LOCAL ECOLOGICAL KNOWLEDGE, THE BENTHOS AND THE EPISTEMOLOGIES OF INSHORE FISHING

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Abstract

The thesis presents a re-theorisation of inshore fishers' Local Ecological Knowledge (LEK) of the benthos in Southern England. The benthos needs greater consideration as European Union and United Kingdom assessments of marine stocks continue only to quantify demersal stocks, rather than considering the benthic ecology of the seabed. There is also a gap in knowledge, concerning the changing nature of fisher LEK of inshore fishers.

This doctoral research was initiated with participant observation of the fishing techniques of inshore fishers around the South of England. These revealed different approaches to learning about the seabed benthos, and the impacts of different fishing techniques. This informed the questions used in semi-structured interviews with fishers in 24 fishing harbours located around Southern England. They were selected to ensure different influences were considered, including proximity to over 10m fishers, ports, industrial development activities and different conservation challenges. Sixty fishers were interviewed, including both skippers and crew members.

Previous definitions of LEK have related to Traditional Ecological Knowledge (TEK). These TEK definitions have been based on the cultural transmission of knowledge in indigenous communities. Differently the critical realist framework applied in this thesis, facilitates a new understanding of fisher LEK by examining how actions are changed into outcomes through mechanisms which have influenced fisher LEK and / or combined fisher LEK with scientific knowledge.

The originality of this thesis includes an examination of how broad mechanisms of scientific research, technology, and governance contribute to the development of fisher LEK of the benthos. Previous research has suggested that LEK is simply becoming universally available global harvesting knowledge (GHK). This research proposes the original view that recent interactions of fisher knowledge with scientific knowledge, through specific mechanisms including boundary spanners in conservation programmes, discarding assessments, new technologies and habitat mapping have transformed fisher LEK. Under a second broad mechanism of technology, the specific mechanisms shaping fisher LEK include more accessible techniques for sensing and recording the seabed, new telecommunication forms between fishers, and new social media.

The third broad mechanism of changing governance includes an emerging social movement of fishers as a specific mechanism which influences fisher LEK. This specific mechanism has seen knowledge adapting to demonstrate its compatibility with scientific quota assessment, challenging the quota property rights assigned to the over 10m fleet. The broad mechanism of changing governance identifies that fisher LEK has also changed through threats to habitats and livelihoods, including industrial fishing, port development, aggregate dredging and wind energy, initiating responses from fishers and in some cases key stakeholders.

The thesis sets out how the current system of marine governance could be improved to support the inclusion of LEK that affords an integration of fisher knowledge with scientific evidence. The findings of this doctoral research suggest that improved marine management outcomes require political changes and emancipatory mechanisms, in order to move towards a marine democracy and healthier seas through interactions between fishers, scientists and governance. This thesis has proposed new term for the epistemic rights of fishers, their Pescastemic Rights, the right to a way of knowing as well as a right to be included in research and governance processes.

Table of Contents

Figures

List of tables

Graphs

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Author's Declaration

I declare that the research contained in this thesis, unless otherwise formally indicated within the text, is the original work of the author. The thesis has not been previously submitted to this or any other university for a degree and does not incorporate any material already submitted for a degree.

Signed Jeremy Evans

List of acronyms used

Cefas – Centre for Environment Fisheries and Aquaculture Science

CFP – Common Fisheries Policy

DEFRA – Department for Environment Fisheries and Rural Affairs

EBK – Experience Based Knowledge: Form of knowledge based on experience of fishing techniques

EA - Environment Agency, responsible for estuarine migratory fisheries and water quality.

EEZ – Exclusive Economic Zone

EUNIS - The European Nature Information System has been implemented for the establishment of a marine European habitats inventory. Its hierarchical classification is defined and relies on environmental variables which primarily constrain biological communities (e.g. substrate types, sea energy level, depth and light penetration). The EUNIS habitat classification scheme relies on thresholds (e.g. a fraction of light and energy) which are based on expert judgment or on the empirical analysis of the above environmental data.

FPO – Fisheries Producer Organisation

GHK - Global Harvesting Knowledge: Description of knowledge asserting that technology has made fisher knowledge generalisable across habitats and ecosystems.

ICES – International Council for the Exploration of the Seas

IFCA – Inshore Fishing Conservation Authority

ILO – International Labour Organisation

IROPI – Imperative Reasons for Overriding Public Interest

LEK – Local Ecological Knowledge

LIFE – Low impact fishers of Europe

MCAA – Marine, and Coastal Access Act (2009). An Act to make provision in relation to marine functions and activities; to make provision about migratory and freshwater fish; to make provision for and in connection with the establishment of an English coastal walking route and of rights of access to land near the English coast; to enable the making of Assembly Measures in relation to Welsh coastal routes for recreational journeys and rights of access to land near the Welsh coast; to make further provision in relation to Natural England and the Countryside Council for Wales; to make provision in relation to works which are detrimental to navigation; to amend the Harbours Act 1964; and for connected purposes. It does not have an explicit reference to the ecosystem approach or the preservation of biodiversity, habitats, and species.

MCZ – Marine Conservation Zones

MMO – Marine Management Organisation

MPA – Marine Protected Area

MSP – Marine spatial planning

NFFO – National Federation of Fisheries Organisation

NGO – Non Governmental Organisation

NUTFA – New Under 10m Fishing Association

SAC – Special Areas of Conservation

TAC – Total Allowable Catch – calculated by ICES for different species under the CFP

TEK – Traditional Ecological Knowledge: understanding developed by indigenous peoples in regard to their cultural relationship to the environment and their hunting and harvesting in ecosystems.

TAC – Total Allowable Catch – contested measure for single species quota

TURF – Territorial Use Rights Framework - The framework implies a series of rights; among them are the right of exclusion, the right to determine intensity and kind of use, the right to extract benefits and the right to future returns

VMS – Vessel Monitoring System

ZPD – Zone of proximal development

Glossary

Aggregate Dredging – using trailer suction hopper dredger vessels to remove aggregate from the seafloor for use in the construction industry.

Bathymetry – the study of the shape and topography of the seabed.

Beam Trawling – a form of trawling that deploys a heavy metal beam dragged along the seabed on skis, keeping the net open.

Benthic – species of the seabed ecosystem.

Benthos – seabed ecosystem. Contains many fish species which are more localised, and less likely to be migratory. While many demersal and pelagic species are migratory, and largely occupy the water column above the benthos, as juveniles they maintain a relationship to the seabed in nursery grounds, as well as through a continued relationship to spawning grounds

Boundary spanners – NGOs and researchers who link interest groups; such as fishers and government.

Capital Dredging – dredging a new area of the seabed for a port by removing a new layer of sediment.

Circalittoral zone - the marine region beyond the infralittoral - that is, below the algal zone and dominated by sessile organisms such as oysters; typically found in offshore areas beyond 6 nm from the coastline.

Cumulative impacts – impacts on an ecosystem that have built up over a long period of time.

Demersal - The demersal zone is just above the benthic zone and forms a layer of the larger profundal zone. Demersal fish live and feed on or near the bottom of seas and interact with benthic habitats and can also be called benthic species.

Echo sounder – Echo locator device used for scanning the topography of the seabed.

Epifaunal – Benthic species such as starfish, flounder, or barnacles, that live on the surface of the seabed, such as on a submerged substrate, rocks or other aquatic plants and animals, but that do not burrow into or beneath the surface.

Fata Morgana – a type of mirage which appears in a narrow band above the horizon.

Ichthyologist – A fish researcher, e.g. someone studying the eyes of a long nosed chimaera.

Infralittoral zone - the algal dominated marine zone which exists to approximately 5 metres below the low water mark.

Inshore fishing – in the UK, defined as fishing conducted between the coast and the 6nm limit. In the EU, it is fishing which takes place between the coast and the continental shelf.

Intra systemic –interactions between separate ecosystems

Marinescape – a blending of the terms marine and landscape, the term describes the totality of regional ecosystems and habitats measured over wide areas.

Marine democracy – a system where different forms of local ecological knowledge held by non-scientists can contribute to decision making through highlighting risk to ecosystems

Nomadic fishing – those fishers that move around the coast; fishing and landing in different areas.

Offshore fishing – fishing beyond 6 nm from the coast.

Olex – a new form of 3-dimensional mapping of the seabed; created by Olex TM, Trondheim. The majority of fishers make use of single or double echo sounders. Multibeam echo sounders such as WASSP will become cheaper and more accessible in the future.

Pelagic – species of fish higher in the water column closer to the surface and typically migratory.

Pescastemic Rights – the right to full training to fill in gaps of marine ecological and environmental understanding. As a condition of access rights to fishing the sea, this training should be completed to ensure stewardship. As a starting point, all research programmes involving fisheries and conservation need to explain why they are occurring and involve fishers in the praxis of research. Furthermore, to ensure environmental justice, testimonial justice needs to occur. That is for marine governance not to be biased against the testimonies of holders of LEK such as when they identify ecological risk.

Pulse Beam Trawling - trawling using a towed net and sumwing incorporating an aerofoil which glides above the seabed, sending out electric pulses in all directions in order to stun fish.

Rational fishing - an approach deployed in order to assess single species fish stocks over large geographical regions such as ICES, rather than localised ecosystem approaches to assessment.

Seine netting - a method of fishing that employs a seine or dragnet. A seine is a fishing net that hangs vertically in the water with its bottom edge weighed down and its top edge buoyed by floats. Predominantly used by fishing vessels over 10m, seine nets are used to encircle shoals of fish.

Smothering – the blanketing with mud or other debris of a marine habitat such as a reef, due to port dredging or disposal of dredged material.

Static gear – fishing gear that remains in a fixed local position, such as lobster, crab and cuttlefish pots, set nets and rod and line.

Sublittoral – the marine zone permanently covered with sea water; also known as the neritic zone. It is the relatively shallower part of the ocean above the drop-off of the continental shelf, approximately 200 meters (660 ft) in depth. From the perspective of marine biology, it forms a relatively stable and well-illuminated environment for marine life, from plankton to large fish and corals, while physical oceanography views this zone as the region where the oceanic system interacts with the coastal. It refers to the zone of the ocean where sunlight reaches the ocean floor; that is, remaining in the photic zone.

Towed gear – fishing gear towed along behind a fishing vessel, such as trawls and dredges.

Trammel netting - Trammel nets are a type of gill net which targets a wide range of fish sizes. Essentially, a trammel net consists of three layers of netting attached together on a common float line and common lead line. The two outer layers of netting (known as walls or brails) are constructed of large mesh netting (12" to 18" square) with a twine size of #9 multi-filament nylon or .81mm to .90mm monofilament. In the south coast of the UK, trammel nets are typically anchored to the seabed.

Triple otter board trawl – Otter trawling derives its name from the large rectangular otter boards which are used to keep the mouth of the trawl net open. They also act like a plough, digging up to 15 cm into the seabed, creating a turbid cloud, and scaring fish towards the net’s mouth. The net is held open vertically on an otter trawl by floats and/or kites attached to the "headline" (the rope which runs along the upper mouth of the net), and weighted "bobbins" attached to the "foot rope" (the rope which runs along the lower mouth of the net). These bobbins vary in their design depending on the roughness of the seabed being fished, varying from small rubber discs for very smooth, sandy terrain, to large metal balls, up to 0.5 m in diameter, for the very rough terrain. These bobbins can also be designed to lift the net off the seabed when they hit an obstacle. These are known as "rock-hopper" gear.

Chapter 1. Introduction to Local Ecological Knowledge, the Benthos and the Epistemologies of Inshore Fishing

1.1 Introduction to the thesis

By creating new understandings of fishers' interactions with the inshore seabed and its life, the benthos, this thesis re-theorises Local Ecological Knowledge (LEK). Using a critical realist approach this doctoral research analysed the developing influences upon the epistemic framework of inshore fishing in Southern England. It is timely research as the political changes sought by some for UK fishing can create a space for new democratic forms of marine governance after Brexit. The term epistemic framework in this thesis refers to inshore fishers' philosophical approaches to knowledge of their livelihood. It includes how they value species and consider fragile marine ecosystems and the environment in their approaches to fishing (Adams, 2014). Recent changes in UK marine conservation and fishing policy along with significant technological, market structural and socio-economic shifts in the fishing industry have caused fisher LEK to fracture in unexpected directions. These changes in UK fisher LEK of the benthos have not been previously fully examined by researchers, and are discussed and analysed in chapters 5, 6, 7 and 8. This thesis will examine where fishers are currently incorporating knowledge gained outside of traditional fishing techniques, such as netting and potting, into their LEK. This includes through involvement with scientific research, the influence of new technology, and engagement with marine governance as fisher LEK can evolve through inclusion in adaptive co-management and marine spatial planning. There are well-documented disempowering socio-economic and political processes which influence LEK (Escobar, 2007). This thesis adds the innovative approach of applying Bhaskar's (1975) critical realist perspective to illuminate and provide new insights on the underlying mechanisms of technological, market and socio-economic shifts in the fishing industry that influence the development of fisher LEK.

The thesis also provides an original perspective on fisher LEK through its focus on the benthos which is those species, habitats, and ecosystems on the sea floor (Eleftheriou, 2013). Benthic ecosystems contain many fish species which are more localised, and less likely to be migratory. The majority of fisheries management research focuses on demersal and pelagic species that are migratory and largely occupy the water column above the benthos, except as juveniles (Elliot et al. 2017; Worm et al. 2009; Pauly et al. 1998). While the term demersal only considers the fish caught, the focus on the benthos integrates a fuller more geographical understanding of how fishing processes are determined by the morphological forms or bathymetry of the marine locale. This is significant as anthropogenic influences from fisheries, wind power, and aggregate extraction are increasingly changing the benthos over time and space, continuing the marine biodiversity crisis identified by authors, including Costello

(2010). As well as providing an original detailed examination of the interaction between LEK and the changing benthos in Western European waters, the thesis acknowledges that LEK of the benthos is also shaped by fishers' interactions with marine species in the water column. Fisher LEK of the benthos is influenced by learning both in the community and individually from wider influences from society including media and politics across the study area.

1.2 Introducing how fisher LEK of the benthos is changing

1.2.1 Fisher LEK of the Benthos

The research in this thesis demonstrates that, over the late 20th and early 21st century, in Southern England, that scientific research involving fishers has increasingly influenced their LEK. Where once entirely insular, fisher LEK is now evolving. The compatibility of fisheries science and fisher LEK will be examined in this thesis.

The invention of the aqualung in 1943 by Gagan and Cousteau has increased access to the benthos and has been used in conservation science, which in turn has also influenced fisher LEK. The advent of diving has also brought to the attention of the public some of the ostensive negative ecological impacts on the benthos caused by fishing and industrial development: this was previously out of sight and out of mind. As the fishing industry has expanded, research into the marine biology and marine conservation science has also therefore grown commensurately. This thesis will investigate how marine research science has been feeding back into fisher LEK through fisher involvement in scientific research and the co-production of LEK with scientists.

Fishing practices have responded to the cumulative effect of many years of industrial pollution and developments in fishing technologies. Despite these responses, this thesis supports the perspective that environmental conservation and indicators of marine biodiversity need to be critically assessed and overhauled in order to help protect and maintain UK precious fish stocks (Costello et al. 2010). Furthermore, this thesis suggests that the fishing industry, because of its inherently destructive nature, should be required to adopt a more philosophically aware stance in order to stabilise and safeguard marine ecosystems and biodiversity from potentially negative anthropogenic impacts. While apex predators such as sharks naturally stabilise their prey's populations, human or anthropogenic impacts on the marine environment are not subject to the same checks and balances by other species. Furthermore, as fishers depend on living marine ecosystems for their livelihoods, it is in their interest to promote and safeguard marine ecological health through practicing sustainable fishing and harm reduction in the use of damaging fishing methods (Grieve et al. 2015). The findings of this research support the view that fishers should form an intrinsic part of the solution to facilitate improvements in marine health and biodiversity, as they represent one of the primary anthropogenic drivers causing negative impacts on the ecological health and biodiversity of the marine environment (Eastwood et al. 2007). A key contribution of the thesis is in detailing the cooperative learning process involving both fishers and researchers and the influence on one another. In addition, it examines how fishers understand biodiversity and its relationship to habitats. Biodiversity is now decreasing at 1,000 to 10,000 times the average rate of decrease identified throughout history; described as the sixth mass extinction (Chivian and Bernstein, 2008). A greater understanding of the causes and drivers of this loss in marine biodiversity requires the involvement of fishing communities and their distinct LEK. Fishers' views on these issues and the extent to which they are aware of decreases in marine biodiversity in recent years, linked to their views on the need for marine conservation, will also be discussed and are central to the analysis presented in the thesis.

1.2.2. How technology is changing and influencing the development of fisher LEK of the benthos

Fisher LEK is influenced by shared learning in the community using traditional and modern techniques (Cullis-Suzuki and Pauly 2010). While it has been argued that inshore fisheries generally have a lower environmental footprint, with offshore fisheries becoming increasingly efficient and capitalised, there are increasing questions about the management of the impacts of these changes upon inshore stocks and ecosystems (Phillipson and Symes, 2010). Although the different gear types deployed inshore can be rated on a scale of high to low ecological impacts with many, such as potting having a low impact, because of the range of fishing techniques involved, the anthropogenic impacts on the inshore benthos remain significant. Murray et al. (2006) argued that fisher LEK has turned into Global Harvesting Knowledge (GHK) and that LEK is becoming globally homogenised through the influence of new fishing technologies. This research, however, demonstrates that fisher LEK cannot simply be described as GHK as it is locally influenced in specific ways by local habitats, risks, and research programmes. Relating to what Schneider and McMichael (2010: 476) called the 'knowledge rift', this research shows how inshore fishers are adapting their LEK in novel ways in the face of these contemporary challenges to the fishing industry. This work is original in its examination of fishers' understanding of benthic impacts of their own gear, other fishers' gear and other external anthropogenic impacts.

The different techniques of fishing gear interacting with ecosystems, lead to fishers learning signals of stress, disturbance or abundance. However, in contrast to Davidson Hunt et al. (2006), this thesis acknowledges that, while fishers may recognise signs which suggest poor ecological marine health, they may continue to fish due to neoliberal pressures. To an extent, new technologies and interactions with research science can, however, lead to fishers adapting to signals of stress, disturbance or abundance.

1.2.3. The Interaction of Quota Governance, Social Organisation and Fisher LEK of the benthos

This thesis will investigate whether the evolution of fisheries and other marine governance in Southern England influence fisher LEK, such as through increased participation of fishers in marine governance. The thesis scrutinises how civil society, through Non-Governmental Organisations (NGOs), influences fisher LEK, such as through campaigns linked to the social sustainability of the quota system and the fishing opportunities for inshore fishers. While Johnsen et al. (2014) drew attention to the utility of fisher LEK for marine governance, the critical realist approach taken in this thesis, which pays attention to context, allows for additional reflection upon how neoliberal markets influence the nature and biases of fisher LEK. Inshore under 10 metre(m) 'Fishers of England' have long campaigned through the new 'Under 10m Fishermen's Association (NUTFA' (See Nutfa.org) to have a fair share of the UK's fishing opportunities and be involved in inshore fisheries management. Their concern, beyond quota shares, is that their fisher LEK of the benthos from fishing grounds does not feature as information in the determination of the Marine Management Organisation's 'Fixed Quota Allocation'. This is suggested by fishers involved in this research as top-down, inflexible and having limited potential for adaptive co-management. The inshore fishers of the newly recognised 'Coastal Producer Organisation' say they will manage quota adaptively without permanently gifting fishing rights to individuals (Coastal PO, 2017). Analysis of fisher narratives forms the basis of the findings presented in this thesis, including specifically examining the implications of how new technologies such as Catchapp can support power-sharing, be used in conservation programmes, and the ramifications for fisher LEK of the benthos. Catchapp can be a way for members to record fish caught photographically and by GPS to integrate their fisher LEK to form the basis for real-time updates to changes on fishing grounds.

Socio-ecological resilience in the context of inshore fisheries LEK of the benthos means a dynamic balance between the number of people fishing and the health and numbers of species influenced by fishing (Kinzig et al. 2006). Contributing to this definition of socially sustainable numbers of fishers includes how mechanisms allow for the intergenerational transmission of benthic LEK (as suggested by Moncrieffe, 2009 in the intergenerational transmission of poverty). This thesis therefore also examines relationships between property rights and intergenerational transmission of LEK. The distribution of fishing opportunities relates to property rights. How the distribution of fishing opportunities and property rights for the inshore fishing sector has led to increased distrust for the Common Fisheries Policy is included in the analysis. The different approaches suggested for fisher LEK of the benthos by the 'Fishing For Leave Campaign' (ffl.org.uk), and other public advocacy initiatives are also critiqued. How social organisational forms influence benthic fisher LEK is interrogated including considering traditional fishermen's associations, civil society organisations and spatial adaptive co-management schemes.

1.2.4 Marine Licensing, Conservation, and Spatial Planning Governance and fisher LEK of the Benthos

The demands for blue economic growth are increasingly guiding government decisions in the context of the EU (Jones et al. 2016). This research examines the extent to which inshore fishers in England remain disconnected from marine management processes and planning locally and nationally. This includes understanding the potential benefits for fisher LEK of the benthos to support interventions intended to decrease disturbing and polluting activities. Marine developments which disturb the health of ecosystems threaten the continuation of inshore fishing. This also has ramifications for the progression of biodiversity and conservation under the 'Marine Strategy Framework Directive' (Qiu and Jones, 2013). 'Ecosystem-Based Marine Spatial Planning' was originally conceived to improve ecological health by integrating humans into, for example, marine ecological conservation mapping (Jones et al. 2016). In this era of what Moore (2015) calls the 'Capitalocene', multiple users of inshore waters have seen the environmental status of the UK's regional seas decline (Defra, 2005). Fishers' understandings of the problems of aggregate, port dredging and dumping, and wind farm development, are considered alongside gaining an understanding of mechanisms that increase or decrease risks to the benthos of different forms of development and increase the integration of LEK. The interface of fisher interactions with marine protected areas and their forms of governance, including the efforts of social movements and NGOs to include fishers and their benthic LEK is also analysed. How conservation governance can progress the integration and increased shared understanding between fishers and scientists is also discussed.

1.3 Reflexivity and motivations for research

My own personal reasons for casting off on this research voyage firstly relate to my lifelong interest in the inherent complexity of fisheries. While raw materials and environmental impacts in land-based industries can be typified as predictable, controllable, and readily quantifiable, those of the fishing sector remain chaotic and difficult to quantify. The participant observation in this thesis showed that fishing involves a high degree of risk to both the ecosystem and its marine life. While the majority of the contemporary workforce is separated from the natural environment through the computer interface, inshore fishing maintains a practice that requires both intellectual and physical attributes. Historically traceable back to the Palaeolithic era, continuity of fishing with the marine ecosystem speaks to an inner human; a hunter-gatherer. Its interactions with the prevailing weather conditions, the dynamic nature of the marine environment's currents of change and the seasonal ecological shifts in marine creatures' behaviour and movements, makes fishing a continuously challenging profession. It is these prevailing tensions the fishing industry has with the marine environment that has drawn these issues to popular attention in recent years. Taking into account modern planetary boundaries of biodiversity and biomass, and the limits to which pollution and acidification can be absorbed and accommodated by the earth's ecosystems; the ways in which fishing as an industry has contributed to this damage, and indeed how it could play a part in solving these pressing issues, is personally fascinating. Furthermore, the fishing industry's longstanding denial of its own destructive influence on marine habitats in terms of its relationship to the killing of marine organisms remains a source of cogitative dissonance; its focus upon mass slaughter for profit is a fact which is personally difficult to digest.

Growing up in a small fishing village in Cornwall, where certain families of fishers were held in notoriety, concern about the goings on of fisher-folk were always the subject of speculation. The marked sense of the difference between those who were local ethnic Cornish fishers versus those in retirement, on holiday, or those able to afford to come from elsewhere to fish, was palpable. This maintenance of identity by self-selecting groups of fishers by 'othering' of outsiders is, of course, found along the coasts of the UK, from the Shetlands to Guernsey. Gaining a brief experience of lobster and crab potting as a teenager wetted my appetite for further explorations into the marine industry. Fishers, by their nature, have vested interests in regards to the sea whilst remaining core members of their local communities. In regard to my own bias in the research presented in the thesis, I have attempted not to romanticise fisher LEK, as certain authors have done with Traditional Ecological Knowledge (TEK), by maintaining a critical realist approach. Furthermore, as the literature on towed gear adopts a comprehensively critical assessment of its benthic impacts (including Jones, 1992; Kaiser et al. 2006; Grieve et al. 2015), in this research I will seek to address my own bias in assessment of their potential contribution through LEK, by balancing this with a comparison with the benthic impacts of static gear.

1.4 Summary of chapters

In the next chapter, the context of contemporary fisheries governance from global to local is introduced. A review of the different fishing gears and technologies is presented in section 2.5, alongside the context of fisheries communities, property rights, and conservation policy in chapter 2. This chapter on context explains how fisheries governance works from the global to the local inshore under 10m fishing boats.

The third chapter reviews the literature on fisher LEK. In order to understand LEK more fully, the chapter begins by examining literature regarding TEK, its definitions and applications. It critiques the dominant application of a cultural relativist approach to understanding TEK for promoting sustainable development. Traditionally TEK has been described as a body of knowledge defined by its cultural transmission handed down the generations in relation to humans and their relation to the environment (Berkes, 2012).

Chapter 3 considers the debates regarding the accuracy and validity of TEK versus scientific knowledge. It continues by reflecting on how the majority of the literature on fisher LEK is influenced by a scientific epistemology, simplistically treating fisher LEK as a data source (Pauly, 1995; Johannes, 1998; and Azurro, 2011). Moreover, while previous research shows fishers have a diverse knowledge of specific stocks, there has been very limited research on fisher LEK and the seabed, particularly in European waters, and its interaction with conservation science. Countervailing this logic, this research takes a different epistemological approach that aims to understand the nature of fishers' benthic LEK, but also to advance the understanding of how fisher LEK is influenced by broader socio-economic and political processes. Of particular interest is the influence of the power relations that affect fisher interaction with research science and governance. The chapter shows that no other studies have considered fisher knowledge of the benthos in Western European waters, and in particular, how changing praxis and perceptions of practice under neoliberal market forces interact with research, new technologies, social organisation and governance are largely ignored.

Chapter 4 explains the critical realist approach taken in the research and examines how Bhaskar's (1975) approach can be specifically applied to inshore fisheries. The chapter introduces the mixed qualitative methods that were used to understand fisher LEK of the benthos, such as participant observation to understand fisher praxis, and semi-structured interviews with fishers and key informants. While constructivism defined fully in 3.1.2 emphasises the importance of culture and rituals in regard to TEK, critical realism affirms socioeconomic and scientific influences; the objective and the subjective.

The findings from the research are presented in four chapters that focus on: how LEK combines local learning with scientific research; how technology is changing and influencing LEK; the influence of social organisation on LEK; and the influence of marine governance on LEK. Chapter 5 draws on interviews, firstly providing an analysis of the current state of inshore benthic LEK. Fisher LEK is introduced in regard to its habitats, species, environmental signals, patterns of invasive species, and biodiversity. Research sites were chosen on this basis and LEK across the different sites is discussed. The discussion of findings explores how research science has been interacting with LEK. It investigates examples of how different marine science, fisheries, and industrial research programmes have involved fishers, and how fishers have become increasingly scientific in their approach and in turn how this has influenced power relations between fishers and scientists. The discussion continues by examining how fisher LEK working with natural science can draw attention to benthic habitat disturbance and risk.

Chapter 6 interrogates how fishing technologies have been changing over time, and how this influences knowledge generation and its dissemination through the fisher community. Work from Johnsen, (2009) showed how the rationalisation of knowledge is affecting fishing associations organisationally. LEK is theorised in this thesis including considering how, as knowledge becomes increasingly codified and centralised in the fishing organisation, crews are increasingly removed from different local ecosystem processes as they fish and become increasingly migratory. While Murray et al. (2006) discussed the inevitable change of fisher knowledge into universal GHK through modern sensory technologies; this neglects fishers' interest in local ecological changes to ecosystems they rely upon. Fishers' interplay with conservation research and technologies of conservation are discussed and how this feeds back onto their understandings of scarcity, habitats, and biodiversity.

Chapter 7 examines how fishers' changing social organisation interfaces with governance. By analysing the fisher LEK of those involved in fisher social movements, it illuminates the current environmental injustice of the quota system. While the UK government has created a quota market to apparently improve economic efficiency, this has left inshore fishing marginalised. The chapter investigates how social organisations and their epistemic communities are influencing LEK and how quota governance in the UK is influencing intergenerational transmission of knowledge. It also discusses how this relates to fishers' access rights and the rights of the community to limit access to those disturbing the benthos. Suggestions developed through interviews with fishers are offered as a mechanism for achieving fisheries democracy.

