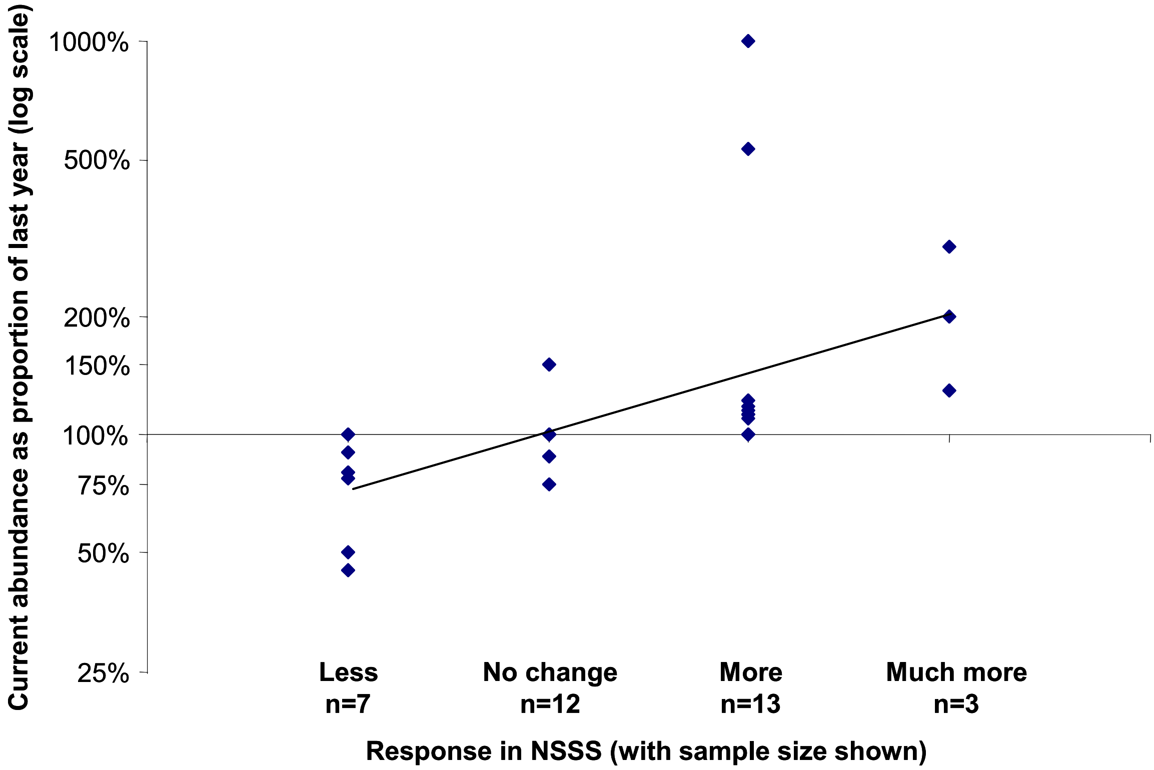


Figure 6.2. Fishers' quantitative estimates of abundance changes of cod, whiting and Nephrops from interviews compared with their responses to abundance questions in the NSSS

Although there was some overlap in reported percentage change between each of the categories, there was a very highly significant correlation between the answers given in the NSSS questionnaire and the % change estimated during interviews (Spearman's coefficient 0.780, $p<0.001$). When the NSSS responses were represented as numbers (2,3,4,5 for less, no change, more and much more respectively) the correlation between the NSSS response and the percentage change was not significant ($r^2=0.324$, $p=0.058$), but the correlation between the NSSS response and $\log_{10}$ (percentage change) was very significant ($r^2=0.543$, $p=0.001$, Figure 6.2), suggesting that the scale used in the NSSS may be best interpreted as a log scale.

6.3.3 **Reliability of the survey**

The reliability of the survey answers, and whether there was a temptation for skippers to inflate their answers, was discussed in 87% of interviews. There were basically three views expressed as shown in Table 6.2.

Table 6.2. Percentages of respondents with different views on the reliability of the survey

Opinion on reliability of the survey	Percentage of respondents **(n=20)***
1. Answers are generally reliable and honest	85%
2. Some respondents may inflate answers	40%
3. Many answers may be inflated	15%

* Some respondents gave both answers 1 and 2 leading to a total of over 100%

Most fishers conceded that a minority of respondents to the NSSS may be tempted to inflate perceptions of stocks but believed the majority would fill it in honestly:

> *…you might get the odd one thinking, "oh we'll bump the stocks up to this and that" but I think it'll only be the odd one so I think overall the majority will be from the heart*

Interviewees claimed that the survey was, on the whole, reliable, supported their assertions with three different reasons:

a) the futility of trying to artificially improve the perception of stocks as it would not be believed:

> *…that'll show up straight away, if you're saying there's loads of cod and other fishermen are saying there's not and the scientists are saying there's not. They're gonna notice!*

b) the fact that the fishers who participated in the NSSS would have been the most conscientious fishers. Those more likely to exaggerate catches would not be likely to engage with the survey:

> *most of that fishermen that's no filled it in's just, they're just ignoring it. But those who've filled it in have done it for the right reason.*

c) that the culture of the industry had a greater appreciation of issues of sustainability than before, through a change in perception of individual fishers and the exit (through decommissioning) of skippers who did not have a long-term outlook for the industry. The remaining fishers had significant investments and were looking for a sustainable future:

> *we do know now, it's been drummed in and we all know – we're not daft – that we have had overfishing in the past*

> *…the fishermen that are left at sea now are pretty conscientious I think …and they wouldn't be putting in something that's not [true].*

> *we're not just wanting what we can get for this year and next year, we need to know there's something there 15, 20 years down the line*

Contrary to the responses above, one interviewee expected some systematic inflation in the fishers' answers to be the norm, and also expected this to be taken into account by the users of the data:

> *they would already interpret a certain amount of bulling up surely … you would expect fishermen to be positive where you would expect scientists to be negative. I think the two would even themselves out*

Even if NSSS respondents report their perceptions honestly, some interviewees suggested reasons why they may struggle to perceive trends. For example, several prawn fishers said that they did not have a clear perception of fish stocks because they don't catch much fish due to bycatch regulations:

> *Well just with the small drops of fish you couldnae really tell because they're catching that little fish nowadays*

The weather was also seen to affect fishers' perception of the stock:

> *[if] you spent the whole of January fishing on the east [because of weather] it look's like the monks have gone but it's just you canna go where the monks is*

Interviewees also commented on the difficulty of observing recruitment with large mesh sizes:

> *With the likes of whiting, of haddock, our mesh size is too big to tell if there's nae small ones on the grounds.*

One industry interviewee thought the limited days available to fishers undermined fishers' ability to explore grounds and perceive trends in the stock:

> *…any experimental fishery isn't done now because of the restriction on being out there.*

6.3.4 **Fishers' views on the NSSS**

6.3.4.1 General impressions of the survey design

The design of the NSSS questionnaire was assessed by 97% of the interviewees. Fifty-nine per cent used phrases to express their approval of the questionnaire:

> *I think it's a dish for a dish, simple and to the point and that's the whole idea of it*

The current level of detail was seen to be appropriate, and several interviewees described the potential pitfall of increasing the complexity or scope of the survey as dissuading fishers from completing it.

> *…any more detail and the fishermen will maybe lose sight of what they're trying to fill in*

On the other hand, 23% suggested the survey was not detailed enough:

> *the survey was kinda vague*

Other individuals made specific suggestions for improvements to the survey, such as including information on discards as a percentage of catch rather than a comparison with last year; more details on economics; observations of total fishing effort on the ground; more detailed descriptions of gear characteristics; and observations on pollution. For example, on gear characteristics, one fisher said:

> *we did a lot of pair trawling, you could split that up maybe in your categories because in a pair trawl [working soft bottoms] you'll probably target different species than you would in a hard ground trawl*

No interviewees expressed difficulty with any of the questions in the survey, or thought that the survey was already too detailed.

The spatial resolution of the survey was discussed by 61% of interviewees. Half of these thought that the size of the zones of the North Sea used to give spatially explicit answers were too coarse to depict patterns in fishing activity or stock trends (particularly sizes of fish caught). They indicated detailed spatial knowledge which was not captured by the survey:

> *Our area is area 4 on the map. It's a hell of a big gap. I mean fishermen 5 miles apart can have a totally different opinion because they might have a lot of whitings just 5 mile away and we might not see one so I'll fill in saying "whitings are extinct" and another fisherman will say "the sea's full of whitings' y'know."*

> *…it's the same with the haddock, smaller ones are inshore and the bigger ones are more offshore*

The questionnaire also did not allow respondents to report different trends which occurred in different areas. For example, a fisher observing very different trends in cod in the northern and southern North Sea has to choose one single response for cod. Respondents reported opposing trends from different areas:

> *…like that's the sort of way with cod, small ones seem to be south and the bigger ones north*

> *… you could give a better answer if it was split up a bit more, maybe the similar questions for each area*

6.3.4.2 Awareness of the use of the survey

There were varying levels of awareness of how the NSSS was used. Of the 96% of interviewees who commented on this question, 59% indicated that they didn't really know what happened with the results of the survey, while 32% specifically stated that they didn't receive feedback on the results of the survey. Only two fishers (9%) made vague reference to feedback from the survey:

> *Erm I think we do get a…, once it's been digested we get the consensus of everybody that's filled it in*

> *I did read it but I've forgotten*

All 13 fishers who offered views or guesses on how the survey was used suggested that it was to get an overall impression of fishers' views for the use of scientists, fishers' representatives, or to feed into a stock assessment system. However, the language of these responses on the use of the NSSS reflected a level of uncertainty.

> *I just presume that it went into the pot and then it was discussed at meetings etc*

I assume it's fed into a system for, for the scientists, I'm not sure. I know it gets fed into a system

One respondent, who held a senior position in an FO, was confident that UK and Dutch scientists used the survey, although he stated it was "probably" not used enough.

6.3.4.3 Motivations to take part in the NSSS

Eighty three percent of interviewees described their motivation to take part in the NSSS as based on a general expectation that the survey should benefit fishers. 63% linked these benefits to providing information and improving fisheries science:

…if we're going to be run by the science, we'd like the science to be as accurate as possible

…the more information you get the better it is for us in the long run

Fifty eight percent specifically mentioned the hope or expectation that the provision of data would be rewarded by more favourable management decisions for the industry:

I've answered the questions as good as I can because I want things done for the good of the fishing and for the good of the industry

Thirty two percent felt a sense of duty or imperative to take part in the survey for the sake of the industry or from loyalty to the FOs promoting the survey:

I think it's our duty to put these surveys in and answer them as honestly as we can

I'm an [FO] member and I support what the [FO] is doing

6.3.4.4 Disincentives to take part in the NSSS

Factors dissuading participation in the survey was discussed by 87% of respondents. A lack of tangible improvements in decisions and scepticism about the management system, was cited by 55% as the main factor discouraging fishers from participating, making a direct link between unfavourable decisions and lack of participation:

> *I think there's definitely a conception now of fishermen thinking, "Och to hell with that what we filling that in for? Fill it in every year and they keep cutting our quotas."*

Mistrust of scientists and the management system was thought by 30% to be a major barrier to persuading fishermen to be involved. This was expressed in terms of a fear that the NSSS results could have negative consequences:

> *there's always the fear – and this is maybe the reason why some fishermen don't fill it in – that the information would be used against you*

or a more general mistrust of scientists:

> *It's just the anti-science sort of feeling … "you shouldn't cooperate with the enemy"*

Reasons for this suspicion include previous bad experience of providing discard data and the perception that fishers were penalised as a result. One interviewee also suggested that some boats would be more reluctant to participate because they relied on cod which would be portrayed poorly by the NSSS:

> *…it's the big boats that's catching cod. ... I think the surveys not returned will be the big boats and its most of the [smaller] prawn boats will put them back.*

60% of those discussing disincentives mentioned the practical inconvenience of filling in the survey, and this was often brought up when interviewees were discussing potential elaborations of the survey design.

In the same way that loyalty to FOs was an incentive to take part, two interviewees suggested that the level of participation in the survey was affected by lack of support for the FOs involved:

> *some that it's been posted to and they haven't bothered with it. Because some fishermen are a little bit pissed off with the [FO]'s lack of bite on some policies*

> *I'm really surprised [the return rate of NSSS questionnaires] was as low as that. See there was a lot of internal strife inside [FO]*

6.3.5 **Trends and process knowledge of fishers and scientists**

6.3.5.1 Perceptions of long term trends

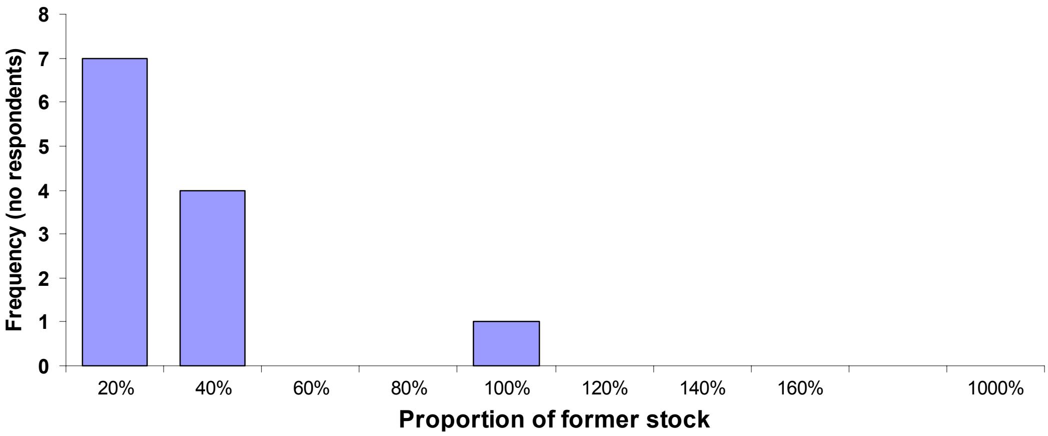


Figure 6.3. Fishers' perceptions of current cod stock as a proportion of the stock '20 years ago'

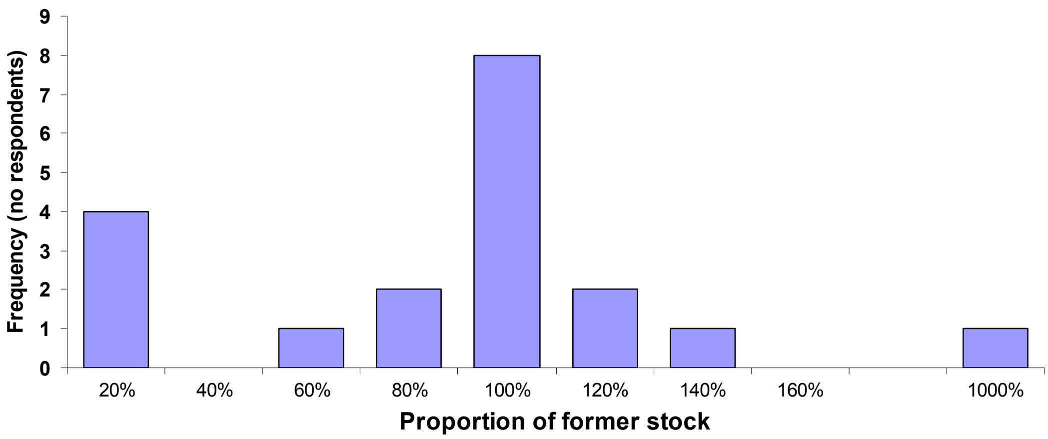


Figure 6.4. Fishers' perceptions of current cod stock as a proportion of the stock in 2000

Table 6.3. Estimates of current and previous biomass and catch levels of cod in the North Sea, Eastern Channel and Skagerrak from the 2006 ACFM report

Time period		Biomass (tonnes)	Catch (tonnes)
Stock 20 years ago (mean '83-'87)		625,555	298,911
Stock 6 years ago (mean 1999-2001)		228,461	104,406
Most recent estimate (2005 or 2006 for SSB)		12,8231	54,745
Most recent estimate as a proportion of:	mean '83-'87	20%	18%
	mean 1999-2001	56%	52%

Interviews included quantitative questions on the percentage changes of main species over longer timescales (6 and 10 years) than the NSSS includes (1 year). Figures Figure 6.4 and Figure 6.5 show the distribution of fishers' perception of cod abundance relative to previous times. The 12 interviewees who gave opinions on the current status of cod stocks compared to "20 years ago" or "back in the 80s" mostly fell within a similar range as the scientific estimate. All but one estimated that the stock was less than 30% of 20 years ago, and 7 estimated that stocks were less than 20% (Figure 6.3). One interviewee perceived cod stocks as being the same as 20 years ago but he qualified this answer questioning the representativeness of his perception and citing contradictory evidence:

> *…but then 20 years ago I didn't have the experience that I've got now and we're not a whitefish boat as such. You don't see them [cod boats] now. So*

that speaks for itself that the cod aren't there or they would still be chasing it.

Recent scientific assessments of cod biomass and catches as a proportion of the mid 1980s (Table 6.3) are similar to those of interviewed fishers at 20% (Figure 6.3), but there is less accord between scientific and interviewees' perception of the stock now compared to six years ago (Figure 6.4). The ACFM analysis suggests that stocks are about half of that around 2000. 42% of interviewees did not perceive a significant change in cod abundance, while four thought that stocks were less than 20% of those in 2000 (Figure 6.4). Four perceived an increase since 2000, although one of these (1000% increase) was a shellfish fisherman reporting specifically on recent and unusual abundance of young cod in his creels (50-80 per day rather than 5-8 back in 2000).

6.3.5.2 Perceptions of ecological processes

Although no questions on ecological knowledge were included in the semi-structured interview, many fishers spoke about their perception of changes in ecology and understandings of factors driving stock populations. This was often notably at odds with the views implicit in the Commission's attempts to reduce fishing effort to allow cod recovery. Some interviewees apparently agreed that overfishing may have occurred in the past but many highlighted other factors:

Yes, I have my hand up that there's a shortage of cod, there's no question of that. But why is there not a shortage on par with all other species? Something has happened climatically or something like that.

Interviewees doubted that fishing mortality was preventing cod recovery, as they had observed a marked decline in fishing especially on some banks:

> *…they can’t blame the boats now Tim. There’s no boats to be doing no damage. I can go weeks at sea and hardly see a boat. So they canna blame overfishing. To me they could shut the whole North Sea down and the cod won’t come back.*

Several fishers described individual sites that had been productive fishing grounds in the past, but were now barren areas, in which nobody fished and where there were still no fish. Links were made between climate, seal predation, food supply and, on one occasion, other parts of the fleet.

Although interviewees agreed that cod had experienced long term decline, implications of this for management again differed from Commission policy with a more historical perspective taken by some fishers. Cycles of abundance were seen as natural, and not something which should lead to further controls on the industry.

> *…if the cod stopped that wouldnae surprise me either because. This is not a new thing…80-90 foot wooden sailing ships…sailed from Britain to Iceland for cod…more than 100 years ago. Now you didn’t do that ‘cause there was cod here ... And then in recent history, my father is 71 now, he started in the 60s and he could tell you and any other fisherman that age could tell you there were no cod here at that time either. What they fished at that time was whiting, because there was no cod here*

Haddock and Nephrops stocks were in good health and lucrative new fisheries for squid and red mullet had developed. Nephrops were thought to have increased their range and new grounds were opening up.

6.3.6 Fishers' perceptions on fisheries science and management

Interviewees also often spontaneously offered their views on the current system of fisheries science, advice and policy, ranging from questions or critiques about scientific investigations, to statements about problems of the political system in addressing their needs. The relationship with science was variable amongst interviewees. Even amongst this sample of the most engaged of fishers, many still disagreed or had deep rooted scepticism of science and questioned scientific survey methods. However, there was a general perception that relationships with scientists had recently improved and interviewees were glad of improved openness of scientists to fishers' views. There was a consensus on the desire for scientists to spend more time at sea out with the fleet so they can see what the fishers are seeing.

6.3.7 Role of the NSSS in scientific assessments and advice

Assessment scientists were enthusiastic about the provision of the NSSS data but found practical difficulties interpreting it and integrating it with their knowledge systems:

> *…the problem being is that mathematically it then becomes quite tricky because… what does an increase mean to a fisherman?*

Although scientists seemed to expect the NSSS to have been provided in good faith, there were questions over the validity of the dataset, including the lack of a spatially balanced sample, and the fact that fishers move locations to maintain CPUE rates, obscuring stock fluctuations.

However, the contextual knowledge about the industry could be used much more extensively in the future to help the interpretation of and identify linkages between fisheries and regulations. Interviews and informal discussions with scientists identified several areas of uncertainty where fishers could make a major contribution to improving stock assessments. Reliable estimates of discards and true landings are vital, but were absent for many assessed stocks (Daw 2006a). There were considerable uncertainties in contemporary and historical catches, discards, targeting, recruitment and black landings. If accurate and spatially detailed logbook information was available, most scientists saw little need for further impressions on stock status from fishers, but contextual information such as the targeting and spatial behaviour of fleets is useful for interpreting catch trends, assessment results and resolving or identifying stock identity questions.

One scientist insisted that the answers that fishers gave in response to his questions are of less use than the questions which might be asked of his approach by fishers, because they are approaching the problem from a different framework. Fishers' involvement in the process could provide a practically-grounded critique of the assumptions and approaches to assessments and advice and they may flag up issues which would not otherwise be raised in assessment working groups.