Chapter 8 presents how fishers' local learning highlights problems of port dredging pollution, aggregate impacts and disturbance from wind farms, and the challenges for fisher LEK participation in marine governance. It evaluates decision-making in marine management, and how particular forms of scientific knowledge that are seen to facilitate project development are prioritised. In the chapter mechanisms that could better facilitate the integration of fisher LEK are discussed including the assessment of fisher LEK, and how this could better interact with conservation governance. The interplay of conservation research with fisher awareness of the scarcity of habitats is also considered. This has ramifications for governance of the commons, and also relates to the developing attempts of co-management through bodies such as the Inshore Fishing Conservation Authorities (IFCAs) the Marine Management Organisation (MMO) and the government's Centre for Environment Fisheries and Aquaculture Science (Cefas) to improve the system.

The research aims and questions are finally returned to and summarised in chapter 9, the concluding chapter, including summarising how fisher LEK is being influenced by research bi-directionally, through changing technology as well as the influence and integration of LEK into conservation marine governance.

Chapter 2 The Context of Inshore Fisheries

2.1 Background history to inshore fisheries

The influence of fishing on humankind gained increased and controversial currency through the aquatic or waterside ape theory, as first advanced by Hardy (1960). This argues there is a period in human development when instead of being forced upright by the demands of the increasing savannah, humanities' struggle with other life in the trees brought them to the water's edge, swimming, diving and walking on two legs in the shallows. It led to the raising of human consciousness, intelligence and ability to plan, splitting early hominids from chimps. The complex cogitation needed to connect astronomical observation, tidal character and fishing at different seasons has been evidenced in Africa at least 100,000 to 1,000,000 years ago (Marean, 2014). This development could be called the beginning of the history of inshore fisher LEK of the benthos. The coast saw the rise of the first villages based on fishing. With access to regular surplus food, the development of social and technological features unusual to hunter-gatherers saw reduced mobility, increased population packing within smaller territories, and more wide-ranging gifting and exchange. The use of coastal resources in a 'systematic' manner has been theorised to have led to expansion out of Africa (Oppenheimer, 2009). Scientists have recently published research that provides evidence that at an unknown point in the last five million years, humans became dependent on fatty acids and iodine, found abundantly in sea resources, essential for the efficient function of the human brain (Stewart et al. 2014).

More recently, inshore fishing from boats has been carried out in the UK at least since the upper late Palaeolithic period circa 11,500 BC. In this period, fishers used basic skin boats across Western Europe, as the practice of migratory hunting culture spread (Dunkerly, 2014). However, it changed significantly from supporting primitive communal societies (Dickens, 2000), through to rapid increases of catches of herring and cod after AD 1000 after the Norman Conquest (Barrett et al. 2004). As society during this period moved towards political centralization and feudal models of organisation, coastal fishers began the first early fishing industries, transporting their catch to metropolitan areas and supplying fresh fish to the rich. Fish became increasingly important for religious reasons and for social prestige. Moreover, the importance of fishing accelerated with the increasing dominance of forms of capital in inshore fishing through the 16th century (Roberts, 2010). Developments in Cornwall echoed expansion in Newfoundland as new fishing technologies emerged. This included seine fishing, a technique which encircles the catch in a ring net, as described by Rowse (1941: 68):

> Upon the Cornish coast, seine fishing was introducing new conditions and displacing the old arrangements. It tended to cut out the smaller men since the seine landed much larger catches, and the size of the net demanded the cooperation of three or four boats, each of them with six

> men or so apiece. This necessitated much more capital and in turn, led to the domination of the markets by the merchants.

Historically, attitudes to fisheries management have been lassiez-faire. Soaked in the antiquated dogma of Hugo Grotius' 'The Free Sea' from the early 17th century, the fisher worldview has been one of open access for all to the high seas (Grotius et al 2004). Fisheries governance and fishers' participation in management or governance has been a recent phenomenon. In the 1860s, Thomas Huxley in his inaugural address to the London International Fisheries Exhibition of 1883 proclaimed that: 'I believe that the great cod fishery, the herring fishery, the pilchard fishery, and probably all the great fisheries are inexhaustible; that is to say that nothing we do seriously affects the number of fish' (Knauss, 1994: 11). It is now well known that this is false, and the development of new industrial technologies has, through the oxygen of capitalism, produced an unsustainable metabolic rift between society and nature (Foster, 2000). Technologies of fishing exploit ecosystems capacity beyond their capacity to replenish themselves if left to unregulated markets. How these ecosystems are recorded and understood needs transparency, democracy and scientific participation at a different scale (Ostrom, 1990).

2.2 From global to local governance

Globally the world now sees over two-thirds of continental shelves overexploited, at multiple threshold levels, through the introduction of new industrial fishing technologies (Swartz et al. 2010). Progress in fishing technology since the 1950s, (including cheap fossil fuels, freezers, sonar, and GPS) has led to the over-exploitation of the high seas (Cullis-Suzuki and Pauly, 2010). The greatest global catch volumes were recorded in 1988, coinciding with the peaking of the value of the world's fisheries market. The total real landed values for fisheries globally was US$24 billion in 1950. From 1950 to the early 1970s it rose steadily to US$90 billion, increasing to a peak of US$100 billion at the end of the 1980s, subsequently declining to US$80 billion in 2000 (Sumaila et al. 2007).

Governance of 60% of the global ocean remains in areas beyond national jurisdiction. Historically the oceans (including the water column, seabed, and living and mineral resources) were long left as an open-access resource open to all with economic interests (Payoyo, 1997). The establishment of the 'International Seabed Legal Regime', under the United Nations Convention on the Law of the Sea or (UNCLOS), has placed the seabed under the 'Common Heritage of Mankind' alongside Antarctica, the Moon, and Mars (Payoyo, 1997). Nevertheless, authors from a neoliberal economic background such as Lewis, (2009) purport dangers of maintaining common property governance for markets.

To curb overfishing, a major breakthrough was seen in the United Nations Conference on the Law of the Sea in 1978, successfully establishing exclusive economic zones as the responsibility for states (Jentoft, 2003). Resulting in formal legislation with the United Nations Convention on the Law of the

Sea (UNCLOS) on 10th December 1982, the Food and Agricultural Organisation (FAO) and the United Nations Environment Programme (UNEP) have initiated a network of Regional Fisheries Management Organisations, (RFMOs).

These RFMOs were consolidated in 1995, after the United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks (UN Fish Stocks Agreement), and the 1995 United Nations Food and Agricultural Organisation Code of Conduct for Responsible Fisheries (FAO 1995). Through the statutory authority of their member nations, they have the legal authority to manage the fishing for stocks. To fish in the high seas, commercial fishing fleets must abide by RFMO regulations. These RFMO areas, whilst predominantly areas beyond national jurisdiction, also overlap with exclusive economic zones of coastal states. There are six RFMOs that are specifically tuna focused, while 11 are multi-species management organisations. Some areas of the international high seas, however, remain open access through the historic dispute, such as the South Atlantic Fisheries Management Area around the Falklands and Argentina.

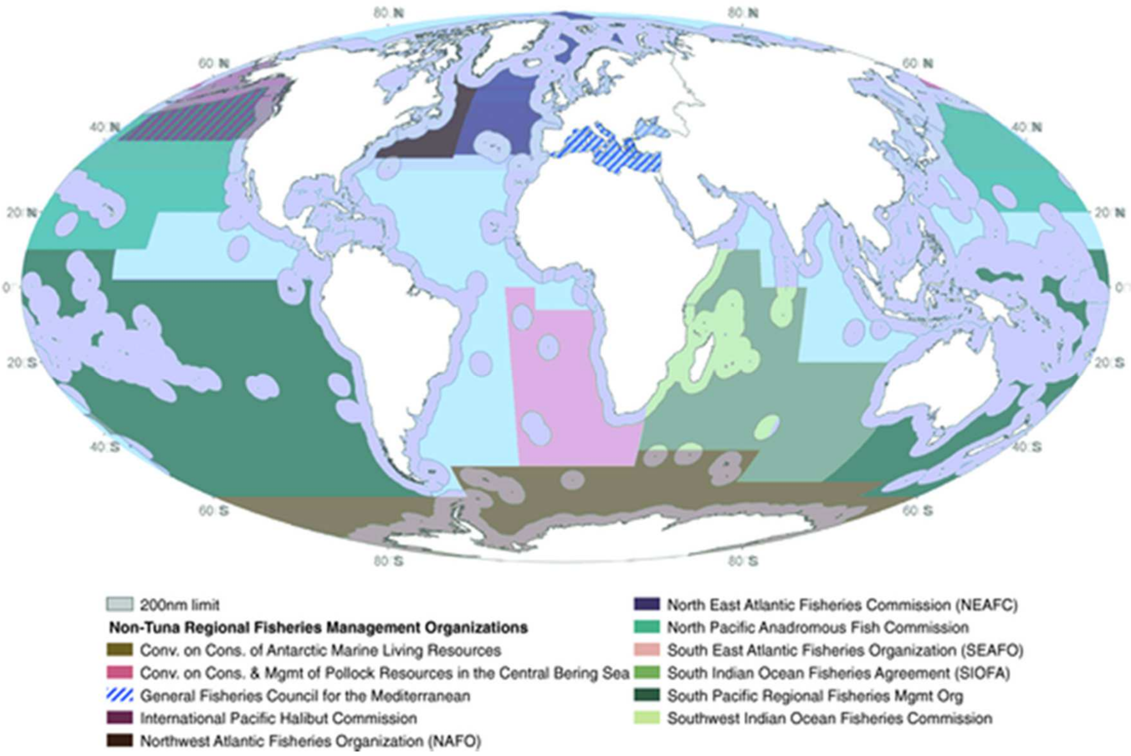

Figure 2. RFMOs that manage bottom fisheries and species other than tunas. Notable gaps exist in parts of the Atlantic, Indian, and Pacific Oceans. (Ban et al. 2014).

Table 1 of RFMOs, their acronyms, and stocks adapted from work by Cullis- Suzuki and Pauly (2010).

Acronym	**Name**	**Number of species/fish stocks managed**
CCAMLR	Commission for the Conservation. of Antarctic Marine Living Resources	Multiple species
CCBSP	Conv. on the Conserv. & Mgmt. of the Pollock Resources in the Centre of the Bering Sea	1 stock 1 species
CCSBT	Commission for the Conserv. of Southern Bluefin Tuna	1 stock 1 species
GFCM	General Fisheries Commission for the Mediterranean	Multiple species
IATTC	Inter-American Tropical Tuna Commission	3 stocks 1 species
ICCAT	International Commission for the Conserv. of Atlantic Tunas	8 stocks 1 species
IOTC	Indian Ocean Tuna Commission	3 stocks 1 species
IPHC	International Pacific Halibut Commission	1 stock 1 species
IWC	International Whaling Commission	9 stocks 9 species
NAFO	Northwest Atlantic Fisheries Organisation	Multiple species
NASCO	North Atlantic Salmon Conserv. Organisation	1 stock 1 species
NEAFC	North East Atlantic Fisheries Commission	Multiple species
NPAFC	North Pacific Anadromous Fish Commission	3 stocks multiple species
PSC	Pacific Salmon Commission	1 stock 1 species
SEAFO	South East Atlantic Fisheries Organisation	Multiple species
SIOFA	South Indian Ocean Fisheries Agreement	Multiple species
SPRFMO	South Pacific Regional Fisheries Management Organisation	Multiple species
WCPFC	Western and Central Pacific Fisheries Commission	Multiple species

As many of these organisations are focused on particular species, and particular stock populations, they have limited data about the whole of the ecosystem. Overall, the stocks assessed and managed by these organisations are declining, a consequence of historic open access (Cullis- Suzuki and Pauly 2010). Furthermore, instead of integrating activities in these international areas, as might be possible under one umbrella organisation, UNCLOS designates responsibility for specific activities to an array of sector-based international organisations and conventions. Rather than promoting an integrated ecosystem-based management approach, it separately delegates the water column to the RFMOs, while the International Seabed Authority (ISA) manages the global seabed (Ban et al. 2014). Nevertheless, a popular comprehension of ecosystem-based management and one that I critically reflect on in the findings of chapter 8 is “an integrated approach to management that considers the entire ecosystem, including humans” (Douvere 2008: 764).

Having a balance of industry and conservation stakeholders in governance at this international scale is a challenge, more easily integrated at a local scale (Shiva, 2016). An ecosystem-based management approach is beginning to develop, with the establishment in the North Atlantic of the first set of marine protected areas (MPAs) on the high sea. The Charlie-Gibbs Marine Protected Area (CG-MPA) is part of the first set of six new conservation areas that have ever been established in international waters (O’Leary, 2012).

Contemporarily, some success has been seen with an international agreement banning bottom trawling in certain locations through the UN general assembly, allowing for RFMOs such as the North East Atlantic Fisheries Commission (NEAFC) to implement zoned areas (Wright et al. 2015). Successful conservation planning at this scale has been challenging, with the domination of sectoral interests such as fishing, energy and more recently deep-sea mining. While there are scientific surveys, there is a lack of detailed knowledge of the ecosystems being exploited beyond single stocks on a high scale (Cullis- Suzuki and Pauly 2010). The main source of ecological knowledge comes from fishermen landing fish, their logbooks and the patterns they observe (Cullis-Suzuki and Pauly 2010). Within states of the EU, governance on a fine scale has not been fully realised, and still focuses on single stocks as discussed in the next section.

2.3 Fisheries science and governance within EU states

In correlation with this fractured approach on the international high seas, governance in the EU and the UK focuses on single stocks. Replicating this, the majority of research considering LEK also focuses on single species stocks (Johnson et al, 2010, Brehme 2009 and De Souza et al. 2013). There is very limited research considering LEK of the entire local marine ecosystem, and its interactions with conservation research. This shortfall relates to how the unit of observation has shifted historically, from local scale measurements to fish stocks being averaged over much larger scales from the 1920s onwards, through ‘rational fishing’ management discourse, which eventually became dominant in the 1990s (Hoefnagel et al. 2006). Before this fisheries research evolved through the fishing industries’ questions, around catch variability, and the concept of overfishing (Petersen, 1903).

By adopting a large-scale averaging approach, fisheries research has, at the same time, alienated itself from the observations and understandings that are associated with the commercial fishing activity, where the high resolution in space and predictability is required (Dengbol, 2003). The resulting basic unit of management is still the stock, and the mainstream fisheries science scale of relevant knowledge remains 100+ miles. Fishing management remains based on the single stock, and not the ecosystem, which means that modern fisheries management lack interspecies consideration in its predictions, alongside anthropogenic interactions. Mainstream fisheries science predicts current biomass as a proportion of unexploited biomass, multiplied by growth rates, subtracting fishing effort to get the catchability of different stocks, averaged over time and space (Walmsey et al. 2005).

A classic example of this has been the evolution of the Common Fisheries Policy (CFP). The initiation of this high level of scale was thought necessary to counter the problem of overfishing through international collaboration (Carpenter et al. 2016). The CFP act of accession had the effect of making marine fisheries a common property resource among EU members, particularly in the area from 12nm to the edge of the Exclusive Economic Zone (EEZ) (De Santo 2013).

Importantly the scale of fisheries designation is so large at 100+ miles meaning it has distanced itself from fishing activity per se. The unique insights and observations of fisher LEK have been marginalised, in order to gain a perceived increase in objectivity and predictability through the production of high-resolution spatial assessments of fish stocks (Dengbol, 2003). Additionally, through the 'equal access principle', the mechanism for assigning quota for species is highly complex. Decisions are made by the EU Director General of Fisheries and Maritime Affairs, supported by assessments made by the International Council for the Exploration of the Sea (ICES). Nevertheless, as negotiation for the total allowable catch (TAC) for individual stocks is completed in political competition with other nation states, scientific evidence is typically ignored through attempts to placate industrial fisheries (O'Leary et al. 2011). Extraordinarily, through industry pressure, during the period 2001 to 2015, EU TACs were set 20% above scientific recommendation for exploitation. Out of the countries involved, the UK and Denmark received the largest increase to their TACs (Carpenter et al, 2016).

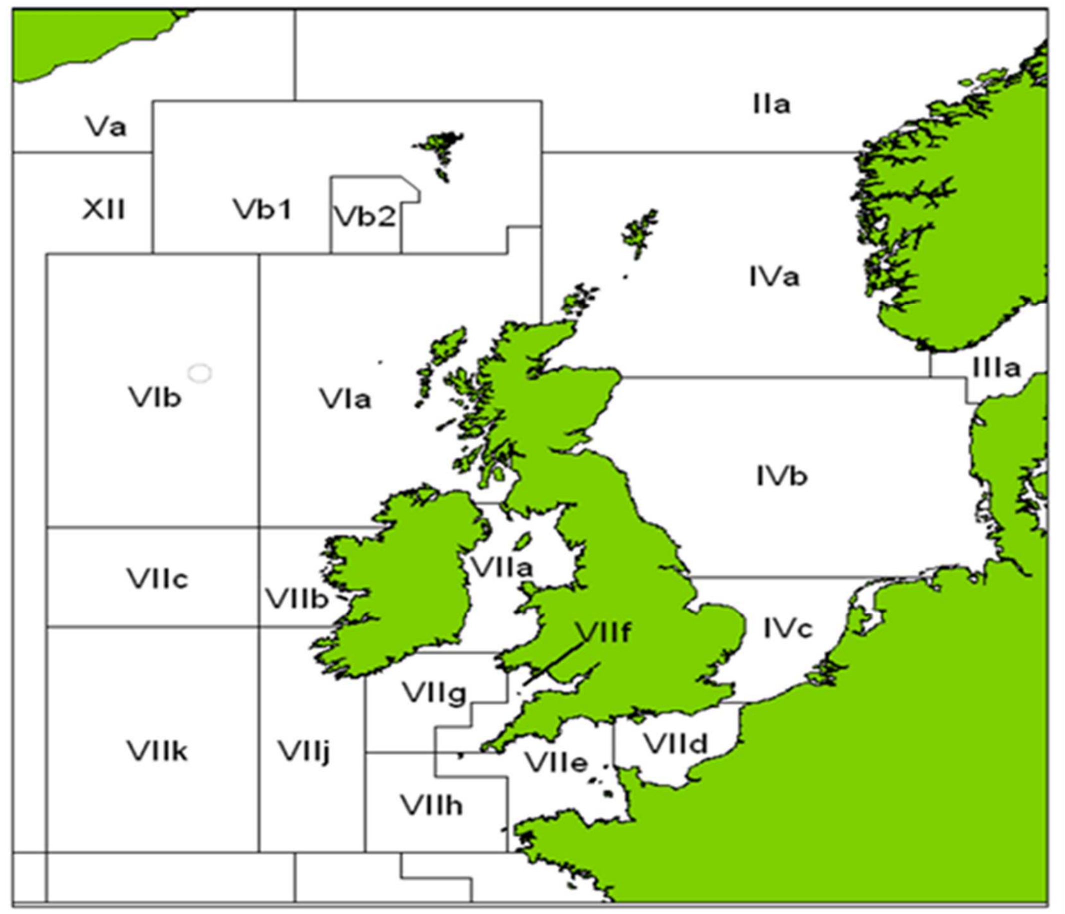

Figure 3 ICES map of fisheries areas. These box areas are used for ICES species stock exploitation assessments. They are large to encompass the migratory nature of the species. The study areas include VIIE, VIID, and IVC.

Historically, the EU's Total Allowable Catch TAC has been influenced by the concept of Maximum Sustainable Yield (MSY). Member States and the EU subscribed to the MSY objective almost thirty years ago in the 1982 UN Convention on the Law of the Seas. They then reiterated it in the 1995 UN Fish Stock Agreement, in 2002 in the Johannesburg Declaration on Sustainable Development and finally in 2010 at the Nagoya Convention on Biodiversity (Europa, 2015). Nevertheless, it has been historically criticised as inadequate, most famously by Larkin's (1977) epitaph:

Here lies the concept, MSY,

It advocated yields too high,

And didn't spell out how to slice the pie,

We bury it with the best of wishes,

Especially on behalf of fishes.

We don't know yet what will take its place,

But we hope it's as good for the human race. (Larkin, 1977).

It was conceived as a tool of government policy rather than science. The foundational doctrine of the MSY applying to halibut, tuna, and salmon fisheries emerged at a time when the US government was using science to promote its own forms of technology and knowledge, helping to ensure that American ships could pass through the world's seas unimpeded (Finley 2013). MSY is the largest average yield (catch) that "can theoretically be taken from a species' stock over an indefinite period under constant environmental conditions" (Ocean 2012, 2012). Nevertheless, one of the many problems with MSY is that it continues the individual species approach rather than an ecosystem approach. In mixed fisheries, MSY is set to the most vulnerable stock (Finley 2013). As the biomass of MSY is typically a target set for a single species, so a joint BMSY target in a multi-species context would mean that some species would be fished below MSY, and some overfished, with the risk that sensitive ones might collapse. A further criticism that raised by this thesis is insufficient attention given to the benthos and the fishers' benthic LEK. Through the continuation of the term demersal in calculations of MSY as well as the EU's TAC, benthic ecosystems and the fishers' knowledge of them are ignored (Hilborn and Orlando, 2014). Without a specific reference to the benthos, the type of gear impacting on the benthos and its species is not calculated. As Larkin pointed out in the 1977 epitaph above, it didn't spell out how to slice 'the fish pie'.

2.4 The UK Property rights and different forms of fisheries governance

The UK accounts for 13% of the EU's total landed weight in 2014, making it one of the EU's biggest fishing nations. In the EU, the UK also has the largest EEZ of any EU country, excluding overseas territories. The UK fleet consists primarily of smaller vessels, with 4,281 under 10-metre vessels and 1,252 over 10-metre vessels (NEF, 2017). In England, the inshore under 10m boats comprise 78% of the fishing population. Controversially, fisheries are calculated at a scale beyond the activities of local fisheries and ecosystems and have historically been influenced by lobbying. It has been highlighted that stakeholders from the fisheries industry feel that scientific advice also suffers from low legitimacy and a lack of transparency (O'Leary et al. 2011). While this may have been true in the past, scientific accuracy has been better integrated since the latest CFP in 2014 (Carpenter et al. 2016). This has meant the CFP process and access to its quota have been politicised and is not well understood by inshore fishers. The different property types and how they relate to common pool resources are perhaps not always well understood by fishers or policy makers.

A common pool resource is a resource that benefits a group of people, but which provides diminished benefits to everyone if each individual pursues his or her own self-interest (Ostrom, 1990). However, there are different legal property rights governing these common pool resources with different results. The different forms of rights are state (res publica), private (res privada) or common (res communalis) property and open access (res nullis) (Davidson Hunt, 1996: 1). Common property is that to which we all have inalienable rights. State or public property is that which the state owns, and can dispose of as it sees fit, such as to create private property for profit (Lerch, 2009). Common property is conflated with open access resources by mainstream fisheries economists. Gordon's seminal (1954) paper led comprehensions by defining common property resources as those that "are free goods for the individual and scarce goods for society" (Gordon, 1954: 135). While private property rights have been historically most popularly applied in common pool resources, this definition may relate to the conflation of common properties with open access government failures (Gordon 1954 and Hardin 1968). As illuminated by Mansfield, (2004), prescriptive one size fits all market solutions are widely applied to solve governmental problems (Pritchett and Woolcock, 2004). Gordon's (1954) main argument was that the lack of private property drives a non-equilibrium pattern in fisheries, such that total effort levels will always rise to the point that they dissipate any potential profits, thus leading to inefficient use of capital and fish. Following Gordon, Hardin (1968) wrote the 'Tragedy of the Commons' equivocating that the commons are without rules, being the same as an open-access regime further encouraging the use of private property rights in natural resources

Fisheries common, public and private property rights are overseen by 4 key forms of institutional arrangements. As described by Imperial and Yandle (2006: 495) these are (1) private property or market based; (2) bureaucracy based without power sharing; (3) common or community-based arrangements; and (4) contemporarily, co-management has emerged with power shared between the state and fishers. Additionally, building upon a human rights approach, attention for rights-based fisheries management, relating to existing and new associations of fishing communities are increasing which relate to both community and co-management approaches (Allison et al. 2012).

In consideration of common community-based property, authors researching from the indigenous or TEK school of thought highlight that indigenous traditions of exploitation and property rights have produced long-term sustainability over millennia (Berkes et al. 1989; Larson and Bromley 1990). Writers such as Bavinck et al. (2015) highlight that certain traditional common property rights have had some success in evolving with modern demands. Those that successfully integrate fishers' LEK into forms of co-management include the Spanish Cofradia, the French Prud'homie, the Lofoten management system, the Polish Mazoperias, the Indian Panchayat system, and the Indonesian Sasi (Jentoft et al. 2000). Contemporary co-management is designed to incorporate fisher participation and can include LEK in decision-making processes (Jentoft et al. 2000). Co-management is a collaborative and participatory process of regulatory decision making between representatives of user groups, government agencies, research institutions, and other stakeholders (Mikalsen and Jentoft, 2001). The sharing of power associated with co-management fits more neatly with the scale of the fisher communities, and the spatial scale that fishers, such as inshore fishers, operate on in everyday work. Nevertheless, the majority of traditional forms of fisheries governance have seen changing technology and new market pressure, leading to industrial over-exploitation. This has made the benefits of certain traditional forms of common property moribund under pressure from corporate globalization (Harvey, 2012). It has resulted in private property rights in some cases. This thesis will examine how the different forms of property relate to inshore fisheries LEK.

There are two types of private property rights promoted; tradable non-spatial private property rights over quota; and spatial private property rights over a portion of seabed benthos. The first has been advocated by Costello et al. (2008), who suggest the answer lies in the alignment of incentives because individuals who lack secure rights to part of the quota, have a perverse motivation to 'race to fish', to out-compete others. However, in wild sea fisheries with species enjoying some degree of local migration, there is no potential to secure the activities of marine life without tagging every single living creature in the ocean with tracking devices and enclosing them with laser sensors. Logically then, the best available knowledge in the common pool resource needs to be combined, such as fisher LEK combining with scientific knowledge.

Spatial private property rights over the seabed for fisheries have also been promoted. Following from Gordon (1954), an example neoliberal scholar, Adler's, (2002) work promotes private property rights over a shellfish bed. However, this lacks consideration of the whole ecosystem including the water column. In Chile, private properties have been granted for industrial aquaculture, however this lacks consideration of water quality as a common pool resource which influences other areas outside of the private property (Tecklin, 2016). Adler (2002) justifies not giving a full review to other alternative institutional arrangements, including democratically managed common pool resources, quoting Hayek who argue that the use of markets for decision making were superior against central socialist planning, and that effective fisheries management depends on local and technical knowledge beyond the reach of any centralized management agency (Hayek 1945: 519) Nevertheless Adler (2008) is bereft of any consideration of how "this knowledge problem" can be solved by decentralized, adaptive forms of co-management supported by participation in research.

The dominant logic of economic efficiency has led to the more common tradable non-spatial private property rights over quota for migratory species evolving in the United Kingdom (Appleby, 2013). Nevertheless, as Sumaila (2010) demonstrates, this logic typically entails a consolidation of use rights into the hands of larger operators, leaving out concerns about social and environmental justice. Similarly, wider accumulation around the world through market enclosure has seen fisheries rights concentrated with big business through 'blue grabbing' (Benjaminsen and Bryceson, 2012). Similarly, in the UK property rights have only been made available only to certain scales of fishing. In the case study area of this thesis, there are two different forms of property rights enforced by governance. These are both species quota rights, with open access ultimately continuing in all areas outside of MPAs, where bylaws limit certain types of fishing. For inshore fishers within 6nm using under 10m boats, rights are bureaucracy based delegated monthly by the MMO, while those offshore beyond 6nm, whose boats are over 10m, operate under a market-based form of property rights. While fishing was already a public right in the UK by law, Fisheries Producer Organisations (FPOs) were originally intended by the CFP to ensure fishing is carried out rationally, using methods to support sustainable fishing. While their names relate to geographical regions such as South West or Eastern England FPO, in reality, the boats of the FPOs migrate around the coast offshore by buying and renting quota. FPOs are allowed to manage their quotas as they see fit and are responsible for ensuring that they do not overfish their allocations (Appleby, 2013). At the same time, inshore fishers are separately policed by the IFCAs and the MMO.

The Fishery Limits Act (1976) saw the UK declare an exclusive fishery zone (EFZ) up to the 200 nm limit. The declaration of the EFZ claimed sovereignty over fishing rights. Surprisingly the Act was silent as to the ownership vehicle of the UK's new fishing rights. The division of this quota was opaque under MAFF and is shrouded in controversy. It has led to the quota total for inshore fishers being much lower than would be expected, considering their total population of over 70% of the fleet. The original assessment evolved so that only over 10m offshore fishers were asked to record their activities. This has resulted in 98% of the fixed quota allocation system (FQA) being held by fishers in FPOs (MSEP 2015). The introduction of CFP led to 'track records' for the over 10m fleet being recorded from 1986 onward (Hatcher 1997). Following that, the FQA system introduced in 1999 was based on vessels' historic landings during a reference period from 1994 to 1996 under the registration of buyers and sellers (Defra et al. 2013). However, the original recording of landings only applied to the offshore fleet from 1986, creating the inequality. Inshore vessels' landings had not been recorded formally, and before 1986 many of the stocks fishers enjoyed had been open access (Symes and Phillipson, 1997). This has led to the social injustice of the inshore fleet only having 2% of quota, despite having 70% of the total numbers of fishing boats. It is worth noting that across the UK the over 10 metre fleet accounts for 88% of the UK's fishing capacity (vessel tonnage) (NEF, 2017).