The 2006 NSSS collected 249 questionnaire returns from 5 countries. Returns were lower than the previous year in all countries, and the lowest on record for all countries except Denmark. All the data were summarised in a report submitted to WGNSSK (Laurenson 2006). This included a presentation of the time series of abundance trends from five years of the NSSS data for each species in each area of the North Sea. This was based on a quantitative index calculated by scoring and averaging fishers' responses for each region and plotting the change (Figure 6.5). These area-based summaries of stock trends from the NSSS were presented in the WGNSSK report for each species alongside scientific trawl survey trends for the same time periods (Figure 6.5). The level of agreement between these trends and indications from the stock assessments and survey indices was commented on, for example:

> *… the time series are broadly in agreement in recording a stable overall stock abundance in the central North Sea, declining abundance in the western North Sea and increasing abundance in the north east. The IBTS survey [Figure 6.5b] has more variability due to the inherent variation, but shows declines in areas 1 and 7 whereas the fisher's survey records strong increases, this requires analysis to resolve where the differences are occurring and whether they occur as a result if the scale of the analysis. (ICES 2006b)*

This quote illustrates the primary use of the NSSS as a yardstick to compare with scientific results. No quantitative integration of the NSSS results was made into the assessments, but scientists suggested the contribution was useful, if not significant for the result:

> *I'm not sure that any of the advice has actually changed, I would think the advice is pretty well dictated by what the analytical assessments are showing. I think it's in terms of raising the uncertainty level in the assessment if you're hearing one suite of information which is contradictory to what you're seeing*

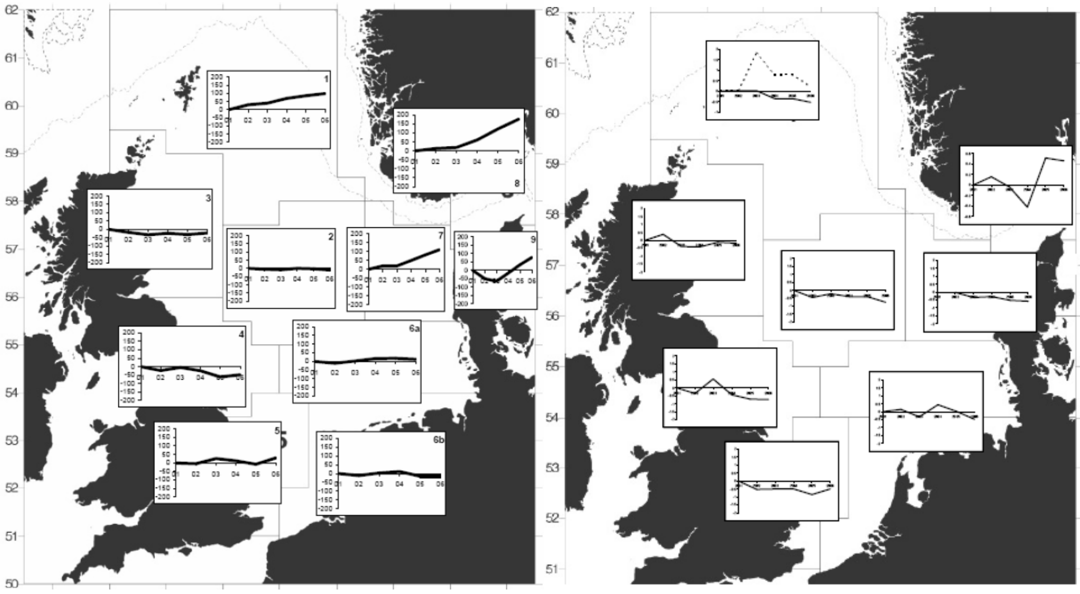


Figure 6.5. Presentation of NSSS trend index (a) and scientific trawl survey data (b) in the ICES Working Group report (ICES 2006b)

One example cited by several scientists was the way in which spatial patterns in the NSSS confirmed localised trends which had been observed in scientific surveys and indicated stock structure that was problematic for assessments.

The treatment of the NSSS was similar in ACFM. Outputs like Figure 6.5 were also presented in the ACFM report, but there was no formal integration of the results into assessments, and there was no evidence of the NSSS having any direct influence on the scientific advice generated (Daw 2006a). Results of other NSSS questions on discarding, recruitment and fish size were not included in ICES reports or during the ACFM meeting (pers obs.).

The practical difficulties of interpreting and integrating the NSSS results into the scientific work were compounded by the institutional environment of scientists, and the complex models and methods which they have evolved to provide stock assessments. The WGNSSK report itself states:

> *The workload of WGNSSK, in common with all assessment WGs, has been steadily increasing in recent years. It is clear that such a workload is unlikely to be addressed satisfactorily without substantial intersessional investment in time and resources (ICES 2006b, p6).*
>
> *the meeting was restructured to limit potentially unproductive method exploration, but the WG[NSSK] have still found it difficult to fulfill their extensive workload (ICES 2006b, p47).*

The time constraints and workload particularly constrained the impact of the NSSS when the results were initially submitted to the WGNSSK in 2003:

> *[2003] was difficult because they [WGNSSK] were under a lot of pressure, with erm, with everybody. They were trying different methods, they were having to justify what they were doing, their backs were really against the wall and then this survey turned up as well and it was just the last thing they needed (fisheries scientist interview).*

The traditional and complex nature of the ICES institution makes it slow to adapt to new situations or opportunities. This is illustrated by the problem with whiting stock identity in the North Sea. ACFM rejected the assessment provided by the WGNSSK in 2005 due to these problems, but the same assessment was conducted by the WGNSSK in 2006 because no progress had been made in providing extra information on whiting stock structure. So although the NSSS helped to confirm trends evident in scientific surveys, which were relevant for assessments, the workload and institutional inertia of the ICES assessment procedures limited the application of that knowledge (Daw 2006a).

Although the NSSS data were not substantively integrated into the assessment knowledge, scientists seemed aware of the political importance of being seen to take the NSSS seriously as is evident from the following exchange during the editing of the ACFM report:

> *Scientist 1 - I don't know where it's [paragraph on the NSSS for one of the stocks] going except to thank the industry for doing it*
>
> *Scientist 2- So do you want to take it out?*
>
> *Scientist 3 - I don't think take it out because NSC [North Sea Commission] has exerted considerable effort to provide perceptions of industry and to throw it out would give bad impression. I can live with it. there is a conclusion.*
>
> *Scientist 4 - I agree and would leave it in. Would be a very bad message to delete it.*
>
> *Scientist 2 - Do you have any suggestions?*
>
> *Scientist 1 - I would cut it down, I agree that it should not be cut out.*

The final ACFM report, released in October 2006 suggested that there had been little recovery of cod and advised a 0-catch of cod in 2007. Resisting closing the North Sea to cod fishing (which would have effectively closed all demersal fisheries) but taking account of the fact that cod are caught in other fisheries and the fact of the recovery plan, the Council reduced the cod total allowable catch by 14% and fishing effort by between 7 and 10% for all fisheries thought to take a bycatch of cod (EU 2007). The NSSS had no discernible impact either on the regulations of North Sea fisheries or on the fishing opportunities of fishers who participated, but it may have increased scientists’ perception that the survey data used for the assessment was reliable.

6.4 Discussion

The NSSS has now been running for five years. This data collected here allows the assessment of the contribution of the NSSS according to both the FK-utility and governance perspectives.

6.4.1 The impact of the NSSS from the FK-utility perspective

To fulfil the objectives of providing useful knowledge for science and management, the NSSS must address the practical challenges of engaging fishers and collecting reliable and representative data, which is useful, and is used, for management.

6.4.1.1 Engaging fishers

Interviews with participants illustrated three dilemmas in designing an initiative like NSSS to maximise the motivation of fishers to participate:

- It should be as simple as possible to reduce the inconvenience of completing it, but some fishers found it overly simplistic or spatially crude, lessening its credibility.
- The narrow scope of the survey keeps its size down but means that it does not address issues which fishers are commonly keen to address.
- Fishers are interested to hear more feedback on the way the NSSS is used, but explicitly stating the limited impact the NSSS has on stock assessments may further damage morale and willingness to participate.

In addition, the willingness to participate is dependent on factors external to the design of the NSSS. Several interviewees linked willingness to complete the NSSS with support for, or discontent with, participating FOs. Others linked motivation to wider management issues affecting the industry. Although fisheries management policies of the European Commission and the politics of decisions on management measures are not linked to the NSSS, and the objective of the NSSS was not to influence these, it is clear from interviews that objection to high level policies and management decisions affects participation in the NSSS by lowering overall morale and increasing cynicism. This is expressed by the following quotation:

> *If they turn round and everything we've said is disregarded again then we go to meetings in December and we get bloody stuffed again then, what's the point?*

For fishers who fear their livelihoods are endangered by an unfair and flawed science and governance system, the NSSS does not address the issues with which they are urgently concerned, and may seem irrelevant. A similar problem was experienced by the Dutch collaborative F-project in 2003 when skippers withdrew their cooperation as a result of their opposition to December council decisions (pers comm., Floor Quirinis, RIVO). Thus the success of initiatives like the NSSS is dependent on the larger political and governance context.

6.4.1.2 Reliability of answers

Perceived abundance trends from NSSS did agree with quantitative perceptions collected by more in-depth interviews (Figure 6.2). This shows the NSSS methodology is capable of semi-quantitatively recording fishers' perceptions. The most common use of the NSSS (e.g. Figure 6.5), however, relies on attributing absolute values to answers. Correlation between the log of respondents' answers and the answer category gives some evidence that the relationship between 'No Change', 'More' and 'Much More' should not be considered linear. The two extreme outliers illustrate the problem of interpreting answers as indicative of percentage changes. When stocks reach low levels, small absolute increases represent disproportionately large percentage increases. So two fishers who perceived 500-1000% increases only responded ‘More’ to the NSSS.

Also, there is some ambiguity as to whether the survey is collecting information on catch rates, landings, or perceptions of stock abundance, even though it asks for answers based on ‘catch rates’. Some fishers answered strictly based on change in their own catch rates, while others gave their general perceptions of stock informed by understandings about factors other than abundance affecting catch rates. Interviewees described several factors affecting catch rates, including targeting behaviour, gear regulations, markets and the enforcement of quota restrictions. Overall, fishers’ perceptions may be more informative than their catch rates, as they allow fishers to take account of factors affecting catch rates which are not clear from data available to stock assessment scientists (e.g. changing strategies in the light of higher fuel prices).

Self-interested biases in fishers’ information are rarely explicitly discussed in literature on co-management and use of FK, but are one reason for scientists’ reluctance to engage with FK. A European Commission representative, for example, expressed the problem that:

> *…it’s very difficult to assess, how far industry knowledge is being provided on an unbiased basis.*

However, scientists appeared to assume that fishers would complete the NSSS honestly and this was generally sanctioned by interviews with fishers, although fishers also gave evidence that some respondents would be tempted to inflate their answers. Anonymous questionnaires like the NSSS may provide more candid responses than open meetings or politically charged exchanges between scientists and fishers. On the other hand, the anonymous nature means that no respondent can be held accountable for his answers, so there may be less pressure to be conscientious than in a meeting or interview situation.

The NSSS is widely distributed to collect as many views as possible. This allows information to flow direct from a large number of skippers bypassing the usual channels of communication by representatives and FOs, and, therefore, potentially supplying novel perspectives. However, as willingness to participate was related to feelings towards the participating FOs, the NSSS may not collect FK from fishers who are distant from or disaffected with FOs.

The ad-hoc sampling achieved by the NSSS does not take account of the uneven distribution of knowledge within fishing communities (Maurstad 2002; Davis and Wagner 2003). To serve FK-utility aims, ideally expert fishers should be prioritised and given more weighting, but the NSSS conforms more to the governance perspective by allowing all fishers to contribute equally. In terms of reliability of data from an FK-utility perspective, it can be hoped that that poor answers will get swamped by a majority who choose to contribute reliable information. Interviewed fishers suggested that most answers would be reliable, but conceded that some respondents may have adjusted their answers to present an optimistic perception. Quantitative estimates of stock change from the interviews showed the existence of extreme outliers, apparently due to unusual gears and local conditions. The semi-quantitative 5-point scale serves to limit the impact of such outliers on the overall mean result.

The NSSS, therefore, appears to successfully engage fishers in the collection of reliable and representative information. I now question the types of knowledge collected by the NSSS, and how it is ultimately used.

6.4.1.3 Categories of knowledge engaged

Holm (2003a) describes how the process of collecting, filtering and interpreting fishers' ecological knowledge creates a new, refracted body of knowledge. As an extractive method, the NSSS can only collect a limited subset of FK. This is then further attenuated by the institutional context of fisheries science and management in the North Sea (Table 6.4). From the FK-utility perspective it is important to know whether useful FK is retained and applied to improve understanding of the fishery and resultant management.

Fishers were able to give accurate estimates of long term stock trends (Figure 6.3) and offered useful knowledge on ecological and economic processes (examples from the qualitative interviews are shown in the first column of Table 6.4). Of this body of potentially useful FK, the NSSS questions are limited to one-year trends in stock abundance, discarding, recruitment and economic conditions; the abundance of recruits; and the sizes of fish being caught.

Assessment scientists recognised the potential usefulness of FK about contextual information like fleet behaviour, illegal landings, discards and spatial characteristics of stocks, while considerable uncertainties in catches, discards, targeting, recruitment and black landings were observed during the ACFM meeting. These emphasise the potential for FK to provide indications of trends in these factors. For example, indications of contemporary trends in discards from the NSSS could be particularly useful, and historical information is also important for the evaluation of long term trends, for example, in understanding past trends in catches of Nephrops (Daw 2006a)

Once the NSSS data is passed to the WGNSSK, the scientists are limited by time and methodologies to using the results as a yardstick. The science advice structure is institutionalised and slow to adapt to fresh information. Complex assessment methodologies and data provision systems have been developed over decades, and working groups, struggling to manage their evolving workloads, have limited capacity to experiment with new approaches or incorporate data in alien formats. This is similar to experiences of extractive FK-engagement in Australia, in which scientists welcomed the research, but a lack of methods to incorporate it and ‘institutional inertia’ meant that the results were not utilised by stock assessment scientists (Baelde 2007).

Table 6.4. Attenuation of FK as it is collected by the NSSS and passed on to scientific assessment and EU decision-making procedures. Information that is potentially useful for fisheries management or associated with uncertainty according to interviews with scientists and meeting observations is in italics.

	FK in semi-structured interviews[1]	FK in NSSS	Stock assessments[2]	Management regulations
FK topics	***Short term abundance trends***	*Short term abundance trends*	*Short term abundance trends*	No evidence of NSSS contributing to regulations
	Short term discard trends	*Short term discard trends*		
	Sizes of fish caught	Sizes of fish caught		
	Recruitment level	*Recruitment level*		
	Economic trends	Economic trends		
	Long term abundance trends			
	Impact of technological creep			
	Abundance of seals			
	Ecological impacts on cod populations			
	Prevalence of black fish			
	Locations of juvenile cod aggregations			
	Targeting behaviour of fleet			
	Opinions about science			
	Opinions about politics			
Types of FK	***State of nature***	*State of nature*	*Trends (short term)*	
	Trends	*Trends (short term)*		
	Process knowledge			
	Management knowledge			
	Worldviews			

[1] Topics in bold were included in the interview schedule, others were volunteered by interviewees
[2] Includes only knowledge taken from the NSSS. Other avenues are available for the contribution of FK (e.g. attendance of industry observers at ACFM)

Focusing analysis of the NSSS on short term trends in stock biomasses means that the information gleaned duplicates scientific stock assessment results, rather than complements knowledge gaps in the scientific advice process. Trends from the NSSS roughly agreed with scientific survey results, but this agreement is in contrast to the strong disagreements process-FK had with other aspects of science. Finally, the nature of the North Sea management policies (dominated by a Cod Recovery Plan, which placed restrictions on all fleets operating in the North Sea) meant that despite the complex system, the diverse range of indicators available, and the extensive data collection and assessments, decisions were largely dictated by a single indicator: the current status of the cod stock.

6.4.2 The impact of the NSSS from the governance perspective

The NSSS appears unable to make much direct contribution to science and management from the FK-utility perspective. I now assess the impact of the NSSS from the governance perspective. First, I will discuss whether participants were aware of the underlying aims and likely outcomes of their participation. I will then consider the contribution of NSSS to the development of participatory fisheries governance in terms of legitimacy, development of social networks, common understandings, trust, knowledge transfer, and deliberative democratic rights.

6.4.2.1 Managing Expectations

According to responses of the survey participants, motivation to take part may be based on a false premise of expecting rewards for participation. Given the design and scope of the NSSS and the current systems of assessment and management, expectations of direct benefits to the industry are unrealistic. Thus there is a risk that trust and relations between fishers, scientists and managers can be damaged by disappointment if the results of participation do not live up to expectations. If fishers become cynical about participation they are likely to 'go quiet' (Maurstad 2002), and stakeholder apathy could undermine subsequent participatory processes (Glaesel and Simonitsch 2003). The aims of the survey, therefore, need to be clarified and the expectations of participants actively managed. In this light, other initiatives in the North Sea which are more participatory and can improve social relations and respect between fishers and scientists (for example the NSRAC) are needed to support the continued participation in the NSSS.

Comparisons of NSSS data and scientific trawl surveys suggest a shared understanding between fishers and scientists. However, this is based on comparisons of short term trends as observed by NSSS compared with regional trawl survey indices, a small portion of filtered FK and one aspect of the body of scientific knowledge. The comparison between the survey and scientific data presents the impression of harmony between fishers' and scientists' knowledge. However, although interviewees roughly agreed on recent year-on-year trends in stocks, their process-FK, worldviews and management views often disagreed strongly with assumptions underlying the scientific or management process. Thus the agreement between trends from the NSSS and scientific surveys should not be interpreted as meaning that a common understanding has already been achieved. For example, fishers generally agreed on the long term abundance of cod, but they disagreed on the processes controlling fish stocks and were disenchanted with management assumptions and principles. The NSSS cannot serve as a conduit to communicate this sort of disagreement.

6.4.2.2 Collaborative learning

As an arena of collaborative learning, the NSSS is limited by the shortage of feedback and the limited categories of FK with which it engages. Scientists have no opportunity through the NSSS to learn from novel FK, understand fishers' worldview, or gain from management suggestions. Likewise, fishers have no opportunity to learn from scientists and managers, as there is no dialogue established. They may vent frustrations or opinions in the comments box on the NSSS questionnaire, but will not receive answers or explanations in return. The apparent agreement between trends according to the NSSS and scientific trawl surveys should not limit the opportunity to highlight, deconstruct and resolve disagreements. Adams et al (2003, p1916) state "Where cognitive conflict is important, policy dialogue needs to be structured so that differences in knowledge, understanding, ideas and beliefs in the public arena are recognised".

6.4.2.3 Legitimacy and Trust

It is possible that the NSSS serves as a token for trust building. It is often cited by FO representatives as an example of how the industry is willing to assist with the science, and is looked on favourably by scientists as a genuine attempt to help out (ICES/NSCFP 2005). Conversely, scientists are aware of the importance of its inclusion in their reports to show that they listen to the views of fishers. The congruence between NSSS trends and scientific surveys may legitimise scientific methods and diffuse some industry criticisms of scientists' use of randomised trawl surveys. The inclusion of NSSS results in the ACFM report may add some legitimacy to the scientific advice. Fishers' representatives also use the congruence to demonstrate to the scientists that the industry is a reliable source of information, in effect legitimising FK. Thus the NSSS may be a symbol of cooperation and a tool to enhance mutual trust in each others' knowledge which can contribute to future developments. For example, it was hailed during Pelagic Regional Advisory Council meeting as an example of how fishers' knowledge can be collected for use in management (Pers. observation, PRAC WG meeting Edinburgh 6/2/07).

6.4.3 **Conclusions**

The NSSS questionnaire appears to be an appropriate methodology to semi-quantitatively assess FK of short-term stock changes, and it successfully compares a subset of FK with one data source used by the stock assessment scientists. From the FK-utility perspective, however this sample of FK duplicates, rather than fills gaps in, scientific knowledge, and methodological and institutional means to incorporate the collected knowledge into management decisions appear to be lacking.

From the governance perspective, the NSSS provides an example of FK interacting with scientific knowledge and the apparent agreement between the two may help to build legitimacy between scientists and fishers for future co-management. However, expectations of the survey need to be managed as participants may lose interest in participation if they do not see expected positive results. A lack of effective feedback limits any contribution to collaborative learning and development of common understandings. There remain deep cognitive conflicts which the NSSS cannot address as it stands, and it cannot directly help to build relationships and trust. More participatory tools like collaborative research and the NSRAC are therefore essential.

This case emphasises the importance of distinguishing between different types of FK. There was general agreement between scientific perceptions and trends-FK, but the extractive approach did not engage with the process-FK, worldviews-FK or management-views-FK. The case highlights that extractive approaches to FK can suffer from ambiguity of results; it is not clear if answers relate to CPUE or to more judicious perceptions of abundance which may integrate other knowledge. Finally, this extractive approach does not promote wider social networks which might allow for combinations of different knowledges in a social learning process, as envisaged by adaptive co-management approaches (Olsson et al. 2004). These processes however, have been developed to some extent in the North Sea fisheries case by parallel and recent face-to-face cooperation between fishers' representatives and scientists, notably the NSRAC.

Chapter 7. Synthesis

This thesis has investigated the relationship between FK, science and fisheries management through a wide range of literature, cases and varied empirical investigations. This chapter summarises the main findings of the preceding chapters, draws out key practical lessons for engaging with FK, discusses the four key research themes introduced in Chapter 1, and reviews what may be the most promising way forward for engaging with FK in the future.

7.1 Summary of Findings

Chapter 1 reviewed a range of literature relevant to FK, science and fisheries management and presented the two perspectives that have led to an interest in engaging with FK.

The first has emerged against a backdrop of widespread failure of conventional fisheries management and some high profile stock collapses (Hilborn et al. 2003). Fisheries scientists and managers are becoming more aware of the utility of FK to complement science in understanding and monitoring fisheries (Haggan et al. 2007), while the social and political dimension of fisheries and the complex nature of social-ecological systems demand a wider range of knowledge sources than conventional fisheries science could provide (Jentoft 2006).

The second is related to the increasing influence of principles of participatory governance in fisheries as politically organised fishers and indigenous peoples claim rights of representation, and to have their knowledge considered in resource management decisions, and fisheries managers increasingly experiment with co-management. Participatory governance promises better managed fisheries through increased legitimacy and compliance (Jentoft 1989), and the possibility of multi-scale governance which better matches the scales of social and ecological processes governed by fisheries management (Berkes 2006).

Thus two perspectives, the FK-utility and governance perspective, result in scientists and resource managers increasingly ‘engaging’ with FK in terms of: using FK for science; competing with FK on the reality of fisheries; and committing to FK as a valid input into management decisions.

These trends raise important questions of how best to engage with FK. What kind of FK is there and how does it relate to science? What are the implications of different styles of engagement? How can FK and science be integrated into management to achieve both the practical application of FK to understanding fisheries, as highlighted by the FK-utility perspective, and the legitimacy, appropriate scales of management and democratic accountability implied by the governance perspective?