There has been a historic shift from light touch fisheries governance through the Sea Fisheries Committees and Ministry of Agriculture, Fisheries and Food (MAFF) which was disbanded in 1999, to full quota enforcement and bureaucratic management under the Marine and Fisheries Agency, as an agency of DEFRA. This saw the Marine Management Organisation (MMO) introduced in 2010 by the Marine and Coastal Access Act 2009, bringing together regulating, licensing and decision making, and proposed marine planning. The new IFCAs replaced the Sea Fisheries Committees. It is this shift to top-down management, alongside the decrease in the amount of quota and its neoliberal marketisation, which has politicized fishers in the Southern England area. The different techniques of inshore fishing will now be discussed.

2.5 Defining inshore fishing and types of fishing

Inshore fishing is defined in the UK as fishing up to 6 nautical miles from the coast, while the EU the definition specifies fishing to the edge of the continental shelf. The inshore fishing sector, therefore, dominates fleet and employment profiles of EU fishing fleets (IFREMER, 2007). In the UK, over three-quarters of the inshore fishing fleet are 10m and under, though they represent only a tenth of fishing capacity and a third of total fleet power (Phillipson & Symes (2010). Furthermore, the inshore fishing population represents 76% of the British fleet and lands 27% of its catch (IFCA, 2013). Inshore fishing definitions remain contested across European contexts, particularly by fishers. For example, the Netherlands and France have a 12m length definition and a 12 nautical mile limit (Van Ginkel, 2009). Other such as Symes and Phillipson (2001) argue that these divisions between inshore and offshore are now misplaced with many 10-12m vessels being capable of working out to 40 miles. In the UK, 10-12m vessels have to maintain a written log book of catch data, while over 12m vessels have to keep an electronic logbook. While the UK inshore under 10m fleet do not have this bureaucratic challenge, there is less chance for participation in fisheries science, such as with the 'Fisheries Science Partnership', which continues for over 10m fleets.

Urquhart and Acott (2013) highlight that inshore fishers generally fish in coastal waters for periods of less than 24 hours. Symes & Phillipson (2001) suggest that more nomadic inshore vessels can and do fish for longer. Inshore fishers typically work in small crews of 1 to 3 persons and experience a low division of labour between tasks. An awareness of the demographics of gear usage is important. While the overall size of the UK fishing fleet has declined over the last 20 years from 9900 to 6500 vessels, the number of vessels using pots and traps as their main gear has doubled from 1700 to 3500 (Coleman, 2013). Comparatively, towed gear vessel totals have fallen from 1775 to just 755 over the same period (Fleet Register, 2014). There are now also fishers diving for scallops and other shellfish.

Inshore fishing is also called artisanal fishing, small boat or small-scale fishing, but this is somewhat romanticised (Symes and Phillipson, 2001). These can be grouped into static gear and towed gear groups, which have been argued to be lower impact and high impact groups respectively (Gascoigne and Wilsteed, 2009). Static gear low impact fishing methods include: gill netting (also known as trammel netting, targeting flatfish such as sole, turbot, plaice, skates, and rays); rod and lining (targeting bass, squid and mackerel); potting (targeting lobsters, crabs and cuttlefish and whelks) (Symes, 1999). These practices can be grouped given their continuous targeting of specific static underwater places, according to seasonal patterns. These fishers typically work in small crews of 1 to 3 persons and see low division of labour between tasks. Furthermore, these static gear fishers maintain a closer relationship to their local ecology and geography.

Towed gear fishers, such as trawlers and dredgers, who use gear such as pair trawls, beam trawls, and the triple otter board trawl, however, see higher divisions of labour through an increase in mechanisation of gear dispersal and retrieval. These larger, more nomadic capitalised vessels have greater fishing power and range, often landing fish at different ports, increasingly using GPS, fisheries acoustics and other technologies (Fishcher, 2000; Johnsen, 2005). These towed gear methods such as trawling are empirically considered to have more impact on the seabed (Jones, 1992; Thrush and Dayton, 2002). Towed gear fishing processes to be investigated include otter board trawling (targeting lemon soles, plaice, dover soles, turbot, red mullet, affecting many other associated species); beam trawling (targeting similar species); and shellfish dredging (targeting scallops, oysters, clams, and cockles). The towed gear sector can be grouped as higher impact in terms of seabed impacts, upon the associated species, alongside fuel use. Towed gear industrial boats are more commonly associated with larger businesses, as they land more fish, and are more expensive to run (Suuronen et al. 2012).

The groups of inshore and offshore, under 10 and over 10m boats, are subtly different, with the under 10m vessels more likely to maintain fishing in a localised area, given the restrictions posed by weather, engine power, and capacity. However, a new sector in the under 10m fleet has emerged recently, identified as ‘the super 10s’ by fishers and mentioned in the results. These are catamarans with greater width and capacity, which can stay at sea for longer, move into the deeper water more safely, and commit greater fishing effort. By contrast, over 10m deep-sea fishing is predominantly nomadic, and typically such fishers do not need to develop such a detailed understanding of local ecosystems, as they seek to fish in new areas. They can apply techniques that are universally applicable and more relevant to what Murray et al. (2006) call GHK. The offshore fishing effort is managed by FPOs. While fishing is a public right, FPOs have been delegated responsibility as quasi-public bodies from the Crown. They are allowed to manage their quotas as they see fit and are responsible for ensuring that they do not overfish their allocations (Appleby, 2013). Their names superficially relate to geographical regions such as the South West or Eastern England Fish PO, while their boats migrate around the coast by buying and renting quota. The predominantly corporate organisations of those involved in FPOs is important to contrast to those involved in the more traditional, informal organic associations of fishing communities found inshore. As these FPOs can lease quota to inshore fishers there has been a significant influence on the development of LEK inshore. The extent that these different forms of social organisation are influencing LEK is examined in Chapter 7.

2.6 Inshore fishing and coastal communities

The most recent update of the EU's Common Fisheries Policy (2014) recognizes the importance of inshore fishing for maintaining coastal communities' social fabric, cultural identity, and economy. It describes the need for access to low impact and socially sustainable fisheries; however, this is yet to be implemented by the UK government (European Commission, 2014). In light of the recent Brexit, this seems less likely to be implemented. In the UK, fishing is part of a broader network of socio-cultural and economic activities in coastal locales. In these areas, fishing is a deeply embedded tradition; described as "…the glue that holds the community together" (Brookfield et al. 2005: 56). These fishing communities, however, have experienced different levels and types of social cohesion, often as a result of the historical, geographical and socio-economic differences between the fleets. While historically fishing crews were typically drawn from neighbouring households, contemporary crews are drawn from, and live in, much wider geographic areas, and are more likely to include new arrivals, thus making their connections and common interests weaker (Symes and Phillipson, 2009). These recent changes in inshore fishing communities demonstrate the diversity in this sector, and consequently, this may affect the attributes of fisher LEK (Urquhart et al. 2013; Reed et al. 2013).

The continuity of the fishing community also relates to the extent of democratic governance and the continuation of quota. Organisations including the New Under 10m Fisheries Association (NUTFA) have developed a critique of the current lack of access to quota for inshore fishers. Under 10m inshore fishers see significantly lower levels of quota access than over 10m boats in FPOs. By contrast, forms of co-management are relevant to fishers with under 10m boats as they can potentially integrate LEK, different to the top-down management present with England's FQA system. Co-management is designed to incorporate fisher participation and can include LEK in decision-making processes (Jentoft et al. 2000). Co-management is a collaborative and participatory process of regulatory decision making between representatives of user groups, government agencies, research institutions, and other stakeholders (Mikalsen and Jentoft, 2001) This is cooperative rather than consultative management. Different fisheries around the world that successfully integrate fishers' LEK into co-management and support communities include the Spanish Cofradia, the French Prud'homie, the Lofoten management system, the Polish Mazoperias, the Indian Panchayat system, the Indonesian Sasi, the Japanese cooperatives, as well as the Chilean Territorial User Rights (TURFs) (Gelcich et al. 2010). The sharing of power associated with co-management fits more neatly with the scale of the community, and the spatial scale that fishers, such as inshore fishers, operate on in everyday work. Different property rights then can support the development of fisher LEK, as well as increasing the potential for participation. This is particularly covered in later chapters considering fisheries governance and fisher LEK, and also 3.4.3 in the literature review. The research in this thesis explores the degree to which differences in communities and governance have affected the current evolution of fisher LEK, its renewal, intergenerational transmission in Southern England.

2.7 Policy background: ecological impacts and conservation

Inshore coastal waters support a myriad of dynamic marine habitats, species, and communities, such as charismatic mammal, bird and fish species. Being a transit zone between the intertidal or neritic zone and the deep-sea continental shelf or circalittoral, there is no clear boundary line between inshore and offshore biologically (Symes and Phillipson, 2001). Globally, inshore and estuarine waters support an estimated two-thirds of all breeding and spawning grounds, and considerable areas are designated as Special Areas of Conservation (SACs) under the EU's Natura 2000 programme. Fifty new Marine Conservation Zones (MCZs) have recently been designated, as shown in Figure 4 below (Phillipson and Symes, 2010; Natural England, 2013). Furthermore, Connor et al. (2006) have highlighted that there are 44 types of classified seabed marine landscapes (now to be referred to in this thesis as marinescapes); with topographic and physiographic characteristics considered to be important in determining the nature of the local biological communities.

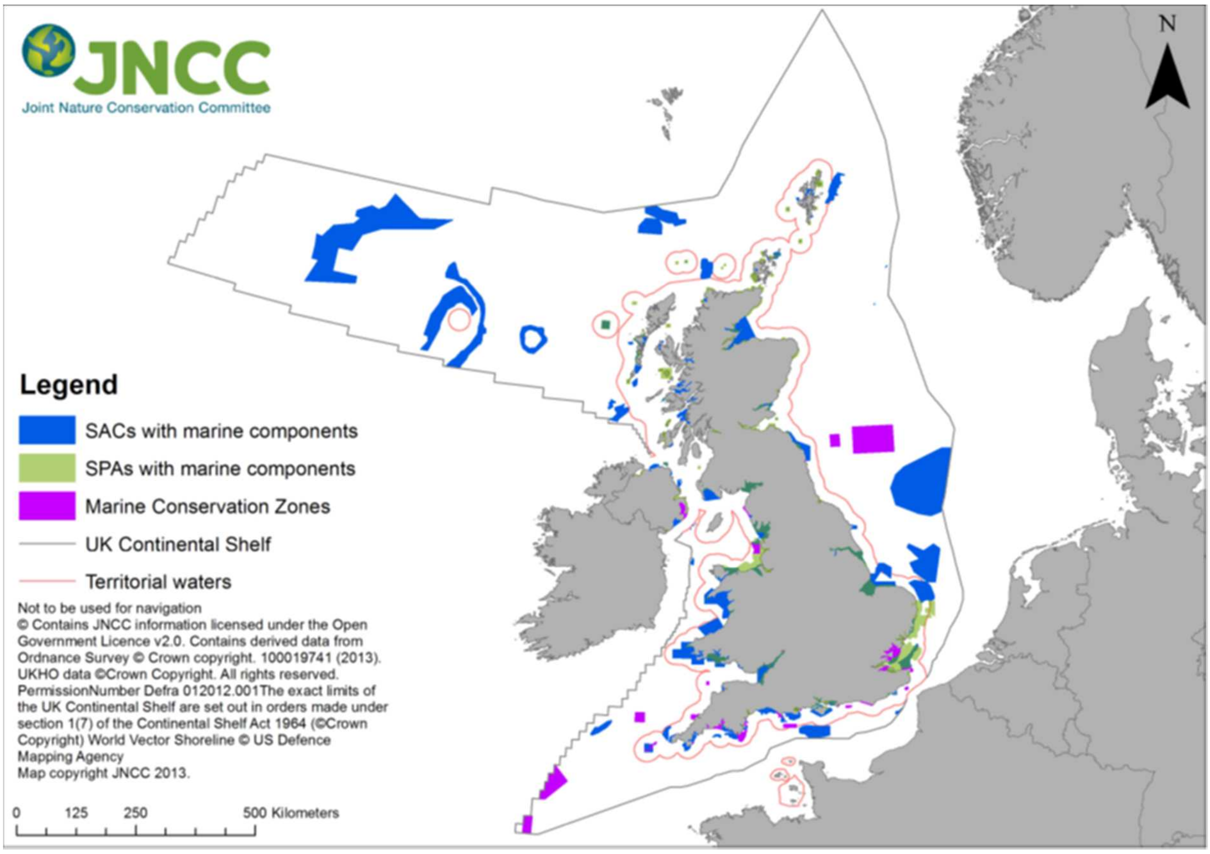

Figure 4 Marine Protected Area network and regions of assessment. Map demonstrates current designated SACs, SPAs and the most recent MCZs. It is the responsibility of the IFCAs to enforce the bylaws of these protected areas from fishing, but only up to 6nm. Map from Joint Nature Conservation Committee (2017).

Rossi (2013) underlines the damage to multiple complex systems of species in inshore waters by bottom trawling fleets, where a plethora of species is caught simultaneously. This 'animal forest' is under threat from this type of fishing and consists of sponges, cnidarians, bryozoans, ascidians and other benthic sessile animal organisms that are engineering species, facilitating the availability of resources to other species (Jones et al. 1994). Thrush and Dayton (2002) highlight that, in the north Atlantic, there is a simplification of benthic ecosystems through bottom trawling; impacts include sediment compaction, the destruction of the most fragile and long-lived species, as well as the interruption of marine biological corridors. This has led to the depletion of at least two-thirds of the top predators, long-lived structures and large animals since the 1950s in our oceans (Christensen et al. 2003).

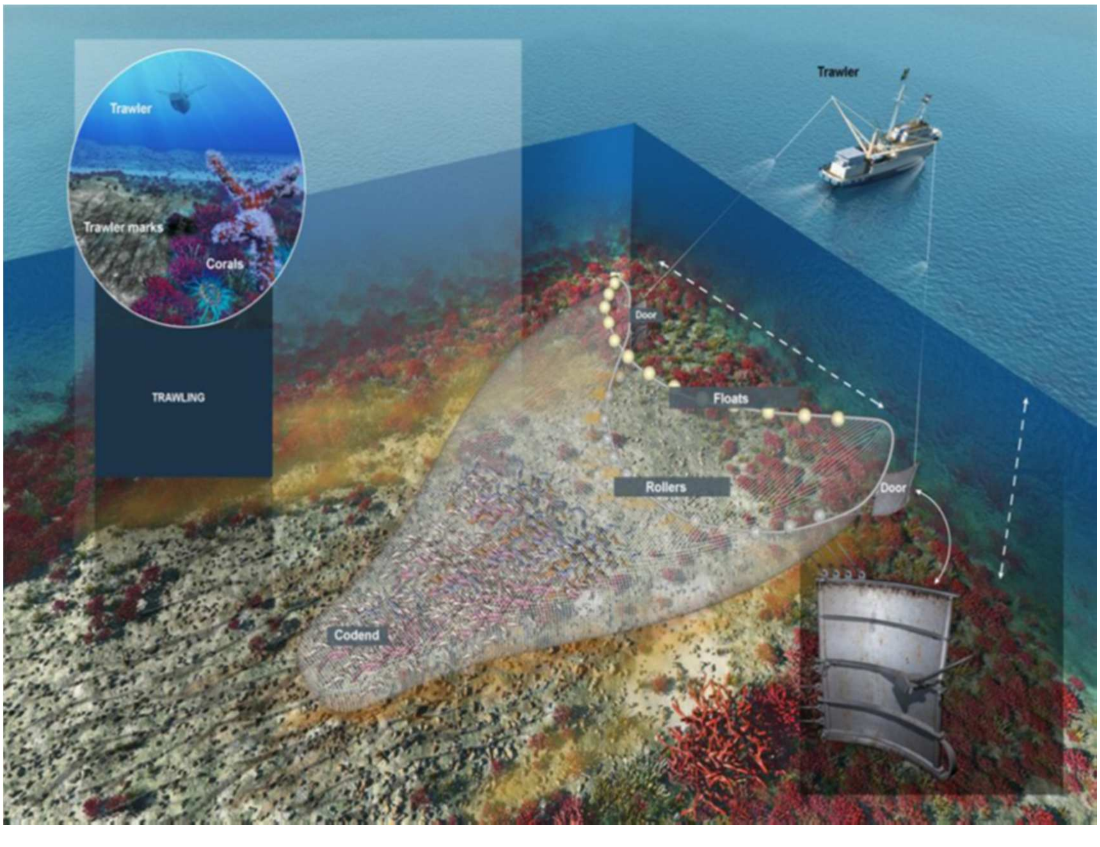

Figure 5 Disturbance by bottom trawling. The significance of this impact is one the reasons for new marine protected areas, such as protecting biogenic habitats from debilitation from trawling through IFCA bylaws. (Oceana, 2016).

Puig et al. (2012), describe how bottom trawling, in place since the 1970s in the Mediterranean, is pushing sediment to fill in gaps on the bottom on a daily basis, resulting in smooth undersea plains. This is thought to have impacts ranging from a loss of species diversity due to the loss of unique habitats to changes in how the ecosystem as whole functions. Safina (2005) argues that with bottom trawling being the world's most lucrative fishing method, it is replacing more benthos friendly methods like hook-and-line, and trapping. The extent to which this is occurring in this thesis study area will be investigated. As is the effect on LEK of the Marine and Coastal Access Act (2009) that introduced MMO and the IFCAs the latter to manage and enforce marine protected areas as well as to improve fisheries management. How they influence the development and participation of LEK are of interest and is addressed in this thesis.

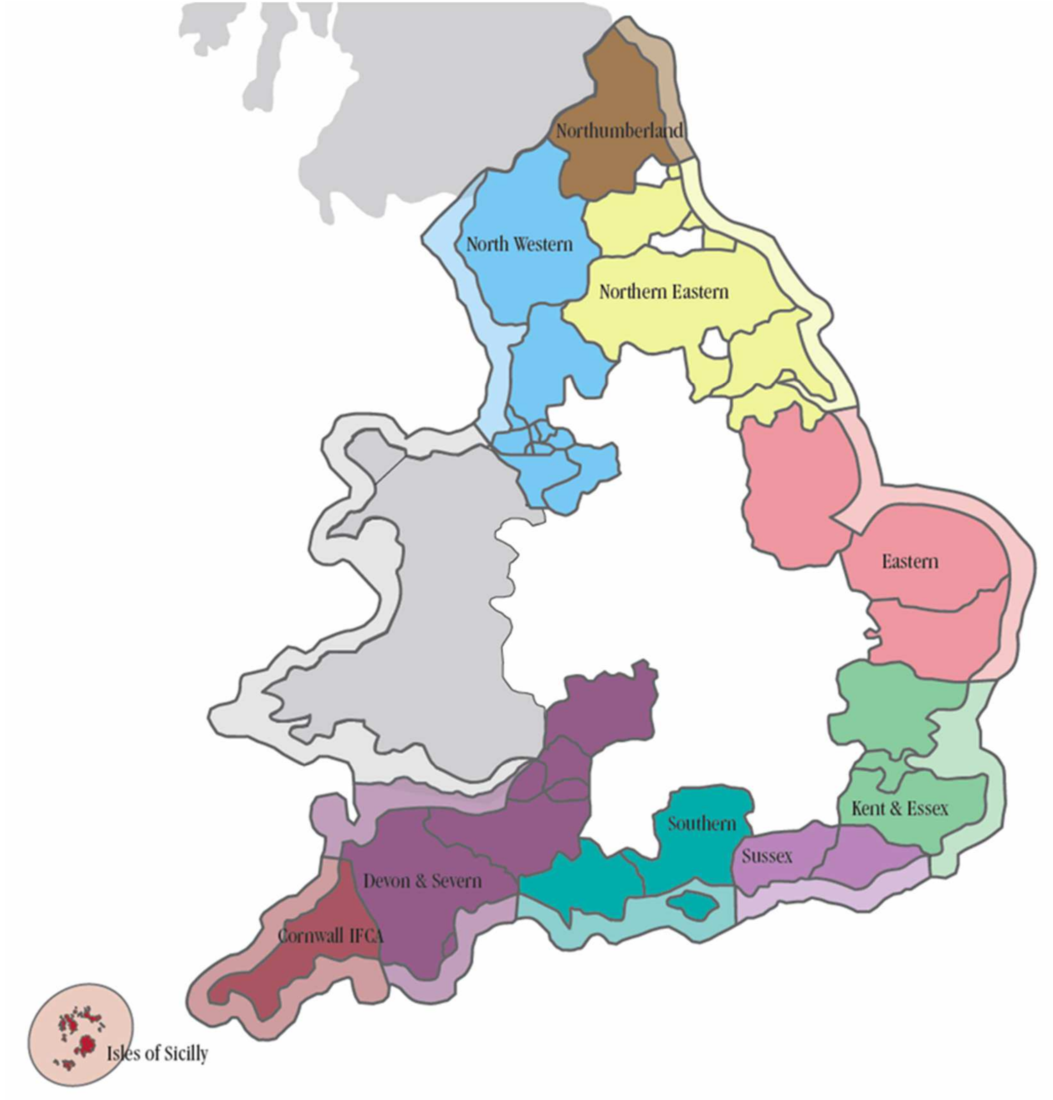

Figure 6 Map of the Inshore Fishing Conservation Authorities' responsibilities from Association of IFCAs. Each IFCA is responsible for creating and enforcing bylaws to protect MPAs from under 10m fishing impacts.

The economic, social and environmental importance of inshore fishing and inshore fishers' LEK is acknowledged by Murray et al. (2005: 273) who states that the concentrations of fishers inshore are greatest, the fish ecosystems inshore are the most abundant, and it is inshore fishers' LEK which is the most difficult to integrate with governance. This thesis examines how LEK is developing, through changing interactions with science, technology, and governance. These considerations are addressed in the review of the literature in the following chapter, relating to academic considerations of fisheries and LEK.

Chapter 3. Literature Review Including Conceptualisations of LEK

3.1 Introduction

This chapter aims to examine the understandings presented in the current literature in relation to fisher LEK of the seabed, marine biodiversity and habitats, and key processes affecting the evolution of LEK. In keeping with the critical realist approach in this thesis, applied to the developing nature of fisher LEK, this chapter highlights the necessity of comprehending the context including structures of power and socioeconomics that shape fishers' LEK, as discussed previously in chapter 2.

The first section presents literature theorising TEK, in order to understand how LEK is different, the need to redefine it, and why the term has been chosen. TEK has been celebrated in regard to its potential application for sustainable development. Nevertheless, critiques of the popularity of TEK in regard to the culture and belief of its holders need to be addressed, as this influences its compatibility and accessibility to scientific knowledge. This provides literature to undergird the primary research question of how fisher LEK of the benthos has developed, and how this literature informs the need to re-theorise LEK.

The second major section relates to the second sub research question, how fisher LEK interacts with scientific knowledge and fisheries governance, and how fishers develop expertise. This is of relevance to the core research question regarding how fisher LEK has developed over recent years in southern England. In response to the challenge of codification literature considering power relations and the perceived hierarchies of scientific knowledge is examined. It goes on to interrogate authors' work on the interface of conservation research and the feedback of LEK.

The chapter then considers the ramifications of the third sub research question, considering how fisher LEK is developing and changing in response to new technologies and their impact on fisher practice and knowledge. Following on from the literature in the context chapter, this includes arguments about how LEK is influenced by neoliberalism, new technologies and the global market for fish products. The next section considers how technological changes are changing fisher LEK, and how conservation practice and access to scientific ecological knowledge is developing fisher learning.

This relates to the fourth sub research question of how marine governance and social organisation influences the development of LEK. Different forms of fisheries organisation have evolved, and are moving toward contemporary corporate businesses, beyond the concerns of local community organic associations. The intergenerational transmission of fisher learning is discussed, and the barrier created by different forms of organisation and governance. Consideration of different property rights and how different power structures of governance interact with LEK are then considered. Inevitably, the key debates around whether private property rights and neoliberal approaches are more effective than common properties are examined, introduced in chapter 2. Discussion of key literature on the tragedy of the commons, and how common pool resources can be more democratically organised through reflection on TURFs are included. How this relates to the challenges of fisher LEK participation with marine licensing and marine spatial planning processes is then considered in relation to port development and dumping, aggregate dredging and wind farms. How existing hierarchies of governance validate knowledge such as LEK is reflected on including how the system could evolve. Similarly, how fisher LEK is interacting with conservation governance is critically appraised. While a small minority of fishing communities are beginning to see progressive interaction, national policy has not joined up different programmes. Supporting this evolution can enhance research, governance and fishers' learning and participation. In order to define and theorise LEK, the next section critically appraises the TEK literature. This will help to comprehend how LEK is different, why the term has been chosen, and why it needs to be fundamentally re-theorised through critical realism.

3.1.1 The importance of defining and re-theorising LEK

Increasingly over time authors have been using LEK to fill gaps that scientists miss (Pauly, 1995), for participation in adaptive co-management (Armitage et al. 2009), or to increase socio-ecological resilience (Andersson et al. 2007). While attempts have been made to define LEK, it is not well understood. In response, this thesis demonstrates that LEK fundamentally needs re-theorising through 'Critical Realism' (Bhaskar, 1975).

Critical realism helps to define that LEK is the continued experience of non-scientists, those people recording and working in ecosystems such as fishers, farmers, and hunters. That their recordings of ecological processes are changing is key, in regard to the influence of scientific research, technology and governance. The definition has particular relevance for countries such as the UK in the industrialised north but could be generalized elsewhere. A critical realist approach is important as it allows for validation of both the social and the natural sciences. To understand how LEK is evolving, one must understand how the natural sciences are influencing LEK, through social science methods. The following literature review shows why it is imperative to re-theorise LEK in this light. Contrasting to the critical realist approach, the evolution of LEK has been irrevocably influenced by the literature on TEK, its definitions and the constructivist methodology.

Historically Local knowledge was first considered by Geertz (1983: 2) as relating to two concepts. Firstly, that it is geographically and historically embedded, and secondly that local contexts affect the nature of the knowledge produced. Haraway (1991:12) postulated that local knowledge is "…embodied and partial, or 'situated' within complex social constructions, which are processes of collective interaction, negotiation, and debate". However, these early theorisations lack consideration of ecology and changing interactions of LEK with technology, marine governance, and the scientific research context. The lack of consideration of these issues in relation to the definition of fisher LEK has meant earlier theorisations developed definitions influenced by writing on TEK.

Authors often define LEK using TEK literature (including Davis and Wagner, 2000, Anadon, 2009). This includes Charnley et al. (2007: 1), who discuss how traditional and local ecological knowledge can potentially contribute to biodiversity conventions, such as Article 8(j) of the United Nations Convention on Biological Diversity. LEK needs to be disentangled from its prior conceptions of the spiritual, social and cultural elements of TEK for it to have wider relevance and application (Morin-Labatut 1992, Berkes, 1993, Gadgil, 1993). With Harvey (2012) highlighting the pervading influences of economic and cultural globalization, the theorization in this thesis posits that TEK / LEK systems are unlikely to be isolated from dominant market forces, overriding the local social organisation and 'ways of knowing'.

Another commonly used definition of TEK is that of Berkes's (2012:7); "as a cumulative body of knowledge and beliefs, handed down through the generations by cultural transmission regarding the relationship of living beings including humans, about one another and their environment". It is this emphasis on cultural transmission, through a constructivist approach to knowledge, which will be reflected upon next. To do this, the previous literature on TEK and LEK definitions are examined. TEK often relates to indigenous groups that have yet to receive state recognition but maintain some form of common property organisation (Kymlika 1998). Conceptualisations have become popularised as embodying a way of continuing to develop sustainably, as its users are celebrated, and described as coexisting in harmony with nature (Berkes, 2008). The defining elements of traditional/indigenous ecological knowledge also need clarifying, as there is a considerable overlap between 'indigenous' and 'traditional'. It is problematic that 'indigenous' is often substituted with 'traditional' in regard to knowledge, because of its cultural relationship to the knowledge of the inhabitants originating in that particular geography (Morgan, 2005:1). TEK in this sense often relates to what Kymlika (1998) calls stateless or 'Fourth World' nations. TEK and Indigenous Ecological Knowledge (IEK) in this thesis are considered to relate to customs, belief systems, and local wisdom, which influence behaviour, and in turn knowledge creation. This continues through a socialization process from generation to generation, in a population within a defined locality (Morgan, 2005: 1). Considering the terminology, it can be confusing to focus on these original inhabitants, if the society is not closed to outside influences, or does not have rules and laws ensuring these elements are maintained.

What is generalisable across traditional/indigenous and LEK in regard to ecology, comes from Osherenko, (1998)'s description of it being generated by the everyday experience of harvesting, travelling, searching, hunting, skinning, butchering and eating, which leads to learning and knowledge. The present thesis contributes to this theorisation by incorporating these considerations into LEK. The following table sets out the historical progression and increasing use of LEK constructed from the literature.

Table 2. The different schools of ecological knowledge

Form of knowledge held by non-scientists	Key Authors	Period	Geography
TEK	Morin-Labatut 1992, Berkes, 1993, 2000, Gadgil, 1993.	Particularly dominant in the mid-90s post Rio Summit.	North America in association with Man and Biosphere programme.
IEK	Woodley, 1992, Williams, 1993. Agrawal, 1995, Rao 2003.	Particularly dominant in the early 1990s	South America from the anti-colonial school.
LEK	Davis and Wagner, 2000, Gilchrist and Mallory, 2007, Anadon, 2009.	Increasingly dominant in the 2000s.	Europe and North America, Oceania.

The table shows that over time, perhaps through the confusion of the definition of TEK as pertaining to cultural transmission, there has been an increased need to use the term LEK. Indeed, LEK has emerged steadily as increasingly relevant to natural science, particularly in the last decade. Humans interacting continually with ecosystems, such as farmers, hunters, and fishers, can be aware of important environmental details missed by scientists. Through their continual, diachronic local association with a place, and these groups of people have unique insights into difficult to quantify aspects of ecosystems, such as nonlinearity, unpredictability, and complexity (Grafton and Kompas, 2005). Through the ability of TEK to observe environments over extended time frames, and incorporate larger sample sizes, some have argued it is of suitable quality to be shared with scientific researchers (Ruddle, 1994). Following this approach, these authors providing such insights into TEK can be grouped by specialties regarding biodiversity; (Gadgil et al. 1993); rare species (Colding, 1998); environmental impact assessment (Stevenson 1996); and protected areas (Johannes 1998). This is theoretically because TEK is recognised as an important source of accurate ecological and environmental knowledge, in particular in regard to adaptive management (Berkes et al. 2000; Allan and Stankey, 2009) filling in gaps in the data that scientific methods struggle to reach (Baker and Mutitjulu Community 1992; Huntington, 2000). LEK is also often referred to as relevant for natural science research, as technical and biological data (Wilson and Klebman, 1992; Johannes, 2000; Azurro et al. 2011). For the purposes of this research, LEK is different as it acknowledges that the knowledge is changing over time, such as through scientific influences. It is different to TEK/IEK as it does not need to have accumulated over many generations within a group's cultural context. In this sense LEK as a body of knowledge can evolve within the wider culture of the society of an industrialised nation. It may or may not relate to continuing common property institutions. It definitively relates to those working in ecosystems, whether utilizing private, public property, or open access resources. This thesis shows that LEK is influenced by scientific research, technological change and governance.

Important to the definition of LEK is consideration of the local by Geertz (1983) and Haraway, (1991), rather than traditional (Berkes et al. 2000). That is the sense of ownership of local ecology that does not have to be political culturally, such as with the legally unrecognised stateless nations (Kymlika, 1998). The local will be explored in this thesis in regard to understanding of local ecological impacts. Devine Wright (2009: 426) identifies "The Role of Place Attachment and Place Identity in Explaining Place-protective Action", as the beneficial aspects of NIMBYism and similar writers highlight how place attachment can lead to individual and collective protective action, through positive emotional connections (Manzo and Perkins, 2006). Nevertheless, while mentioning the psychological impacts of place disruption due to ecological processes such as floods and landslides, and specifically onshore wind farms, this body of work neglects the impacts in regard to stewardship and the knowledge of ecosystems, a key consideration of this thesis. Previous writers do, however, highlight what has been called the epistemic or testimonial injustice and Fricker (2007) argues that the state generally continues to argue against the value of LEK while contesting development. This thesis will provide evidence that LEK itself has not been more widely applied to understanding of the marine environment through inherent preconceptions about the nature of the knowledge of non-scientists in the knowledge hierarchy (Sayer, 1984). Key issues central to the ecosystem approach as defined by the Convention on Biodiversity (2004); include social sustainability and environmental justice, integrating local and expert knowledge; decentralised management with a high degree of participation (Agyeman, 2003). TEK and IEK came to prominence in relation to the celebration of the cultural relationship of stateless nations with ecosystems (Berkes et al. 2000); Davidson Hunt (2006); and Leff, (2012). By separating out the local from the cultural in this redefinition of LEK, both indigenous groups that have been placed as objects of science, colonialism and epistemic injustice, and other non-scientists working in ecosystems can be brought together to consolidate epistemic rights. To achieve what Agyeman, (2003) called environmental justice requires righting epistemic injustice and prejudice against non-scientists such as fishers, farmers and others working in ecosystems by defining LEK as something that does not have to be cultural.

3.1.2 Refutation and contestation of TEK and constructivism

The following section examines the historical development of TEK, its celebration, and the problematic domination of its approach by Constructivism. The Constructivist epistemology can be defined as a methodological framework which sees knowledge of the world as always, a human and social construction (Crotty,1998). Differently critical realism through the combined philosophies of transcendental realism validates natural science as a measurement of the underlying physical reality, whilst allowing for social science approaches to understand its methods through critical naturalism (Bhaskar, 1975). Application of TEK for natural sciences was first referred to in regard to sustainable development by such authors as Morin-Labatut and Akhtar (1992), and Inglis (1993), through such work as 'Our Common Future' (WCED, 1987) and the 1989 World Conservation Strategy (Berkes, 1993). Another considerable turning point in the consideration of TEK was consolidated by the Rio Earth Summit in 1992. This saw the development of Agenda 21, "…a far-reaching program for reaching sustainability…'', that included the 'Convention on Biodiversity' (Inglis, 1993). Their work reflected on the premise that "…sustainable management of resources can be achieved only through scientific development which includes the priorities of local population" (Morin-Labatut and Akhtar 1992: 1). Politically this can be seen alongside states' lack of inclusion of local priorities, such as where colonised nations in the fourth world lack participation.

Nevertheless, it has led to a growing assumption that people who interact with their environment also co-exist in harmony with nature, led by authors such as Berkes (2000), Folke (2004), Davidson Hunt (2006) and Leff (2012). Relating to what Inglis (1993: 4) underlined as "…critical to the implementation of Agenda 21 is recognition of the contribution of indigenous peoples and their knowledge in the quest for a sustainable future", through the emphasis upon indigenous peoples. It suggests that TEK culturally relates to an alternative way of knowing, suggests that there is a lack of consideration of the feedback from research, upon the TEK communities themselves. Nevertheless, this work will address the dominance of constructionist approaches to TEK that has not led to a potentially wider application of local knowledge in the guise of TEK. Critique by positivist natural scientists on the validity of TEK following this cultural emphasis includes authors such as Howard and Widdowson, (1996), Milton, (1996) and Dahl, (1993). While this may well be a defence of their domain, the other authors suggest that the importance of this TEK in ecological and environmental sustainability is overemphasised and based on the myth of primitive environmental wisdom (Milton, 1996; Howard and Widdowson, 1996). While Berkes et al. (2000) emphasise its spiritual component, TEK has been argued to be a threat to environmental assessment, as spiritualism impedes a rational comprehension of the planet (Milton, 1996: 106). When the Australian Broken Hill Proprietary Company Limited Panel carved out an environmental impact assessment on a diamond mine, a decision was made to consider TEK. According to the Government of the Northwest Territories, Canadian policy (1993) includes "…knowledge and values... acquired...from spiritual teachings" (GNWT, 1993, and Milton, 1996: 45). This literature then demonstrates a revisionism; continuing a narrative of romanticising indigenous cultures. Moreover, these representations unveil more about the fantasies and anxieties of a discontent modernity than the indigenous people themselves (Alexiades, 2003). Ellen and Harris (2000: 13) note that in this alternative perception, stateless groups are given attention through the novelty of their cultural practices, not in spite of them. Other authors such as Forsyth (1996) Nygren (1999) and Briggs (2005) also highlight a trend to academically romanticise TEK, considering that pre-industrial people are able to live in fine adaption to their ecosystems, through their rich environmental comprehension. Milton posits that while livelihoods may achieve balance with ecosystems in some instances, this is a coincidence of practice, rather than being actively planned by the people concerned (Milton 1996, 113:3). The new definition of LEK needs then theoretical consideration of the form of governance and the property relations.

While Agrawal (1995) argues that Western and Traditional knowledge are different types and domains of knowledge, the constructivist approach of the TEK scholarship means there is a fundamental need to move away from TEK (e.g. Dahl, 1993). The potential for critical realism, with its origins as an "under-labourer and occasional midwife", can help bring together science and the social sciences (Bhaskar, 2010: 182). The constructivist approach to knowledge and the associated cultural relativism in regard to certain non-scientists working with nature and not others needs reconsideration (e.g. Milton, 1996). Furthermore, it does not mention how TEK communities are changed through greater market integration and enclosure by states. With the over-romanticisation of these communities continuing in the TEK literature, TEK cannot be used to accurately define LEK (e.g. Howard and Widdowson, 1996). Therefore, a new definition of LEK needs to evolve from this thesis. How LEK has interacted with research science is a key part of this evolution, examined through a review of the literature in section 3.2, 3.3 and 3.4.

3.2 The relevance of Fisher LEK and the interaction with scientific research

3.2.1 The significance of LEK in fisheries research governance

Existing research on LEK is dominated by a scientific epistemology and is particularly concerned with how fisher knowledge can be converted into valid data for marine ecosystem management purposes. This positivist epistemology, while considering the significance of ecological and environmental processes upon marine biology, tends to lack an understanding of the underlying social processes and structures shaping and developing knowledge. It leaves little consideration of fishers' interaction and understanding of scientific knowledge, which in turn influences LEK, and how this interacts with governance.

The main body of literature considering LEK is highly relevant to this thesis because it highlights the need for the different epistemological approach that this thesis, based on critical realism, provides. An emancipatory approach developed through Critical Realism can begin to overcome this barrier of natural science maintained under current management structures in England. This relates to different perceptions of the validity of knowledge of non-scientists. Existing research on LEK is dominated by a scientific epistemology and is particularly concerned with how fisher knowledge can be converted into valid data for marine ecosystem management purposes. This positivist epistemology, while considering the significance of ecological and environmental processes upon marine biology, tends to lack an understanding of the underlying social processes and structures shaping and developing knowledge. It leaves little consideration of fishers' interaction and understanding of scientific knowledge, which in turn influences LEK.

A series of authors since the 1980s has highlighted the importance of fisher LEK with regard to improving fisheries. Pauly, (1995: 124) brings attention to the fact that historic baselines for the world's ocean fisheries are largely unknown, as it remains impractical for fishery scientists to reach many regions in the global south where fisher LEK remains the key source of information. Fisher LEK can fill knowledge gaps that science cannot (Wilson and Klebman, 1992; Johannes, 1998, 2000). Over the last ten years, increasing numbers of writers on fisher LEK have become interested in its practical application while maintaining a scientific epistemology. Azurro et al. (2011) specify the potential contribution of LEK to the monitoring of coastal ecosystems with the addition of technical and biological data. An example of this subject/object ontology typical of scientific epistemology is identified by (Sayer, 1984), and can be demonstrated again by Azurro et al.'s (2011: 1) work, who refer to the need for methodologies to "…extract data and information from individuals' memory". This has no real consideration of the nature of community feedback on LEK, its development or other influences of the study.

Similarly, in regard to conservation, Sousa et al. (2013:2), refer to the potential contribution of fisher LEK: "…in the development of effective conservation measures as well as to the scientific knowledge of organisms and their ecological characteristics". He does not, however, specify how this use of knowledge might affect the local fishers themselves and their knowledge system, or the interactions between separate knowledge systems. A similar critique can be applied to work in regard to LEK and conservation from authors such as Diegues, 1999, Peterson et al. 2008, and O'Donnell et al. 2010.

Many authors only reflect descriptively on the application of fisher LEK, rather than considering how fishers also respond to scientific knowledge. Regarding spawning grounds, (Ruddle and Akimichi 1989; Ames 1998; Neis et al. 1999); Habitats, feeding areas (Hamilton, 1999); nursery areas (Johannes and Ogburn, 1999), the authors only highlight fisher LEK as a data resource rather than social praxis. Similarly, in regard to seabird aggregation sites (Nakashima 1993), Marine Protected Areas, (Johannes 1998; Scholtz et al. 2004), research and essential fish habitats for Ecosystems Based Fisheries Management (Bergmann et al. 2005), describe fisher LEK only as potential data for management and decision-making. These studies all tend to focus on marine biology and ecological data rather than related issues highlighted in the previous chapter which explains how knowledge evolves, such as the deep and surface structures of power, and the socio-economic processes which underlie on-going community fisher learning.

A very small number of studies specifically focus on the importance of fisher knowledge regarding the benthic ecosystem, but again, scientific epistemologies tend to dominate. In the US and Australia, Brehme (2009)'s thesis on cogitation strategies for spatial learning describes how fishers learn, recall and record the topography, geology and vegetation patterns of the submerged terrain in regard to lobster habitats using acoustic equipment, GIS, memorisation and continual interaction with the seabed and with lobster pots. While this study's use of Lackoff's (1987) experiential realism is relevant to how the knowledge is firstly gained, this thesis's use of critical realism brings attention to the underlying socio- economic context. Brehme (2009) places the research in the field of behavioural geography and GIS science, with methods of examining human cogitation and computer interaction. This geographic cognition research within the field of Behavioural Geography examines how direct experience is integrated into cognitive maps as well as incorporating alternative sources of spatial information. This is in order to understand the accuracy of lobster fisher mapping, and how this is affected by tool usage. Brehme's (2009) study, therefore, is concerned with the interactions between humans, technology and mapped information, rather than the social processes that shape knowledge, which is the concern of the critical realist epistemology of this thesis. Similarly, from a business-led approach, Turner et al. (2014) analyse the success of lobster potters through their information-sharing networks.

Moreover, Williams and Bax (2005) present in an innovative way the integration of fisher benthic knowledge with scientific quantitative data to map ecological structures and use of the seabed off the coast of Australia. However, this study does not consider how the fisher knowledge has developed or how it is changing in response to contemporary influences. Similarly, Le Fur and colleagues (2011) use quantitative analysis to compare fisher benthic knowledge of habitats, substrate preferences, the location of nurseries, reproductive cycles, fish diet, and the trophic network of the Sciaenid community, with scientific knowledge to increase reliability. The study does not, however, consider how this knowledge emerges or changes. While St. Martin et al. (2007) suggest a reorientation of fisheries' Social Science in step with ecosystem approaches in regard to LEK; this does not consider the influence of the market or the various competitive pressures at play. Further Orduna et al. (2014) collected fisher benthic ecological knowledge as a new way of examining governance relating to traditional territorial areas of shellfish fishers in Galicia. This unpublished work can be grouped with the previous authors as it is written for the application of management of data/evidence only, rather than understanding the nature of knowledge.

Significant is Johnsen's (2014: 2) work regarding LEK's relevance for coastal space in terms of governance. Using a postmodernist methodology, the study examines the power relations of scientific translation, arguing that an "…acceptance of LEK as relevant for fisheries governance may shift power from scientific institutions to users…" in relation to fishing grounds, spawning areas, fish farms, marine flora and fauna, and cultural heritage. While this work does mention the seafloor and its topography, it does not refer to the specific question of the benthic ecosystem. Furthermore, it does not provide actual examples of where scientific co - production has occurred, how this occurred, and what the influences upon fisher LEK were. Also, while having a similar focus, this work does not engage with questions of habitats, biodiversity, and marine conservation, how this interacts with industrial fishing, construction, and resource development. Indeed, its postmodernist methodological approach leads it to argue for self-management, forgetting the influence of the market in driving over-exploitation of natural resources. This echoes the position of Berkes (2012), and Leff, (2012) that traditional societies possessing LEK are more likely to live in balance with nature.

The closest epistemological approach to this thesis is Hoefnagel et al.'s (2006) chapter; 'Knowledge Base for Co-Management'. This work considers how fisher knowledge, can be applied for co-management. This experience-based knowledge means knowledge learnt through doing, such as through fishing. This important work focuses on making "…management institutions more sensitive to new developments in the ecosystem, thus facilitating adaptive management" (Hoefnagel et al. 2006: 104). Nevertheless, this does not examine how fisher LEK is changing in regard to technology and the market, conservation science, industrial development and competition as well as questions of feedback into fishers' LEK. It was useful to see how England's Inshore Fishing Conservation

Authorities, as well as the Marine Management Organisation, integrate and influence LEK through aspects of co-management.

No other studies have considered benthic fisher knowledge in European waters, and in particular, the changing praxis and perceptions of practice under neoliberal market forces and technologies are largely ignored. In regard to recreational angling, Zukowski et al. (2011) provide evidence that fishers' LEK, relating to Australia's Murray crayfish, can be a reliable source of information to improve riverine fisheries management. Such studies of fisher knowledge and the recreational sector have yet to be undertaken in European maritime waters. Fisher LEK has been applied to assess biological data, stocks, for conservation, and has been increasingly highlighted as useful for an ecosystem services approach for management. There has, however, been very limited research on fisher LEK knowledge and the seabed, particularly in European waters, and in relation to fishers' comprehension of multiple ecological factors and their comprehension of the ecosystem as a whole, and its sensitivity to specific impacts. Whilst it is significant that the authors discussed above consider the importance of fishers' LEK, their chosen focus and scientific epistemology also leads to a lack of investigation into how fisher LEK evolves and interacts with the scientific knowledge system. While in previous generations, scientists were separate from the communities they studied, such as when Icelandic researcher Saemundsson thought of himself as a mediator, between 'foreign scientists and Icelandic fishers' (Aegir, 1921), whether the divide today between researchers and fishers is less concrete will be investigated. A research gap, therefore, begins to emerge in terms of understanding both commercial and recreational fisher LEK of the seabed. How this has evolved and is changing in response to a range of processes that this section and the others have identified, being important influences on fisher LEK evolution. While fisher LEK in previous research shows fishers have a diverse knowledge of specific stocks and their locations, their knowledge of the seabed is not well understood. Furthermore, some of these previous studies differ in terms of their agreement and disagreement over the perceived accuracy of fisher LEK compared to scientific knowledge, although they do highlight that the development of fisher LEK is shaped through its interactions with scientific knowledge. The next section discusses the literature that considers how fisher LEK is evolving in regard to power relations and codification, which has relevance to how it develops and interacts with the scientific knowledge system.

3.2.2 Codification, combination tensions, and power relations

In order to define LEK more clearly beyond the dominant constructivist approach, and to make space for a critical realist approach that considers the natural and the social sciences, the following includes consideration of the power relations of science and governance. Codification in this section means the combination of LEK and scientific knowledge, to create knowledge for governance, planning or research. This can involve digitisation, but it is not a necessity. A series of papers from European and North American writers since the 90s have addressed the issue of combining TEK and scientific knowledge theoretically and in practice such as Bollig and Schulte (1999), Eriksen (2007) and Oba and Kotile (2001). The section demonstrates that structures of power and their relationships to knowledge holders need to be comprehended socially and economically. Following this is an examination of the literature regarding knowledge systems, which circulate and combine local and scientific knowledge and could become applicable through the adoption of a critical realist methodology.

Due to a historically dominant hierarchical and hypothetico - deductive explanatory framework, Murphy, (1994) argues that there has been an intellectual fallacy about the creation of ecological and environmental knowledge. Early economists such as Malthus (1798) maintained a dichotomy between society and the environment; with humans and their cyclic interactions with nature not considered in an integrated way (Murphy, 1994). Following a similar argument, Sousa Santos (2007: 16) wrote that this emerged as a single global model of scientific rationality, which distinguished itself conspicuously against two forms of non-scientific (and therefore) irrational forms of knowledge which could upset the paradigm; common sense knowledge and the so-called Humanities. Sayer (1984: 4) writing from a critical realist perspective argues that technologically and scientifically rooted intellectual prejudices about the creation of knowledge are connected to misconceptions, such as that "…science can be assumed to be the highest form of knowledge and that other types are displaceable in the hierarchy".

These concerns relate to the historic dominance of positivism, such as the need for falsifiability promoted by Popper (1963) demarking knowledge that is not reproducible in the laboratory as pseudo-science. Feyerenbend contested this in his work 'Against Method' in (1976) arguing that methodological monism, and the demand for increased empirical content actually limited experimentation, and input of other's knowledge. Building on this, from a global South perspective, Fals - Border and Mora – Osejo (2003: 412) posit the need for the creation of a contextualised science, "…an endogenous scientific paradigm, a sum of knowledges capable of valorising popular knowledge and grounding the sustainable development of tropical regions". The debates between positivism and the perceived alienation of traditional, indigenous, and local ecological knowledge, specifically relate to fisher LEK. The positivist approach to fisheries science calculates fish stocks according to International Council for the Exploration of the Sea ICES regions on a vast scale. However, this study will consider LEK on a local scale.

Echoing the above and encouraging the mixing of indigenous and scientific knowledge, Agrawal (1995: 420) critiques the work of the 'neo indigenistas'. Indigenous knowledge here relates to a particular nation or local cultural group. He underscores that their codification ideas only concretise the dichotomy of indigenous knowledge and scientific knowledge by encouraging national archives of such knowledge (Brokensha et al.1980: 8). Opposing leaving this, Agrawal (1995: 432) concludes that this succeeds only in creating a mausoleum for this wisdom, decontextualizing it from its physical ecological moorings.

Campbell and colleagues (2005) writing in regard to science and technology highlight how Geography Information Systems were used to block or subordinate local forms of knowledge and understanding. Smith (1999: 59) underscores that historically, the production of new knowledge, the transformation of knowledge, and the validation of certain knowledge over others, inherently relates to commodification to support colonial extraction of resources. However, this is not always the case. With regards to power relations, Usher (2001: 195) underlines how the use of Environmental Impact Assessments (EIAs) in management affirms the validity and relevance of community knowledge and reverses a long history in which those attributes were ignored. Different to the problems around LEK, certain groups fear the risks of appropriation and dispossession of TEK through codification, removing it from the cultural context in which it operates (Wenzel, 1999). Codification then means putting the knowledge into a form that can be reproduced and edited without the consent of the original fisher, such as through digitalisation. This research will consider whether the use of fisher LEK in port development, aggregates, and wind farm assessments, would be empowering or disenfranchising to fishers.

In regard to local knowledge in biodiversity debates (particularly around the discussion and implementation of article 8J of the Conservation of Bio Diversity (CBD), Escobar stresses that "...this attention is often misguided to the extent that local knowledge is rarely understood in its own terms or it is refunctionalized to serve the interest of Western-style conservation" (Escobar, 2007: 22). There is some concern about the potential for the exploitation of TEK when it is placed in a hierarchical system. This is different to LEK because TEK often relates to indigenous nations and the potential for emancipation, led by perceptions experts with the power of planning and decision -making (Cooke and Kothari, 2001:5). In Australia, states have attempted to create cultural value studies of indigenous water knowledge to inform planning. However, this knowledge is typically imperceptible to planning bureaucracies (Yu 2000; Jackson 2006), as their world lens is only able to incorporate knowledge and expertise produced by conventional disciplines without consideration of local concerns (Nakata 2007: 189).

Relevant to the problem of integrating fisher LEK into governance, Nadasdy (1999) has suggested that this is often because knowledge integration is all too often over-simplified as a technical issue. Ignoring the effects of state power over local people can lead to the commodification of knowledge that benefits only scientists and the state. There is also the potential for the dilution of local knowledge when it is unequally placed in a hierarchy of power, and that the resulting diluted hybridisation of knowledge might invalidate all the systems involved (Jacobs and Mulvihill, 1995). These authors further suggest that because of this risk we should aim for 'co-evolution', allowing all systems to grow independently simultaneously. With validation central to the scientific paradigm, resource managers have a problem when attempting to integrate LEK. Scientists are reluctant to use information when they cannot assess its reliability and error margins. These practicalities of integrating LEK with science are highlighted by Gilchrist and Mallory (2007) who state that only 0.1% papers out of 1929 written on birds published in ornithological or wildlife journals between 2001 and 2005, actually incorporated LEK. Nevertheless, as Lerner (1986: 203) states "…in failing to understand the real limits of science as an approach to reality we tend to disempower ourselves…'' which is particularly true where local context and usefulness is decontextualised from the research. With regards to the ethics of power, Wenzel (1999: 118) asked who should get to select who interprets TEK, and for what purpose? Ruddle (1994) suggests that knowledges can be complimentary where mutual respect and power equality is maintained between them. If LEK is abstracted for use in research science, this has potential ramifications for the value relations of LEK holders with natural resources.

While authors such as Escobar (2006) have been critical of the ecosystem approach as defined by the CBD (2004) in taking a westernised framework to knowledge and conservation, Agyeman et al. (2003) underline it suggests integrating local and expert knowledge; alongside decentralised management with a high degree of participation. This research will examine the extent fisher LEK can participate, and how shared learning of the benthos, habitats and biodiversity can support improved governance, or adaptive co-management (Armitage, 2007).

Additionally, the codification of fisher LEK can result in improved environmental management, as scientists integrate fisher recordings of fish species and environmental signals for governance, allowing the combined research to feed back to a wider audience. For LEK to remain living, it must be allowed to interact with science, and develop in participatory ways that allow for the improvement of resource management. For it to be participatory, the problem of validation must be overcome. Fisher LEK could alternatively be used to subjugate fishers' activity if they are perceived to be less important than other more economically valuable industrial activities. To support a combination of natural and social sciences requires critical reflection upon the consequences of the development of fisher LEK, where the interactions between fisher LEK and science experience the continued dominance of the scientific epistemology. The following section examines how fisher LEK is perceived by scientific knowledge systems.

3.2.3 The perception of fisher LEK in scientific knowledge systems

Following a consideration of codification and power relations, this section will examine the literature relating to continuing differing views on the accuracy of fisher LEK. These different understandings are gained through contrasting knowledge systems due to their respective differences in methodologies and prevailing socioeconomic structures. Understanding how this interaction between fisher and scientific knowledge shapes fisher knowledge is, therefore, a key requirement. Schafer and Reis (2008) acknowledge that fisher LEK is often not used due to researchers' inability to include it in management systems, because this information is often very specific to the region it originates from, and consequently, it may not be useful enough to derive generalisations from. Concerns about utilizing fisher knowledge are to some degree understandable, as unreliable data, whether local or scientific, has been shown to result in overexploitation or damage to natural resources (Walters and Hilborn, 1978). Consideration of fisher bias through the influence of market pressures expressed through LEK is an important consideration in this study.

It is noteworthy that in comparisons between fisher and scientific knowledge systems, there has been both consensus, (e.g. Neis et al. 1999; Begossi, 2008; Lozano-Montes et al. 2008; Le Fur et al. 2011) and disagreement over the accuracy of fisher knowledge (e.g. Otero et al. 2005; Daw, 2008). Ross and Medin (2005) highlight that differences in conceptualisations of accuracy that are often based solely on the means and motivation for accessing information. An alternative to these dichotomies of the accuracy perception is that "…the differences between fishers and scientists...point to different spatial languages and understandings of fish populations, not just a lack of information on the part of fishers" (St. Martin 2001: 129). This relates to the different techniques of fishers and scientists assessing fish and habitat populations, as well as to the different local and macro- scales used.

LEK of catch rates, underwater visual census, and official landings, are compared by Daw et al. (2011) in the Seychelles, concluding that fisher LEK and scientific knowledge sources of data differed in regard to biomass over time. Similar studies have contrasted seasonal abundance patterns revealing no specific conclusions on the accuracy of one knowledge system over the other, however, their interactions would suggest there would be a residual influence on fisher epistemology and methodology, which has been left under investigated. Silvano and Valbo-Jorgensen's (2008) position is that new studies should be created from data that contrasts fisher and scientific knowledge. Combining information sets as opposed to concluding that one knowledge system is automatically more correct, as combined sets of knowledge are more likely to result in a more accurate applied assessment of the subject. This study does not consider how the underlying socioeconomic processes will affect fisher LEK's development. Writing in regard to fishers in the developing south, Drew (2005), emphasizes that local ecological knowledge can be holistic rather than reductionist, in regard to the holder's view of their environment. "They may be aware of linkages between various ecological processes, multiple species, and abiotic factors that influence species biology" (Drew, 2005: 1288). Comprehension of these environmental linkages comes from long-term association with a local geography, and often will not be obvious for those with less in-depth familiarity of the location (Drew, 2005).

A number of authors highlight the continued marginalization of LEK. This has ramifications for the development of LEK on the benthos as it can preclude interactions with scientific knowledge systems that might change and develop fisher LEK's intra systemic understandings. Shipman and Stojanovic (2007) criticize an over-reliance on technical approaches in marine resource organisation which they posit ignores the value of indigenous knowledge; both "traditional" as in the case of fishermen, and also empirical, local knowledge held by modern commercial and recreational users of coastal resources.

Fisher LEK is often qualitative in consideration of the local experience, with fisheries management scientists concentrating on the contrastingly quantitative statistics first, and making before and after comparisons, and with reference conditions (Chapman, 2007). Understanding fisher LEK requires elicitation, which makes it less appealing to scientists and decision makers who normally deal with information as quantifiable data. This marginalizes the benefits of embodied intra systemic knowledge where it continues to exist. The extent to which fisher LEK has become codified through digitalisation, use of electronic media and technology, is investigated in regard to the prevailing power relations, as is how this knowledge is shared.