Chapter 2 introduced the epistemology and methodology for the thesis, arguing for a pluralistic and interdisciplinary approach to investigate different aspects of FK engagement in different situations. A review of 30 existing cases then highlighted the wide range of approaches taken in engaging with FK. A distinction was made between idealist and pragmatic aims for FK engagement, and most cases were found to have pragmatic aims to enhance science. These cases ranged between extractive and participative engagement with FK. The more common extractive approaches relied on questionnaires and other methods to collect specific elements of FK, and often translated or formalised them into systematic or quantitative formats more amenable to integration with quantitative fisheries science. Participative approaches, on the other hand, emphasised the involvement of fishers themselves, rather than just FK, in the process of research. Fishers in participative approaches played key roles in the identification of questions and interpretation of their own knowledge.

Chapter 3 showed that interviews with fishers in Seychelles gave estimates of current daily landings that tended to be less than those reported in official landings statistics but that CPUE per trap from interviews gave a good prediction of CPUE from landings. Perceptions of trends, however, differed markedly between scientific data from landings monitoring, UVC, and fisher interviews, highlighting the need to use a diversity of sources, including FK, when monitoring fishery trends.

Chapter 4 showed that over the large spatial scale of five countries in the WIO, fishers' perceptions of catch rates in coral reef fisheries were not correlated to patterns of biomass as measured by coral reef ecologists. Catch rates were better predicted by country than by biomass suggesting that catches are determined by national-level factors and are unrelated to variables typically measured by reef ecologists. This raised the important question of diverging perceptions and priorities between local fishers and ecologists and conservationists.

Chapter 5 showed that an extractive engagement with FK into scientific models created problems due to de-contextualising the knowledge, because fishers' answers to questions were interpreted through scientific assumptions and mental models. Fishers' process-level mental models were different from assumptions of simple stock assessments, and reconciled their apparently self-contradictory perceptions of declining catches from healthy fish stocks.

Chapter 6 reviewed North Sea fishers' perceptions of the North Sea Stocks Survey (NSSS) and followed the process of FK-engagement from collection of specific knowledge to its delivery to, and use by, stock-assessment scientists. The FK that was collected focussed on short-term trends and reflected the opinions of participating fishers. However, much of the valuable FK was not collected by this method, and the scientific and management regime was too complex and had too much inertia to easily incorporate novel information from FK. The limited impact of the survey created a risk of disappointment for some participants who hoped for 'improvements' in management as a result of the NSSS. Other more participatory and interactive initiatives currently underway in the North Sea, therefore, need to address governance and ensure the sustainability initiatives like the NSSS.

7.2 Practical issues related to the collection of FK

Several practical issues of engaging with FK can be drawn out from this research.

7.2.1 From reality to answers, the refracted chain of knowledge

This thesis has highlighted a range of processes of ecology, technology, psychology, politics, and understanding and framing of questions, that affect the nature of FK which can be engaged. Figure 7.1 highlights how fishers' answers to questions are an indirect view of reality 'refracted' through these processes. Scientific research also produces a view biased by, and contingent on, the methodologies used. Such biases are more clearly understood for scientific information[5] but it can be less clear what refractions may have taken place for information gleaned from engaging with FK. Two of the processes described in Figure 7.1 will be discussed in detail here as the others are discussed in other sections of this thesis.

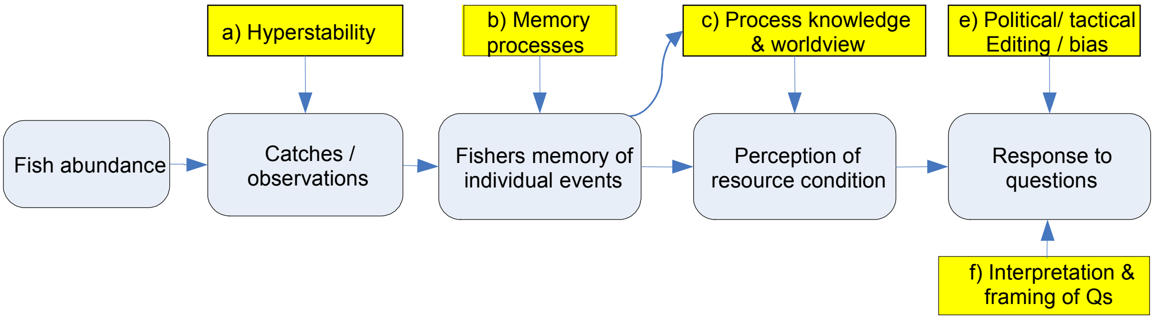


Figure 7.1. The chain of FK on fish abundance from actual abundance to answers to a FK researcher.

7.2.1.1 Hyperstability and hyperdepletion

It is well recognised that catch rates are of variable quality as an indicators of fish abundance due to various factors (Hilborn and Walters 1992). The perceptions of fishers resulting from catch rates are therefore likely to differ from actual abundance (Figure 7.1a) leading to scepticism of their ability to perceive trends. For example, one North Sea fisheries biologist asked, “can fishermen really compare what they get now compared to what they were catching 15 years ago? They’ve changed their boats, upgraded their gear or whatever. They maybe catching the same amount but does that mean they’re putting in double the effort which would give half the stock size”. Chapter 4 showed that, in fact quoted catch rates from a very extractive approach had no relationship with a fishery-independent measure of biomass.

[5] It is also a product of worldview and cultural context (Finlayson 1994), although fisheries scientists with training in ‘objective’ science may be less conscious of this.

However, interviews with fishers show that fishers can be acutely aware of this problem. North Sea fishers described many ecological, spatial, economic and political factors which affected their catch rate, and they also qualified their answers to fish catch changes with important contextual information, such as tactical responses to the regulatory and economic environment to target larger, high value *Nephrops* rather than to maximise CPUE (Chapter 6). In Seychelles, FK of abundance diverged markedly from FK on catch rate trends, and fishers explicitly described problems of declining catchability which disconnected their catch rates from resource abundance (Chapter 5).

7.2.1.2 Framing and interpretation of questions

Answers to questions can be affected by their wording and also the context of the questions (Schwarz 1999). Questionnaires administered across large regions (e.g. Chapter 4) have the added confusion of inexact translations and cultural interpretations of concepts. For example, the common question, "what is your normal catch", used in Chapters 3, 4, and 5, is subject to a range of different interpretations of the meaning of 'normal'. Does that include zero catches or is it just an average of good days? Is that just in the main fishing season or an average for all year? Different heuristics may be used to choose an answer, such as: the first trip that comes to mind; yesterday's catch; or the desired catch to cover costs and make an acceptable profit. Chapter 3 attempted to reduce this confusion by asking about good, poor and then normal days, to encourage respondents to use the same anchoring-and-adjustment heuristic (Tversky and Kahneman 1974), and to remove some variability due to fishers placing more or less emphasis on particularly good catches. This simple technique does not eliminate the problem of different question interpretations, but it provides a more standardised measurement of the perception of current catches to compare between fishers and areas (e.g. Chapters 3 and 4). Problems of standardisation, translation, question interpretation and cross cultural variability may be even more daunting in more abstract and culturally contingent forms of FK (Figure 7.2).

7.3 Theme 1 – Categories of FK

The focus of this thesis is on FK of fish abundance. Even within this distinction, 'FK' encompasses a range of elements with different characteristics and different ways that they engage with science and management. There are many possible ways to categorise FK, such as whether it is discursive or tacit, whether it is written or oral (Hoefnagel et al. 2006), whether it is quantitative or qualitative, or whether it is *in situ* within the minds and practices of fishers or in a collected and filtered form (Holm 2003a).

In Chapter 2, I outlined a typology that aimed to make useful distinctions between the FK discussed in this thesis. Here I develop the typology and discuss each category n the light of the preceding chapters. All categories relate to the abundance of fish resources, and are inspired by literature on mental models (e.g. Fazey et al. 2006), traditional/local ecological knowledge (Berkes et al. 2000), uncertainty in fish stock assessment (Charles 1998), and the case studies within this thesis (Table 7.1).

Table 7.1. Examples of the different categories of knowledge from this thesis

Level of FK	Example
State of nature	Contemporary CPUE and catch reports from fishers (Chapter 3)
Trends	Perceived trends in catches over short (Chapter 6) and longer (Chapters 3, 5, 6) timescales.
Processes	Causal links determining fish abundance (Chapter 5)
Worldviews	View of fish stocks as unpredictable and cyclical (Chapter 6) Values about the rights to fish (Chapter 5)
Management views	Views of fishers on current management arrangements (Chapter 6)

7.3.1 **'State-of-nature FK'**

The first category of Charles' (1998) typology of uncertainty in fisheries science is uncertainty about 'states of nature'. This usefully translates into a category of FK, i.e. knowledge about the contemporary magnitude of a variable, for example, how many fish are there, or what is the current magnitude of catches. In engaging with state-of-nature FK there can be confusion about which variable (e.g. CPUE, catch or biomass, Chapter 6) is relevant or being discussed.

7.3.2 **'Trends FK'**

The second category, 'trends FK', is about trends in the state of nature over time. This introduces complications of perceiving trends from a background level of variance (van Densen 2001), and the different perceptions depending on the length of time being looked at. Chapter 3 suggested that a ten year time window might be too long to collect trends FK, with fishers responding according to recent two-year trends. Trends FK requires comparison of current conditions with memories of the past, which may be affected by psychological (Bradburn, Rips & Shevell 1987) and intergenerational (Saenz-Arroyo et al. 2005) biases. Trends FK introduces a more dynamic understanding of a fishery than state-of-nature FK, and trends in resources are often the important point of discussion for resource management decisions. For example, in the North Sea, the current low biomass of cod influences much of the management decisions because it is so low compared with historical records. Meanwhile, some fishers with longer time horizons than the available data, claim that the perception of catastrophic decline is due to this short time series not including previous fluctuations in the cod population.

7.3.3 **'Processes FK'**

Process knowledge reflects the way that, people organise their observations (of state-of-nature and trends) into 'causal schema' (Tversky and Kahneman 1982) which attribute cause-and-effect relationships between different variables. This category describes knowledge that fishers have on the processes which drive trends in states of nature. This is a more complex level of understanding, as illustrated by research which found that simple taxonomic knowledge was learned quickly by newcomers to an ecosystem, but that they did not gain the indigenous understanding of ecological processes controlling the system (Muchagata and Brown 2000).

Chapter 5 shows the importance of process FK for interpreting state-of-nature and trends FK and coming to conclusions about management. Fishers perceived declining catches but did not believe that these were caused by declining stocks. Furthermore, most fishers did not believe that trap fishing was a major driver of fish populations. Without an appreciation of process-FK, the state-of-nature FK was misinterpreted and the predicted conclusions were at odds with fishers' actual opinions. Even if FK and fisheries scientists agree on the state of nature and trends, for example, that cod stocks in the North Sea have declined dramatically since the 1980s, if there is conflict in process knowledge (i.e. what are the factors causing the decline and continued low abundance), there are likely to be conflicts over the best course of management action (Chapter 6).

Engaging with Process FK may provide a means to address Charles' (1998) category of 'structural uncertainty', or 'scientific ignorance' (Hoffmann-Riem and Wynne 2002), in which scientists do not know whether the models they are working on include the appropriate processes and reliably represent the system. For instance, scientists monitoring bowhead whale stocks in Alaska underestimated the stocks because their data on sightings was analysed with incorrect assumptions of migration routes. Engagement with local process-knowledge on migrations improved the assessment and led to a three-fold increase in the population estimates (Huntington 2000).

Quantitative fisheries science is necessarily based on various assumptions in order to allow quantitative modelling of a limited number of parameters. Process-FK in this case could be vital in challenging these existing models, for example, if they have incorrectly ignored the effect of changing catchability in catch and effort stock assessment models (Chapter 5).

7.3.4 **'Worldviews FK'**

The three previous FK categories are discursive (i.e. easily communicated) types of knowledge, which are needed to model systems: state-variables, trends and the processes and relationships which link state-variables. Many authors have pointed out, however, that knowledge is embedded within a wider cultural framework (Sillitoe 1998). The FK next category is 'worldviews FK' which encompasses individual fishers' beliefs and values and the particular perspective from which they perceive fisheries and fisheries management issues. This is an important component for the engagement of science and FK, because incompatible perspectives can serve to prevent communication of knowledge between fishers and scientists (Neis 1997).

The term 'worldviews' is often used in characterising the difference between indigenous and Western knowledge (Berkes et al. 2000), but interviews with scientists and non-indigenous fishers in North Sea fisheries (Chapter 6) illustrate differences in worldviews, in terms of the value systems and the perspective from which they view the ocean ecosystem. The view of the marine ecosystem from data analysis, modelling, occasional research cruises, and the fisheries science tradition by people whose livelihoods depend on studying it, is apparently different to the view of the world from the wheelhouse, by those whose livelihoods depend on exploiting it. For example, stock assessment scientists and most fisheries managers view the marine ecosystem as impacted by external human forces and in need of protection from overexploitation. Although, many fishers conceded that fish stocks can be overfished, interviews highlighted a worldview of nature as less predictable and controllable by humans than is inferred from the current science. This bears some resemblances to the 'resilience thinking' which sees social and human systems as unpredictable and also coupled so that humans are part of nature (Berkes et al. 2003).

Worldviews also vary as a result of different interests. Fishers depend on exploiting fisheries, while scientists and managers do not. Daniel Bromley (2007) has stated, "The oceans derive their meaning by the uses we have for them". Accordingly, fishers and scientists, may always have difficulty empathising with each other. One North Sea fisher captured this by saying:

> *they [the scientists] have the inclination just to go "oh the cod is in decline, lets just stop it" without thinking about what they're doing to communities … I don't doubt that they think what they're doing is the right thing… but I just think they sometimes don't realise that there's somebody being hurt at the end of it*

Managers and fisheries scientists (especially if hailing from ecological backgrounds which use marine ecosystems as a subject and inspiration for study) are liable to see marine ecosystems as having intrinsic value, while fishers are more likely to have a more utilitarian view, as illustrated by the North Sea fisher who commented that, "fish is not just to grow old and die".

Worldviews also encompass epistemologies, including scientists' reductionist and predictive approach to knowledge. Scientists reduce detail in order to make generalisations and broad predictions, while fishers specialise in detail in order to understand and maximise catches within a highly variable spatial and temporal seascape. Some interviewees, in Seychelles, for example, resisted questions about 'normal catch' repeatedly answering 'it depends'. From my worldview as an external researcher, used to working with statistics and mean values, average catch is the most obvious and salient question. However, for a fisher immersed in, and attuned to constant variation of catches in response to tides, seasons, weather and fish behaviour, it is a meaningless concept. The 'average fishing day' is no more real in terms of practical fishing than an 'average family' of 2.4 children.

Different worldviews affect how questions and knowledge are framed (Miller 2000). In Seychelles, for example, fishers' worldviews influenced their knowledge of issues such as overfishing. Knowing whether there were too many fishers, for example, was an irrelevant question for a fisher for whom the right of any Seychellois to be a fisherman was part of his worldview (Chapter 5).

Table 7.2 gives examples of differing worldviews of fishers and scientists, managers and environmentalist stakeholders who play an increasing role in fisheries governance. This represents 'ideal types' of fisher and non-fisher worldviews and as with any generalisation, exceptions are certainly possible.

Table 7.2. Generalised comparison of the worldviews of fishers and non-fishing groups encountered during this thesis research.

FISHERS	SCIENTISTS / FISHERIES MANAGERS / ENVIRONMENTALISTS
Marine ecology operates in cycles, largely independent of fishing activities	Fishing significantly affects marine populations, which can be management of fishing activities
Marine animals are "to be harvested they're not there to grow fat and die" (F32)	Marine populations exist independently of human activities and have intrinsic value. Their exploitation should not have a significant impact on their natural states.
Quotas should be set to match catchability of species in each year	Quotas should be set to maintain natural spawning stock populations.
Perception of the stock is perception of "what we're seeing out there on the grounds"	Perception of the stock is estimate of total biomass of an individual species.
Fisheries should be managed to maintain livelihoods and the fishing industry	Fisheries should be managed to maintain the integrity of individual fish stocks

These cultural differences between fishers, scientists and managers, implied by their differing worldviews, mean that the actions and rhetoric of one can appear irrational or unreasonable to the other. Peck (1977) captures the importance of worldviews for communication when he writes:

> *human beings, who must deal with each other, have vastly different views as to the nature of reality, yet each one believes his or her own view to be the correct one since it is based on the microcosm of personal experience*

7.3.5 **'Management-views FK'**

The final category, 'management-views FK', is included because engagement with FK, naturally often results in fishers expressing their views on management. For instance, opinions on management formed a large part of the information collected from fishers in both the Seychelles and North Sea contexts where I used qualitative methods, even though that was not the focus of my interviews. Many co-management arrangements are designed to allow fishers to input opinions and ideas about management, which will reflect their own interests as well as their knowledge of the fishery and worldviews (Hoefnagel et al. 2006). From the perspectives of fishers, this is likely to be the most important form of FK to be engaged with. Participants in the North Sea Stocks Survey were happy to answer questions on the state of nature, trends and processes of stock abundance, but would often spontaneously discuss critiques and suggestions for the management system. One may ask whether mere opinions should qualify as a category of fishers' '*knowledge*' but it is included here for two reasons. Firstly, the distinction between knowledge and opinions is indistinct and so it seems more appropriate to be inclusive, to include concepts which play an important role in co-management rather than to exclude them. Secondly, management views are often based on knowledge. For instance, North Sea fishers' objections to the linkage of the status of cod stocks with the catching opportunities of other species, reflected their personal interests but also reflected their state-of-nature FK (other stocks appear healthy), trends FK (recent recruitment of cod seems higher than previous years), process FK (fishing is not the cause of cod decline), and worldviews FK (stock abundances fluctuate naturally outside the control of fisheries managers).

An important point is whether management views reflect the categories of knowledge already mentioned, or whether other categories of FK are formulated to justify management views and material considerations. The 'you-would-say-that-wouldn't-you' issue highlights the possibility of FK being, biased in a way which justifies catching opportunities. Most North-Sea interviewees, for example, thought that some respondents to the NSSS might inflate their answers to give the impression of healthy or improving stocks (Chapter 6). This can occur as tactical editing or biasing of answers, consciously or sub-consciously according to various psychological biases discussed in Section 1.9. For instance, less than half of the Seychelles trap fishers interviewed agreed that trap fishing affected target fish populations.

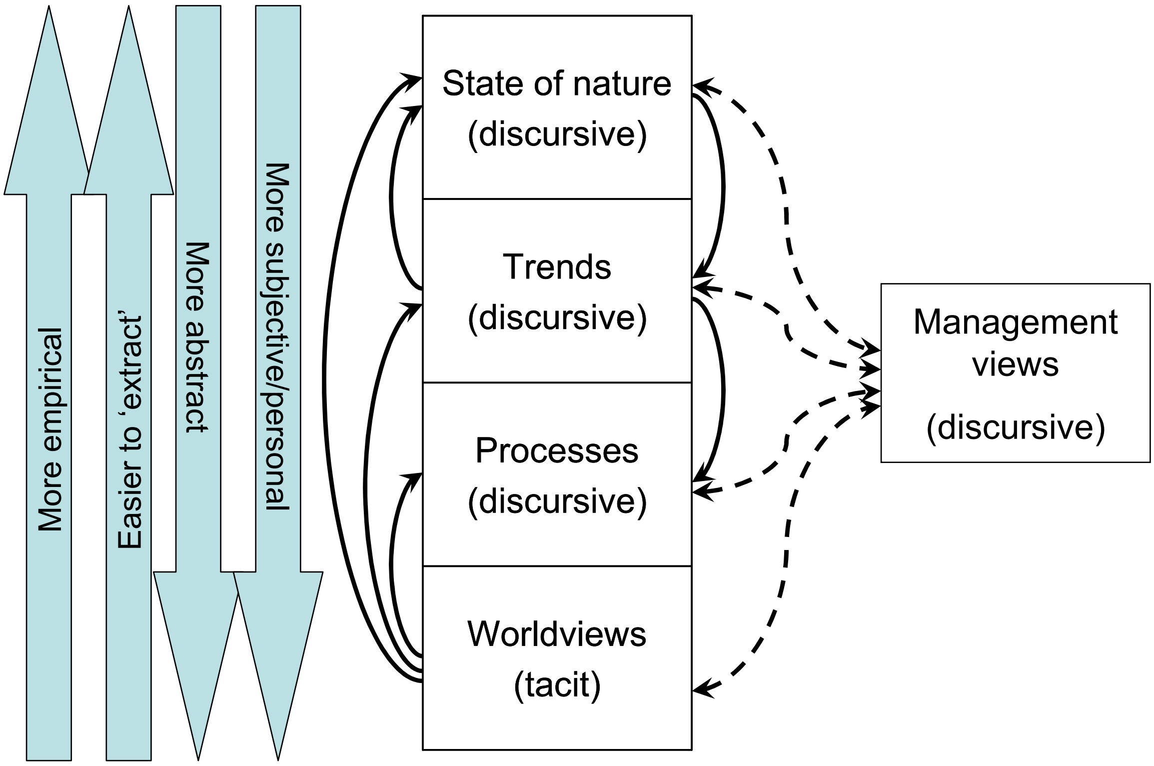


Figure 7.2. Theoretical relationships between the categories of fishers' knowledge

Figure 7.2 shows a conceptual model of these different categories of knowledge and the most obvious interactions between them. For example, perceptions of the state of nature are compared with memories in order to form knowledge about trends. Understanding of processes reflects experiences of states-of-nature and trends of different variables. These forms of knowledge are not self-contained and each would be built up from various sources. For instance, North Sea FK of trends reflected information from other skippers and indications of the market as well as individual catches (Chapter 6). Worldviews are depicted as influencing all other categories, as they 'frame' how fishers perceive their experiences (Miller 2000).

The model arranges the first four categories roughly in a hierarchy of levels of abstraction, with state-of-knowledge being the most empirical and worldviews being the most abstract (Figure 7.2). The more abstract categories are also more subjective and difficult to access through rapid and extractive methodologies for FK engagement. Less abstract forms of FK are closer to empirical experience, and may, therefore, be of greater interest to scientists who are sceptical of FK which is more subjective and reliant on processing and integration of information by fishers. Less abstract forms of FK are also more likely to be more discursive and available for engagement. For instance, the NSSS easily captured fisher perceptions of short-term trends, but did not communicate process FK (Chapter 6). Worldviews, the most abstract and personal forms of FK, are tacit and cannot be communicated without more in-depth and extensive engagement. Likewise, the extractive survey in Seychelles collected state-of-nature FK and trends FK but missed the process FK to interpret these (Chapter 5).