The need for elicitation that can become codification was examined by Silvano and Begossi (2002) during the examination of Piracicabaian Indian's aquatic trophic structures in Brazil. They found that this group's food web closely matched the formalised version held by university researchers, but additionally described several migratory movements of fish that were previously unknown to Western science. Thus, the marginalization of LEK may lead to the importance of less economic species being over looked in terms of biodiversity conservation research. For example, Lobel's (1978) Pacific case study demonstrates that different species are more likely to be named individually if economically important, such as the Tiger Shark (Galeocerdo cuvier). Those of little economic importance, such as surf perches (Embiotoca lateralis) (Kuhliidae), are grouped together, having only a single name in the entire family. This means ecological and biological aspects of marine life are only assigned more cultural significance if they are of economic importance. How the value of local classification of species on the benthos is changing through interactions with scientific and conservation knowledge systems in Western Europe is an area that needs further research. For example, the low value assigned to non-economically important sessile species such as seaweeds, ascidians, cnidarians, and bryozoans that provide ecosystem services such as nutrient cycling, food provision and biodiversity.

This lack of engagement with fishers and failure to share knowledge systems has been noted since the early 1990s when social anthropologists such as Neis, (1992) drew attention to questions regarding fisher LEK (Ruddle, 1994; Mackinson, 2001). Also, with specific regard to warnings given to cod fishers, that their fishing ground stocks had been depleted, while they continued to fish with governmental support (Finlayson 1994; Pinkerton and Weinstein 1995; Harris 1998; Kurlansky, 1998). Hersoug and Rånes (1997) point out that democratic theory prescribes that those who are to be affected by a management decision should be given the right to give their views on it. This is particularly of interest to the implementation of fisher knowledge where overexploitation is occurring, or to improve management areas, such as conservation. This is explored in greater detail in the section on conservation and practice.

Another factor marginalising fisher knowledge highlighted by Harris, (2002) is that as scientist's authority is maintained by being identified as the designated experts, there is resistance to other sources of knowledge and alternative paradigms, such as traditional and local knowledge (Harriss, 2002). This dogmatic institutionalisation in a discipline can lead to what Thorstein Veblen labelled "trained incapacity"— an inability to comprehend solutions outside of one's tunnel vision and validate alternative sources of knowledge and management tools (Merton, 1968: 19; Degnbol et al. 2006). This relates to Kuhn's (1962) work 'The Theory of Scientific Revolutions', which posits that the backwardness of the Social Sciences relates to its pre-paradigmatic nature, as opposed to the paradigmatic nature of the Natural Sciences.

This scientific privilege, which may marginalise fisher LEK, is exacerbated by what Huntington et al. (1998 and 2000) describe as the difficulty in accessing fisher LEK. The authority of scientists means their perspectives are more important, "…creating a contradiction for management systems that hope to benefit from a participatory democracy of user groups" (Jacobsen et al. 2012: 294). Furthermore, the term 'anecdotal knowledge' is still often used in regard to fisher knowledge and its translation into scientific knowledge and management processes (Neis et al. 1999; Palsson, 1998).

It has been highlighted by Hoefnagel et al. (2006) that there are differences between tacit and discursive knowledge, between written and oral knowledge, and between anecdotal and systematic knowledge. They draw attention to how these different forms of experience-based knowledge, or LEK, can be perceived by governments holding power leading to either marginalisation or validation. Through their lack of access to scientific knowledge systems, due to their marginalization in fisheries management, fishers are less familiar with the language and methods of marine scientists. Jentoft and McCay (1995: 345) postulate that typically "…fishers are disempowered and unable to express themselves when presented with detailed scientific studies". The social context of elicitation is then important in ensuring effective integration of LEK. Further, they argue that "…scientists' methodologies and assumptions about validity can hinder their taking into account…" either the language or the specific knowledge of the fishers (Jentoft and McCay, 1995: 345). While this may be true in certain geographies, this research elicits how fishers are becoming more fluent with scientific research and the ramifications it has for their industry. Even if this marginalisation of fisher knowledge can be overcome, one of the challenges of collaboration between fishers and scientists, is to transform knowledge which produces what DeWalt, (1994: 124) calls 'mutable immobiles', that is relatively flexible knowledge specific to the details of a given task in a particular locality – into mutable mobiles or general holistic knowledge that can be applied to similar phenomena, in different contexts. It is argued that often through its practice-based nature, fisher LEK cannot be specified in quantitative scientific data; it can be passed on only by example, from master fisher to apprentice scientist (Palsson, 1998).

In order to overcome these language and methodological differences, anthropologist Johnson, (2009, and 2011) significantly used individuals acceptable to both knowledge groups to combine LEK with Natural Science in fisheries of squid of the Ilex genus. Others highlight boundary spanners as an information bridge through which resource managers and fisheries scientists can gain a fuller understanding of a fish stock's territories and population, by seeking the experiential knowledge of fishers (Begossi, 2008; Hamilton et al. 2005; Johannes et al. 2000; Schulz et al. 2004).

More recently, in the framework of participatory activities, the promise of greater self-sampling has arisen. For a greater knowledge base on fisheries catches and discards among other areas, self-sampling sees fishers gathering samples during fishing trips and is closely linked to participatory sampling (Mangi et al. 2014). Having a prominent role in the collecting of samples allows for restricting economic conditions associated with ICES programmes such as the costs of observers and research vessels and a higher spatio-temporal coverage (ICES, 2008). An emphasis on communication, mutual learning and interpretation are important in collaboration, to establish trust and avoid misreporting (Stanley and Rice, 2007; Johnson and Van Densen, 2009). Analysis and interpretation should be co-produced with researchers (Kraan et al. 2013). As mentioned in relation to the Cefas GAP2 programme, for the over 10m fleet, the extent to which self-sampling has been trialled with inshore fishers, will be investigated.

In these varying locations, different classification systems for species, environmental processes, and the linkages between them, may mean certain aspects are better understood or rarefied through species' economic importance, or local cultural prestige depending on the geography (Label, 1978; Silvano and Begossi, 2002). Fisher LEK classification and valuation of species on the seabed needs to be better understood. How valuation is changing through interaction with scientific and conservation research, such as of biodiversity and ecosystem services will be discussed.

Dickens (2004) explained that the differences between scientific and local knowledge demonstrate Marx's idea of the metabolic rift opening between neo colonial, macro-capitalist societies and nature, also that scientific knowledge often underpins capitalist priorities and is portrayed as separate from local traditional societies. This unilateral exercise of power by urban centres on the economic peripheries continues to perpetuate rural to urban migration, disrupting the intergenerational transmission of LEK. Marx stated this was created by, "…antagonistic relations between town and country" (Moore 2000: 125).

Schneider and McMichael (2010: 460) hypothesise that as people physically move to the urban from the rural periphery, their specific cultural, historical, and geographic knowledge about farming, fishing, local ecosystems, environmental conditions, entwined practice and potential for 'agro-ecological wisdom' dissipates. With the increasing technologisation of practical environmental work, this approach leads to both a division of labour and deskilling, as workers become increasingly involved in highly repetitive un-stimulating processes. Awareness of these divisions goes back a long way. Building on Proudhon (1846), Kropotkin (1898: 172) described the need to heal the class divisions between 'brain workers' and manual workers, by achieving 'education integrale' or complete education.

To understand this, an examination of the literature about the learning dynamic between LEK and research in terms of how they feed back on one another is now presented. Conceptually relevant is Van Kerkoff and Szlezak's (2006) development of Rolling and Jigging's (1998) knowledge system. "A network of actors connected by social relationships, either formal or informal, who dynamically combine knowing, doing, and learning to bring about specific actions for sustainable development" (Van Kerkoff and Szlezak, 2006: 63) relates to the potential feedback upon traditional local knowledge from research (Kelsey, 2003; Houde, 2007). This has parallels with social learning, where learning is a cognitive process situated in social context achieved through public participation (Blackmore 2007; Ison and Watson, 2007; Steyaert and Jiggins, 2007), and other conceptual frameworks including adaptive management, organisational learning, and deliberative processes (Ojha et al. 2008).

With regard to experience-based knowledge, discursive knowledge, by definition, versus tacit knowledge, is able to be articulated. Research that supports articulation of knowledge can enable participation, an important way to mobilise social power (Hoefnagel *et al.* 2006). The extent to which fisher benthic LEK is incorporating scientific knowledge in shaping its own local political discourse will also need investigation. This connects to Engestrom's (1987:174) definition of the Zone of Proximal Development (ZPD) as "…the distance between the everyday actions of individuals and the historically new form of the societal activity that can be collectively generated as a solution to the double bind potentially embedded in everyday actions". Whether the socio-cultural transformation from this learning can be translated into continuing practices between old timers and newcomers remains contested (Davydov and Markova, 1983). The ZPD is defined as the distance between the cultural knowledge provided by the socio-historical context – usually provided through instruction; and the everyday experience of individuals, and the active knowledge owned by them. This is based on Vygotsky's distinction between scientific and everyday concepts, and his argument that a mature concept is achieved when the scientific and everyday practice and skill have merged (Cited in Davydov and Markova, 1983).

Rolings and Jiggins (1998) take the approach that combining competing sets of knowledge to enhance and perpetuate knowledge systems can enhance ecological learning or create learning systems. However, writers such as Agrawal (1995: 433), highlight that this can result in the concretisation of dichotomies between systems of knowing, and that "…the same knowledge can be classified one way or the other depending on the interests it serves, the purposes for which it is harnessed, or the manner in which it is generated". Writers such as Nadasdy (1999), emphasise that relations and structures of power need to be understood alongside the effects of underlying social and economic processes, otherwise the risk of commodification for the benefit of the state and scientists arises. The validity of qualitative fisher LEK in contrast with scientific quantitative research is highly contested. Nevertheless, the scientific research's feedback on fisher LEK and the ZPD is not an issue that is investigated in the literature. In terms of the research discussed in this section, the interaction of scientific knowledge and LEK does not examine the benthos or the feedback loop. This relates to the research question in this thesis of how fisher LEK has recently developed in southern England.

Interrogation of knowledge systems, such as put forward by Rolings and Jiggins (1998), is an important starting point for LEK, scientific combination, and the feedback loop. Further, building on Hoefnagel et al.'s (2006) 'Community Science', which considered experience-based knowledge, the importance of the local is emphasized in regard to where evidence that local ecological knowledge is emerging through combination with scientific research productively. This is, for example, when research in a local community involves more than one fisher and is evidently changing vocabulary, understanding threats, influencing practices, engaging in the valuation of ecosystems assessment of ecological limits, and highlighting the need for conservation. The extent it is influencing social power is also explored in 3.4.4. The following section will examine literature relevant to this learning, and how it interacts with LEK.

3.2.4 On fisher learning and the application of LEK in conservation practice

The following section examines literature from conservation research and investigates the relationship to LEK. It appears likely that conservation management can lead to changes in fisher LEK as a result of interactions with the scientific system, and as a consequence, change the fisher learning system. A number of authors show how fisher knowledge can be practically applied in conservation although they do not really examine how the fisher knowledge system is adapting to conservation knowledge of biodiversity. Many of these authors work in the global South where fishing is less industrialised and recommend an opportunistic hybrid approach to marine conservation (e.g. Johannes 1998; Ludwig et al. 1993; Roberts 2000). They show how conservation can harness available scientific information and indigenous LEK in order to both select locations and to design marine protected areas through underwater visual surveys. An example of where fisher LEK alongside respect for traditional governance has been successful is in Roviana Lagoon in the Solomon Islands. LEK was applied for community-based management initiatives, implementation, and monitoring (Aswani and Hamilton, 2004). Similarly, Russ and Alcata (1999), Soma (2003), and Scholz (2004) have described how integrating fishers into the design process for marine reserves has achieved significantly better results in regard to conservation regulation enforcement and ecological abundance. In regard to fisher perceptional change of marine conservation in the global south, fishers can be trained to collect biological data (Subade et al. 2008) and provide valuable input towards evaluating protected marine areas' performance indicators (Heck et al. 2011; Himes, 2007). With fishers in proximity, early signals of stress or change in the marine ecosystem can be more readily identified, leading to better stewardship (Haggan, 2007). Involvement in collecting related data can also increase fishers' motivation for marine conservation (Versleijen and Hoorweg, 2006).

In Japan during the 2000s, research on fisher LEK similarly highlighted the benefits of applying fisher knowledge to conservation, although it does not examine how LEK is changing. In 1995 in Japan's Shiretoko natural heritage area, the local experience and knowledge of fishers alongside the co-management 'Territorial User Rights Framework' system of fishers. This was organised by the Fishery Management Organisations and divided the seabed into 34 areas and the introduction of temporal marine protected areas in 7 such areas, such as the spawning grounds of walleye Pollock (Matsuda et al. 2009). These voluntary marine protected areas are re-examined yearly, and importantly, are supported by local research stations suggesting this process is adaptive. However, they have yet to receive scientific verification of their validity (Matsuda et al. 2009). In contrast to the Chilean territorial user rights system of protected marine areas and fishers, the Japanese fishers' preference for autonomy means their 'fishing ban areas' are not enshrined in law (Matsuda et al. 2011; Tomiyama, 2009).

However, marine researchers in North Western Europe have highlighted how scientific knowledge is being appropriated and challenged by the fisher knowledge system in regard to emerging conservation protocol with possible consequences for the nature of fisher LEK. Challenges have arisen funded by fishery stakeholders such as those representing the nomadic and offshore sector, who have critiqued assessments of the seabed impacts of fishing as lacking evidence, and by implication, attempting to delegitimise the need to manage them (Gray et al. 2005). However, with impact studies upon rare habitats being illegal or unethical, decision makers can be caught in an evidence trap when dealing with destructive commercial fishing - with no direct evidence of negative impacts: "…a problem that is likely to be widespread and, ironically, unreported in the scientific literature" (Cook et al. 2013). Studies of the effects of dredging and trawling on the seabed have evaluated that reductions of 59% to 90% of epifaunal communities may occur during the first fishing impact (Hall Spencer et al. 2000). Therefore, it becomes increasingly difficult to provide evidence for species richness and the importance of marine biodiversity diversity in areas historically close to traditional fishing grounds (Jennings and Kaiser, 1998; Cook et al. 2013).

Some conservation science proponents argue that measures to conserve sometimes need to be taken in the absence of good quality evidence. It has been suggested that a "reverse burden of proof" is needed in conservation decision making, requiring the demonstration that marinescape disruptive fishing does not in-fact have any significant ecological impacts (RCEP, 2004). Further, while Boyes et al. (2007) and Stelzenmüller et al. (2008) stipulate that an understanding the spatial extent of seabed features and habitats is critical to balancing pressures from different marine resource users, there has, however, been little work on how fishers and other key resource users understand impacts or indeed perceive the marinescape itself. The 44 marinescapes, earlier defined by Connor et al. (2006) as marine landscapes, are combinations of habitats over a larger spatial scale. They experience different levels of sensitivity, species aggregations, and substrates. How this is understood and experienced, such as through changing technology needs further investigation.

How access to both conservation data and studies of fishing's perceived impacts, both positive and negative, may be affecting the development of LEK will also need to be taken into account. The extent to which this relates to fisher LEK and local governance at different seasons will also be considered with regard to the IFCAs and the MMO. Whilst this literature begins to reveal how marine conservation in local communities influences the development of fisher LEK, it often does not consider the wider socioeconomic processes that are likely to be influencing the changing nature of fisher LEK. One such socio-economic process critiqued is the ecosystem services approach. A group of authors, such as Martinez-Alier (2002), Kaime (2013), and Kronenburg (2013), argue that ecosystems are not time-based and do not operate within the same cycles of markets. Therefore, in this context, the potential context of payments for knowledge of ecosystem services will be critiqued in this research.

The feedback of scientific research upon fisher LEK and the ZPD feedback loop is not an issue that is investigated in the literature in relation to conservation. 'The local' is important in the definition of LEK as if fishers are dependent on 'the local', they are dependent on the regeneration of what Shiva (2016) called the sustenance economy. That is the economy that is based on natural ecosystems and their regeneration requires bi directional feedback between conservation research and fishers. Moreover, the local is important in the development of trust relations. If fishery conservation decision-makers do not have long term relationships with those fishing in their locality, they hypothetically will be less inclined to trust those fishers to share knowledge with them, and they to share knowledge with the fishers to help it to regenerate.

Access rights are a related management issue. The rights-based approach described by Allison et al. (2012), draws on human rights and describes a fishing ground area and a percentage of quota commonly owned and organized. This is different to private or individual quota rights, attention for rights-based fisheries management, relating to existing and new associations of fishing communities, is increasing (Gelcich, 2010). The framework implies a series of rights, among them, are: the right of exclusion; the right to determine intensity and kind of use; the right to extract benefits; and the right to future returns (Christy, 1982). It has been put forward by Allison et al. (2012), that more secure fishers have more incentive to participate in conserving fish stocks, and therefore make more effective and motivated fishery co-managers in the context of participatory or rights-based fisheries. Another aspect is how fisheries governance increases trust through fishers' LEK participation, increasing compliance (De Vos and Tatenhove, 2011). The extent to which the forms of governance present in the case study in this thesis, support the interaction of LEK with conservation research and practice, will be assessed. Legitimization of LEK is especially important where institutions are weak, and rely on forms of voluntary compliance (Wilson, 2006). Tsosie et al. (2012) describe the importance of epistemic rights in relation to indigenous communities. How this relates to the rights and needs of fishers to understand conservation and other marine science to be successful stewards of the sea will be explored. In this light, it will be important to assess how explicit the IFCAs, the MMO, and Cefas are about LEK integration in conservation. How neoliberal markets and new forms of technology interact with fisher LEK is discussed in the next section.

This section addressed literature relating to the research question of how scientific research interacts with LEK. This thesis adopts a different epistemological approach of critical realism which is discussed in chapter 4. This is investigated more deeply in the analysis of chapter 5. The previous research on fisher LEK shows that fishers have a diverse knowledge of specific stocks and their locations, although there has been only very limited research on fisher LEK and the seabed, particularly in European waters. Furthermore, the majority of the literature on fisher LEK generally is dominated by a scientific epistemology and is particularly concerned with fisher knowledge as data, (Pauly, 1995, Johannes, 1998 and Azurro, 2011). While Johnsen et al. (2014) consider the application of fisher LEK for governance; such studies also adopt a constructivist methodology. How this relates to literature on technology and LEK is discussed next.

3.3 The influence of new technologies and neoliberalism on LEK

3.3.1 The effect of neoliberal markets on LEK

Researchers studying fishing, who contextualize fisheries more widely in a neoliberalist perspective without specifically mentioning knowledge, tend to explore how expertise and knowledge are affected logic of the market encouraging the race to fish (Mansfield, 2004). The neo-liberalisation of fishing in these locations has involved a shift from traditional local markets, to globalised 'just in time' markets where goods are only received as they are needed. This has significantly influenced the fishing distribution, organisation and technology with possible ramifications for local knowledge. In Newfoundland, fishers' interactions with markets have shifted from a reliance on selling saltfish (cod) to local merchants at the end of the season for pre-set prices, to becoming enmeshed in global seafood markets for fresh products with volatile prices (Murray et al. 2006). Reed, et al. (2013) put forward the view that fishers' behaviour is mainly influenced by neoliberal ideas around financial motivation, therefore needing authoritarian direction to limit the quantities of fish caught in the commons. The intensified demand for fish has also been driven by neoliberal market technologies such as individualist, a single stock, and Individual Transferable Quota (ITQ), which can be transferred internationally. This influences the nomadic fishers' LEK as global markets increasingly influence their business behaviours and attitudes, driving a perpetual race to fish in a finite ocean.

Johnsen et al.'s (2009) case study of the changing dynamic of inshore fishers in Canada highlights that links to the local community became weaker, as the market demanded more target species such as cod. It meant the crew was steaming further offshore for longer periods. This relates to their transition from stationary harvesters using fixed gear on traditional grounds, to nomadic harvesters. Geographic mobility for the purpose of accessing fish is a widespread practice (Johnson and Orbach, 1990; Curran and Agardy, 2002), and a key coping strategy of fishers for dealing with resource fluctuations (Allison and Ellis, 2001). Other authors suggest that with knowledge of the conditions of stock decline, competitive behaviour is motivated and fishers' rational decision-making becomes based on short-term profits (Gordon, 1954; Gatewood, 1984). Rameriez Sanchez and Pinkerton (2013) posit that ethnographic accounts of resource scarcity illustrate a motivation for fishers to hide information rather than share it with each other (Andersen, 1972; Ramiriez Sanchez and Pinkerton, 2009).

In many Western countries such as Britain, quotas and ITQs are allocated according to individual species across wide ICES regions (Daw and Gray, 2005). Nevertheless, this lacks consideration of historic and contemporary port location and fishing effort (Sanchirico and Wilen 1999), and because the resultant spatial heterogeneity in profit "…leads to inefficient use of the spatial mosaic, as the most profitable patches, are relatively overexploited, in spite of the generic incentives provided by

ITQs to maximize value" (Cancino et al. 2007: 398). This demonstrates the division of approach in surviving resource scarcity evident between those in the larger, mobile gear sector of the nominally 'inshore fleet, and smaller fixed gear fishing' (Sinclair, 1987). While the changing inshore fleet has become more capitalised technologically and organisationally in some instances, influenced by the larger more technologically sophisticated offshore vessels, it remains more locally situated geographically, with lower divisions of labour. Further inshore responses to scarcity reflect the knowledge and practices of previous generations of inshore knowledge systems in regard to local ecology and customs, being relatively egalitarian as well as being primarily based on the oral and practical transmission of knowledge and skills (Murray *et al.* 2006). This suggests that they may be more likely to adapt sustainably in times of scarcity.

It can be argued that the inshore static gear sector and some smaller towed gear boats are known to maintain a continuous relationship to certain fishing areas' communities and importantly, specific parts of the seabed to which they return to harvest. This may maintain a relationship with LEK production and benthic spaces, the nature of which will need to be explored. With inshore fishers affected by neo-liberal markets and becoming increasingly efficient, through using more technologically sophisticated equipment, it was necessary to understand how this technology and neoliberal market processes are affecting the development of benthic LEK knowledge. This relates to the second research question of how technology influences fishing techniques and knowledge. The next section examines how these processes have altered fisher LEK more generally through technology.

3.3.2 The influence of fishing technologies on LEK

Previous research has already shown how fisher LEK is affected by the changing use of gear and technique; the species and sizes that are targeted; changing ecological and biophysical conditions; shifting scientific information and changes in the technologies fishers deploy. Following the resulting increasing spatial and ecological intensification and expansion, dramatic increases of effort in the inshore fishery have been seen across such factors as vessel size and materials, engine size, the use of electronics and the amount and type of gear used (Neis and Kean, 2003; Murray et al. 2005).

Murray et al. (2006: 4) underscore the importance of technological changes, showing that fishers' access to knowledge and new technology such as the Decca system allow them to survive the transition to migratory or nomadic fishing. Neis and Kean (2003) underline how spatial, temporal, and ecological intensification and interrelated expansion was also noted for inshore fishing. This acceleration in spatial fishing effort due to technological expansion has increasingly blurred the boundaries between the inshore and offshore sectors in Newfoundland. As cod stocks have collapsed as a result, this has led to fishing down the food chain to new species (Murray et al. 2005). Through their research, Murray et al. (2006) also highlights how fishers, who in the 1950s used compasses and local landmarks inshore, now travel 120 km offshore using sophisticated GPS and fish finding technologies in order to target new species such as snow crab and shrimp. These effects of policy and technological modernisation, alongside resource degradation, have seen a shift to what Murray et al. (2006) call GHK, which has moved away from small-scale, locally situated, long-term, harvest-oriented LEK. In the past, Newfoundland fishers' knowledge and practices more closely reflected the local ecology and customs and were shaped by relatively egalitarian (although gendered and generational) social relations among harvesters, being primarily based on the oral and practical transmission of knowledge and skills (Murray et al. 2006).

With increasing technological sophistication in GPS, radios and other aspects of navigation and communications, many skippers and crew are noted in Newfoundland to be taking additional training at professional fisheries colleges making them develop more rational fishing practices, with values that were shared by managers' fish buyers The scientific requirements of logbook keeping for fisheries managers had begun to affect the way that they fished, with perceptions of improvements in harvests after continued recording (Neis and Kean 2003). This rationalisation of practice and changes in knowledge through neoliberal market influences, technology, and state training, has ramifications for the fishing techniques, in regards to division of labour and scientific knowledge, which is discussed in the next section. However, the studies discussed above, highlight how the development of fisher LEK is affected by the extent of nomadic versus static gear use. More nomadic fishers tend to have less understanding of the links between different ecosystem processes, as they have not developed understanding either locally, or through their own sensory experience, but through technologically removed processes (e.g. Johnsen, 2009). While older fishers using modern technology may have a more intra systemic, holistic comprehension, younger fishers, who only have experience of fishing with modern technology, are less likely to share this approach (Murray et al. 2005). This ecosystem knowledge is also likely to be affected by the combination of the modernisation of the fishing techniques as well as technology. The extent to which intergenerational transmission is influenced by what Strathern (2002: 1) called 'virtualism', through the changing use of technology, is considered in this doctoral research. A brief reflection on how technologies of conservation may influence LEK follows.

3.3.3 Technologies for conservation

In regard to conservation, the fishing techniques and technology, Kincaid et al. (2014) provide evidence that in areas where specific gear use is zoned alongside marine conservation, fishers' perceptions align increasingly with the idea that "fisheries and conservation are inseparable", although static gear users were more positive than netters about the areas closed for fishing. In the context of the South East of England, it was discovered by Blyth et al. (2002) that static fishers tended to support closures to areas that would be more likely to be affected by towed gear used by nomadic fishers. Fishers are more likely to support the closure of areas that would not affect their own gear use. In northern Mexico, specialist Peñasco divers working with sessile benthic shellfish established their own Marine Conservation Zones with University and NGO support. This led to the dive fishers' involvement in biological monitoring and scientific knowledge development, successfully self-enforcing the reserves (Cudney-Bueno and Basurto, 2009). These fishers' attempts at monitoring and enforcement allowed them to confirm an increase in benthic resources after their establishment (Basurto et al. 2013). The extent to which technologies of conservation and involvement in research influences inshore fishers' LEK in the UK was investigated.

This literature relates to the second research question of how technology influences fishing techniques and knowledge, analysed further in chapter 6. While Murray et al. (2006) identified that fisher LEK is evolving into homogenous GHK, this review identifies there is a research gap regarding how new technologies and LEK of locally diverse specific habitats and biodiversity interact. This research will utilise the critical realist framework developed further in chapter 4 to examine how fishers' LEK comprehends benthic impacts of their own gear, other fishers' gear and other external anthropogenic impacts. Chapter 6 develops in full how fisher LEK is adapting to these technologies in novel ways in the face of contemporary challenges. The following section considers the influences of social organisation upon LEK, such as transmission, expertise and internal power relations, in regard to what Johnsen (2009) called the rationalisation of fishing.

3.4 The interaction of governance and social organisation with LEK

3.4.1. Rationalisation of fisheries, social organisation and LEK

The section is about how social organisation research and fisher LEK interact. It explores how fisher LEK of the benthos is used, shared, withheld and adjusts to new processes and interactions. This section also follows from 3.1.1 where the definition of LEK was clarified and defined. A number of authors have identified how the changing organisation of fisheries has influenced fisher LEK. They have reflected on how traditional forms of organisation have led to a greater rationalisation of fisher knowledge, through access to scientific and organisational knowledge, also known as business management. Palsson (2000) notes that on larger vessels, crew members and skippers tend to have somewhat different kinds of knowledge. Furthermore, it is suggested that commercial skippers are known to keep their knowledge to themselves (Palsson, 1998). As the socioecological system in which these fishers are embedded has changed, so too has the knowledge and orientation of these fishers to each other, the fish and their work, (Johnson et al. 2004, and Murray and Neis, 2004). Norwegian author Johnsen (2009), uses an organisational analysis to show how organic associations have become increasingly mechanised, through the industrialisation of fishing on both sides of the north Atlantic. This has relevance to how fisher LEK has become increasingly similar to empirical scientific knowledge.

In organic associations "…control tends to be implicit and internalised; generalised reciprocity and local power dynamics may be integral to their operation" (Johnsen, et al. 2009: 68). In this respect, they are largely self-governing (Kooiman et al. 2005), as decisions can be based on varying degrees on tradition, beliefs and ongoing negotiation among community members about crucial strategic issues for the fishing association including fishing seasons, access to grounds and berths, and when and where it is safe to fish (Johnsen et al. 2009). Contrastingly, in the increasingly mechanised associations that many organic associations are now becoming, power relations have become formalised, with functional hierarchies of procedures and control. Whether to sail or stop fishing is not based upon tradition or experience but guided by formal procedures. Decisions are now rational, "…guided by the formal, scientific or managerial knowledge that defines the relationship between causes and effects and means and ends" (Johnsen et al. 2009: 70).

Norwegian adaption to this technological professionalisation process, such as taking non-local crew and specialised baiters following 'scientific' procedures for baiting, meant a formalised abstraction from local practice and knowledge (Johnsen et al. 2009). Continuing this theme, Johnsen et al. (2009: 55) describe how "…mechanistic associations are characterised by the differentiation of functional tasks and are organised on the basis of more abstract and generalised principles than are found in ‘organic associations’ ’’. These changes in the fishing techniques have similarities with those identified more generally in late capitalism with Braverman’s division of labour and deskilling (1974). These changes result in more scientific bureaucratic managerial control of fishing techniques. The corporate ownership of harvesting attempts to harness scientific knowledge, economics, and scientific management, in order to make “…fisheries more efficient, ‘rational’ and predictable” (Johnsen et al. 2009: 67).

The specialised structures, guided by formalised curriculum procedures in these mechanistic fishing associations in communications and practice that Johnsen et al. (2009) describe as increasingly explicit, are abstract and generalisable knowledge. These are inscribed in books and technologies; echoing the GHK identified in Canadian industrial fisheries by Murray et al. (2006). As these are scientifically evaluated, reproduced and systematically transferred, they gradually undermine support for organic associated processes and practices that cannot be easily evaluated by formal standards and transferred through formal procedures. In contrast, Johnsen et al. (2009: 68) argue that the older organic associations are considered to be more resilient and adaptive within dynamic environments, whilst organic associations’ reputations have previously been considered to be resource degrading and poorer economically (Cadigan 2003).

This mechanical knowledge system - abstracted from space and place - has been further modernised in some associations by what Holm and Nielsen (2007) call a cybernetic system; based on the development and deployment of an abstract, symbolic and formal system of knowledge (Johnsen et al. 2009). These associations interact with fish through an abstracted formal ownership versus former usufruct property relations, using science, control and monitoring, modelling and handling, advanced information and calculation systems and computers that shape, control, govern and structure action and knowledge (Johnsen, 2009).

This more efficient fish catching potential incorporates contemporary navigation, ITC capacities such as Global Positioning Systems (GPS), the internet, satellite and mobile phone connections that both increase the amount of information and the speed of information collection and exchange (Johnsen, 2009). While the work functions as a useful starting point, the use of actor network theory means there is a lack of focus upon the underlying socioeconomic processes driving these different forms of organisation. The research discussed in this section has shown how knowledge has become increasingly codified and centralised in the organisation and how crews are increasingly removed from local ecosystems’ processes as they become more nomadic. How this rationalisation of knowledge is occurring is particularly interesting in regard to the organisation of fishing associations. How mechanisms such as division of labour and deskilling are increasingly affecting crews’ development of benthic LEK in different forms of social organisation is yet to be investigated. How different forms of fisheries associations and types and scales of business organisations interplay with the contemporary governance systems of Southern England needs to be researched, in terms of their access to power relations, and the capacity to involve their LEK in governance to influence it, and further learn from involved in scientific governance. The influence of the market in creating this division of labour and promoting deskilling has arguably been a significant factor limiting the development of LEK. This relates to the third research question of how the social organisation is influencing LEK.

3.4.2 Fisher LEK and intergenerational transmission

This sub-section examines how intergenerational transmission and fisher LEK expertise develops, in regard to access and location. Expertise in this context means advanced or expert knowledge regarding marine biology and ecology and its environmental linkages. Much of the literature on how fisher knowledge evolves considers a number of common key issues including secrecy, transmission between generations, the influence of family and kinship networks and communities. These are also likely to influence benthic fisher LEK. Typically, this expertise is present with the elder fishers (e.g. Neis et al. 1999); as sometimes they are the only sources of information on the history of their fisheries; the only direct links with the marine environments and fish stocks of times past (e.g. Freeman 1997; Pitcher and Pauly et al. 1998; Hay et al. 2000). In artisanal fisheries, older women are often key sources of knowledge about fish and invertebrates gleaned from the intertidal zone. This may not, however, apply in the European context (e.g. McGoodwin, 1990; Hviding, 1996, Johannes, 2000). Mckenna,'s (2008) research with Northern Ireland's Lough Neagh fishermen acknowledges that the core of transmission of their fisher knowledge is the tradition of fishing in family groups. Typically, a father or grandfather or uncle will fish in a team with a son or nephew or brother - "This type of organisation is ideal for the transmission of traditional oral knowledge" (Mckenna et al. 2008). How LEK transmission relates to intergenerational transmission (IGT) is also relevant. It is widely acknowledged that poverty is transmitted 'across generations occur through the transmission of various kinds of deficits' including in inshore fisheries, education, access to the sea and property rights. Moncrieffe (2009) argues that this can only be shifted through sufficient investments in human capital, including in this thesis the support of local learning and access rights. How intergenerational transmission of well-being associated with benthic LEK reproduction needs greater consideration also. However, Sumner et al. (2009) suggest this needs consideration beyond material assets; intergenerational transmission of concern for ecosystems alongside rights to the sea could be relevant in this regard.

In a developing country context, Vermonden (2009) recommends understanding this transmission of experiential expertise through its production in a 'Community of Practice'. It is claimed that knowledge flows from the periphery to the centre of a community of practice as it is progressively incorporated within the practitioner community (Lave and Wenger, 1991). Vermonden, (2009), suggests that within such communities, knowledge can still be considered as an artifact of the investigation of knowledge transmission, but it has to be acknowledged that the corpus of knowledge is also in part produced through the process of elicitation itself, making a focus simply on knowledge transmission inappropriate.

While Mckenna et al. (2008) state that professional lake fishers in Lough Neagh are noted to share their ecological knowledge freely, Grant and Berkes (2007) suggest that long-line fishermen in Grenada, eastern Caribbean, try to keep fishing grounds secret by approaching the village from different directions. They also suggest that in areas in the 'Global North', as far apart as the coast of Maine in the USA and the north Irish coast, lobster and crab fishermen zealously protect their specialist knowledge of areas that they regard as historically 'theirs', and they strongly resent any encroachment by others on their territory. Contrastingly, fishers in diverse locations may engage in information exchanges to reduce the uncertainties and financial risks involved in decisions about where and when to fish (Andersen, 1972; Stiles, 1972; Acheson, 1981; Gatewood, 1984; Salas and Gaertner, 2004; Rameriez Sanchez and Pinkerton, 2009).

Grant and Berkes (2007) demonstrate that fishers from Gouyave in Grenada are adaptive experts because they have the ability to learn from and deal with new situations. They rely on observation, experimentation, and experience through the feedback of fish catches and evaluation, learning adaptively to improve their understanding of the marine ecosystem and the resource within their knowledge system. Aspects of transmission, therefore, are variously affected by community structure, tradition, stock scarcity, and local culture. Different levels of LEK and their transmission can be unevenly distributed through a fishing community. These studies highlight that expertise, secrecy, transmission between generations, the influence of family and kinship networks and communities and practice are important to understand in relation to comprehending benthic fisher LEK. While Grant and Berkes's (2007) work on adaptive learning in the knowledge system has been investigated in relationships between expertise and specific stocks, it does not include ecosystems, habitats, and biodiversity, and the interlinkages with fishing impact adapting fishing techniques and changing fisher LEK. Murray et al. (2010), highlight that too much regulation can influence the adaptive capacity of fisher LEK, as they are less likely to be flexible with regard to focusing on different species, or sharing LEK with scientists, fisheries management, and among themselves.

It also does not investigate how adaptive learning is developing LEK under different government arrangements and forms of property rights. This adaptive learning will be considered in the next section in relation to different forms of social organisation. Additionally, the appetite for participation in scientific research for inshore fishers will be important to analyse, including how far fisheries governance has moved toward supporting the development of local learning. This can be investigated through a review of property rights and institutional arrangements. How different forms of private, public, common and open access rights interact with LEK needs consideration in this thesis.

3.4.3 The influence of property relations and neoliberalism upon LEK

This section examines the arguments between the schools of thoughts promoting different forms of property rights, and how they interact with LEK. The problems of having open access fisheries have been described as the tragedy of the commons, confusing common properties with open access regimes (Hardin, 1968). While Ostrom shows that scientific knowledge is necessary to consolidate socio-ecological systems, she highlights that the social and ecological sciences have developed independently and do not combine easily (Ostrom, 2009). Indeed, this thesis intends to demonstrate the value of a critical realist framework in bringing together the natural and the social sciences (Bhaskar, 1975).

Natural resources are legally categorized as state (res publica), private (res privada) or common (res communalis) property and open access (res nullis) (Davidson Hunt, 1996: 1). Historically, writers such as Locke in 1689 distinguished between private property such as for land, and common property, by which he conflated open-access property, beginning the ongoing confusion of common property by capitalist authors (Cox, 2014). Contrastingly as Shiva (2016) highlighted, the very existence of common property demonstrated the historical capacity of societies to cooperatively organise resources sustainably. Following Locke, Adam Smith suggested that the main function of civil government was to safeguard ownership, as it could not exist without it. His work encouraged freedom through people's right to property, and that such rights always require the ability to exclude others. In (1848) Marx's historical materialist analysis predicted that the capitalist induced governmental crisis would see private means of production ultimately be replaced by social ownership, or common property. Nevertheless, this has not been realized outside of limited areas, including the Zapatistas of Southern Mexico, and in Rojava, northern Syria. These property relations have ruptured in response to both centralising approaches of the state under Marxist-Leninism as well as capitalism (Knapp et al. 2016). Unusually in Rojava, cooperative common properties organized through communal councils, who send recallable delegates to the neighbourhood level, canton level, and to the Confederate Council. These have emerged under the ideology of 'democratic confederalism', influenced by Bookchin's socio-ecology (1965). Undoubtedly, the overwhelming dominance of market logic to property relations has meant this has emerged rarely elsewhere. As Wendy Brown identified in (2015), neoliberalism redefines even non-wealth generating spheres including ecosystems, learning, knowledge or exercising—in market terms so that they can be submitted to market metrics. How alternative property relations such as common properties support the evolution of fisher LEK will be theorised.

With the continued dominance of neoliberalism today, the benefits of property beyond private property are not well described in the LEK literature. The hegemony of market solutions in natural resource management could be construed as a natural evolution. Alternatively, as Graeber (2011) reminded us, markets for specific goods are not always inevitable outgrowths of human nature, and often require external imposition and cultivation by institutions and states following an ideological perspective. Importantly, perhaps influenced by this ideology, authors from neoliberal backgrounds consistently misunderstand common properties. Key authors such as Gordon (1954) and Hardin (1968) conflate them with open access governance failures. This has led to the dominance of neoliberal approaches to property rights as illuminated by Mansfield, (2004), and prescriptive one size fits all market solutions for governmental problems more widely (Pritchett and Woolcock, 2004).

Authors researching traditional property rights from the TEK school of thought highlight that indigenous traditions of exploitation and property rights have produced long-term sustainability over millennia (Berkes et al. 1989; Larson and Bromley 1990). Writers such as Bavinck et al. (2015) highlight they have had some success in evolving with modern demands. Pre-modern community governance that successfully integrates fishers' LEK into co-management includes the Spanish Cofradia, the French Prud'homie, the Lofoten management system, the Polish Mazoperias, the Indian Panchayat system, and the Indonesian Sasi (Jentoft et al. 2000). To be sure, their key lesson for management is subsidiarity or an accessible scale, important for democracy from local to global. Nevertheless, the majority of traditional forms of governance have seen changing technology and new market pressure, leading to industrial over-exploitation. This has made the benefits of certain traditional forms of common property moribund under pressure from corporate globalisation (Harvey, 2012). Indeed, this thesis will examine which forms of property, including Ostrom's (1990) common pool resource literature, are best suited for the development of LEK with the integration of scientific knowledge for conservation.

In order to fully understand the neoliberal consensus, the arguments of neoliberal scholars for privatizing property need reflection. Gordon's (1954) work was a key turning point for creating private property rights in fisheries. He defined common property resources as those that "are free goods for the individual and scarce goods for society" (1954: 135). His main argument was that the lack of private property drives a non-equilibrium pattern in fisheries, such that total effort levels will always rise to the point that they dissipate any potential profits, thus leading to inefficient use of capital and fish. Following Gordon, Hardin (1968) wrote that the 'Tragedy of the Commons' has continued, as the commons are the same as an open-access resource as they are without rules. Within these spaces, rational actors maximise exploitation of the resource for commodity markets, using modern technologies. Under market conditions, it does not make sense for the individual to conserve resources, because the benefits of her action, cannot be shared by others. A secondary 'free rider problem' is that no individual has an incentive to come up with collective action, as the benefits of their action, would then be shared by competitors (Ostrom, 1990: 26). While collective action is more difficult to arrange, the resulting forms of common property see resource access controlled and more equally distributed. Kherbek, asked in (2016) if it is forms of communication that prevent tragedy, why in this era of improved digital communication and social media, is the facilitation of local learning not creating new well organised common pool resources (The thesis will examine whether the importance of fisher LEK alongside these technologies can begin to overturn the dominance of the neoliberal narrative in the property debate).

There are two types of private property rights promoted through the neoliberal logic: tradable non-spatial private property rights over quota; and spatial private property rights over a portion of seabed benthos. The first has been advocated by Costello et al. (2008), who suggest the answer lies in the alignment of incentives. Because individuals lack secure rights to part of the quota, they have a perverse motivation to 'race to fish', to out-compete others. However, in wild sea fisheries with species enjoying some degree of local migration, there is no potential to secure the activities of marine life without tagging every single living creature in the ocean with tracking devices and enclosing them with laser sensors. Logically then, the best available knowledge, such as fisher LEK and scientific knowledge combined needs to be supported.

In this vein, the dominance of neoliberal approach has led to the development of quota as private property through ITQs which are becoming increasingly popular. Chu et al.'s (2009) study demonstrate that 18 countries now use ITQs to manage several hundred stocks of at least 249 species. A recent review by Acheson et al. (2015) quantitatively demonstrates that individual transferable quotas (ITQs), are, however, not good for conserving marine resources. In terms of social justice, where ITQs have been established such as in Iceland, Chambers et al. (2017) identified how the system has led to fishery community collapse as quota rights were sold off to centralized companies away from rural communities. Sanchirico and Newell (2003) study provides evidence across countries that quotas are bought by the most economically 'efficient' and dominant boat owners. Contrastingly those that are less efficient decrease their activity or stop fishing, leaving the same catch shared by fewer boats and owners (Sumalia, 2010). Marx (1867: 762) identified the "transformation of many small into few large capitals". This not only suggests that private quota rights are not healthy for ecosystems; they are ineffective in creating social benefits. How this relates to changes being made in Southern England, such as the creation of a private quota market inshore influences LEK and its continued intergenerational transmission will be part of this research.

Spatial private property rights over the seabed are now reflected upon. Following from Gordon (1954) an example neoliberal scholar (Adler, 2002)'s work lacks consideration of the whole ecosystem. He justifies not giving a full review to other alternative institutional arrangements, including democratically managed common pool resources, quoting Hayek. He argued that the use of markets for decision making were superior against central socialist planning, and that effective fisheries management depends on local and technical knowledge beyond the reach of any centralized management agency (1945: 519) Nevertheless Adler (2008) is bereft of any consideration of how "this knowledge problem" can be solved by decentralized, adaptive forms of co-management supported by participation in research. Alongside open access, private property, public property and common property forms, there are different institutional forms of governance that support these property types and interact with LEK.

Where open access is thought to have continued, an assumption developed that an external Leviathan was necessary to prevent the tragedy of the commons (Larkin 1977). This could be applied historically to include the inshore fisheries of Southern England, Leviathan or bureaucracy-based fisheries management has been unpopular with fishers for being too top-down (Imperial and Yandle, 2005). This means there is little room for participation of LEK, or involvement in scientific research. The extent to which neoliberalism is encouraging private capital free from constraints to ensure market efficiency in Southern England needs investigation, particularly in relation to the regeneration of LEK through quota privatisation (Cahill, 2014). Additionally, the literature on adaptive co-management is also relevant, for example, Ollson et al. (2004). While adaptive and ecosystem forms of management have gained attention, Armitage et al. (2009) point out that overemphasis has led to the domination of natural science, making the translation into the socio-political arena difficult. How critical realism offers methodological solutions to this will be investigated. Understanding political and social science is needed to create flexible social arrangements for rules and incentives of common-pool resource institutions (Ostrom, 2005). In order to facilitate effective collaborative governance, there is potential to link different experimental and experiential learning (Armitage, 2009). Accuracy at different scales can be improved by integrating fisher LEK, as many species are limited data stocks. An example of how the crisis created by neoliberalism in Chilean fisheries encouraged a form of adaptive co-management follows.

In Chile, the failure of the traditional command-and-control regulations in association with neoliberal ITQs introduced under the Pinochet regime, lead to key species such as Loco shellfish collapsing. The 1991 Fishery and Aquaculture Law No. 18 892 (FAL), drastically reformed fishing access between the industrial and artisanal fishing sectors (Gelcich et al, 2010). Territorial user rights were assigned under a co-management scheme, formally known as the 'Management and Exploitation Areas for Benthic Resources' (MEABR) system, facilitating participative collectivism in 747 Management Areas (Castilla et al. 1998). This was realised using a common property approach, which proposes that a well-established rights-based system provides access, withdrawal and management security for individuals and groups of individuals (Ostrom and Schlager, 1996). This was pioneered through community science supported through universities, which is likely to have had an influential relationship with fisher LEK and a bi-directional ZPD.

This thesis will examine the extent marine governance is open access or becoming zoned through deliberative processes alongside the interaction with the creation of property rights. This section considers other forms of marine governance that manage issues alongside fisheries, and the relevance of LEK. In Chile, like other countries such as Japan, beyond the territorial user rights zone of small-scale fishers within 5 nautical miles, the artisanal mid-scale and industrial scale rights are not zoned (Castilla, 2010). Being open access can create ecological problems migrating freely around that strip. How zonation of different fishing techniques and habitat is being responded to through LEK will be considered. Relevant to this is the development of Marine Protected Areas (MPA), alongside marine spatial management planning. Plans that integrate the different spatial needs of marine users' need the involvement of fisher LEK at different scales (Jentoft and Knol, 2014). A review of policy literature reveals there is no specific cut-off for percentage habitat loss through development outside of MPAs. In this context, different understandings of marine disturbance are essential for coastal marine planning to support socio-ecological resilience (Kinzig, 2006). A gap emerges to demonstrate how fishers are identifying ecological patterns missed by marine governance including pollution and disturbance from development. Processes that facilitate deliberation between England's marine management and coastal communities can improve identification of risk, as well as increase parity of participation for environmental justice (Frazer, 2001). The precautionary approach states that the absence of proof of harm is not the same thing as proof of the absence of harm (De Santo, 2010).

The excessive complexity of different public bodies that have responsibility for different domains in England was highlighted by Boyes and Elliot (2015). How fisher LEK responds to the problems of port development, aggregate dredging, and wind farms will be discussed in this light. Johnsen's (2014: 2) work in Norwegian fisheries underlined LEK's relevance for coastal space in terms of governance which is useful to the analysis in this thesis. Using a postmodernist methodology, the study examines the power relations of scientific translation, arguing that an "…acceptance of LEK as relevant for fisheries governance may shift power from scientific institutions to users…". This thesis will demonstrate the gap in the literature that LEK understands the benthos and its disturbance can be important at the coastal marine planning nexus. It will be different to Johnsen's (2014) work in the application of critical realism to analyse the strengths and limitations of LEK in these assessments, by bringing together the social and the natural sciences. Nevertheless, as Appleby and Jones (2012) point out there is no explicit reference to the ecosystem approach and the integration of local and expert knowledge in the objectives of Johnsen's work. The MMO is only answerable to the secretary of state, not the local or national electorate. (See s 3(1) of the Marine and Coastal Access Act 2009).

The extent that the observation of Jones et al. (2016) that marine plans seem disconnected by design from stakeholders across the EU and in England, and that such a lack of public participation may breach the obligations of the Aarhus Convention will be considered in regard to fisher LEK of the benthos (De Santo, 2016). How this then relates to the tensions of property relations and participation will be investigated in this doctoral research.

Different forms of property relations have different outcomes for fisheries management and the capacity for the integration of LEK. This section has identified the relevant literature in order to suggest areas of further research and questions which are suited to a critical realist approach. To create what Shiva (2016) calls an 'Earth Democracy' needs common pool resources with fishers' involvement in scientific research and training as well as fishing. The influence upon LEK from other stakeholders and civil society in developing fisheries governance should not be underestimated and will be considered next.

3.4.4 The influence of stakeholders and civil society on developing LEK

Local authorities, such as County councils form part of the IFCAs committee, facilitating oversight. Pieraccini and Cardwell (2016) argue that to ensure democratic accountability and effective deliberation, stakeholder selection for the co-management group should cover as wide a range of interests as possible. Nevertheless, reflecting on the Lofoten fishery situation in Norway, Mikalsen and Jentoft (2001) described the overriding selection of stakeholders based on economic interest as 'corporatist'. The extent to which such a corporatist approach results in privileging a particular user group such as fishers, a geography of fishers, or a network of fishers over others in environmental decision making will be investigated. The growing changes of fisher LEK in this research is also influenced by stakeholders in their networks, and wider civil society, including NGOs such as Greenpeace and the Blue Marine Foundation. How civil society is influencing LEK and its governance goes beyond its conception in liberal democratic thought in this thesis, drawing upon Gramsci's ideas about how power as 'hegemony' and the 'manufacture of consent' (Gramsci 1971). Critics, including Heywood (1994), have argued that it is reduced to an associational domain in contrast to the state and the market. Instead, it could be conceived of as a public sphere of political struggle and contestation over ideas and norms challenging the bourgeois state through associations, trade unions, and political parties. The extent of civil society including NGOs such as Greenpeace, and fisher associations such as NUTFA are challenging hegemony interfaces with changing LEK and its interactions challenging governance and research. While existing pre-capitalist common properties can continue to be sustainable, they need to be interlinked in a wider international social movement for common property rights and participatory governance if they are to overcome the pressure of the market rationale (Knapp et al. 2016). How fisheries social movements have developed these conceptions and continue to apply them in relation to the relationship between LEK and governance is worthy of investigation.

It has been argued by Shiva (2016: 49) that ecology movements in the third world are different to those in western industrialised countries, "not simply being a luxury of the rich". They are thought to be a survival imperative for those whose livelihoods have been put at risk by the continuous expansion of the market economy into the commons. It will be useful to analyse where LEK of fishers is being deployed to support the survival imperative in Southern England, such as where pollution has developed in a way that debilitates the marine ecosystems which fishers survive upon.

Conceptualising the outputs of the commons, Hardt and Negri (2009: 8) wrote that as 'results of social production that are necessary for social interaction and further production, such as knowledge's, languages, codes, information, effects, and so forth'. The transformation of the public into Commons means connecting the participatory democratic practices to the production of commons services, such as ecosystem services (Constanza et al.1998). How this relates to LEK's accessibility, to governance and the ZPD's interaction with local learning will be an important aspect of the research. How the critical realism approach goes beyond the ecosystem approach to fisheries identified previously will be discussed (Fischer et al. 2015). It was identified by Hoefnagel et al. (2006) that research that encourages the articulation of knowledge can enable participation, an important way to mobilise social power. This relates to how social movements and governmental structures are helping to mobilise social power with fishers in England. The extent these movements and governmental structures can right the epistemic injustice of fishers as knowers was identified by Tsosie et al. (2012) in regards to the poor of the global south and is applicable here. These epistemic rights, are arguably part of the path toward the environmental justice described by Agyeman et al. (2003). If the educational and research benefits of fishers, as full participants of investigative programmes in subject-subject research relationships, can be recognised, then epistemic rights can be theorized as ´Pescastemic Rights´ through the Cornish and Spanish word for fisher, ´Pescador', and are more likely to be realised.

This section considered the research question of how fisher LEK is interacting with governance and social organisation. It highlighted the need to investigate this in relation to quota governance and Marine Spatial Planning explored respectively in chapters 7 and 8. How governmental and research bodies make explicit the importance of the feedback between fishers and scientists will also be discussed further in these results chapters. The following chapter 4 will explain how the critical realist methodology can help identify emancipatory mechanisms in regard to governance and social organisation.

3.5 Conclusion

This chapter highlighted the nature of the research gap regarding benthic fisher LEK through literature on how LEK is defined, how LEK is used, shared, withheld and adjusts to new processes. It did this through discrete sections of literature pertaining to the research questions of how scientific research, technology, social organisation and governance interact with fisher LEK. The literature reveals a number of key issues that are identified as important to understand LEK in this doctoral research.

To understand fisher LEK of the benthos, the impact of scientific knowledge and the different local geographies, ecologies and environmental conditions were identified as aspects investigated in different locations in chapter 5. The literature on scientific knowledge systems and fisher knowledge systems' interactions shows that fisher LEK is marginalised by multiple different processes, which has affected its evolution historically and contemporarily. As fisher LEK knowledge is typically geographically situated (Drew, 2005), this may provide a barrier between knowledge systems, with scientific knowledge tending to aim for generalisability across time and space (Schafer, and Reis, (2008). In these varying locations, different classification systems for species, environmental processes and the linkages between them may mean certain aspects are better understood or rarefied through economic importance, or local cultural prestige depending on the geography (Lobel, 1978; Silvano and Begossi 2002). As has been shown in this chapter, how this classification of species' value on the seabed is developing through access to scientific and conservation knowledge systems in Western Europe could be better understood.

The changes to fisher LEK cannot be typified by what Murray et al. (2006) called GHK. How the emerging forms of fisher LEK are influenced by technology, the changes to single quota stock organisation and governance, and scientific sets of knowledge of locally diverse habitat and biodiversity, is a gap identified in this chapter for further investigation. These issues are explored in chapter 6.

Chapters 7 and 8 focus specifically on how governmental and social organisation shape the interactions between fisher LEK, technology and scientific knowledges. It is this response by fishers to the changes in other parties' knowledge systems and perceptions of value which is considered in these chapters

This allows a consideration in certain chapters of what Tsosie et al. (2012) describes as the importance of epistemic rights, and environmental justice (Agyeman, 2003). This relates to how the critical realism perspective adopted in this thesis brings an appreciation of the way socio-economics and research science are developing fisher LEK of the benthos, and to understand how LEK is different, how it can be defined, and why it needs fundamentally re-theorising.

Therefore, the overarching research question of the thesis is:

1. How has fisher LEK of the benthos developed in recent times, and how does this inform re-theorisation of LEK?

Linked to this overarching question are the subsidiary research questions:

2. How does scientific research interact with LEK?

This subsidiary research question is covered in section 3.2 of the literature review, considering the relevance of fisher LEK and the interaction with scientific research.

3. How does technology influence the development of fisher LEK?

This subsidiary research question is covered in section 3.3 of the literature review in regard to the influence of new technologies and neoliberalism on LEK

4. In what ways do quota governance and Marine Spatial Planning interact with the development of LEK?

Section 3.4 of the literature review considered the interaction of governance and social organisation.

These research questions identified are reflected on in the analysis, discussion of findings and conclusions. How critical realism provides an approach for both the natural and the social sciences that is suitable for answering these research questions will be considered in the following chapter.

Chapter 4 Critical Realist Methodology

4.1 Introducing Critical Realism

This chapter will examine the methodological framework which will be used to examine how fisher LEK of the benthos is being generated, shared, and is changing, through interaction with scientific research, technology and different forms of governance. The context of how fisher LEK is used, shared, withheld, and adjusts is worth noting, such as the growing pressure from lack of quota for inshore fishers, at the same time new CFP regulations are added without accessible explanation. It has left inshore fishers in a contrastingly top down system, while over 10m vessels are allowed relative freedom, including being able to access quota to trade. In addition to outlining the methodology, the chapter presents and justifies the methods that will be employed to achieve these aims. To understand how fisher LEK of the benthos can be defined and why it needs fundamentally re-theorising, the first section highlights how the critical realist approach to knowledge is appropriate to analyse how fisher LEK of the benthos is changing and being influenced. The rest of this chapter outlines how interviews with fishers and key informants along with observation of the different fishing techniques in England elucidated how fisher LEK is developing in different domains in preparation for the analysis which is developed in the discussion chapters. Historically, natural science has perceived traditional, indigenous knowledge and LEK as inaccurate, questioning its validity, owing to its lack of mainstream scientific methods of assessment, most notably through Popper's (1963) concept of falsifiability. Given this general perception of LEK's subordinate position in the knowledge hierarchy to scientific knowledge, critical realism can expand the understanding of how the relationship between science and forms of LEK is evolving (Sayer, 1984). Furthermore, critical realism enables an analysis of the commercial motivations and influences, on fisher LEK. Critical realism is also suitable as a framework to identify emancipatory mechanisms for knowledge. Using critical realism allows for the identification of the processes disempowering target groups and can be used to explain how to replace them (Sayer, 1997).