Management-views FK, not fitting into the abstraction hierarchy of the other four categories, is separate from, but interacts with, other categories of FK. The double-headed arrows between management-views FK and other categories depict the possibility that management views and concerns may affect, as well as be founded upon, other categories of FK.

As suggested by several writers on indigenous knowledge (Agrawal 1995; Sillitoe 1998), extracting subsets of knowledge without an understanding of the wider body of knowledge and beliefs can be misleading. Chapter 5 illustrates the risk of focussing only on state-of-nature FK and trends FK and ignoring more complex categories. The North Sea Stocks Survey is aimed only to collect trends FK and state-of-nature FK, but this may be unsatisfactory for fishers who are frustrated by the assumptions and values of the existing science and management system and wish to have an engagement with their process FK, worldviews FK and management-views FK.

7.4 Theme 2 – Congruence between fishers' knowledge and conventional science

7.4.1 Congruence and categories of FK

The case studies indicate a range of relationships between FK and scientific knowledge depending on the context. In Seychelles, state-of-nature FK on CPUE agreed with conventional scientific landings data, but trends FK differed qualitatively (Chapter 3). In the North Sea, trends FK broadly agreed with stock assessments, but process FK challenged the assumptions which structured assessment models and informed management policies (Chapter 6). Worldviews were not explicitly studied, but qualitative information suggested widely different worldviews (Chapters 5 and 6) between scientists and fishers (section 7.3.4).

The findings of this thesis therefore suggest that disagreement between scientists and fishers is more likely for more abstract categories of FK. This has two implications: Engaging only with less abstract categories of FK may suggest agreement when more fundamental disagreements exist in more abstract forms (Chapter 6), and disputes about state-of-nature or trends may be less important and less intractable than conflicts with process and worldview FK which are more difficult to uncover and resolve. Adams et al. (2003) suggest that addressing 'cognitive conflicts' is essential for resolving common resource management issues. I would add that this will be most challenging, and require the most communication efforts, if cognitive conflicts relate to more abstract categories of FK. Disagreements between FK and science may result from different assumptions/mental models (Chapter 5), experiences, material interests, or the dimensions of a question that is being examined. State-of-nature knowledge may be based on different variables. For instance, abundance of reef fish may be monitored by fishers through catches, and by ecologists through UVC-measured biomass. If the overlap between the two in terms of species, depth or habitat is limited, then disagreements between the two perceptions are likely to occur (Chapters 3 and 4). Alternatively, if catches are controlled more by external factors like the technological efficiency of local gears or local habitat configurations, there may again be few relationships between ecologists' key state-variable (UVC measured biomass) and fishers' (catch rate, Chapter 4). Chapter 5 illustrates an example in which the scientists assumed that catch was an appropriate state-of-nature variable to monitor fish populations, but fishers used direct fisheries independent observation.

7.4.2 Implications of disagreements

From the FK-utility perspective, there are two possible implications of disagreements between science and FK. If the comparison is taken as a validation of FK, disagreements would indicate that FK is unreliable. However, given the uncertainty associated with fisheries science, SK cannot be viewed as a 'gold standard'. Disagreements have often turned out to enrich scientific understanding (Johannes and

Neis 2007), and it is increasingly recognised that alternative sources of knowledge are needed to manage complex adaptive systems (Folke et al. 2003). FK and two types of SK on trends in Seychelles reef fish stocks all disagreed, emphasising the partial view of each individual measure (Chapter 3). It is beneficial for science to have assumptions challenged by alternative perspectives, because science may not be focussed on the key problem, and may not model the appropriate indicators and processes (Hoffmann-Riem and Wynne 2002). Thus, awkward questions fishers put to scientists may be the most useful contribution FK can make to their understanding (Einar Hjorleifsson, pers comm.).

From the governance perspective, disagreements between FK and science highlight potential issues with the legitimacy of science and management, and with the feasibility of co-management or community based management (CBM) or conservation (CBC). If perceptions of fishers and scientists are so different that they are 'living in parallel realities' (Chapter 4), the legitimacy of science-based management measures will be compromised. For example, Seychelles sea cucumber divers and North Sea fishers dispute official stock assessments, and object to the resulting management controls.

Chapter 4 suggested that fish catches as perceived by fishers bore no relationship to ecological measures of biomass. CBM and CBC are based on the principle that resource users will choose to conserve for their own long-term benefits, but if ecological variables of interest to conservationists have no bearing on local uses of resources then this will not result in conservation. This bears a similarity to Adger et al.'s (2001) account of how large-scale, scientific discourses are illegible from local resource users' perspectives.

7.5 Theme 3 – Alternative approaches: Extractive and participative FK-engagement

Given that FK is often at odds with scientific views, and the resultant governance issues, the challenge for fisheries management is for SK and FK to engage and interact. Legitimate management requires an 'intersubjective truth' (Chapter 2), or common understanding between the different actors involved in governing the resource (Ostrom 1990). Approaches towards engaging FK can be divided into two extremes; 'extractive', where FK is collected from fishers to be used *ex situ* in science and decision making; and 'participative', in which fishers themselves become part of the process of research (Fischer 2000) or decision making (Figure 7.3).

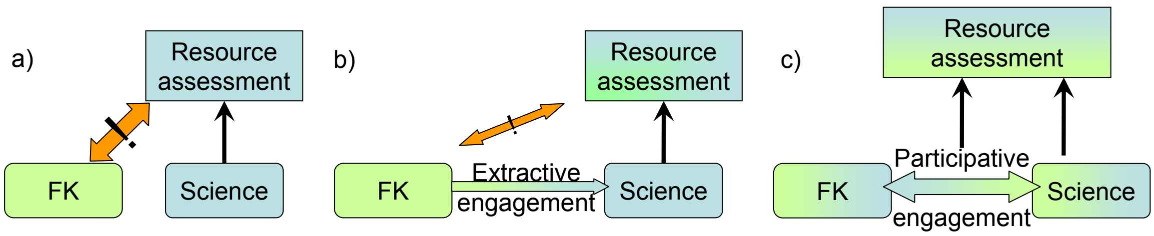


Figure 7.3. Conceptual diagram of 3 types of engagement with FK in terms of the assessment of a fisheries resource. a) no engagement b) extractive and c) participative. ! indicates disagreements between FK and official resource assessments.

These are not mutually exclusive approaches and they form a continuum. For instance, fishers may be involved in the design of extractive approaches and the analysis of its results. Holm (2003a) critiques common practices of extractive approaches as de-contextualising knowledge, when FK-research should be rooted in the development of science which is contextualised within society (Nowotny et al.

2001). The previous chapters allow us to examine how such de-contextualisation affects the outcomes of FK engagement from both the FK-utility and governance perspectives. Advantages and disadvantages of extractive and participative approaches are summarised in Table 7.3.

Table 7.3. Advantages and disadvantages of extractive and participative approaches to engaging with FK according to the FK-utility (U) and governance (G) perspectives

Extractive approaches	Participative approaches
Advantages Rapid to conduct Formalises FK for incorporation with scientific knowledge (U) Targets scientifically useful FK (U) Can include large numbers of fishers (G)	***Advantages*** FK less likely to be misinterpreted (U) Accesses all categories of FK (U) Allows 2-way learning and feedback (G, U) Builds personal relationships and information networks (G)
Disadvantages Potential misinterpretation of FK (U) Fishers lose power over their knowledge (G)	***Disadvantages*** Expensive in time and resources May be dominated by few individuals (G)

7.5.1 FK-utility perspective

The FK-utility perspective on engaging with FK holds that, in the light of limitations of fisheries science and unpredictability of complex fisheries systems, FK is needed to enhance understanding for sustainable management. From an FK-utility perspective, it seems that extractive engagement with FK only engages with an impoverished version of FK, perhaps missing the most scientifically useful information. There is also the risk of misinterpreting the meaning of FK because knowledge is culturally embedded, and it can make little sense to extract abstract elements of it (Sillitoe 1998). Thus de-contextualising FK is seen as lessening its scientific utility and validity.

Chapter 6 illustrates how the NSSS, an extractive approach, was focussed only on short-term trends FK and was unable to capture some of the FK which was more challenging and currently lacking in stock assessments. An extractive survey could be designed to target specific FK identified as needed by stock assessors (an example is the work by Neis et al. 1999) but fully extractive approaches will always be restricted by the questions asked and limited to the more discursive categories of FK (Figure 7.2).

Chapter 5 highlights that by analysing perceptions according to incompatible mental models, an extractive engagement with FK represented FK as indicating that a resource was overexploited, when, in fact, most fishers thought the stock was healthy and that fishing effort was not too high. Meanwhile, the North Sea Stocks Survey collected trends FK but not the contextual process FK of fishers about economic or behavioural factors which may affect catch trends. It was also unclear whether the *ex-situ* trends FK referred to trends in the stocks or perceived changes in catches, thus lessening its scientific utility (Chapter 6).

Other researchers have suggested that the de-contextualisation of knowledge is needed to *improve* its scientific utility. For instance, Fischer (e.g. 2000) suggests recording the observations of fishers rather than their interpretations. For example, the interpretation of *Oreochromis* cichlid fish eating their own eggs was incorrect, but the observation of the young in their mouth could be de-contextualised and correctly interpreted within a scientific frame of reference as referring to mouth-brooding behaviour. This type of research involves directly collecting data from fishers, and so is almost akin to logbooks, which have a long history in fisheries science. De-contextualising FK allows standardised data collection and aggregation to even out variability and identify trends. Dulvy & Polunin (2004) extracted observations on whether villagers still caught the parrotfish *Bolbometapon muricatum*, and used the aggregate results to inform scientific attempts to monitor the species' decline. Neis et al. (1999) took simple statements of vessel descriptions from Canadian skippers and aggregated them to show overall trends in fishing power. In Seychelles, extractive collection of good, normal and poor catches allowed reconstruction of contemporary CPUE-frequency distributions (Chapter 3).

It appears, then, that scientific-validity concerns of extractive approaches may be allayed by using only atomised facts, rather than more complex FK. However, there may be ethical concerns of extracting data from their socioeconomic and values context, as illustrated by the collection of a large number of fishers' observations of fish aggregations as raw data to map spawning aggregation sites (Daw 2004). *In-situ*, FK on aggregations is resource-harvesting knowledge that fishers use to maximise catches and income. *Ex situ*, this FK highlights areas of conservation priority and candidate sites for fisheries closures, without necessarily taking account of the social or economic impacts of such measures. Once FK is collected from fishers within an extractive approach, they have no opportunity to ensure its correct interpretation (validity concern) and no power to defend their interests against it being used against them (ethical concern). Maurstad (2002) discusses such ethical concerns at length and suggests giving fishers control over publication of FK by feeding research back to them before publication. Meaningful feedback of results like this could also allay the validity concerns of extractive approaches by giving fishers the opportunity to correct misinterpretation resulting from de-contextualisation. The NSSS feedback had not apparently been effective at communicating the results (Chapter 6). Feeding back ParFish results to fishers in an iterative cycle of adaptive research and learning as prescribed in the ParFish toolkit would most likely have highlighted the process FK conflict identified in Chapter 5.

In contrast to extractive approaches, participatory approaches have the potential to engage all categories of FK, because fishers themselves are engaged, along with all their FK and they can draw on even the most tacit categories. The participatory lobster assessment in Seychelles (see Chapter 5) allowed more dialogue between FK and scientific knowledge which improved research by challenging scientists, and suggested survey design as failing to account for key variables of lunar phase and reduced catchability in response to fishing. This finding is widely reflected across the literature, with positive reports from collaborative research projects (McCay et al. 2006; Stanley and Rice 2007). Also, observations of the ACFM stock assessment meeting showed face to face dialogue between fishers' representatives and scientists informing the work of the stock assessors in a more direct way than the extractive NSSS (Daw 2006a).

Participatory approaches, as they involve an organic interaction between fishers and scientists or managers, can be more qualitative and flexible. In the case of Canadian cod stock assessments, offshore CPUE (collected by extractive approaches) was favoured because it was amenable to quantification and standardised collection, while inshore effort was awkward to collect and quantitatively incorporate into scientific analysis. However, inshore FK could have been accessed by participatory approaches to give early indicators of the demise of the stock (Neis 1997).

7.5.2 **Governance perspective**

The governance perspective on engaging FK sees the incorporation of FK into science and management as part of a move towards more participatory governance, improving the legitimacy of, and compliance with, management measures, and conforming to ideals of deliberative democracy (Jentoft 2000).

Extractive engagement with FK does not seem as well supported from the governance perspective. Collection of FK and translation into scientific forms can be seen as a means to develop mutual respect between fishers and scientists (Mackinson and Noettestad 1998), but if done badly it can alienate fishers by taking their knowledge and morphing it into forms they do not recognise, and have no control over (Maurstad 2002). This thesis supports Holm's (2003a) contention that purely extractive engagement with FK does not contribute to 'Mode 2 science', as it gives little opportunity for fishers to challenge or contextualise science.

Through the lens of Foucault's (1995) 'power/knowledge' concept, fishers sharing their knowledge can be conceived as sharing what power they have within their knowledge. Extractive approaches can work against the democratisation of knowledge by appropriating FK so that the process of FK engagement leads to a loss of fishers' power. Fishers are aware of the risk of having their knowledge co-opted against their interests. Chapter 6 showed that participation in the NSSS was damaged by suspicion – "there is always the fear that our knowledge will be used against us" – while Pinkerton (2003) cites examples of fishers sabotaging collaborative research by destroying fish tags or removing cooperation. In contrast, participatory approaches like collaborative research appear to contribute to trust and communication between fishers and scientists. Interviews with fishers and scientists in the North Sea case emphasised the improved relationships that had developed through face to face personal contact between them.

Extractive approaches to engaging with fishers' knowledge would be more acceptable to the governance perspective if the objectives and type of 'participation' is transparent for participants, and participation is voluntary. As Silver and Campbell (2005) suggest, perhaps lower forms of participation, criticised by Pretty (1995) are acceptable if the level of participation is made explicit. This is the equivalent of the principle of 'freely given and informed consent' applied in social science endeavours that require the participation of human subjects, but which may not result in material or political benefits for those subjects (BSA 2004). To fulfil participation ideals it is important that the level of participation and expected outputs is clear to fishers when they take part in FK-engagement. There is a risk that FK engagement may be perceived by, or 'sold to', fishers as helping them in some way by supporting their interests (when this may often not be the case, – most cases reviewed in Chapter 2 had science-enhancement aims). Thus informed consent requires the explicit statement of the aims of FK engagement (Chapter 2).

Extractive approaches are the only way to engage with the FK of very large numbers of fishers. In the NSSS, for instance, all demersal fishers operating in the North Sea were invited to participate and had an equal opportunity to contribute their FK (Chapter 6). Inclusion at such a large scale would certainly not be possible with participative approaches; only two industry representatives were present as observers at the 2006 ACFM meeting (Daw 2006a).

7.6 Theme 4 – Allied perspectives on the engagement with fishers' knowledge?

Chapter 1 introduced the FK-utility and governance perspectives on engaging with FK(Jentoft 2000; Gray 2005). These perspectives are often conflated or discussed together during the introduction of FK literature (e.g. Jentoft et al. 1998). I will now discuss whether these perspectives are sufficiently complementary or whether they should remain distinguished. Are they reconstitutions of the same basic goals; common objectives for different aims; or incompatible philosophies which have been artificially moulded together by FK researchers keen to accumulate the maximum rationale for funding their research?

The two perspectives have different objectives. The FK-utility perspective aims for:

- Collection of reliable and sufficiently representative information from fishers (Johannes and Neis 2007)
- FK that is complementary to existing knowledge (Moller et al. 2004)
- FK actually contributing to the science and/or management of fisheries (Johannes 1998).

While the governance perspective aims for:

- Improved legitimacy of management (Jentoft 2000)
- Improved compliance with management measures (Jentoft 2000)
- Arenas of collective learning (Olsson et al. 2004) to allow identification and resolution of cognitive conflicts (Adams et al. 2003) in order to develop common understandings (Ostrom 1990)

- Development of trust and respect between stakeholders, scientists and managers allowing greater cooperation and knowledge transfer (McCay et al. 2006)
- Development of multi-scale governance so that knowledge used for management matches the scales of social and ecological systems (Berkes 2002; Berkes 2006)
- Deliberative democratic rights allowing stakeholders to have their knowledge and values incorporated into the process of decision making (Dryzek 1990)

Although often conflated, the two perspectives may not be served by the same approaches. Are these complementary perspectives or is the existence of two separate perspectives a source of confusion which could undermine progress?

'Adaptive co-management' is an approach which seems to draw equally on both the 'FK-utility' and 'participatory' perspectives as complementary (Olsson et al. 2004). Broadening of participation in management decision-making allows more diverse knowledge to become available for resource management through a process of 'social learning' (Olsson and Folke 2001), and devolution of management allows locally available knowledge to be incorporated into management at appropriate scales (Berkes 2002).

In practice, however, tensions may exist between the two perspectives. For example, Holm (2003a) points out that research focussed on the utility of FK can be 'extractive', appropriating useful knowledge without true participation of fishers, and remaining within a 'Mode 1', elitist knowledge regime (Nowotny et al. 2001), and thus failing from a governance perspective.

Another tension between the FK-utility perspective and the governance perspective appears when designing inclusion processes for FK-engagement. Knowledge is not homogeneously shared through communities (Maurstad 2000) so it is suggested that ecological knowledge research should be directed at community experts (Davis and Wagner 2003). The governance perspective may uphold the right of all fishers to contribute (as is done with the NSSS) while the FK-utility perspective would aim to extract the most valuable knowledge by giving precedence to expert fishers.

Perhaps it is not necessary for FK engagement to be clearly aligned to one or other of the two perspectives. A pragmatic view may say that it does not matter what the underlying aims are; if there are common objectives then they should be exploited without effort wasted on agonising over philosophical ethics. In any case the two perspectives are linked, in that more participation leads to more diverse and valuable knowledge becoming available (Stanley and Rice 2007). Chapter 5 showed that the utility of FK could be reduced by its misinterpretation, but this seems less likely in ongoing participatory processes.

The risk of fishers sabotaging engagement provides another link between the FK-utility and governance perspectives. Lack of attention to the governance perspective can leave fishers disillusioned and unwilling to participate (Maurstad 2002), thereby jeopardising the goals of the FK-utility perspective. The governance context of the NSSS, and the resultant mistrust of scientists, was a major factor in reducing fisher participation (and therefore the breadth of knowledge available). This was also apparent in Seychelles, when sea cucumber divers were reluctant to give interviews due to the perceived ills of the governance regime. Fishers who do provide information (they can be forced to, for example, by compulsory logbooks) can be expected to provide better information if they believe and trust in participatory governance. In Europe, compulsory logbooks have been unreliable data sources due to extensive misreporting for several species (Daw 2006a), whereas voluntary logbook schemes have provided detailed and valuable information (Quirijns et al. 2004).

Thus while the philosophical roots of the two perspectives may differ, in practice they are close enough to be complementary. Participatory governance appears to be necessary to maximise the utility of FK in the long term, and benefiting from the utility of FK is likely to be a natural result of participatory governance. Besides, the perspectives are not inherently incompatible, and it seems that most advocates of engagement with FK concur with some elements of both perspectives. Where problems may occur is where purely extractive approaches are used to support the FK-utility perspective without recognition of the importance of the concerns of the governance perspective.

7.7 The promise of cooperative research

The research and preparation of this thesis has led me on a journey of thought and some experience in the relationship between FK, science and fisheries management. There are many views and perspectives on how FK should be engaged. Hoefnagel et al. (2006) offer three models of how science and FK can interact, while Holm and others engage in a vigorous debate on the merits and perils of de-contextualising FK

(Hall-Arber 2003; Holm 2003a and replies; Holm 2003b; Neis 2003; Pinkerton 2003). Both debates come to similar conclusions: that fishers and scientists working together on collaborative research is a valuable way forward, culminating in the ideal of 'community science' (Hoefnagel et al. 2006), a clear example of a participative approach. For Hall-Arber (2003), such collaborative research qualifies as moving towards 'Mode 2' by broadening expertise, and sharing the definition of problems and research priorities (Nowotny et al. 2001). 'Intersubjective truths', 'Common understandings' and the resolution of 'cognitive conflicts' have been suggested as important factors in resolving tragedies of the commons (Ostrom 1990; Adams et al. 2003). Stanley and Rice (2007) relate how collaborative research with fishers as equal partners, led to an exchange of skills and knowledge and an eventual common understanding.

The chapters of this thesis point me towards similar conclusions. There is wide disagreement of some kind between FK and conventional scientific knowledge in all of the cases studied (Chapters 3-6), and it appears that such discrepancies will be a problem for any form of co-management or community-based management (if this is assessed from Western ecological perspectives, Chapter 4). Collection and translation of FK into quantitative forms which can be subsumed into stock assessment models both in Seychelles and the North Sea, cannot address key conceptual differences between stock assessment science and fishers; nor allow science to learn from the novel insights held by fishers; nor allow fishers to understand the work and insights of scientists. Although not studied in detail in this thesis, the advantages of collaborative research (for instance the Seychelles lobster stock assessment) in which fishers are respected as knowledgeable partners, seems to open up lines of communication which bring the common understanding and resolution of cognitive conflicts required, while allowing scientists and fishers to interact and learn from one another, gaining an appreciation of each others' worldviews. This conclusion concurs with the importance of trust, conflict resolution, combination of diverse knowledge and arenas for shared learning recommended by Olsson et al. (2004).

Achieving common understandings will always be challenging considering the differing vested interests of fishers and scientists leading to the 'you-would-say-that-wouldn't-you problem'; and the different worldviews of scientists and fishers. The simplified models necessary for quantitative science (Hall-Arber 2003) may always appear crude and inappropriate to fishers. However, despite these challenges, the findings of this thesis suggest that attempts to reach common understanding between fishers and scientists are worthwhile or even necessary for sustainable fisheries. The alternative, of accepting that the two groups continue to exist in their own parallel realities, will be a major impediment to reaching agreement on management actions as more participatory management evolves. Participatory engagements allow fishers to learn and understand scientific approaches, and this has been accelerated in Europe by the employment of scientists by fishers' organisations (Hoefnagel et al. 2006) who can act as 'knowledge brokers'. Meanwhile, fisheries scientists are becoming increasingly aware of the value of FK, the inherent unpredictability of fishery systems, the non-biological complexities of fisheries, and the need for adaptive management and alternative perspectives.

In conclusion, this thesis suggests that participatory rather than extractive approaches offer the best opportunities for engaging with FK for more relevant science and more efficient, sustainable fisheries management in the future. Extractive approaches can also contribute where time and resources are limited or if the aim is to engage FK from a large number of fishers. However, these should be made as participatory as possible by involving fishers in the design and analysis and supplying extensive feedback. This will help to minimise the risks of misinterpretation of the limited categories of FK collected, and to maximise the possibility of feedback and social learning.

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Appendix 1. Interview form for Seychelles trap fishers

Background information:

Fisher Name		Date	
Port		Interviewer	
Community		Location	
Skipper☐ Boat owner☐ Fisherman☐			

Effort:

Question	Answer	Comments / Notes	**Change?**
Importance: 1. For how many years have you been trap fishing?			
Last year's effort: 3. How many months did you use traps during the past year?			
4. How many days per month did you fish last year?			
5. How many traps do you use per day?	VN:		
	VS:		
Typical effort: 9. Was this a typical year? ***If not, Why? Record typical year's activity***			
Vessel Description: Vessel Name:			
Length:			
Engine type and power:			
Catch capacity:			
Cabin:			
Nav equipment:	ES: GPS:		
Fishing Grounds: Normal fishing grounds?			
Maximum distance to grounds?			
Minimum distance to grounds?			
Maximum trap depths			
Minimum trap depths			
Typical soak time?			
Changes in time Since nav lights were put in at AAP (5-6yrs), has the way you fish changed?			

Perceptions of resource, and catch rates

Question	Answer	Comments / Notes				
Resource condition perception Do you think population of fish you catch are in a good state?						
Trends in catch rate: Over the last 6 years, are you catching more, less or the same amount of fish per trap?						
Why do you think this is the case?						
Current Max catch rate: Now, on the best days, how many packets do you catch? How many traps do you use? ***What are the main species in this answer?***	No: Traps:					
Current Min catch rate: Now, on the worst days, how many packets do you catch? How many traps do you use?	No: Traps:					
Current Normal catch rate: Normally, how many packets do you catch in a day? How many traps do you use?	No: Traps:					
Current target spp: Which species do you catch mostly now? (If you have 100 packets how many would be each spp?)						
Former Max catch rate: 6 years ago, on the best days, how many packets did you catch? How many traps did you use?	No: Traps:					
Former Normal catch rate: 6 years ago, normally how many packets did you catch? How many traps did you use?	No: Traps:	Types				
Former Min catch rate: 6 years ago, on the worst days, how many packets did you catch? How many traps did you use?	No: Traps:					
Current target spp: Which species do you catch mostly now? (If you have 100 packets how many would be each spp?)						

Hypothetical Questions

Question	Answer		Comments / Notes
Catch rate for unexploited stock: 8. In you found a place never fished or which has been left for a long time without fishing), what is the most and least number of packets you could catch? How many traps would you use?	Min	No: Traps:	
	Max	No: Traps:	
How did you come up with this answer?			
Recovery time: 9. If no-one fished on your grounds, how long do you think it would take for the stocks to recover so that it was like that? ***How did you come up with this answer?***	Immigr.☐ Growth☐ Reprod.☐		Time unit

Perceptions:

Question	Answer		Comments / Notes
Perception of total fishing effort: 10. Do you think the amount of fishing (no traps) for the size of the resource is OK? ***How many traps should there be? Why do you think that?***	Could be greater		
	Just right		
	Too much		
Species changes Are there any species which have changed particularly since 6 years ago?			

Factors affecting stocks What things control/affect the population of the fish you catch? *(Ask open Q then prompt)* How does this affect fish?	Trap fishing	V Y N	
	Other Fishing	V Y N	
	Predation	V Y N	
	Food	V Y N	
	Habitat quality	V Y N	
	Reclamation	V Y N	
	Recruitment	V Y N	
	Immigration	V Y N	
	Tsunami	V Y N	
	Coral Bleaching	V Y N	
	Other	V Y N	
Of these, which is the most important?			

Management Opinions: What do you think should/needs to be done to manage the kasye fishery?		

Management Opinions: What do you think should/needs to be done to manage the kasye fishery ***How much/when/ How?***	Limited licences	V Y N	
	Closed season	V Y N	
	Closed area	V Y N	
	Mesh size	V Y N	
	Others	V Y N	

Overview of fishery Do you see catches from other kasye fishers? How? How many? From where? How do you get information about the state of kasye fish stocks?		
Do you know what SFA think about the state of stocks and the kasye fishery? Do you agree?		

Personal Information:

Question	Answer	Comments / Notes
How old are you?		
How many years of formal education did you do?		
Ownership of gears Do you own the boat you use?		
Do you own your kasye?		
Do you have any loans to pay on fishing		

vessel/equipment used for barbara?		
Fisher importance - Dependents: Including you, how many people rely on your income?		
Other income Other than kasye fishing. What other fisheries or work do you have for income?		
Fisher importance - Dependence on fishing: What proportion of your income comes from kasye fishing?		

Appendix 2. International WIO household survey form

Household No: Survey ID

Household Surveys
I. DEMOGRAPHIC INFORMATION

Date_______________
Village_____________
Interviewer_________

1. Where are you initially from?

This community	This region/island	This country	Other country

2. How long have you lived in XXX?_____________

3. Why did you move to XXX?

Fishing	Other work	Family & friends	Health/spiritual
Other			

II HOUSEHOLD ECONOMICS

4. How many people live in your house?

Adult male	Adult female	Male children	Female children

5. What jobs do you and other people in your house do that bring in food or money to your house?

a. ACTIVITY	b. Inter-viewee?	c. # of People	d. Rank of Importance	e. Notes/Detail
Fishing				
Gleaning				
Mariculture				
Marketing Marine Products				
Farming				
Cash Crops				
Salaried Employment				
Tourism				
Informal Economic Activities				
Other				

f. Total number of occupations_________ g. Number of different occupations________

6. What other work have you done in the last 5 years?

a. Occupation	b. Main job?	c. Why stop?	d. Could get similar now?	e. Prefer this to current activity?

6f. *(if never fished)* Would you ever be a fisherman?

III. COMMUNITY PARTICIPATION

7a. Do you belong to any community organizations? 7b. How many?

7c. What are the greatest threats to this organisation?

8a. If there is a decision to be made in your community, are you involved in that decision? How?

No	Passive	Active

IV. PERCEPTIONS ABOUT COASTAL RESOURCES

9a. Is there more or less fish in the sea now compared to 5 years ago?

9b. How do you know?

10. What can affect the number of fish in the sea? How?

Factors & Mechanisms		Individual logic statements							
		A	B	C	D	E	F	G	H
Fisheries-related	Number of fishers								
	Fishers from outside								
	Over fishing								
	Spear Gun								
	Seine Net								
	Gill Net								
	Other Gear								
	Gleaning								
	Dynamite								
	Poison								
Human	Coral mining								
	tourist activities								
	Land-based pollution								
Environ.	Weather								
	Season								
	Environmental changes								
	Bleaching								
Ecology	Habitat								
	Feeding for fish								
	Reproduction								
	Life history stages								
	Fish moved/hiding/behaviour								
Sociccultural	Political/economic conditions								
	Market demand								
	Social cohesion								
	Supernatural/Superstition								
	Religion /God								
	Other								
	Nothing								
	Don't know								
	Kills fish – fish mortality								

11. What could be done around XXXX to so that there would be more fish in the sea?

Reduce number of fishers	Exclude other fishers	Reduce fishing effort	Closed areas	Enforcement of fishing regulations
Reduce explosive use	Reduce poison use	Reduce gill net use	Reduce seine net use	Coral mining
Education	*Land-based*	Political/economic conditions	Social cohesion	Fish moved/hiding
Supernatural	Nothing	Don't know	Other	

V. MATERIAL STYLE OF LIFE

12. Household items & facilities.

Generator	Electricity	Vehicle	Modern stove
TV	Electric fan	Satellite dish	Piped water
Refrigerator	Radio/cassette player	VCR	Water tank

13. Roof material

Thatch	Metal	Tile	Other

14. Floor material

Cement	Mosaic (tile)	Dirt	Plank Wood	Bamboo/palm	Other

15. Wall material

Cement	Wood (plank)	coral	Bamboo	metal	Other

16. Toilet

Flush toilet	Outhouse	Public toilet	No toilet	Other

VI. MORE SOCIOECONOMIC QUESTIONS

17. Age__________ 18.Sex________

19. Religion 20. Languages 21.Ethnicity

22. What is the highest grade of education you have attained?

23. Last fortnightly expenditures

VII. FISHERIES INFORMATION (*For fishers only*)

24. How did you get into fishing?

.25a. When you or other household members go fishing, what equipment is involved??

a. Gear	b. Rank of Impor-tance	c. Trips /week	d. Own/ Use?	e. # People	g. Description (net length, net gauge, hook length, etc.)	25b. Areas fished	25c. 5 years
Hand line (reef)							
Hand line (pelagic)							
Hand line (demersal)							
Lasenn Makro (encircling gill net)							
Lasenn Sardin (encircling gill net)							
Kazye							
Octopus spear							
SCUBA for sea cucumber							
Longline (poton/swordfish)							
Purse seine net (pou ton)							
Lasenn drivan							
Gleaning							
Lezot? Others							

(If more than one fisher in household, circle main gear of respondent above)

25b. Please look at this map of the fishing area. Please tell me the three most important areas (ranked) for each of *your* gears in each season.

25c. Have these areas changed in the last 5 years (record notes on which numbered areas have changed) i.e. Do you fish in different areas than 5 years ago?

26. Do you use a boat?

a. Boat type	Small/large (< or > 5m)	Motor HP?	Owned?	Notes
	S L		Y N	
	S L		Y N	

All with same gear (i.e. with interviewee's principle gear

VII. CATCH PER UNIT EFFORT PERCEPTIONS

GEAR		No. of people	

27a. With your main gear, how much fish do you catch on a (a) good day, (b) poor day and (c) normal day.

27b. How much effort do you put in on a good/bad/normal day (hrs, traps, etc)

	Units	poor day	Good day	Normal day
27c. **Catch**				
27b. **Daily effort** (hrs, traps etc)				

27c. How much is the catch worth on a normal day?

28. On an average day, how many fish are consumed and how many fish are sold?
%food_______ %market_________

29i) What was a normal day's catch and effort with this gear 5 years ago? (*Include units for each*)
ii) How much was it worth?
a. Value …….……. b. Weight......................c. Daily effort

30xi. Why is your catch different now to 5 years ago?

Table 4

Less fish	*More fishers*	*Adjust/improve gears*	*Change gear type*
Change daily effort		*Change areas*	*Other*

30xii. Have you changed the way you fish to try and catch more fish since 5 years ago? How? Rank success of each?

a. Change	*b. Rank success/importance*

30xiii. Imagine if nobody else was fishing in those grounds. What do you think your average catch and effort would be?(compare to normal daily catch and effort):

catch:
effort:

VIII. DISTURBANCE OPTIONS

30a. If you were to consistently get 10% less all year what would you do?

keep fishing at same amount	fish harder	move locations	change gear	leave fishery-where to?
Other				

30b. If you were to consistently get 20% less all year what would you do?

keep fishing at same amount	fish harder	move locations	change gear	leave fishery-where to?
Other				

30c. If you were to consistently get 30% less all year what would you do?

keep fishing at same amount	fish harder	move locations	change gear	leave fishery-where to?
Other				

30d. If you were to consistently get 50% less all year what would you do?

keep fishing at same amount	fish harder	move locations	change gear	leave fishery-where to?
Other				

31. What jobs could you do in the near future?

a. Offered	Yes	No	Occupation	b. Would you prefer that?
			TOURISM	
			Selling souvenirs to tourists	
			Taking tourists in boats (glass bottom, snorkeling)	
			Watersports (jetski, kayak, windsurf rentals)	
			Tourism service (hotel, bar,other work)	
			Other fishing gears	
			Fishing with traps	
			Fishing with line	
			Fishing with spear	
			Fishing with nets	
			Aquarium fishery	
			Selling marine products	
			Aquaculture	
			Agriculture	
			Salaried employment (factory, teaching, government work)	
			Informal economy (driving taxi, selling on the street, casual labor)	

IX. AWARENESS OF REGULATIONS
32.

Management type	**Description**	**Do people still (go there, use that gear, etc)**			
		No	Just a few	Most	All
Are there places where people are not supposed to fish?					
Are there certain gears that people are not supposed to use?	A explosives				
	b. poison				
	c. net				
	d. other				

Do people agree with the regulation?

X. OTHER INFORMATION

33. Is there anything else you would like to tell me about fishing, livelihood and fish stocks?

Appendix 3. 2006 Survey of North Sea Stocks

The purpose of this questionnaire is to ensure that fishermen's knowledge of the state of fish stocks is considered during the development of TACs.

The questionnaire should be completed by
comparing conditions in January - June this year with conditions in January - June last year.

All information will remain strictly confidential. Data will be pooled before presentation to the Advisory Committee on Fisheries Management. To ensure complete confidentiality please *do not* write your name, or the name of your vessel, on this questionnaire.

Instructions

The questionnaire refers to the North Sea only.

The questionnaire is in four sections that will help us use the data
Vessel size and gear type
Information on the eight main species
Your financial status compared to last year
Any other information you may wish us to know

Questions should be answered by putting a tick in the appropriate box (see example below).

EXAMPLE						
Question 1	Answer 1	√	Answer 2		Answer 3	

SECTION 1

VESSEL & GEAR						
Size	Under 15m		15-24m		Over 24m	

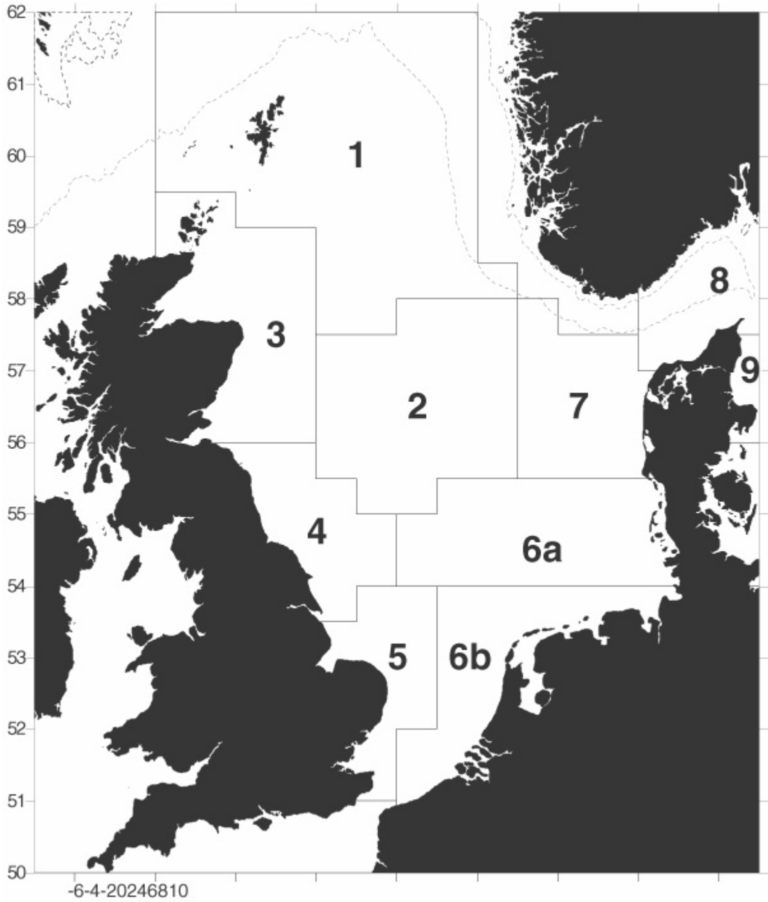
Main fishing method last year	Trawl		Nephrops Trawl		Beam Trawl		Gill Net		Seine	
	Other (please specify)									

Main fishing method this year	Trawl		Nephrops Trawl		Beam Trawl		Gill Net		Seine	
	Other (please specify)									

SECTION 2

When completing the question on fishing area in this section, reference should be made to the numbered boxes on the map below.

Information on abundance should be provided on the basis of catch not landings



COD										
Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of cod changed since last year? No ☐ Yes ☐
If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of cod discarding changed since last year? ☐No ☐ Yes
If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small		All sizes		Mostly large	

Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

HADDOCK										
Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of haddock changed since last year? ☐No ☐Yes
If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of haddock discarding changed since last year? ☐No ☐Yes
If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small		All sizes		Mostly large	

Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

WHITING										
Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of whiting changed since last year? ☐No ☐Yes
If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of whiting discarding changed since last year? ☐No ☐Yes
If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small			All sizes			Mostly large	
Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

SAITHE										
Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of saithe changed since last year? ☐ No ☐ Yes
If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of saithe discarding changed since last year? ☐ o ☐ Yes
If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small			All sizes			Mostly large	
Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

MONKFISH										
Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of monkfish changed since last year? ☐ No ☐
Yes
If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of monkfish discarding changed since last year? ☐ No ☐ Yes
If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small			All sizes			Mostly large	
Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

NEPHROPS										
Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of Nephrops changed since last year? No ☐ Yes ☐
If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of Nephrops discarding changed since last year? ☐ No ☐ Yes
If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small			All sizes			Mostly large	
Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

SOLE										
Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of sole changed since last year? No ☐ Yes ☐
If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of sole discarding changed since last year? No ☐ Yes ☐
If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small		All sizes		Mostly large	

Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

PLAICE

Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

Has the abundance of plaice changed since last year? ☐ No ☐ Yes
If yes:

Change in Abundance	Much less		Less		More		Much more	

Has your level of plaice discarding changed since last year? No ☐ Yes ☐
If yes:

Change in Discards	Much less		Less		More		Much more	

For this year:

Size range	Mostly small		All sizes		Mostly large	

Abundance of young fish about to enter fishery	Low		Moderate		High		Don't know	

SECTION 3

ECONOMIC CIRCUMSTANCES

Have your economic circumstances changed since last year?

Difficulties in obtaining or retaining crew	Much less		Less		Same		More		Much more	
Operating costs	Much less		Less		Same		More		Much more	
Profits	Much less		Less		Same		More		Much more	
Are you more or less	Much less		Less		Same		More		Much more	

optimistic about the future?										

SECTION 4

Have you any additional information on the fisheries?

Thank you for your contribution.

Appendix 4. Interview guide for NSSS participants

Do fishermen think the survey is well designed what would be their suggested improvements?

1. What do you feel about the survey?
    a. Is it well designed?
    b. Is the level of detail appropriate?
2. How could it be improved?
3. Is there any other information that you think should be included?
4. How long did you spend answering the survey?
    a. Did you find any questions difficult to answer?
5. Did trends vary with area?

How do fishermen go about answering the survey?

6. Can you talk me through how you chose which box to tick for abundance questions (much more, more, less, much less)
7. Do you answer questions based only on your own experience or that of other boats too?
8. How did you answer questions on the abundance of young fish about to enter the fishery? What would you consider a 'young fish'?

One of the problems for scientists using the survey is the difficulty of quantifying what people actually mean when they tick 'a lot more'. Can you try to give me some indications of the % this year compared to last year?

	Cod	Whiting	Nephrops
Stock abundance as % of last year			
Discards as % of last year			
Large fish size			
Amount of large fish			
Perception of recruitment			
Abundance as % of 2000			
Abundance as % of 20 years ago			

Influence of Technical changes on fishermen's perceptions of stocks

9. Are you fishing more efficiently now than you were then?

   a. If you were to go back in time with your current gears and fish alongside your old self how much more would you catch?
   b. Does that affect your perception of the abundance?

How do fishermen perceive the survey is used?

10. How do you think the results of the NSSS are used?
11. Do you feel the results of the NSSS are used enough? Why?
12. Do you expect the results to agree or disagree with scientific assessments?
13. Do you think the results are reliable? Why?
    a. Is there a temptation for fishers to err on the optimistic side?

What motivates fishermen to participate?

14. Why do you take part in the survey?
15. Did you complete the survey last year? Every year?
16. Will you participate in the survey next year? (no, yes)
17. What could make more fishermen participate in the survey?
18. Would anything deter you from participating in the survey in future?

Fisher-science relationships in UK?

19. Do you tend to agree with the findings of fisheries scientists in the North Sea?
    a. Can you give details/examples?
20. Do you think the relationship between scientists and fishers has changed in the last few years? Why?
    a. Has the attitude of fishers towards science changed?
    b. Has the attitude of scientists towards fishers' knowledge changed?
21. Do you think management is more based on science now than in the past?
    a. Are you pleased about that?
22. What effect have environmental groups had on the way fishers deal with fisheries authorities and scientists?
23. Do you think the NSRAC will improve management of the North Sea? Why?
24. Have you ever worked with scientists or provided them with any information?
    a. Can you describe how?
25. Are you involved with the SFF/NFFO?

Attributes of individual fisher

26. Vessel type
27. Vessel length Engine HP:
28. Length of time vessel owned
29. Main Gears used Mesh size:
30. ICES areas fished
31. Target species
32. Length of time a fisherman
33. Length of time a skipper
34. Age

Appendix 5. Report on a Review of the North Sea Stocks Survey 2006

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Contents

Executive Summary

This report summarises findings from qualitative interviews with 24 Scottish and English fishermen who took part in the North Sea Stocks Survey (NSSS) in 2006 supplemented by information from observation of the 2006 ACFM meeting and interviews with some stock assessment scientists. Interviewees were those fishermen who responded to a request distributed in conjunction with the 2006 survey.

Fishermen's perception of the NSSS

Most fishermen approved of the design of the NSSS, which was quick and easy to complete. About a quarter of the interviewees thought the NSSS was not detailed enough particularly that the spatial resolution was crude.

Few interviewees reported receiving feedback on the NSSS results although most interviewees participated in the NSSS expecting that it would in some way benefit the industry. Some interviewees hoped to improve science while others merely supported the initiative for the sake of their representative body.

Interviewees thought that the low return rate of the NSSS was due to the practical inconvenience of completing the NSSS or general disaffection with the situation of the industry, management decisions or suspicion of fisheries science.

Answers to the NSSS Related to Perceptions of Stocks

Most interviewees had completed the NSSS based on their own general perceptions of stock or catch trends. Alternative strategies were to use information from other information sources or consult logbooks for direct comparison of catch rates. Some Fishermen described factors which disrupted their perceptions or the relationship between catch rate and stock abundance.

Interviewees were asked to estimate this year's abundance of cod, whiting and Nephrops as a percentage of last year, 2000 and 20 years ago. The answers relative to last year were correlated to the response which interviewees had given on their NSSS forms although there were small inconsistencies. Two outlying estimates of extremely high percentage changes were due to comparisons of extremely low abundances observed last year.