It is worth noting here that while actor-network theory is an alternative way to consider the infrastructure surrounding scientific and technological achievements that involve LEK. An especially well-known use of actor-network theory to study fishing activity was Callon's (1986) account of the scallops of St Brieuc's Bay. However, certain critics of this study have argued it attributed too much to the agency of the scallops (Collins and Yearly, 1992). Indeed, it appeared that equal agency was given to all actors, whether fishers, scientists or scallops, leaving no explanation for power imbalances, and the potential emancipation of knowledge. (Collins and Yearly, 1992). Different to actor-network theory, critical realism attempts to realise emancipatory mechanisms for the different forms of knowledge. Through its identification of the hierarchy of knowledge, it looks to ways to move toward a more democratic and inclusive approach to the development of knowledge (Sayer, 1984, 1997). Through acknowledgment of the existing socio-economic relations and their influence on the hierarchy, the emancipatory mechanisms can be more strategically identified and supported (Sayer, 1984). Also thought problematic was actor-network theory's use of social constructivism, which suggests that the agency of inanimate objects is under-considered (Law, 1987). This contradicts the critical realist approach which attempts to balance the natural and the social sciences (Bhaskar, 1975).

Ideas around the significance of LEK's formalisation of data or orderings of knowledge are brought to light by the critical realist methodology. Critical realism claims that reality exists outside of our conscious perception, and our senses only allow for the discovery of certain knowledge objectively, as our senses are not entirely reliable (Bhaskar, 1998). Indeed, critical realism acknowledges that ecosystems exist independently of our senses and that its properties and actors will continue to exist undersea whether or not we perceive or misperceive an event (Bhaskar, 1975). The scientific epistemology of fishing is then experiential; however, the awareness and measurement of an event are not the same as understanding the totality of the event in spatial and temporal terms (Johnston and Smith, 2007). Moreover, natural science's confidence in its capacity to have total event understanding is further muddied through its consideration of knowledge as a product - a product that is only fully realised when abstracted and codified, without consideration of its social production and social use (Sayer, 1984: 14). Contrastingly, LEK does not rely on this codification and producing data is not a goal nor a necessity of its practice-based continuation. It is then, the understanding of the enduring underlying causal relationships which lie beyond the empirical domain of scientific study, which bring a much deeper and fuller understanding of the production of knowledge (Niiniluoto, 1999). A critical realist analysis of LEK, therefore, can elucidate the generative mechanisms underlying and producing observable phenomena and events. This can explicate not only how the embodied experience, technologies, and economic priorities of LEK's practices lead to the development of ecological knowledge, but also the extent to which this is different to the generation of empirical data in the Natural Sciences (Bhaksar, 1988: 32). This relates to understanding the underlying mechanisms of knowledge production, as detailed in figure 7 below (Mingers, 2004).

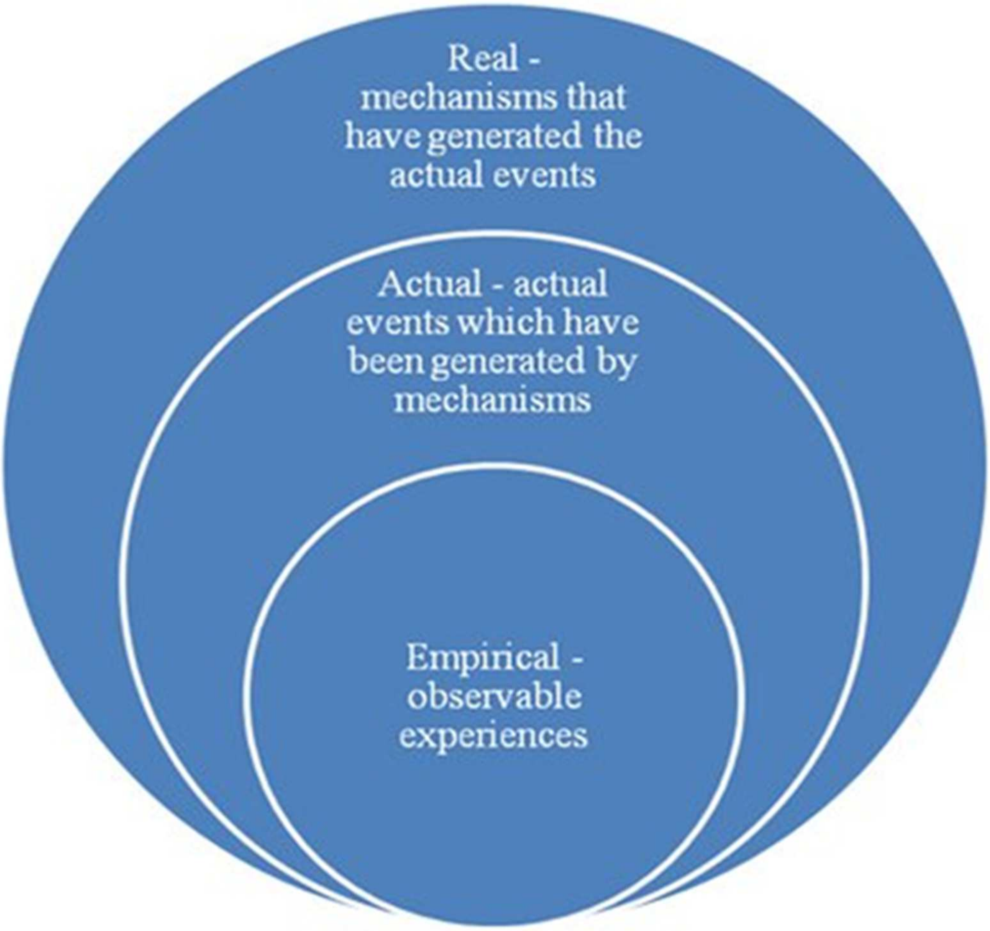

Figure 7 Critical Realism understanding mechanisms (Mingers, 2004).

Critical realism comparatively grounds this inquiry within a robust conception of social structure (Rees and Gatenby, 2014). Phenomenological methods situate authority with the idea of a socially constructed reality, encouraging an exclusive focus on uncovering the subjective interpretations of individuals. Porter (2002: 53) laments the loss of structure from the ethnographic imagination and phenomenology ignores analysis of how social structures and processes influence individual's interpretations. Davies (2008), and Rees and Gatenby (2014: 4) suggest that while incorporating the insights of different standpoints can be informative, going beyond relativity by adopting critical realism allows examination of the causal effects of the social world upon individuals' subjectivities. This can improve our understanding of the complex processes at work in extensive fields of study. For this reason, critical realism is the most relevant approach for this investigation of fisher LEK.

With regards to the postmodernist philosophy of science and the concomitant position of authority afforded to the researcher, Rees and Gatenby (2014: 4) argue that Postmodernism is flawed as it suggests that it is impossible to have confidence in the epistemological superiority of one interpretation of the social domain over another. This approach can lead to social research being seen as nothing but the creative expressions of their authors (Porter, 2002). This gives them no claim to academic superiority of their own analysis over anyone else's, delegitimising its potential application methodologically. This emerging space for critical realism addresses the weaknesses of and simultaneously makes use of the strengths of positivism/empiricism, and constructivism/relativism or post-modernism. This is achieved through critical realism's acknowledgment of the potential of science, whilst recognising the social dimensions of scientific knowledge systems. It is an approach that addresses some of the issues associated with constructivism and empiricism; that the social reality of those involved in a researched process is ignored. This appreciation encourages an approach that validates multiple types of truth; sensory or empirical data, qualitative and quantitative. This can allow for a deeper understanding of causality and relationships in quantitative and qualitative data; in order to explicate and theorise about social patterns such as fishers' interaction with ecosystem complexity, and the subsequent knowledge creation which results (Bhaskar, 1975; Christ, 2013).

To navigate, Bhaskar (1975) located critical realism against judgmental relativism, positioning it with epistemological relativism and judgemental rationality. This allows for reaching contingently reasoned and accurate judgments about reality (Lipscomb, 2010). Qualitative judgments require inductive analysis. Attention to emergent structures and their properties present a useful way to organize the available information to generate additional insights to supply strong evidence for the truth through an inductive approach (Tropser, 2005). Divulging the multiple truths of these differing sets of knowledge using this methodology can mean using "retroduction" techniques to formulate "conceptualizations" of the "subjective" and "objective" coded and merged data, in order to explain patterns in data (Christ, 2013: 111). Sayer (1984: 107), describes retroduction as "…a mode of inference in which events are explained by postulating (and identifying) mechanisms which are capable of producing them". Downward and Mearman, (2002: 80) suggest that retroduction requires the 'triangulation' of research methods. This is argued, "…to unite research contributions in such a way as to transcend the use of specific methods in a disciplinary sense". Relating to Olsen and Morgan's (2005)'s definition that methods are ways of collecting and transforming data, whereas methodologies comprise combinations of methods, where the interpretation of the academic influences the practices involved in their implementation. The approach then triangulates through retroduction; which Webb et al. (1966) posit, increases the persuasiveness of evidence and adds completeness to accounts through manifest interdisciplinarity (Shih, 1998). A critical realist methodological framework then is useful to understand both underlying processes, as well as more abstract, qualitative theoretical approaches. All these aspects will need to be considered throughout commencement of the specific research methods chosen.

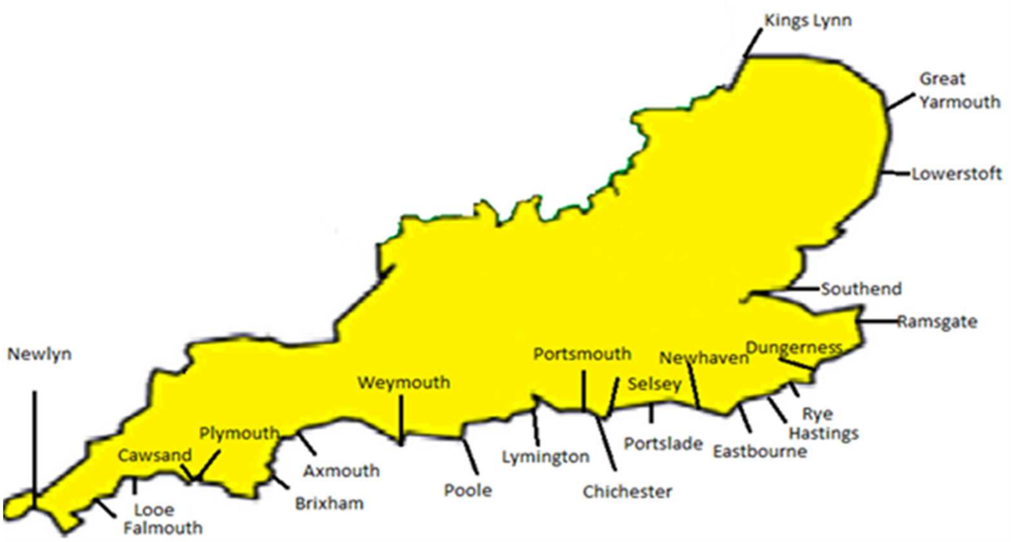

Figure 8 Map of the study area and primary harbours researched in Southern England. Produced by author.

4.2 Methods

4.2.1 The study area

To address the underlying mechanisms identified in the research objectives and questions influencing how fisher LEK of the benthos is developing, the researcher targeted a cohesive study area with a shared fisheries system shown mapped in figure 8 above. It is worth mentioning here that a much smaller case study could have led to more emancipatory outcomes. The designations of the Geography of Inshore Fishing (GIFs) Project meant fishing communities were selected from the Cornish west coast to the English Regions on the south coast, up to the Wash estuary on the east coast. While the opportunity to research in the Netherlands, Belgium and France arose, the researcher was advised that time would not allow for in-depth research in all these areas. The study area at first glance might not be described to be what Steake (2000: 19), called in “epistemological harmony” with the reader’s experience, because of its scale. Due to the sheer size of the area researched in the thesis, generalisations of its findings in comparison to other western EU countries can be supported. The study’s rich data was gathered across multiple interlaced cases of fishing communities. Ports and harbours were selected, both through snowballing techniques via contacts with other fishers in the area, reputations of fishing communities, and thorough assessment of fishing techniques, proximity to MPAs and their volumes of landings. Fishing harbours in river estuaries, such as the King’s Lynn community on the Wash, the Thames estuary, the Plymouth fleet on the Tamar and Newhaven, have developed as there is continuous shelter from storms for vessels. Peninsula and island fishing communities, such as around Cornwall, Isle of Wight, Selsey Bill, and Thanet have developed for reasons of good access, and fishing availability in multiple directions. Evidence of continuous fishing communities is also observable in such historic fishing harbours as Hastings, Newlyn, and Brixham. Through their relationship to these coastal features, these fishers communicate more readily with those other communities in proximity, such as Hastings, Rye and Eastbourne, Ramsgate and Whitstable, Brixham, Plymouth and Looe, and King's Lynn and Wells next the Sea. The greater levels of face-to-face, and proximal interaction at sea stimulates greater sharing of knowledge through the local underwater geography and seabed. Selection of these case study areas was also influenced by the activity of the social movement, the New Under 10m fishing Association, who were known to share knowledge within their network. Retrospectively, Lyme Bay was also found to be a well-populated area of inshore fishing, and more attention should have been paid to the Lyme Bay Reserve group from the start. These locations are listed in Table 4 below.

4.2.2 Selection of participants and fishing techniques

Across the case study of Southern England, 60 inshore fishers were interviewed as detailed in table 5. Given the diversity of different fishing techniques found across Cornish and English areas, the focus was given to the six major techniques of fishing. As already discussed in the context chapter these can be grouped into the lower impact static gear and higher impact towed gear (Gascoigne and Wilsteed, 2009). Static gear fishing methods include; (i) gill-netting (also known as trammel netting) - involving targeting flatfish such as sole, turbot, plaice, skates, and rays); (ii) rod and lining - targeting bass, squid, and mackerel; and, (iii) potting - targeting lobsters, crabs and cuttlefish and whelks (Symes, 1999). These practices can be grouped according to seasonal patterns - given their continuous targeting of specific static underwater locations.

Towed gear methods such as trawling are empirically considered to have more impact upon the seabed (Jones, 1992, and Thrush and Dayton, 2002). Towed gear fishing processes to be investigated include: (i) otter board trawling - targeting lemon sole, plaice, dover sole, turbot, and red mullet, (although also affecting many other associated species); (ii) beam trawling - targeting similar species to otter board trawling; and, (iii) shellfish dredging - targeting scallops, oysters, clams and cockles. The towed gear methods can be grouped as higher impact in terms of seabed disturbance, its effect on associated species, alongside requiring increased fuel use. This group primarily includes otter board trawling, beam trawling, and dredging. It was important to give equal attention to participant observation of both gear groups. Towed gear industrial boats are more commonly operated by larger businesses, as they land more fish, and are more expensive to run. It was important to investigate this group of fishers, more influenced by business rationalism, who were predicted to be less engaged by conservation research. Trips were made with all gear types to scope fishing techniques except long lining and seine netting in the offshore fishing sector.

While all these types of fishing are found in operation in the inshore area, interviews took place with skippers working on offshore beam trawlers, in order to test differences in the development of techniques, labour divisions, and knowledge. The groups of inshore and offshore, under 10 and over 10m fishing vessels, are subtly different, with the under 10m vessels more likely to maintain fishing in a localised area, given the restrictions imposed on them by weather, engine power, and catch capacity. However, a new sector in the under 10m fleet has emerged recently, identified as the 'super 10s' by fishers. These are catamarans with greater width and capacity, which can stay at sea for longer, move into the deeper water more safely, and commit greater fishing effort. The specific vessels that were chosen to observe and participate with depended on the availability of vessels in the different geographic regions of Southern England. While the first fishing boats to assess the fishing, process were in Hastings and were involved in the Geographies of Inshore Fishing and Sustainability programme, the second was based on recommendations made by those fishers, in nearby Eastbourne. In effect snowballing within social networks ensured an effective link-up between boats. Where social networks were not interconnected, the researcher built a rapport with those fishers available in the harbour, who were amenable to research. Section 1 of the appendices gives more detail on the environmental impacts of these sorts of fishing. Fishing trips took place on all the above six gear types in order to carry out an observation. Where the gear was considered to be a higher impact, such as dredging and trawling, more than one trip took place in order to fully understand the specific fishing techniques involved. The schedule of trips is listed in table 3, below. Critical discussion on fishing techniques by the researcher may have influenced the fishers' understanding of impacts and how they analysed their gear's impact upon benthic habitats.

Overall, 60 fishers were interviewed across the study area - as detailed in table 5 in appendix 1. Demographically speaking, the majority of skippers interviewed were over 50. While this reflects an ageing demographic, there are no demographic statistics available currently from the MMO to confirm this. Those fishers who had a local reputation for experience and wisdom were chosen, as they were considered by other fishers more suited to explain long-term patterns, and further make an observation of changes to ecological patterns. Crews were noticeably younger, with less than half under 30. An effort was also made to speak to skippers involved in larger businesses with greater access to capital, as well as those who were individual or co-boat owners. This was determined by how vessels were owned., however this was only something made apparent after interview. There were no women found working aboard the fishing vessels sampled; historically women have been considered to be bad luck, although this may change in the future, explaining why the term 'fisher' has been used throughout the thesis, rather than 'fishermen'. At least 10 crew members were interviewed, and it was quickly noted that skippers have much better developed LEK. Crew members were often reticent to be interviewed. Skippers generally had higher levels of experience, greater power over decision-making as they were typically vessel owners. The responsibility for the recording habitats on the charts allows for greater depth of LEK development than their crews. Therefore, more skippers were interviewed than crew members. It is worth noting that crew members were also increasingly difficult to find as many inshore boats can no longer afford to hire a crew. An attempt was made to reach skippers with different levels of benthic sensory technology and to identify bigger fishing organisations that explicitly had more than one boat and their own fishing shops. Fishers' access to quota was transparent; those who suffered from little quota were more explicitly critical of the system that didn't work for them. While the majority of inshore fishers complained about access to quota, those that had closer relations with FPOs or were bigger fishing organisations did not. These aspects will be identified during the analysis, and those interviewed will be given pseudo names.

More fishers from the static or low impact gear sector were interviewed (n=37) as trawler and dredger crew were more difficult to find (n=23), reflecting the shift in gear use identified in Chapter 5 towards lower impact gear. While elements of LEK may be tacit knowledge - by questioning fishers on these themes this knowledge became oral, discursive knowledge; that is, the knowledge that can be discussed and potentially facilitate fisher participation in co-management. Certain themes attempted in the pilot were discarded, such as pelagic species knowledge. However, specific themes were decided upon in the interview schedule after preliminary analysis. Other categories were added to these themes by fishers as the interviews progressed.

4.3. Stages of research

4.3.1 Stage 1 Participant observation and fishing techniques

The rationale for observing and participating in the different fishing techniques was to comprehend fully the different types of fishing. Without fully understanding the techniques, it would not be possible to understand how they interact with science, technology and governance. Participant observation firstly took place via 10 trips with the low impact fishing technique group, including rod and lining, potting and netting and four with high impact fishers, including forms of trawling and dredging as described in the last section. Two trips took place offshore with a scallop dredger and a beam trawler. Fishing as part of the crew was invaluable to understand in greater depth how fishers develop their LEK. As listed in table 3, the fishing trips continued for a year, on an approximately monthly basis. During participant observation, relevant considerations were recorded using a notebook and camera. They provided a useful reflection point as the research progressed; being continually reviewed and updated as decisions and theories evolved. Secondly, audio observations during participation with fishers were noted using a digital recorder, to be later coded according to the themes identified in the interview schedule. Participant observation relates to the sharing of the activities of the group studied, in this case, techniques of fishing (Goffman, 1968). Use of anthropological ethnographic methods was used to translate between Natural Science knowledge and LEK, for example, to clarify the use of folk taxonomies such as the fishers' identification of species and ecological processes (Berlin, 1992; Ross, 2004). By working as crew, it was possible to gain detailed insights and comprehension into the transformation of living fish into a commoditised raw material through the changing technology of fishing (Marx, 1853: 226). In the UK, Fish are 'ferae naturae', or 'wild by nature', being ownerless until captured. The captor only has a possessory title over fish caught, so if fish are to return to the sea, they become ownerless once more (Halsbury, 2007; Appleby, 2013: 3). Palsson (1998) observed practicing skippers during actual fishing trips and recommended learning via fishing, much like a novice learns from his skipper in the course of production.

Participant observation was first advocated by Bjarni Saemundsson, a pioneering Ichthyologist in the 1890s, who spent time observing various new types of fish on board Icelandic vessels. Saemundsson thought of himself as a mediator between foreign scientists and Icelandic fishers (Aegir, 1921). Participant observation allowed for 'active participation', fully embracing skills and customs for the sake of complete comprehension of tacit knowledge creation (De Walt et al., 1998). Since much of what is learned is tacit and intuitive, translation is the problem (Palsson, 1998).

Through taking part in the practice, greater levels of trust were developed between the researcher and fishers. This resulted in further elicitation of practices to the apprentice fisher researcher, as well as access to apocryphal knowledge relating to aspects of successful fishing, and the ecosystems of the seabed (Vermonden, 2009).

Different sized vessels and organisational practices influenced the dynamics of exploitation and control. This structured antagonism in the workplace is manifested by the social relations between capital and techniques at sea (Edwards, 1990). This aspect was particularly brought to light by the two fishing trips on offshore beam trawlers and scallop dredgers. While the discursively constructed human subjects of constructivism are emphasised to have a 'character of all seeing' through language (Deetz 2003: 424), critical realism recognises that social agglomerations are separate from human actors and these underlying powers. Social agglomerations within fishing techniques do not necessarily make themselves explicit through language, as seen with the division of labour and deskilling (Braverman, 1974).

A classical economic approach to fishing might encourage continual growth with investment in vessel size, labour and technology. Contrastingly critical realism's association with critiques of mainstream economics makes us aware of the tendency of the rate of profit to fall. This can be related to biophysical limits. The extent these limits become apparent as intra - systemic LEK through fishing techniques was a key consideration. Different scales, techniques, and organisations of fishing demonstrated differing attitudes to conservation and ecological sustainability, as discussed in the results and analysis chapters that follow. Participant observation occurred across a variety of specific harbours, marinescapes, habitats, and deployment of gear, described in Tables 2 and 4 on p259. This allowed for comprehension of how practice interacts with the seabed under different conditions. It developed an understanding of how intra - systemic LEK development expands and is limited.

Table 3 Participant Observation of Fishing Techniques

Fishing techniques	**Location**	**Habitats**
Triple otter board trawling	Cornwall / Devon Plymouth Sounds	Sublittoral muds, sands, eelgrasses, rocky reefs
Trammel Netting	Hastings	Sublittoral mud, sands, rocky reefs
lobster / crab Potting	Selsey Bill	Sublittoral mud, sands, rocky reefs, kelp forests
Set nets	Eastbourne	Sublittoral mud, sands, rocky reefs
Triple Otter Board Trawling	Newhaven	Sublittoral mud, sands, rocky reefs
Dredging	Portsmouth	Sublittoral muds, sands, eelgrasses, rocky reefs
Cuttlefish potting	Portsmouth	Sublittoral muds, eelgrasses, rocky reefs
Whelk potting	Portsmouth	Sublittoral muds, eelgrasses, rocky reefs
Scallop dredging	Brixham	Sublittoral muds, eelgrasses, rocky reefs
Beam trawling	Shoreham	Sublittoral mud, sands, rocky reefs

This confirmed the extent of differences between gear user groups with different ecosystems. Some gear groups, such as those towing trawls, were predicted to have less appreciation for maintaining the ecological integrity of the seabed. It was predicted that they were likely to have a less well-developed appreciation for seabed biodiversity and habitats or to see its ecological value, an issue discussed further in the results and the context of the interviewing process.

4.3.2 Stage 2 Interviews with fishers

Interviews were a key research tool in interrogating fisher LEK and the factors that influence its development and exchange. Certain positivists have hypothesised that the dialogical process of interviewing necessarily requires neutral interviewers, careful control of variables, and maintenance of a uniform structure of homogeneous questions, in order to replicate responses and overcome researcher bias (O'Connell Davison, 1994: 117-121). In contrast to this, critical realism acknowledges the importance of dialogue and exchange between interviewer and interviewee. This follows the subject - subject ontology (Sayer, 1984) allowing for mutual learning, or as Engestrom (1987) calls it, the ZPD - with knowledge flowing in both directions. While this relates to the interpretative approach, it is non-relativist in that it remains contextualized within pre-existing social structures and understandings (Smith and Elger, 2012: 6). This is relevant when the respondent does not wish to provide answers to the prepared questions but instead wishes to answer in a novel, relevant if unstructured fashion (McEvoy and Richards, 2006). As this type of interviewing is characteristically qualitative, it allows for greater depth of data with the individual rather than quantitative breadth, providing a more active role for the researcher (Wimmer and Dominick, 1997). Furthermore, while relativist work on social structures from interviewing is based on the constructivist approach, where authors consider that there are no constraints on social action or context, critical realism reflects on the importance of the feedback mechanism (Smith and Elger, 2012: 5). Relating to historical materialism, critical realism considers the interview to be embedded within the causal powers of social relations, affected by the systemic forces of capitalism (Smith and Elger, 2012).

Some argue that due to the small scale of a sample it is difficult to generalise conclusions to larger groups. In regard to the sensitivities of fishers' LEK, an in-depth face-to-face approach is a necessity, especially considering the importance and complexity of local differences. With low numbers of fishing vessels per harbour, each local marinescape, seabed study sites need to be investigated in-depth, both qualitatively and quantitatively. While the open-ended nature of the questions can cause confusion to the respondent in regard to its focus and can take more time to gather and to analyse, it can give respondents a sensation of being able to talk freely (Wimmer and Dominick, 1997). The themes of the questions below were selected according to Braun and Clarke's (2006) thematic analysis. Themes were decided upon after speaking to key informants in relation to significant trends of marine ecosystems and fisheries, as well as an evolving reflexive dialogue on the part of the researcher. After the table which details locations, gear interview length and habitats, the following sections describe in greater detail how the interviews took place.

Participant observation was first advocated by Bjarni Saemundsson, a pioneering Ichthyologist in the 1890s, who spent time observing various new types of fish on board Icelandic vessels. Saemundsson thought of himself as a mediator between foreign scientists and Icelandic fishers (Aegir, 1921). Participant observation allowed for 'active participation', fully embracing skills and customs for the sake of complete comprehension of tacit knowledge creation (De Walt et al., 1998). Since much of what is learned is tacit and intuitive, translation is the problem (Palsson, 1998).