Estimates of cod abundance compared to 20 years ago was largely in agreement with the latest stock assessment from ACFM but few interviewees perceived major changes since 2000 while the ACFM analysis indicates stock abundance has approximately halved.

Fishermen generally thought that the responses in the NSSS would be reliable and honest but it was conceded that a minority of skippers may inflate their answers to improve perceptions of the stocks. The futility of such a course of action, the genuine motivation of those that completed the NSSS and the general shift in attitudes within the industry were cited as reasons why the NSSS would be completed honestly.

In addition to the NSSS, interviewees also discussed trends within the fishing industry, issues of illegal reporting, opinions on fisheries science, ecological forcing of fish stock abundance and criticisms of the current regime of fisheries management.

Use of the NSSS
There was little evidence of the NSSS being used for fisheries science or management beyond comparison of the time series of abundance trends with scientific trawl survey indices used by stock assessors. Further use could be made, particularly of discard and recruitment data.

Implications of the results
The type of information collected by the survey allows comparison with trawl survey results but does not target gaps in the knowledge of stock assessment scientists or issues which are of most concern to fishermen. It is not clear whether the NSSS is aimed at perceptions of stock abundance or an indication of CPUE. These are not necessarily the same and have different implications for the potential use of NSSS data and the design of the NSSS.

The link between an expectation of beneficial outcomes from the NSSS and fishermen's motivation to participate may be problematic as the format of the NSSS and the management regime makes this direct expectation unrealistic. Greater feedback of the NSSS was requested and may help morale, although explicitly stating its limited impact may have the opposite effect.

Some fishermen see completing the NSSS as a duty to support the industry and their organisations and so their participation may be relatively unaffected by such trends.

The risks of complicating the form and reducing participation and the disruption of the time series speak against changing the format of the survey. However some fishers did want more spatial detail. Some possibilities are discussed briefly. Better use could be made of qualitative information by expanding the space to add comments and giving guidance on the types of useful information.

Ultimately the design and strategy adopted for the NSSS depends on its aims. Currently it serves to highlight agreement between some aspects of scientific and fishermen's knowledge. Alternatively, the NSSS could aim to enhance scientific assessments by filling knowledge gaps or to highlight disagreements in perceptions of fishermen, scientists and managers, stimulating discussion and ultimately assisting the development of shared understandings between fishermen, scientists and managers.

Acknowledgments

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Introduction

Following the distribution of the North Sea Stocks Survey (NSSS) in 2006, Tim Daw, a postgraduate student from Newcastle University conducted qualitative telephone interviews with 24 skippers from the British demersal fishing fleet to investigate perspectives of fishermen towards the survey and the questionnaire's ability to collect the knowledge of the fishermen.
This report summarises findings for the ICES review of the NSSS in December 2006.

Methods

Sampling

Fishermen were contacted through the distribution of the 2006 NSSS and contact numbers were requested to allow follow up interviews. Scottish Fishermen's Federation (SFF) members were requested to return a short reply slip directly to Tim Daw in a supplied stamped addressed envelope. To allow the individual questionnaire responses of individual fishermen to be compared with their interviews, questionnaire forms were numbered and each fisher was requested for the unique number of their questionnaire. In England, National Fishermen's Federations Organisation (NFFO) members were requested to add their contact details to the cover sheet of the usually anonymous forms. Forms completed in this way were copied and forwarded directly to Tim Daw by NFFO. The sample of fishers selected are not therefore representative of the population of British North Sea demersal fishermen or even of the fishermen who completed the survey. Only fishers who completed the survey were interviewed and of those who completed the survey, it can be expected that it was the most engaged or outspoken who chose to return their contact details to be interviewed. This is reflected in the fact that only 3 of the 24 interviewees were not involved with their representative organisation, not attending meetings, while 8 of the interviewees were deeply involved, sitting on executives or sometimes attending European-level meetings. One Scottish fisherman was an exception who responded by the mail out by telephone to express his views about the state of the fishing industry and the survey but was not interested in completing the survey.

Table 1. Level of response to NSSS questionnaires, contact detail requests and number of interviews conducted in 2006

Country	No. of NSSS responses (% of surveys distributed)	No. of contact details returned (% of NSSS responses)	No. of details returned with unique survey Numbers	No. of surveys conducted (% of NSSS responses)
Scotland (SFF only)	46 returns (16% response rate)	29 (63%)	17 (37%)	17 (37%)
England	19 returns (response rate NA)	8 (42%)	8 (complete forms)	6 (32%)

Table 2. Home region of interviewed fishers

Region	No. interviewees
Shetland	2
Orkney	1
N Scot	2
NE Scot	11
Fife	1
SE Scot	2
NE England	2
Yorkshire	3
Total	**24**

Table 3. Gear types of interviewed fishers

Main Gear	No. Interviewees
Creels	1
Fish trawl	7
Pair trawl	1
Prawn	9
Prawn/Fish	4
Seine	2

Interviews

At a mutually agreed time, telephone (and one face-to-face) interviews were conducted between 11th July and 20th August and lasted between 30 and 80 minutes. The interviews were based around the open-ended questions in Appendix 4a but were conducted as semi-structured conversations in order to gain an insight into perceptions and opinions of fishermen and to give them the opportunity to elaborate on topics which they felt were important. Specific questions were asked about fishers' opinions on the survey, the status of cod, whiting and *Nephrops* stocks this year compared to last year, 2000 and 20 years ago, and the work of fisheries scientists and their interactions with fishermen. Interviews were recorded with the permission of the interviewee, transcribed and coded by topic using the qualitative data analysis software Nvivo.

Comparisons between interviews and NSSS responses

The NSSS returns of the interviewees from SFF were identified by the unique number quoted in reply slips while copies of the survey forms of NFFO fishermen were forwarded along with their contact details. The perception of the current stock levels of cod, whiting and Nephrops as a percentage of the last years' stock were then compared with the responses to the appropriate NSSS abundance question.

Observation of meetings and key informant interviews

As fieldwork for TD's thesis, participant observation was conducted of several scientific and stakeholder consultation meetings (Appendix 4b) and the opportunity was taken to interview fishermen's representatives and scientists involved in the generation of scientific advice on North Sea stocks.

Results

Opinions about the design of the NSSS

Fishers generally approved of the survey design, 12 fishers used phrases to express their approval of the current level of detail, for example:

> *"I think that was a fair way to put it because that way you would get a feel of whether the stock had increased or decreased"*
>
> *"it would be too complicated if it had any more detail"*
>
> *"Aye, yes, it's nae bad"*
>
> *"I think it's a dish for a dish, simple and to the point and that's the whole idea of it"*

On the other hand, five interviewees suggested the survey was not detailed enough,

> *"the survey was kinda vague",*
>
> *"it could be doing with more detail, because the more information you get the better it is for us in the long run,"*

while other individuals made specific suggestions to include information on discards as a percentage of catch rather than a trend, more details on economics, observations of total fishing effort on the ground, more detailed descriptions of gear characteristics and observations on pollution.

> *"we did a lot of pair trawling, you could split that up maybe in your categories because in a pair trawl you'll probably target different species than you would in a hard ground trawl, working softer bottoms."*

No interviewees expressed difficulty with any of the questions in the survey nor that the survey was already too detailed.

Several interviewees made comments and suggestions on the spatial scale of the survey, which can be summarised as two main points.
a) The most common point (offered by 7 fishermen) was that the zones were too large to depict patterns in fishing activity or stock trends (particularly sizes of fish caught)

> *"Our area is area 4 on the map. It's a hell of a big gap. I mean fishermen 5 miles apart can have a totally different opinion because they might have a lot of whitings just 5 mile away and we might not see one so I'll fill in saying 'whitings are extinct' and another fisherman will say 'the sea's full of whitings' y'know."*
>
> *"it's the same with the haddock, smaller ones are inshore and the bigger ones are more offshore"*
>
> *"Two years ago we caught, we filled out the survey, och must have been 3,4 years ago there was a tremendous number of haddocks off the north coast of Scotland off what we call Strathy point, off of Scrabster, West side of Orkney and the last 2 or three years there's been absolutely nothing you know, but if you come round to the east side of Orkney there's been a lot of haddock"*

b) Different trends were observed in different areas but the survey did not allow these to be described. The survey only accepts one trend answer for each species, so that for example, a fisher observing very different trends in cod in the northern and southern North Sea has to choose one single response for cod.

> *"like that's the sort of way with cod, small ones seem to be south and the bigger ones north"*

> *"I've covered quite a lot of areas and it's no usually too big a problem but you could give a better answer if it was split up a bit more, maybe the similar questions for each area"*

Despite these issues with the spatial resolution and suggestions for more detail, several fishers described the trade off and potential pitfalls of increasing the complexity or scope of the survey as dissuading fishers from completing it.

> *"but it's like far do you start and far do you stop? You could make it mair, … pernickety, how pernickety can you be? It's a never ending thing, splitting hairs"*

> *"any more detail and the fishermen will maybe loose sight of what they're trying to fill in"*

Some fishers were still supportive of the idea of collecting information on finer or at least disaggregated spatial scales.

> *"You probably could, you could get a lot more information out of it without too much work."*

How fishermen go about answering the NSSS questionnaire

There was variability in the way in which fishermen chose their responses to the NSSS questionnaire. It was seen by nearly all as being a quick job taking between 10 and 75 (mean 25) minutes to complete and only one fishermen mentioned consulting their records,

"Yes just a quick look, I wasn't counting, I mean you could see how we fished roughly and it was just done like that but they wouldn't hold up to scientific scruitiny".

Just over half of fishers based their answers on general perceptions while a third of interviewees spoke specifically about their memories of catches or landings (Table 4),

> *"Well I just thought aboot it ken, and says well this time last year we were maybe landing 1000 boxes and this time we're maybe landing 1200 so it would be slightly more. So we just thought about it a minutey… it's all in my memory".*

Eighteen of the interviewees completed the survey based only on their own experience (Table 4) but notable exceptions incorporated information from other boats catches or producer organisations and markets in order to formulate their opinions, especially if their own practices limited their ability to perceive changes in abundance:

> *"well I've answered different questions in different ways. I've answered the cod question based on my own fishing, I've answered the haddock question due to what the pair trawlers were landing at the start of the year*

and due to what my haddock buyer has been seeing and I answered the whiting question with information that I've had back from the PO."

Fisherman: Well basically you're just doing it on your own catches but then you might generally think, you might have an overall perspective on how it's going on with some of the other boats.

Interviewer: And would you use that information when choosing your answers?

Fisherman: Yes I would say that because you'll say och no I've heard the pair seiners or trawlers is getting big fishing in such and such an area so you do generally kinda, although you're using your own information you probably tend to have a good picture on what the other boats are doing as well like.

Table 4. Basis of answers to NSSS abundance questions

Experience base	% respondents (n=21)	Data source	% respondents (n=16)
Only own experience	82%	logbooks	13%
Also other fishers	14%	catches	31%
Also other sources	5%	general impressions	56%

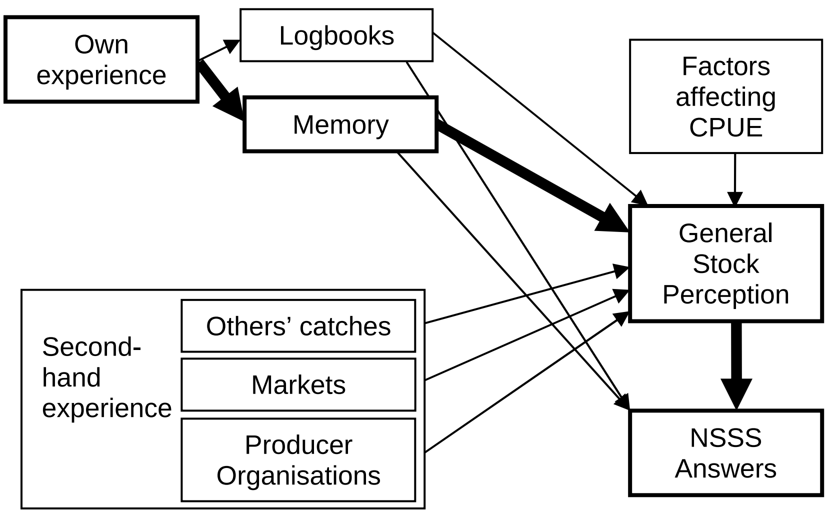

Figure 1. Sources of information contributing to NSSS answers. Thick arrows indicate commonest route according to interviews

Factors affecting perceptions and NSSS responses

Several fishers gave qualifications for their estimates of abundance or commented on factors which have affected catch rates and their answers. The catch rates were therefore not always thought to be indicative of stock abundance. Several prawn fishermen said that they did not have a clear perception of fish stocks because they don't catch much fish due to bycatch regulations.

"Well just with the small drops of fish you couldnae really tell because they're catching that little fish nowadays"

"if there's not the prawns we've got to move on so really a prawner's not got a great idea really how much fish there is in the North Sea. If we see fish we've got to move on"

"nowadays there isn't a 2 net rule and we can't be seen to, well we're just not allowed to land them, so we're not going to catch them so we're concentrating much more on the Nephrops fishery"

The registration of buyers and sellers, increasing fuel prices and enforcement of strict fish bycatch limits for prawn boats has reportedly had a large impact on the targeting behaviour of the fishermen which has also affected catch rates. Several prawn fishers stated that they were changing fishing grounds in order to aim for large prawns and maximise the returns from their quota.

"it's probably not a good year to do a survey 'cause there's been so much change. Probably the smaller boats in the fleet, the smaller prawn boats, 400hp 15, 16,17m boats you'll probably get a better idea from those boats than you will from boats like our own that have been trying different things and trying to change our mode of fishing"

"We haven't caught so much tonnage of prawn this year but it's not because we couldn't, it's because we've been looking for better prawns."

"At the moment we're working the soft bottoms a lot because it's easier on fuel and a lot higher value of species, you've got your prawns a lot and quite a few pout and turbots and soles, the higher value of fish to replace the lack of cod."

The weather was also seen to affect fishermen's perception of the stock.

"[if] you spent the whole of January fishing on the east, it look's like the monks have gone but it's just you canna go where the monks is"

Interviewees also commented on the difficulty of observing recruitment with large mesh sizes.

"With the likes of whiting, of haddock, our mesh size is too big to tell if there's nae small ones on the grounds."

Finally, the limited days available to fishermen were also thought to undermine fishermen's ability to explore grounds and perceive trends in the stock,

"They're there on a restricted time limit so any experimental fishery, isn't done now because of the restriction on being out there."

Comparisons with interview and NSSS results

Table 5 shows the average percentage changes offered by skippers for cod, whiting and Nephrops with the relevant answer they gave on their NSSS questionnaire. No 'much less' responses were collected from the interviewed fishermen. There was some inconsistency between the NSSS and the answers given in interview. Four fishermen who checked 'more' on their questionnaire reported 0% increase during the interview while 3 fishermen who checked 'no change' on the NSSS indicated a change in the interview (50% increase and a 0-25% and 25% decrease). Two NSSS statements of 'less' were reported during the interview as 0% changes. Two clear outliers existed in the 'more' category of 533 and 1000% increases. These interviews related current catches of whiting and cod compared to extremely low levels last year, giving the very high percentage change for a limited absolute change.

Table 5. Mean range and standard deviations for stock abundance of cod, whiting and Nephrops as a percentage of last year grouped by answers given on NSSS forms

Answer	Mean	Min	Max	StdDev	n
Less	78%	45%	100%	22%	7
No Change	101%	75%	150%	17%	12
More	210%	100%	1000%	265%	13
More (2 Outliers removed)	109%	100%	123%	8%	11
Much More	210%	130%	300%	85%	3

Although there was some overlap between the categories, there was a very highly significant correlation between the ranks (Spearman's coefficient 0.780, $p<0.001$). When the NSSS responses were represented as numbers (2,3,4,5 for less, no change, more and much more respectively) the correlation between the NSSS response and the percentage change was low ($r^2=0.324$, $p=0.058$) however the correlation between the NSSS response and $\log_{10}$ (percentage change) was much higher and significant ($r^2=0.543$, $p=0.001$, Figure 2.) suggesting that the scale may be best interpreted as a log scale.

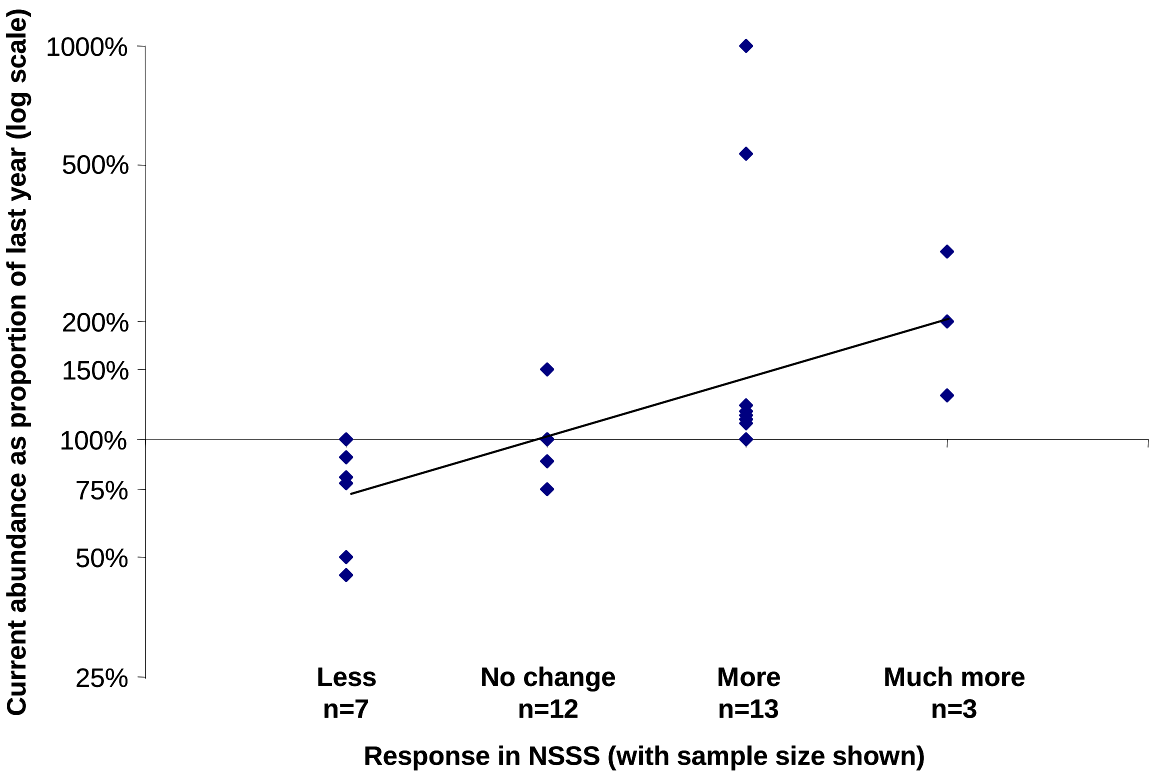

Figure 2. Quantitative estimates of abundance changes of cod, whiting and Nephrops from interviews compared with responses to abundance questions in the NSSS

Awareness and perception of the use of the NSSS

There were varying levels of awareness of how the NSSS was used. Of the fishermen who answered this question (n=22) 59% indicated that they didn't really know what happened with the results of the survey while 32% specifically stated that they didn't receive feedback on the results of the survey. Only two fishermen (9%) made vague reference to feedback from the survey:

"Erm I think we do get a…, once it's been digested we get the consensus of everybody that's filled it in"

"I did read it but I've forgotten"

Those 13 fishers who did offer views or guesses on how the survey was used suggested that it was to get an overall impression of fishers' views for the use of scientists, fishers' representatives, or to feed into a stock assessment system. Their responses on the use of the NSSS often reflected a level of uncertainty.

> *"I just presume that it went into the pot and then it was discussed at meetings etc"*
>
> *"I assume it's fed into a system for, for the scientists, I'm not sure. I ken it gets fed into a system"*

A senior member of the NFFO, was confident that CEFAS, and Dutch scientists used the survey, although stated it was "probably" not used enough

Motivations to take part in the NSSS

Fishermen's perceptions on the use of the NSSS give some insights into their motivation for participating. They were also directly asked about their motivation to take part in the survey and their hopes and expectations for how it would be used. Fishers hoped to improve fisheries science win rewards for participation or chose to fill in the form to support the fishermen's organisations responsible for it. There was a general expectation that the survey should benefit fishermen:

> *"I'm doing it to help the fishing rather than to seeing it as another nail in the coffin"*

Although interviewees were often vague in their own motivations for taking part in the survey, many hoped for more favourable management as a result of the NSSS. Nineteen interviewees spoke about their incentives to participate. For 63% of these this was directly linked to improving the science and the assessments of stocks:

> *"if we're going to be run by the science, we'd like the science to be as accurate as possible"*

> *"Anything that I can do to help let you understand what's going on better, because it's a hard thing to study. I understand that"*

58% specifically mentioned the hope or expectation that the provision of data would be rewarded by more favourable management decisions for the industry.

> *"Just well to help in any way, any sort of help for the industry"*

> *"I've answered the questions as good as I can because I want things done for the good of the fishing and for the good of the industry"*

> *"fishermen are not getting rewarded for trying to work with the scientists"*

Some fishermen felt a sense of duty or imperative to take part in the survey for the sake of the industry or from loyalty to the organisations promoting the survey.

> *"I think it's our duty to put these surveys in and answer them as honestly as we can"*

> *"Interviewer: Will you fill it out in the future?*

> *Fisherman: Oh yes. You have to"*

> *"I'm an NFFO member and I support what the NFFO's doing"*

Disincentives to take part in the NSSS

Twenty fishermen spoke about factors dissuading people from participating in the survey. A lack of tangible improvements in management decisions and general scepticism of the process was cited by 55% as the main factor discouraging fishermen from participating, making a direct link between unfavourable management decisions and participation in the survey.

> *"Brussels is speaking about more cuts of effort on cod and all that so you immediately begin to think, what's the point of me filling it in if Brussels are going to do what they want anyway"*

> *"if they turn round and everything we've said is disregarded again then we go to meetings in December and we get bloody stuffed again then, what's the point?"*

> *"I think there's definitely a conception now of fishermen thinking ""Och to hell with that what we filling that in for, fill it in every year and they keep cutting our quotas."" "*

The one Scottish interviewee who was not an NSSS participant also linked his dismissal of the survey with wider management issues. When asked why he thought the NSSS was "a waste of time" he gave an irate and detailed account of the way in which pressure from environmental groups had destroyed the market for his skate catch based on flawed and incorrect environmental 'science'.

Mistrust of scientists and the management system was thought by some interviewees to be a major barrier to persuading some fishers to be involved. There was a fear or suspicion that the NSSS results could be used against them.

> *"there's always the fear – and this is maybe the reason why some fishermen don't fill it in – that the information would be used against you".*

Sometimes this was a general opinion.

> *"Some fishermen won't have nothing to do with it, like. It's black magic like…*
>
> *It's just the anti-science sort of feeling … 'you shouldn't cooperate with the enemy' "*

In particular, some Scottish fishermen felt that the response to the survey was impacted because of the perceptions that Scottish fishers had been penalised as a result of providing discard data to FRS in the past.

> *"quite a lot would be sceptical because of what happened with the scientists about 3,4 years ago"*

One Scottish prawn fisherman also suggested that the results of the survey would be good news for the prawn fleet and so they would be more willing to fill in the survey than large cod-catching fish boats for whom the results of the survey would be bad:

> *"the 70 footers, they probably think it's a heap o' shite … Ken that boys, they depend on cod, and it's the big boats that's catching cod, ken cod north of 61 and away west and that … In case if affected them. I think the surveys not returned will be the big boats and its most of the prawn boats will put them back."*

60% of those discussing disincentives mentioned the practical inconvenience of filling in the survey, and this was often brought up when interviewees were discussing potential elaborations of the survey design.

> *"there's a questionnaire to fill in and you think well. I've got better things to do with quarter of an hour of me time"*
>
> *"It doesn't sound very much but it's the last thing you want to do, especially if you're towing a net and you've got your job to think about. It's just finding the time."*
>
> *"the more elaborate you make it, the less fishermen will fill it in"*

In the same way that loyalty to FOs was an incentive to take part, two interviewees suggested that the level of participation in the survey was affected by general support for the fishermen's organisations involved:

"some that it's been posted to and they haven't bothered with it. Because some fishermen are a little bit pissed off with the NFFO lack of bite on some policies"

"I'm really surprised it [the return rate of NSSS surveys] was as low as that. See there was a lot of internal strife inside SFF"

The non-participating interviewee also questioned the legitimacy of fishermen's organisations. He claimed his more sceptical views reflected "the thinking of the guys at the coal face", which was different to the views of the formal representatives:

"when you go into these meetings. You get the same type of person. When you meet with the NFFO or with the SFF or these people. They're all singing from the same hymn sheet but sometimes they're very out of touch with the grass roots."

Reliability of the survey

Twenty fishermen discussed the reliability of the survey answers and whether there was a temptation for skippers to inflate their answers. Their points can be categorised into three positions as shown in Table 6.

Table 6. Percentages of respondents with different views on the reliability of the survey

Opinion on reliability of the survey	**Percentage of respondents** (n=20)
Answers are generally reliable and honest	85%
Some respondents may inflate answers	40%
Many answers may be inflated	15%

Most fishers conceded that a minority of respondents to the NSSS may be tempted to inflate perceptions of stocks but believed the majority would fill it in honestly.

"you might get the odd one thinking, oh we'll bump the stocks up to this and that but I think it'll only be the odd one so I think overall the majority will be from the heart"

"I would think that most of the guys would just, write it as it is. I think that most of the guys that I work with would do that. I mean you're always gonna get one or two, that will maybe err on the side of optimism"

"I wouldn't think that fishermen would over emphasise anything. There might be a perception that they would"

One might not expect the interviewees to openly undermine the reliability of the survey and it could be suspected that they would downplay the impact of dishonesty on the survey answers. However, interviewees claiming that the survey was on the whole reliable did support their assertions with credible reasoning.

Their confidence in the reliability of the answers was attributed to three factors:
a) the futility of trying to artificially improve the perception of stocks,

"if they put in a pack of lies it's nae going to help them so it's a waste of time"

"At the end of the day, with the log sheets and catch data they'll know if it's crap."

> *"some fishermen want to make on it's all rosy in the garden and I says 'that'll show up straight away, if you're saying there's loads of cod and other fishermen are saying there's not and the scientists are saying there's not'. They're gonna notice!"*

b) the fact that the fishermen who would fill the survey in are the most conscientious fishermen while those more likely to exaggerate catches would not be likely to engage with the survey.

> *"most of that fishermen that's no filled it in's just, they're just ignoring it. But those who've filled it in have done it for the right reason."*

c) that the culture of the industry had changed with a greater appreciation of issues of sustainability, both through a change in perception of individual fishers and the exit (through decommissioning) of skippers who did not have a long-term outlook for the industry. The fishermen that are left have significant investments and are looking for a sustainable future.

> *"If you'd asked me that 10 years ago, I would have said "sorry you're up a gum tree" but nowadays I would think it would be more reliable"*

> *"we do know now, it's been drummed in and we all know – we're not daft – that we have had overfishing in the past"*

> *"I think the fishermen that are left at sea now are pretty conscientious I think …and they wouldn't be putting in something that's not [true]."*

> *"we're not just wanting what we can get for this year and next year, we need to know there's something there 15, 20 years down the line"*

Contrary to the responses above, one interviewee expected some systematic inflation in the fishers' answers to be the norm and also expected this be taken into account by the users of the data.

> *"they would already interpret a certain amount of bulling up surely because you would expect fishermen to do that just like you would expect fishermen to be positive where you would expect scientists to be negative I think the two would even themselves out like"*

Long term perceptions of stocks

The NSSS questions ask about perceptions of stock changes within the previous year. To get an insight into interviewees' longer term perspectives they were asked their perception of current stock levels relative to 1, 6 and 20 years ago. Responses were only sought from the time span of individuals' fishing experience and not all fishermen were willing to state a quantitative estimate for each species. Figures 3-11 indicate the range of responses obtained for Cod, Whiting and Nephrops.

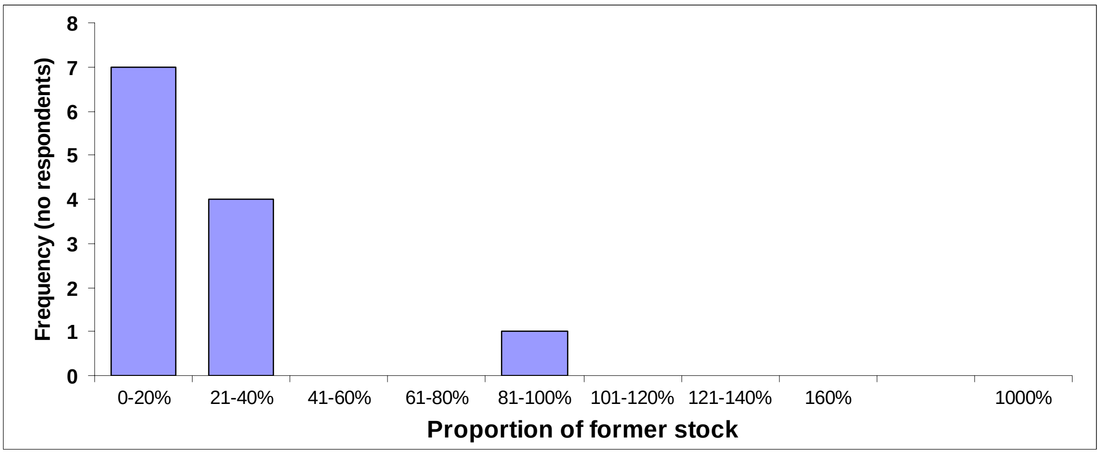

Figure 3. Perceptions of current cod stock as a proportion of the stock 20 years ago

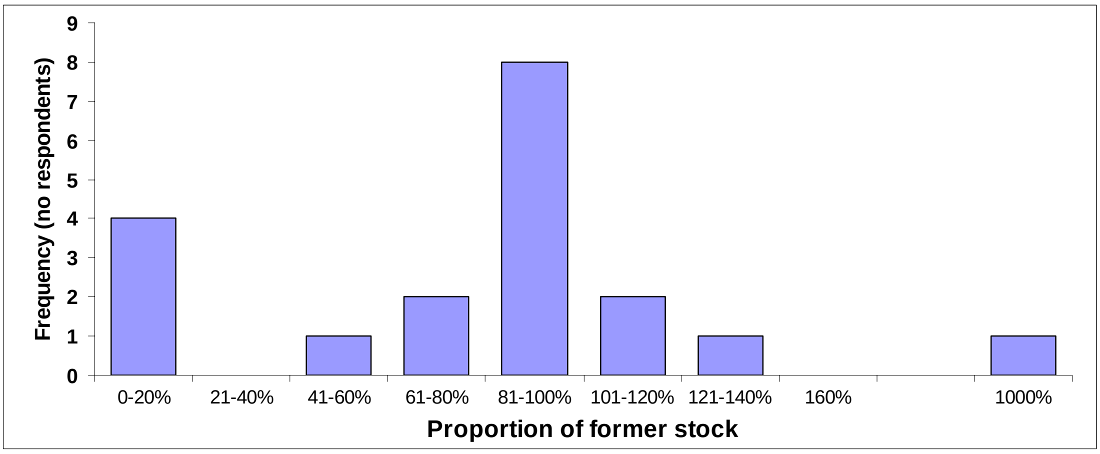

Figure 4. Perceptions of current cod stock as a proportion of the stock 6 years ago

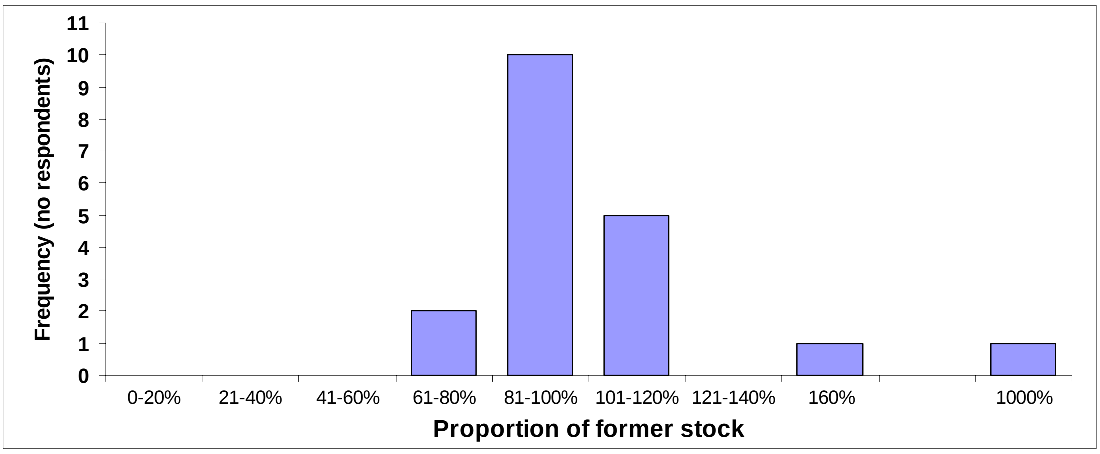

Figure 5. Perceptions of current cod stock as a proportion of the stock 1 year ago

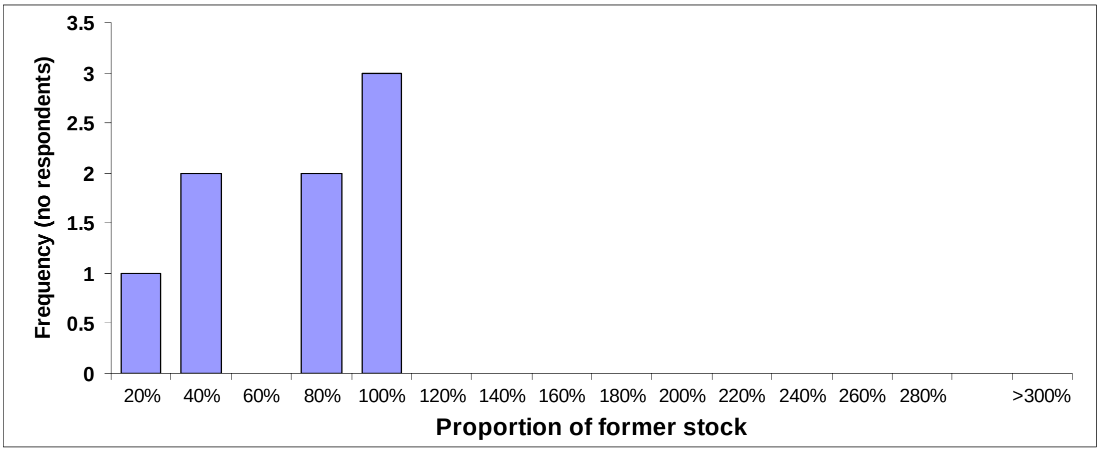

Figure 6. Perceptions of current whiting stock as a proportion of the stock 20 years ago

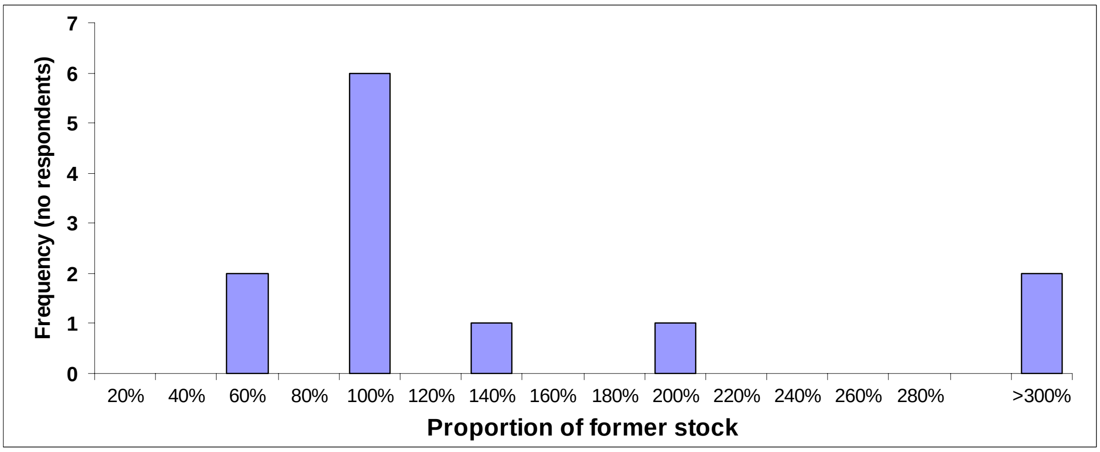

Figure 7. Perceptions of current whiting stock as a proportion of the stock 6 years ago

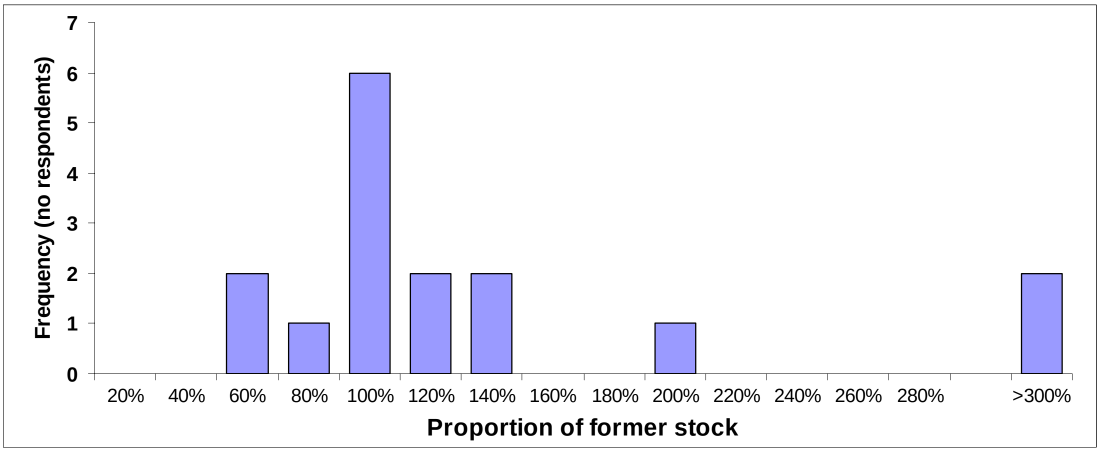

Figure 8. Perceptions of current whiting stock as a proportion of the stock 1 year ago

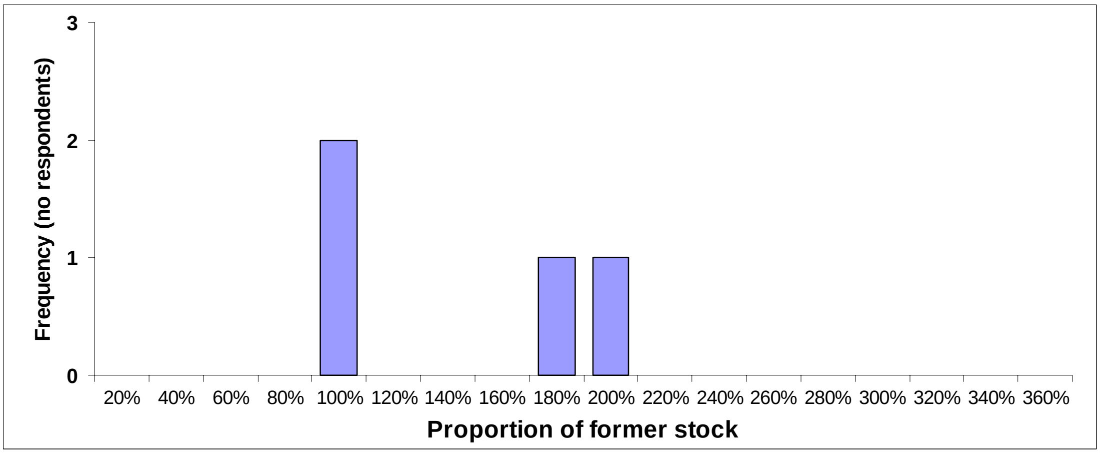

Figure 9. Perceptions of current Nephrops stock as a proportion of the stock 20 years ago

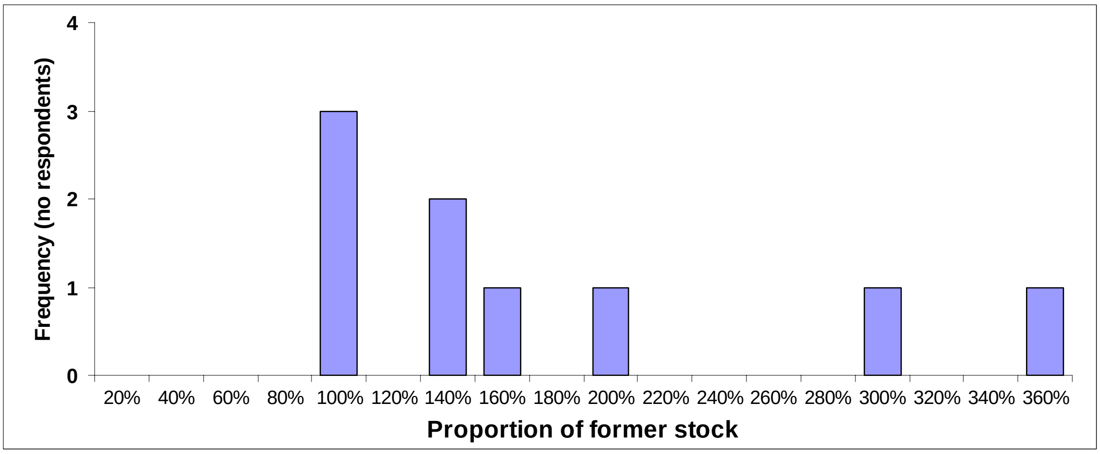

Figure 10. Perceptions of current Nephrops stock as a proportion of the stock 6 years ago

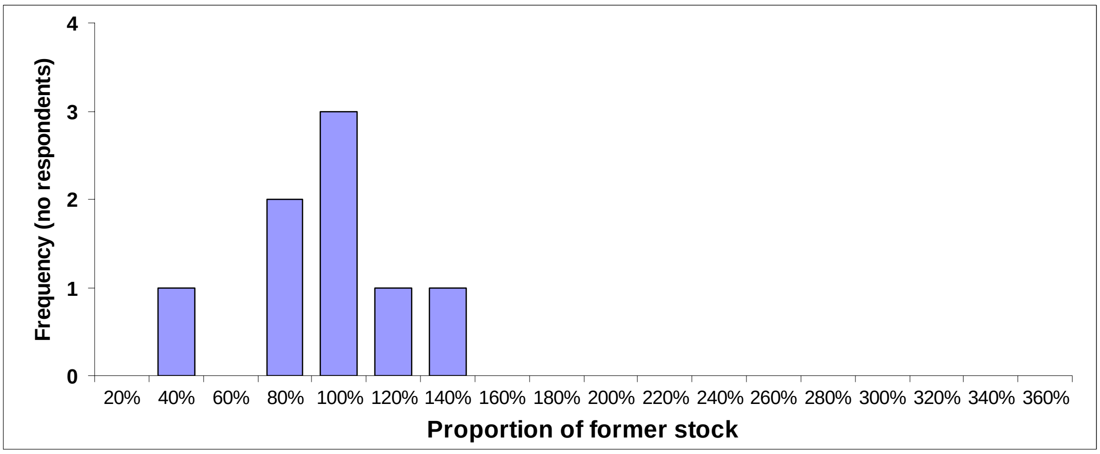

Figure 11. Perceptions of current Nephrops stock as a proportion of the stock 1 year ago

Table 7. Estimates of current and previous biomass and catch levels of cod in the North Sea, Eastern Channel and Skagerrak from the 2006 ACFM report

	Time period	Biomass	SSB	Catch
Stock 20 years ago	mean '80s	671,441	130,534	323,550
	mean '83-'87	625,555	119,351	298,911
	1985	478,360	118,028	247,031
Stock 6 years ago	mean 1998-2002	251,367	53,076	115,706
	mean 1999-2001	228,461	50,046	104,406
	2000	254,951	45,933	96,271
Most recent estimate (2005 or 2006 for SSB)		128231	31542	54745
Most recent estimate as a proportion of:	Mean '80s	19%	24%	17%
	mean '83-'87	20%	26%	18%
	1985	27%	27%	22%
	mean 1998-2002	51%	59%	47%
	mean 1999-2001	56%	63%	52%
	2000	50%	69%	57%

For Cod, Table 7 shows equivalent scientific estimates of abundance and catches from the most recent ACFM analysis. The 12 interviewees who gave opinions on the current status of cod stocks compared to "20 years ago" or "back in the 80s" mostly fell within a similar range as the scientific estimate. All but one estimated that the stock was less than 30% of 20 years ago and 7 estimated that stocks were less than 20%. Depending on which statistic and which average is taken for the former stock levels the ACFM analysis gives a perception of current stocks as 19-27% of those in the 1980s. The single interviewee who claimed his perception of cod stocks as being the same as in the 1980s also qualified his answer by saying:

> *"Well to me it's just the same but then 20 years ago I didn't have the experience that I've got now and we're not a whitefish boat as such. But I'm sure the likes of the Whitby men that used to go to the cod, they used to work up the ground edge there 3 miles off. You don't see them now. So that speaks for itself that the cod aren't there or they would still be chasing it."*

There is less accord between scientific and interviewees' perception of the stock now as a proportion of 6 years ago. The ACFM analysis suggests that stocks are about half of that around 2000. Most (8/19) interviewees did not perceive a significant change in cod abundance while four thought that stocks were less than 20% of those in 2000. The outlier at 1000% was a creel fisherman who reported that he catches 50-80 codlings per day in his creels rather than 5-8 back in 2000.

Although the NSSS specifically asks for changes within the last year, there was evidence that some interviewees' longer term perspective on stock changes influenced their answers:

> *"Oh well I think I just put much the same you know. There's no been any abundance of fish, you couldn't see any less. It's just the same. The thing collapsed I think 20 years ago"*

"Interviewer: How do you go about answering what you're going to answer there?
Fisherman: On my experience of fishing, on this type of fishery in excess of 25 years."

Additional information and perceptions from interviews with fishermen

Although not analysed here in detail, interviews provided a lot of further information and perspectives of fishermen about other aspects of fisheries, fisheries management and fisheries science.
Changes in the industry were described by several interviewees as a result of fuel prices, clampdowns on black fish landings, and decommissioning.

The relationship with science was variable amongst interviewees. Even amongst this sample of the most engaged of fishermen many still disagreed or had deep rooted scepticism of science and scientific methods.

However, there was a general perception that relationships with scientists had improved and interviewees were glad of improved openness of scientists to fishermen's views. There was a consensus of opinion on the desire for scientists to spend more time at sea out with the fleet so they can see what the fishermen are seeing.

Use of the NSSS during the scientific advice process

Observation and interviews at the 2006 ACFM meeting indicated that there was limited use of the survey. The area-based summaries of stock trends from the NSSS were presented in the WGNSSK report for each species and the level of agreement between these trends and indications from the stock assessments and survey indices was commented on. There was no formal quantitative integration of the NSSS results into the assessments. Only the question on abundance was presented or mentioned. The other questions on discarding, recruitment and fish size were not mentioned at any point. The lack of quantitative integration of the NSSS into the assessments is unsurprising considering the relatively short time series (5 years), the nature of the data and the sophisticated modelling approach already established for assessments. However the considerable uncertainties in catches, discards, targeting, recruitment and black landings observed for many stocks during the meeting emphasise the potential for anonymously collected FK to provide indications of trends in these variables.

It was not clear why none of the other questions were used. Given the repeatedly mentioned uncertainty of discards one would expect that the discards question could offer some useful information for stock assessors.

Despite the limited use of the NSSS, scientists were unanimously positive about the initiative. An often-cited benefit was that the agreement between regional trends in scientific trawl surveys and the NSSS trends had demonstrated to fishermen that the science was valid. This reflects the survey achieving a political, or governance aim rather than a scientific one.

Discussion

Types of knowledge accessed by the NSSS

Focussing the NSSS on trends in stock biomasses means that the information gleaned will duplicate scientific stock assessment results rather than compliment knowledge gaps in the scientific advice process. The agreement generally apparent between NSSS results and regional trawl survey indices give the impression of harmony between fishermen and the science whereas even fishermen interviewed during this review (expected to be a biased sample of the most engaged fishermen) expressed major objections to aspects of the scientific or management regime. I.e. they may agree on year on year directional trends in stock size but may vehemently disagree on the status of the stock in relation to historical experience, sustainable boundaries of biomass and fishing mortality or assumptions underlying the scientific or management process. Such a disagreement is masked by the selective questions included in the NSSS.

Although most fishermen did not suggest adding extra topics to the survey, they were keen to discuss their perceptions of ecological linkages and management practicalities (e.g. the impact of fishing relative to other factors on stocks, discussions about quotas, blackfish etc) and challenge assumptions about these factors.

There is therefore a tension between the information requested by the questionnaire and the types of information which fishers are anxious to express. Currently, the NSSS does not record perceptions of ecological processes or management practises. Nor can fishers express perceptions on the absolute status of stocks relative to long term trends or absolute levels of discarding. The results of the NSSS are therefore never going to challenge the emphasis and assumptions inherent in the current management regime. In addition, such broader issues and knowledge are arguably more interesting and relevant for the formulation of scientific advice and management proposals as it is in these topics that fishermen can contribute new perspectives and fresh knowledge which is currently lacking within scientific assessment circles
The interviewees did not see seem to perceive the survey as being the appropriate tool to collect such perspectives, but their desire to see beneficial management changes resulting from the NSSS is unrealistic when it only collects basic, knowledge on short-term trends. Expanding the scope of the survey to include perceptions of management and ecology may make it more relevant to the concerns of fishermen. However it may also appear to offer fishermen a level of input into policy which it cannot realistically provide. Extending the survey to cover such issues would also increase the complexity and inconvenience of completing the survey as well as massively increasing the analysis and processing time of the resultant data.

Catch rates or perceptions of stock?

Although the survey states “Information on abundance should be provided on the basis of **catch** not landings” it is unclear whether the survey is targeting CPUE or perceptions of stock abundance. The two things are not the same, as illustrated by the way in which many interviewees described several factors affecting CPUE (e.g. targeting behaviour and gear regulations), in addition, overall perceptions of stock status can be related to other sources of information like the catches of other fishermen or quota availability. Some fishermen answered strictly based on the difference between catch rates in the two years while others gave their perceptions of stock trends. It would be useful to be clear which is requested by the survey, an indication of catch-rate trends or an impression of fishers' overall perceptions of stock trends. The former would be analogous to CPUE data while the latter would more thoroughly reflect the views of fishermen. It may be pragmatic to target overall perceptions as even if specifically requesting fishermen's views on catch rate, other factors (e.g. profitability, political desire to make stocks seem healthy) may affect how they are reported. Overall perceptions may be more informative ultimately as they allow fishers to take account of factors affecting CPUE which are not clear from data available to stock assessment scientists (e.g. changing strategies in the light of higher fuel prices).

Motivations of participants and expectations of the NSSS

It has been suggested that those fishermen who fill out the survey do so if they 'have an axe to grind'. These interviews do little to support that theory. Motivation was explained in terms of a hope to improve science, an expectation to somehow be rewarded with more favourable management decisions, or out of a sense of duty. The lack of an 'axe-grinding' incentive is perhaps not surprising considering the focussed nature of the survey and the limited scope it gives for airing complaints with the management system. Interviewees felt that disenchanted fishermen were more likely to have ignored the survey as was the case with the individual who made contact to express his views.

Motivation to participate is tied to wider management issues affecting the industry. The fact that "*Fishermen are just a bit fed up to be honest*" is seen as a problem for motivating participation in the NSSS. The blurring of wider issues facing the industry and the willingness to take part in the NSSS can be seen in the way in which one fisherman spoke about the impact of environmentalist activities on the skate market when asked why he thought the survey was a waste of time. There is no direct link between the anecdote and the NSSS. In fact, it could be suggested that the NSSS should be more important to him in the light of alarmist claims about conservation. However, the point also still stands: in the eyes of this fisherman the main issue is not about year-on-year abundance trends but much wider issues of management, environmental discourses and political power. This fisherman perceives that he is being forced out of business as a result of an unfair and flawed science and governance system. In this regard, this sceptical fisherman is correct that the NSSS does not address the issues with which he is concerned.

According to responses of the survey participants, their motivation to take part appears in many cases to be based on a false premise (the expectation of rewards for the industry). The limited scope of the survey and the current fisheries management policies, make it entirely unrealistic that they will experience better (in their eyes) management and certainly not improved catching opportunities as a result of their participation in the NSSS. Thus the NSSS presents a familiar risk of fisher participation projects of disappointment if the results of participation do not live up the expectation of the participants. Although North Sea fisheries management policies are not directly linked to the NSSS, it is clear from the interviews that disagreement with these high level policies and management decisions affect the overall morale of fishermen and their willingness to participate in a process like the NSSS. A similar problem was experienced by the Dutch collaborative F-project in 2003 when skippers withdrew their cooperation as a result their opposition to December council decisions (pers comm., Floor Quirinis, RIVO). This illustrates how the success of initiatives like the NSSS is dependent on the larger political and governance context.

The mismatch between the expectations of fishers and the format and possibilities of the NSSS raises questions about the sustainability of the initiative. If discontent with fisheries management continues the willingness of participants to engage with the survey may erode, lessening the breadth of knowledge accessed and ultimately the usefulness of the survey.

Maintaining participation

Fishermen were generally not aware of the results or usage made of the survey suggesting that more resources could be expended on feedback.
Some Scottish fishermen were disappointed and surprised to hear of the low rate of returns of the survey while one noted that they had not heard other fishermen talking about it. He suggested that more publicity (particularly in Fishing News) could help to obtain a higher return rate.
The results of the interviews illustrate several dilemmas in how to maximise the motivation of fishers to participate in the survey: The survey should be as simple as possible to reduce the inconvenience of completing it, but some fishers found it overly simplistic or spatially crude. The narrow scope of the survey keeps its size down but means that it does not address issues which fishermen are commonly keen to address and it does not collect contextual knowledge which is arguably more able to contribute to knowledge gaps in the scientific advice process. Fishermen are interested to hear more feedback on the survey's use but if the limited impact of the survey on stock assessments is explicitly stated morale may be further damaged. Despite the above points, the impact of these issues on fishers' participation may be overstated, as several interviewees appeared willing to dutifully complete the survey regardless of these overarching issues.

These considerations would suggest different options for sustaining the participation of fishermen in the survey:

1. Continue with current practise, hoping that the general trend in fisher-scientist relations, development of participatory governance structures, improvements in catch opportunities (as a result of stock recovery) maintain morale and the appetite for completing the survey.

2. Keep the survey in the current format but expend greater effort to explain how it is being used. There is a risk that fishers could be disappointed to hear that it makes no substantive input and that it doesn't address common objections with management assumptions nor hold hope for any automatically improved catching opportunities.

3. Change or add to the survey to include more issues that fishermen are engaged by in order to increase the interest in the survey. Such views could be taken up by NSRAC, ICES and the European Commission. This option also has a risk of disenchantment in the long run if it suggests that fishermen have more of a meaningful input into high-level decisions than is politically feasible.

Potential Design Changes of the NSSS

Interviews gave little support for further complicating the design of the NSSS. No interviewees thought that the questionnaire was currently too complicated but many warned of the effect of further complications on the rate of response. Although some fishermen would have liked an opportunity to add more detail to their answers there was no clear consensus on topics which needed elaboration. Adding further detail would presumably be even less popular amongst the total population of fishermen than amongst this sample of the most engaged and discursive fishermen.

A balance has to be struck between making the survey too simplistic, in which case it risks being viewed as ineffective, and making it so complex that participation rates drop due to the inconvenience of completing it.

Most discussion by interviewees on survey design was focussed on spatial detail. Some fishermen wanted to answer questions with a higher spatial resolution although this would inevitably complicate the results and analysis. The fact that all responses are related to all zones fished presented problems for fishermen if they experienced different trends in different areas. This could cause noise in the analysis because trends observed in one area get ascribed to other areas.

This effect could be reduced by asking fishermen to tick only the “main” fishing area for each species. This would reduce the amount of data available for less heavily fished areas but if the data from these zones were actually coming from trends in other areas then the accuracy of the survey would be increased. Alternatively, respondents could be given the option to differentiate trends between different areas to improve the quality of responses from those fishermen whose range extends over several zones. This would be less straightforward and require a reworking of the form. One possibility would be to include a copy of the map for each species and integrate tick boxes for each area with the zones on the map.

Another suggestion is for discards to be reported in terms of proportions of catches rather than trends from one year to the next. For example: What proportion of the whiting you catch do you discard? Most (>⅔), Half (⅓-⅔), Few (<⅓) or None? Many interviewees were at pains to point out the low discard levels (or high levels in the case of saithe) but the current format in which discard amounts are given relative to last year does not allow the opportunity to contribute that. However, the current year-on-year trends may be easier to present in a format that can be broadly used by assessment scientists.

This document only reflects the views of participating fishermen. Judgement of the merits of complicating the survey would also need to be made in light of the cost of disrupting the current time-series and the scientific usefulness of additional information or detail.

One option would be to allow more space for open ended responses or comments in addition to the checkboxes so fishers could add detail where they wish. This would not increase the complexity of the form considerably or change the existing questions. However much more time and effort in terms of analysis would be required to make use of such information.

Some qualitative guidance or suggestions on what would be useful for section 4 (e.g. recruitment pulses, changes in fleet behaviour, explanations of answers & factors affecting them, effects of unusual seasonality etc) and extending the amount of space allocated to section 4 may result in more useable qualitative information being offered.

Use of the NSSS data

Given the uncertainties expressed by assessment scientists around discards levels and contemporary recruitment, there appears to be considerable potential for utilising the discard and recruitment questions from the survey. Currently, only the abundance question is presented in a form which condenses and integrates all data by area and the working groups only comment on this question. Similar treatment of the time series of discard data (perhaps by fleet) may be a useful first step in using this information.

Clarifying the Aims of the NSSS

The detailed aims of the NSSS should inform future developments or directions of the survey. For example the emphasis of the survey would be different for each of the following different aims:

1. to identify agreement between fishermen's experience and scientific surveys

2. to collect useful information which scientists are missing in order to improve stock assessments

3. to assess fishermen's perceptions of stocks to identify disagreements with science and management.

The NSSS currently serves the first of these aims. The second aim would be served by the collection of different/additional data tailored to match key gaps in the information available to assessment scientists and discard and recruitment information should be utilised. For the third aim, the focus should be on general impressions of stocks, encouraging fishermen to take account of other factors (rather than just CPUE) and questioning fishermen about their perceptions on status of the stocks in relation to long-term trends and the appropriateness of current fishing effort levels.

Pursuit of the third goal would allow specific feedback to be related to fishermen based on disagreements, with the NSSS to initiating an 'arena of collaborative learning' where differing perceptions can be highlighted. Identifying and engaging with root disagreements between fishermen and scientists can help to address disengagement and improve governance, stewardship and shared understandings. One of the problems of the CFP has been top-down science which has no legitimacy among stakeholders. Identifying those gaps in perspectives allows them to be picked up in collaborative arenas and allow monitoring the success of developing common understandings as a result of other initiatives (e.g. NSRAC, FSP).

Potential options for the future of the NSSS

Table 8 presents options and potential recommendations which have arisen from this data and analysis along with a summary of the pros and cons of each.

Table 8. Options for the future design and management of the NSSS.

Option	Advantages	Disadvantages
Business as usual	• Other changes in fisheries governance (e.g. NSRAC, FSP projects) may improve response rates • Survey format is approved and not too complicated • Time series is not disrupted	• Participation appears to be declining and was at lowest level in England and Scotland in 2006 • There is a mismatch between expectations of fishermen and potential for survey to deliver • Fishermen's main interests/concerns are not covered • Gaps in scientific knowledge are not targetted
More publicity of survey (e.g. in fishing News in UK)	• Elicit more responses	•
More feedback to fishermen of the results and use of NSSS	• Demonstrates that the survey data is processed • Generate more publicity	• Highlights limited impact of survey
Focus answers on CPUE	• Very clear what the question is about	• Answers may reflect other impacts on perception of catch (e.g. price, profits) anyway (i.e. even if specifically ask for CPUE, answers are likely to have element of general perceptions) • Duplicates information which should already be available • May not be indicative of stock trends or fishermen's perceptions

Option	Advantages	Disadvantages
Focus answers on fishermen's perceptions of stocks	• Gives indication on what fishermen actually think about stock trends • Answers would integrate complex factors like targeting behaviour and effect of regulations	• Unclear what the data source would be • As a more 'fuzzy' and subjective variable, might be more influenced by long-term memories or desire for larger TACs
Incorporate questions on ecological processes	• Maps onto a major concern and interest of fishermen • Provides anecdotal information not currently available to scientists • Useful generally in understanding fishermen's perspectives and engaging them in dialogue with scientists	• Qualitative and difficult to analyse • Complicates survey
Incorporate questions on management or practical industry behaviour	• As above • Relevant for policy formulation • Useful for developing dialogue with managers.	• As above • May make NSSS overly political
Higher spatial resolution in questionnaire	• Easier to complete for fishermen who observe localised trends • More useful data? • Survey would appear more scientific and useful	• Complicates survey & disrupts time series • By itself, doesn't allow differences between areas to be explicitly stated
Allow different trends in different areas (e.g. repeat questions for each area for each species)	• Easier to complete for fishermen who observe different trends in different areas • Survey would appear more scientific and useful • Prevents trends in one area artificially being ascribed to another	• Complicates survey
Ask for response only in fishermen's 'main area' for each species	• Prevents trends in one area artificially being ascribed to another • Easy to fill in	• Obtain less data on areas fished less intensively

Option	Advantages	Disadvantages
Ask for discards as a percentage of catch	• Gives more quantitative indication of discarding behaviour • Addresses an issue fishermen are keen to express	• No indication of absolute quantities discarded • Adds another question format to the survey and so complicates it • Loss of time series
More space for qualitative data in section 4 or additional space for comments on each section	• May encourage more useful anecdotal data • May help interpretation/evaluation of responses • Allows fishermen to elaborate where they wish	• More processing and analysis resources required
Attempt to make more scientific use of discard and recruitment questions	• Addresses uncertainty affecting scientific assessments and management proposals • Shows NSSS being used	• May politicise responses as e.g. discards of cod become a big issue
Ask about trends relative to long time span	• Provide indication of trends extending beyond reliable scientific time series • Reflects fishermen's perception of stock abundance relative to long term trends (and therefore the status of the stocks) • Might prevent long term perceptions colouring questions on one year trends	• Complicates survey with an extra question • No indication of the effect of technical creep • Only relevant for older fishermen or fishermen with access to local knowledge of old/retired fishermen

Appendix 5a – Interview guide for semi structured interviews with fishermen

Do fishermen think the survey is well designed what would be their suggested improvements?

1. What do you feel about the survey?
   a. Is it well designed?
   b. Is the level of detail appropriate?
2. How could it be improved?
3. Is there any other information that you think should be included?
4. How long did you spend answering the survey?
   a. Did you find any questions difficult to answer?
5. Did trends vary with area?

How do fishermen go about answering the survey?

6. Can you talk me through how you chose which box to tick for abundance questions (much more, more, less, much less)
7. Do you answer questions based only on your own experience or that of other boats too?
8. How did you answer questions on the abundance of young fish about to enter the fishery? What would you consider a 'young fish'?

One of the problems for scientists using the survey is the difficulty of quantifying what people actually mean when they tick 'a lot more'. Can you try to give me some indications of the % this year compared to last year?

	Cod	Whiting	Nephrops
Stock abundance as % of last year			
Discards as % of last year			
Large fish size			
Amount of large fish			
Perception of recruitment			
Abundance as % of 2000			
Abundance as % of 20 years ago			

Influence of Technical changes on fishermen's perceptions of stocks

9. Are you fishing more efficiently now than you were then?
   a. If you were to go back in time with your current gears and fish alongside your old self how much more would you catch?
   b. Does that affect your perception of the abundance?

How do fishermen perceive the survey is used?

10. How do you think the results of the NSSS are used?
11. Do you feel the results of the NSSS are used enough? Why?
12. Do you expect the results to agree or disagree with scientific assessments?
13. Do you think the results are reliable? Why?
    a. Is there a temptation for fishers to err on the optimistic side?

What motivates fishermen to participate?

14. Why do you take part in the survey?
15. Did you complete the survey last year? Every year?
16. Will you participate in the survey next year? (no, yes)
17. What could make more fishermen participate in the survey?
18. Would anything deter you from participating in the survey in future?

Fisher-science relationships in UK?

19. Do you tend to agree with the findings of fisheries scientists in the North Sea?
    a. Can you give details/examples?
20. Do you think the relationship between scientists and fishers has changed in the last few years? Why?
    a. Has the attitude of fishers towards science changed?
    b. Has the attitude of scientists towards fishers' knowledge changed?
21. Do you think management is more based on science now than in the past?
    a. Are you pleased about that?
22. What effect have environmental groups had on the way fishers deal with fisheries authorities and scientists?
23. Do you think the NSRAC will improve management of the North Sea? Why?
24. Have you ever worked with scientists or provided them with any information?
    a. Can you describe how?
25. Are you involved with the SFF/NFFO?

Attributes of individual fisher

26. Vessel type
27. Vessel length — Engine HP:
28. Length of time vessel owned
29. Main Gears used — Mesh size:
30. ICES areas fished
31. Target species
32. Length of time a fisherman
33. Length of time a skipper
34. Age

Appendix 5b – Meetings Attended

Meeting	*Meeting participants*
ICES/NSCFP Study Group on the Incorporation of Additional Information from the Fishing Industry into Fish Stock Assessments (SGFI) Den Haag, Netherlands. 3–4 February 2004	Scientists and industry representatives
North Sea Commission Fisheries Partnership (NSCFP) Den Haag, Netherlands. February 5th, 2004	Scientists and industry representatives
Consultation between ICES Working Group on the Assessment of North Sea Demersal Stocks (WGNSSK) and the NSCFP Copenhagen, Denmark. 4-5th October 2004.	Scientists and industry representatives
North Sea Commission Fisheries Partnership (NSCFP) Copenhagen, Denmark. 5-6th October 2004.	Scientists and industry representatives
Fishing 2006 Trade Show. 17th May 2006	Industry representatives
NSRAC Demersal Working Group Den Helder, Netherlands. 15th June 2006	Scientists and stakeholder representatives
NSRAC Executive Committee meeting Den Helder, Netherlands. 16th June 2006	Stakeholder representatives
ICES Advisory Committee on Fisheries Management Copenhagen, Denmark. 5-12th October 2006	Scientists