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Table 4 Interviews with fishers, locations, techniques, organisational background and habitats

Where	**Fishing techniques**	**Organisational Background**	**Habitats**
Hastings	Trammel nets – flatfish	Independent skipper	Gravel, mixed sediment, shingle
Cornwall / Devon	Otter board trawl, scallop dredger, beam trawler	Independent skipper	Sand, gravel
Cornwall / Devon	Otter board trawl, scallop dredger	Independent crew member, family group	Sand, Gravel
Shoreham	Beam Trawl	Non- owner crew part of large corporation	Sand, rock
Portsmouth	Whelk potting / clam dredging	Non-owner skipper part of large corporation	Mixed sediment, rocks, reefs, eelgrasses,
Portsmouth	Cuttlefish potting	Independent Skipper	Mixed sediment, rocks, reefs, eelgrasses,
Brixham	Otter board trawl	Non-owner skipper part of large corporation	Mixed sediment, sands, reefs, rocks
Eastbourne	Trammel nets - Skates and rays	Independent Skipper	Mixed sediment, rocks, limestone reefs
Shoreham	Lobster and Crab potting	Owner of several vessels	Mixed sediment, sands, reefs, rocks
Portsmouth	Whelking, crabbing	Non-owner crew part of large corporation	Mixed sediment, rocks, reefs, eelgrasses,
Newhaven	Trawling	Independent Skipper	Mixed sediment, rocks, reefs,
Selsey bill	Lobster, crab potting, netting, trawling	Independent Skipper	Mixed sediment, rocks, reefs, ledges, holes

Selsey bill	Lobster, crab potting, netting, trawling	Independent Skipper	Mixed sediment, rocks, reefs, ledges, holes
Portsmouth	Whelking	Non-owner crew part of large corporation	Mixed sediment, rocks, reefs, eelgrasses,
Portsmouth	Beam trawling	Non-owner crew part of large corporation	Mixed sediment, rocks, reefs, eelgrasses
Ramsgate	Tangle netting	Independent Skipper	Gravel, mixed sediment, shingle, chalk reefs
Ramsgate	Trawling	Independent Skipper	Gravel, mixed sediment, shingle, chalk reefs
Southend	Trawling	Skipper and owner of several vessels	Mud flats, mixed sediment
West Mersea	Trawling, potting	Non-owner crew part of large corporation	Mud flats, mixed sediment
King's Lynn	Trawling	Non-owner crew part of large corporation	Mud flats, mixed sediment, sabellaria reefs
King's Lynn	Trawling, Long lining	Independent crew family members	Mud flats, mixed sediment, sabellaria reefs
Great Yarmouth	Long lining	Independent Skipper	Mud flats, mixed sediment, sabellaria reefs
Great Yarmouth	Potting, Long Lining, Trawling	Skipper and owner of several vessels	Mud flats, mixed sediment, sabellaria reefs, chalk reefs
Lowestoft	Long Lining	Independent Skipper	Mud flats, mixed sediment, sabellaria reefs,
Lowestoft	Trawling	Non-owner skipper part of large corporation	Mud flats, mixed sediment, sabellaria reefs,
Whitstable	Cockle Dredging, Trawling	Independent Skipper	Mud flats, mixed sediment, chalk reefs
Whitstable	Cockle dredging, trawling	Independent Skipper	Mud flats, mixed sediment
Whitstable	Potting, dredging, trawling	Independent Skipper	Mud flats, mixed sediment
Weymouth	Trawler	Independent Skipper	Maerl, sandstone reefs and ledges, mixed sediment

Weymouth	Bass rod and line	Independent Skipper	Maerl, sandstone reefs and ledges, mixed sediment
Looe	Long lining	Independent Skipper	seagrass beds, sheltered muddy environments and large subtidal sediment banks and reefs
Falmouth	Scallop dredging, trawling	Non-owner skipper part of large corporation	Seagrass beds, maerl, rocky reefs, mixed sediment
Mevagissey	Ringnetting	Independent Skipper	Rocky reefs, mixed sediment
Mevagissey	Ringnetting	Independent family crew	Rocky reefs, mixed sediment
Newlyn	Potter, netting	Independent Skipper	Rocky reefs, mixed sediment, seagrasses, kelp forests
Brixham	Beam trawling	Non-owner skipper part of large corporation	Rocky reefs, mixed sediment,
Brixham	Beam trawling	Non-owner crew part of large corporation	Rocky reefs, mixed sediment,
Brixham	Scallop diving	Independent skipper	Rocky reefs, mixed sediment,
Beesands	Potting	Independent skipper	Rocky reefs, mixed sediment,
Dungeness	Trawling potting	Independent skipper	Mixed sediments, gravel
Hastings	Potting, netting	Independent skipper	Mixed sediments, gravel
Newhaven	Beam Trawling, Netting	Independent skipper	Mixed sediments, gravel
Plymouth	Rod and Lining	Independent skipper	Rocky reefs, mixed sediment
Plymouth	Rod and Lining	Independent skipper	Rocky reefs, mixed sediment
Axmouth	Potting, netting	Independent skipper	Rocky reefs, mixed sediment
Chichester Harbour	Dredging, trawling	Independent skipper	Seagrasses, sublittoral muds, mixed sediments
Chichester Harbour	Dredging, trawling, potting	Independent skipper	Seagrasses, sublittoral muds, mixed sediments,
West Bay	Scallop diving	Independent skipper	Rocky reefs, mixed sediment
West Bay	Netting, potting	Independent skipper	Rocky reefs, mixed sediment
West Bay	Netting, potting	Independent skipper	Rocky reefs, mixed sediment
Lyme Regis	Scallop diver	Independent skipper	Rocky reefs, mixed sediment
Lyme Regis	Scallop diver	Independent skipper	Rocky reefs, mixed sediment

Lyme Regis	Scallop diver	Independent skipper	Rocky reefs, mixed sediment
Lyme Regis	Static gear	Independent crew	Rocky reefs, mixed sediment

4.3.3 Stage 3: Key informant interviews

In order to gain a greater understanding of the ways that governance interacts with the fishing industry and fisher LEK of the benthos, further interviews were required with those working in marine governance, the Non-Governmental sector, as well as non-fisher fishing industry representatives. Those interviewed were selected via email to their organisation, via reputation, or meeting them previously at an event. Key informants gave insight into community pressures and the human geographical differences around England. Interviews included the representatives from the IFCAs who specialise in inshore fishing enforcement of bylaws to control fishing effort seasonally. This includes timing of oyster harvesting, as well as ensuring the right aged and sized lobsters are landed. They also specialise in bylaws and enforcement to ensure that MPAs are protected. For example, the Kingmere chalk and sandstone reef are now zoned to ensure towed gear is not used, supporting the benthic nesting and breeding of Spondyliosoma cantharus black sea bream. Given their continual scientific research on MPAs, species, and habitats, it was important to ascertain the extent their research programmes explained their programmes and more importantly integrated fisher LEK of the benthos. Similarly, Natural England continues to be the primary advisor for marine ecological research on MPAs. Working closely together with the IFCAs, they carry out the majority of habitat monitoring and have the only scuba diving teams to assess the benthos. While not enjoying a face to face enforcement role with fishers, their research does occasionally involve them. Thus, it was important to ascertain the extent they integrate and validate their benthic LEK. Next considered was the MMO. Like the IFCAs, the MMO has enforcement officers around the different coastal regions of England. Differently, they do not enjoy the benefit of enforcement boats or diving inspectors. They enforce aspects of CFP law, including discarding, gear usage, and over-catching quota. They inspect the local fish markets to ensure standards. Importantly they also oversee marine licensing and marine planning. The extent the MMO is able to integrate fisher LEK in these different domains will be investigated. The MMO is supported by Cefas, who are the primary scientific advisors for fisheries and other impact assessments. Cefas provide onboard vessel observers, such as to inspect the new discard ban which sees a landing obligation of all fish caught. The extent that Cefas are willing to involve fishers and their LEK of the benthos will be shown. Semi-structured questioning of a Devon Biosphere Reserve manager also took place regarding how and if the Biosphere Reserve project aimed to integrate or involve fisher LEK. A DEFRA representative was interviewed regarding how the current governance system validates fisher LEK of the benthos. How they envisioned increased participation in the future was investigated, as well as how biodiversity and ecosystem services were understood during DEFRA MPA economic impact assessments.

From the Non-Governmental Sector, a representative from the New Economics Foundation was interviewed. Regarding how their mission statement, which aims to develop a new economy where people are really in control could emerge, questions were raised relating to inshore fisheries, social and environmental justice and the governance of benthos. Greenpeace was questioned specifically how their campaign to see a redistribution of quota to the inshore fleet might influence understanding of the benthos, and their perspectives on the discarding ban plan. The Blue Marine Foundation was interviewed in relation to the Lyme Bay Reserve project. They were asked about the extent the research and governance taking place were thought to be influencing fisher LEK of the benthos. Other key informants included those working directly for the fishing industry. Representatives from the Fishermen's Associations and Protection societies were interviewed regarding their experiences of scientific research, technological change and the governance of the benthos. Similarly, representatives from FPOs were interviewed on these themes. They were particularly asked about the quota system and the inshore fleet, as well their interactions with scientific research. Also interviewed were leading representatives from the fisheries social movements, namely NUTFA, and the Fishing for Leave groups. This was to find out how their alternative visions interacted with how fisher LEK of the benthos was changing, and how governance influenced this.

Authors such as Tremblay (1957) describe key informants as part of the traditional anthropological process; of crucial importance in order to gain insight into the organisation, economic system, political structures, and practices surrounding a specific human activity. While the emphasis is on qualitative aspects, quantitative aspects of the group can also be gained, such as changes in demographics, trends in quantities of species caught over time, changes in running costs, and market fluctuations over time.

Table 5 Key informant interviews

Organisation	Topic focus	Where	When	Length
Sussex IFCA	MCZ management and participation	Shoreham	April 2013, August 2016	1.5 mins 46 mins
Greenpeace	Bycatch and discarding	London	May 2013	1 hour
MMO Newcastle	Fixed quota allocation system	Newcastle	May 2013	1.5 hours
MMO Plymouth local office	Fisheries quota and participation	Plymouth	April 2014	40 minutes
NUTFA with DEFRA and MMO	Fisheries quota and participation	Plymouth	September 2014	1.20 minutes

NUTFA	MCZs Quota system and participation	Ramsgate	April 2014	1.5 hours
Cornish IFCA	MCZs and participation	Newlyn	April 2014	1 hour
Portsmouth independent fishers with DEFRA, MMO, and IFCA	MCZs and perceived economic impacts	Portsmouth	June 2014	2.5 hours
MMO enforcement	MCZs and enforcement issues	Newlyn	April 2015	1 hour
Blue Marine Foundation Local fishers	MCZs and participation in research	West Bay	June 2015	1.5 hours
Devon IFCA	MCZs	Brixham	May 2015	1 hour
Southern IFCA	MCZ participation	Poole	April 2016	1 hour
New Economics Foundation	Quota system and participation	Lewes	May 2017	1 hour
Eastern IFCA	MCZs Quota system and participation	King's Lynn	June 2017	40 minutes
Coastal Producer Organisation	Quota system and participation	Bristol	June 2017	1 hour
Devon Biosphere Reserve	MCZs Quota system and participation	Barnstaple	July 2017	1 hour
Fishing for Leave	Quota system and participation	Ramsgate	August 2017	1 hour

Such key informants can be interviewed intensively over time to gain a fuller understanding of a group and at the same time as other members of the group, such as when meeting with other governmental stakeholders or fishers. The researcher attended meetings such as Marine Conservation Zone impact assessments, the Lyme Bay Reserve, and the Chichester Harbour Partnership Initiative. Interviews with specific key informants followed up specific gaps about governance, such as when unclear from interviews with fishers.

A list of key informants is contained in Table 5. Reading Frey and Oshi's (1995) work brought the researchers' attention to the dangers of disruptive group dynamics. Awareness of the backgrounds of key informants such as local opinion leaders, their interactions with scientific research, and the extent of its influence and their response patterns to it, allowed the researcher to amend interview questions in order to focus more effectively on the key themes. To be able to do this, the approval of fishers and key informants was necessary through consent forms. (See section 4.6 on Ethics).

4.4 Key themes addressed in interviews

4.4.1 Scarcity and abundance

It was an a-priori assumption that with their focus on single species stocks, consolidated by the single species quota system (Cancino, 2007), fishers indeed had an appreciation of the ecosystems around their hunting targets. This inductive theorising was derived through autobiographical knowledge, reflection, and reflexivity during the case study research. Fishers were questioned about the scarcity and abundance of species, and how these trends have changed over time. Interviews began with a focus on the fishers' appreciation of the benthic ecosystem through their target species. This included predator-prey relationships in the associated food chains. Regarding these species associations, environmental and ecosystem signals relating to different seasonal changes were noted as significant for the ecosystem approach. Significant behavioural changes were recorded, such as spider crabs appearing in great numbers in September, new invasive species arriving (Molnar, 2008), or spring temperature changes affecting migration and abundance are important for adaptive management (Olsson, 2004). These patterns may relate to why fishers work specific locations, at specific times of the year, which relates to their understandings of marine habitats. This depended on the gear type deployed, for instance, investigating cuttlefish potters' understanding of cuttlefish predators. Fisher's awareness of signals of abundance was the second subject that was probed, as it seemed an unobtrusive line of questioning via which to broach the subject of scarcity. Abundance was explored over time or diachronically in regard to species found alongside the focus genus. The extent to which associated species of flatfish, such as starfish or dogfish, skates, and rays, or species fulfilling similar niches to the target were considered. Questions investigating aspects of scarcity followed in regards to those benthic species which have disappeared or become rare, such as angel shark, skate and ray, conger eel and wolfish, which led to respondents discussing their reflections on trends in biodiversity.

4.4.2 Seabed characteristics

It is recognized that geophysical features are important in determining the nature of biological communities (Stelzenmoller et al. 2008). The ways in which different types of gear change seabed features through fishing techniques was an interesting issue on which to elicit fishers' views. How differences in tidal stress, estuary mixing, rocky ground, gravel beds, sandy conditions, and muddier marinescapes create different habitats for different species is a topic not covered previously in the literature. How these aspects are known to link, through such concepts as blue corridors, is discussed in chapters 5 and 6. In addition, the ways in which depth influence habitats and ecotonal zones link these subtle marinescape shifts, mixing habitat patches, were investigated. Also, the ways in which ecotonal zones are changing due to the influence of climate change was of particular interest. Other submarine landscape concepts investigated included gradual changes in habitat, such as ecoclines, and how ecoclines and ecotopes appear to influence both habitats and biodiversity.

4.4.3 Seabed habitats and biodiversity

Interviewing fishers regarding biodiversity was a core research aim, as fishing is understood to be one of the key anthropogenic drivers decreasing species richness (Costello, 2010). With certain benthic species becoming rarer due to the impacts of bottom trawling by-catch, techniques which are not species specific in their targeting needed critical investigation. Structurally complex habitats and those that are relatively undisturbed by natural perturbations such as deep-water circalittoral muds are more adversely affected by fishing than unconsolidated sediment habitats that occur in shallow coastal waters (Jennings et al., 1998). These habitats also have the longest recovery trajectories in terms of the recolonization of the habitat by their associated fauna. Comparative studies of areas of the seabed that have experienced different levels of fishing activity demonstrate that chronic fishing disturbance leads to the removal of high-biomass species further up the food chain. Consideration of these impacts through fishing techniques was probed; alongside the extent to which they can inform understanding of other disturbances in terms of socio-ecological resilience (Kinzig, 2006).

Of particular interest are habitats such as limestone reefs, sandstone reefs and other geological forms of the reef with higher rugosity, which give rise to high biomass and rich biodiversity (Boulcott and Howell, 2011). An appreciation of the factors which promote the health of nursery grounds for target species such as cod, and why certain conditions are best suited for species at different ages, were elicited successfully. Questioning the tactics employed for protecting these areas which are crucial in allowing juvenile fish to develop was also important, as well as how this led to knowledge sharing in the fisher community. In regard to these habitats, an appreciation of the specific factors which give rise to nursery grounds, such as cobbled boulders, and why certain conditions are best suited for specific species at different ages, were investigated. Questioning the tactics deployed for protecting the development of nursery areas was important in terms of the influence of knowledge feedback, fisher reflection on practice, as well as knowledge sharing within the fisher community.

4.4.4 Sessile species and biogenic reefs

Although dragging fishing gear along the seabed may be de-minimus or within background levels in certain conditions, bottom trawling may be deleterious to biogenic reef species. Habitat creating species such as ross worm (Sabellaria spinulosa), mussel beds (Mytilus edulis) seagrasses, (Zostera marina) and maerl (Lithothamnion corallioides) are known to support biomass and biodiversity (Reisen and Reise, 1982, Hall Spencer and Moore, 2000, and Kamenos et al. 2004). This linked to questions regarding an appreciation of which sessile species are involved in creating and maintaining the habitat, such as seaweeds, oysters, mussels, or rarer species such as seapens. How fishers understand the impacts of their gear relative to the capacity of these species to continue under disturbance is further elucidated in the following chapters.

4.4.5 Human nature relations

Seasonal patterns provide the logic of why fishers work certain locations at different times of the year, which relates to their understandings of habitats. This line of the investigation focused on how fishers have identified spatial locations for fishing. Attempts were made to gain an appreciation of the fishers' detailed knowledge of which environmental factors create these optimal local habitats for different seabed species. In addition, how fishers perceive species that are of little or no economic value was of interest. Species supporting ecosystem functions and other species important ecologically which are not perceived to be instrumentally valuable were also discussed (Ray, 2013). The conception of the intrinsic value of biodiversity was also an interesting matter to explore with fishers, in regard to how species diversity supports the continued health and resilience of the entire ecosystem (Justus, 2009). While fishers might consider predators of their chosen target species as pests, how this is changing in regard to assessing overall ecological health from such sources as scientific knowledge, was intriguing. These apex predator species such as dolphins, seals, and arguably spider crabs, have been traditionally conceived as a nuisance by fishers. How fishers attempt to control their populations in light of research interactions was investigated. Where fishers' understanding of the risks of decreasing biodiversity may not be as high as the researchers', a critical pedagogical exchange took place. In the past, where fishers' actions were ongoing without reflection, as Freire discussed in 1970, this research shows that debate of fishers' considerations, and the extent to which they now value biodiversity, has positively developed, as shown in Chapter 5.

4.4.6 Influence of the scientific knowledge system and governance

New knowledge from the designation of MPAs in local fishing areas could be argued to be changing fisher knowledge of biodiversity and habitats. While Agrawal (1995: 2) argued that differentiation between Western and traditional knowledge systems has been overplayed, the current research looks at how conservation programmes using towed cameras for habitat identification integrates these systems and the associated power relations. Considering historical periods of scientific knowledge, Foucault (1966) described these shifts as epistemes of understanding. The following chapters show how the influence of scientific research is changing LEK through fisher involvement and examines whether we are seeing an emerging period of more in-depth comprehension of habitats and biodiversity. Using Sayer's (1984) critical realist approach to different hierarchies of knowledge supported analysis of the extent to which governance is now taking LEK seriously and examines the consequences of this. Fishers have been particularly interested in relying on LEK to highlight disturbance from competing pressures. Impacts upon ecosystems include offshore fishing practices, port development, dredging and marine aggregate collection. This relates to the new theorisation of LEK beyond the GHK described by Murray et al. (2006). Technologies utilised by industrial fishing have energised the use of LEK in the social movement of NUTFA. How groups such as Greenpeace have been influencing perceptions of low impact fishing and its relationship to coastal communities is analysed in chapter 5. Research programmes are evidently changing fisher terminology, seeing insular local learning becoming increasingly fluent with the scientific challenges of the benthos. Different experiences with Cefas stock assessments of fish are analysed in regard to perceptions and understandings of scarcity, biodiversity, and discarding of catch. Investigation of co-management in oyster stocks in Chichester harbour is a relevant case considered in the analysis section. Benefits from conservation programmes depend on the success of the IFCAs in increasing fisher participation. The influence of different forms of social organisation on fishers engaging with conservation is examined in the light of the differences between the organic associations and cybernetic organisations described by Johnsen et al. (2009). How this relates to participation in governance and the impact of pollution on the marine environment will be questioned. How groups such as the Lyme Bay Reserve have encouraged a changing means of knowing through stakeholder exchange is also reflected upon. Furthermore, how fishers from different gear groups perceive the interactions between their gear use and scarce marine habitats are becoming increasingly important. With 50 of 127 conservation zones designated, the benefits of and barriers to critical engagement are unfurled in the following chapters.

4.4.7 The influence of the market

With current UK neoliberal economic policy focused on short-term economic growth, many conservation features remain under threat (Jones, 2014). How bodies such as the MMO and the local bylaws of IFCAs are adapting to the need for protection from fishing is being influenced by different social organisations, and in regard to the specific gear, types are investigated in later chapters of this thesis. The extent to which fishers' behaviour is irrevocably influenced by neoliberal ideas about access to marine resources is discussed in relation to the fishers' own unique way of knowing about their harvest grounds (Reed, 2013). Fishers' sensitivity to their environment and the extent to which they are able to comprehend these aspects through the sensory medium of fishing techniques were also examined. In addition, the ways in which different forms of organisation have become dominant through the market have been highlighted, and the relationship to scientific knowledge is discussed. The interactions with the pressure on fishers to compete for a catch in the commons is a continuous theme and interrelated with key research questions such as how fisher LEK is developing, how technology is changing, the influence of social organisation, and fisher interactions with scientific research. The key questions asked are dealt with in the appendix in section 3. Semi-structured interview questions regarding seabed ecosystems.

4.5 Analysis

Analysing the interviews was supported by Hay's (2005) work, which outlines a two-step process - commencing with basic coding in order to distinguish overall themes. Firstly, interview notes were transcribed digitally. Overlaying the approach is a critical realist approach to analysis, through critical realism's focus on the search for causation. It allows for the identification of demi-regularities, abduction (also known as theoretical re-description), and retroduction during analysis (Fletcher, 2016). As introduced in the interviewing section, narratives were first selected through Braun and Clarke's (2006) and Clarke and Braun's (2014) thematic analysis. In 2006 the authors identified that thematic analysis is widely used but has previously been under-acknowledged. Thematic analysis leads to making choices which need to be made explicit and considered before analysis. In this chapter, section 4.4, Key themes addressed in interviews made explicit these choices. The themes capture the significance of patterns in the data that relates to the research question. The data set may demonstrate a patterned response or meaning, which is important to code according to the research question. It is not important if the theme is present in 50% rather than 47% of one's data set, being a qualitative approach is to be determined by the researcher's judgement. In the case of critical realism as the research epistemology informing the meaning of the data, theorisation of motivations experience and meaning is straightforward, as realist approaches assume a unidirectional relationship between meaning, experience, and language of those interviewed (Potter and Wetherell, 1987). Thematic analysis begins with data collection through writing notes, not at the end as with statistical or other quantitative approaches. Ensuring that transcription was accurate meant writing out the material verbatim. While the majority of the interviews were transcribed from the digital recorder, notes were also made at sea, interviewing fishers whilst working or chatting at in the wheelhouse. A first attempt was made using Nvivo, however, the richness of the fisher technique terminology meant the computer struggled with the grammar and unknown words. It required an orthographic transcript that is a spelling out of all verbal and non-verbal utterances. Nvivo was also less useful as it turned out that writing out the interviews allowed for greater reflection in depth. While contestation on the significance of the validity of qualitative research has continued for years, two schools of thought remain as to the value added by the use of qualitative analysis software (Welsh, 2002). In terms of analysis and interpretation, linking the tapestry of notes together became more efficient on the computer, after written note codification had taken place.

Going over the interview data from beginning to end meant identifying patterns where data was 'messy' or not immediately apparent (Ryan and Bernard, 2000: 780). Indeed, it is a recursive process, needing analysis back and forth through the material. The researcher took the opportunity to do what (Layder, 1998: 41) calls 'pre coding' - highlighting, circling underlining and colouring sections of interview notes that present themselves as immediately relevant and useful. These were then identified and copied under sub-titles of the above themes in 4.4. An example of which was the differences between static and towed gear fishers who after interviewing showed different approaches such as to conservation and other research. Awareness of the potential influence of different geographies around England was important, as they interlinked to other emergent themes. These also included discerning how different ages, (as well as different types of organisations and crew types where possible) led to the selection of quotes.

As all the interviews followed the basic pattern described in 4.4, the sections of the interview were repositioned into these themes which formed the basis of the chapters.

These included:

- seabed habitats and biodiversity,
- interactions with scientific research and bi-directional feedback,
- influence of new technologies, knowledge sharing and interplay with social movements,
- how the market has influenced inshore fisheries and the ramifications for fisher LEK,
- External disturbance to the benthos identified through fisher LEK and its governance,
- Governance of conservation and fisher LEK participation

While the interviews were semi-structured as laid out in section 3 of the appendix, they followed an overarching format based on these themes. When fishers' answers moved from one theme to another according to their flow, the emerging narrative to that theme was linked, by copying and pasting into the appropriate section.

Where elements of the transcriptions did not fit into the described interview themes, they were colour coded for further analysis. Alongside these, the research questions formed architecture for the analysis, with the first question of how fisher LEK is changing continuing throughout, alongside the contribution of critical realism - bringing insight to socioeconomics and the influence of scientific research. The question of how technology and social organisation influence LEK formed the focus of the analysis of the first results chapter. The second results chapter relates to the inductive analysis of emerging local ecological themes, drawing attention to aspects that were not predicted in the interview structure, such as aggregates and port development. The inductive approaches' primary purpose is to allow for analysis to pick up recurrent, persistent elements found in the raw data, beyond the restraints of the structure of this thesis (Thomas, 2006). This work examined some of the ecological challenges to the benthos external to fishing that interviewees, based on their LEK, drew attention to. These external impacts to ecosystems including aggregate extraction, port dredging, wind farms, and outfalls were also discussed with key informants. Key informants included those from the IFCAs, the MMO, Natural England, Greenpeace, Blue Marine Foundation, The New Economics Foundation and individuals working within fishermen's associations and Producer Organisations as detailed in table 5. These supported the analysis by providing further insight from different perspectives from governmental NGOs, or an industrial fishermen's perspective. This meant key informant interviews focused on a particular theme, such as governance of conservation and fisher LEK participation with the IFCA or Natural England in that region. The reflections of harbour masters and those in aggregates were given credence to ensure that pro fisher bias did not occur. Whilst the author went into the research aware of personal bias against activities disrupting marine conservation, this bias was overcome. The anticipation of conflict of interest between forms of dumping, dredging, and fishing, meant effort was made to ensure all sides of the story were taken into account. Similarly, judgment had to be reserved on the preconceived impacts of industrial forms of fishing on benthic ecosystems in order to not bias the analysis. Inevitably, the logic of these questions has influenced the elicitation of the fishers' responses to these issues and their reflections upon them. At all times the substantive conclusions of fishers were represented, however. These key informants influenced the direction of the analysis, such as reflecting on how the quota system has evolved into a commodity market rather than simply conserving ecosystems, and the resultant influence upon fisher LEK. Similarly, that while governmental scientists are becoming more aware of the importance of making the research participatory, they were also explicit about their own preconceived notions of the validity of fisher LEK of the benthos.

4.6 Ethical research approval and ethics

It is important to remember one's power over the interviewee's response, and its use through codification. Interviews which are based on a relationship of power have the potential for the infraction of human rights (Fletcher, 1992). The ethical approval process saw the project objectives and questions presented to an ethical approval board. Researchers can realise their obligation to ethics by being aware of the power they wield, and their obligations regarding adherence to the relevant ethical standards framing the area of study (Bhopal, 1995). Ethical dilemmas included ensuring there was no bias against older or younger fishers, fishers from the towed gear sector of whom which the academic literature describes as more ecologically disturbing, or against those from the larger fishing businesses after key informants from inshore fishing described them as unjustly rewarded with fishing opportunities.

Adherence to research ethics was achieved firstly by informing fishers about the nature of the present research regarding the investigation of their LEK. While sometimes fishers approached down the harbour were busy repairing gear, or exhausted from a night of fishing, the researcher offered to come back at a better time when more appropriate. Generally, fishers approached were pleased to talk about their expertise, or happy to rearrange for a better time. It is important to note that interviewees should not be exploited for personal gain (Anderson, 1991). Fishers were typically happy to be gifted a pint, or be helped on the boat whilst at sea, by gutting fish, sifting through debris, hauling gear, deploying a trawl or other forms of gift exchange in exchange for being interviewed. Many fishers were very pleased to have their voices taken seriously during the process of explaining the ramification of taking part by reading and signing the form and listening to the implications. They were all made aware they were being digitally recorded. Retrospectively getting fishers to sign the consent form on page 226 was one of the more challenging aspects of this study, as not all were literate, some had difficulty writing, or had to find their glasses. On certain occasions, the researcher had to return to the form at a later time. The ethical approval form is attached in part 3 of the appendices. Ethical approval was granted by the ethics committee of the School of Environment and Technology at the University of Brighton. Recognition of the fishers' contribution was made in the acknowledgements at the beginning of the thesis. Ethical standards relating to interviewees' anonymity was achieved through the use of pseudonyms, identifying them only by fictional names or by mentioning their organisation (Mero-Jaffe, 2011). The following chapters provide analysis of the findings of the study and theorise answers the research objectives and questions.

Chapter 5 Fisher LEK of the Benthos, Local Learning, and Interactions with Scientific Research

5. Introduction

Fisher LEK of the benthos is irrevocably changing through shared learning with scientific research. How fisher LEK is used, shared, withheld, and adjusts according to these interrelations is described here. The context of new scientific regulations of the EU CFP for by catch and discarding and quota assessment is important here, given it is ultimately managed from Denmark and Brussels. Also important is the context of the growing number of MPAs primarily driven by EU legislation. The chapter presents the results of the fieldwork, beginning with participant observation on fishing boats; interviews with fishers; and follow-up discussions with key informants. There are four chapters to present findings: the first on the development of fisher LEK in Southern England; the second on how technology is influencing LEK; the third on governance, quotas and social organisation in relation to fisher LEK; and the fourth on the interaction between participation in conservation and different forms of marine governance and fisher LEK. In this first of four findings chapters, exemplary quotes were selected relating to the core research question of how fisher LEK of the benthos has developed in recent times, and how this informs the re-theorisation of LEK. Fisher quotes were selected according to what Braun and Clarke (2014) describe as thematic analysis. An equal spread of interviews from static fishing techniques and towed techniques were coded according to the themes. The sub-themes of the interviews considered included age demographics, regional differences, gear differences and whether the fisher was skipper or crew.

The chapter begins by examining how fisher LEK of the benthos is built through assessments of bathymetry, environmental signals, species and temperature over the seasons. It goes on to examine how fisher LEK understands biodiversity and invasive species. It goes on to explore how fishers have been involved in scientific research and the bi-directional from fishers back into research. The extent that marine research is increasingly inclusive of fishers, making them more familiar with the language and methods of marine research is relevant to how benthic fisher LEK is changing. The chapter will conclude whether there is a conscious effort or not by those involved in research to support this learning feedback through the ZPD. The following section explains how this changing influence from research is developing.

5.1. The changing influence of scientific research on LEK

This section considers the influence on fisher LEK from fisher research involvement and the consequences for its evolution in regard to ecological understanding and sustainability. Historically, fishing communities were geographically isolated and insular to other forms of learning. As Polanyi (1967:4) highlighted as "we can know more than we can tell'. As one Icelandic skipper explained in relation to tacit knowledge: "it's so strange when I get there it's as if everything becomes clear. I might not be able to tell you the exact location, but once I'm there it is as if everything opens up" (Palsson, 1998: 53). In some of the cases presented below, interaction with scientific research has made fisher LEK, what Hoefnagel et al. (2006: 88) call discursive knowledge. The extent that inshore fishers lack access to scientific knowledge systems due to their marginalization from fisheries management will also be presented (Jentoft and McCay 1995).

With the expense and difficulty involved in accessing the seabed, the benthos has traditionally been excluded from much scientific research (Steinberg, 1999). Indeed Palsson (1998:49) emphasises that multi-species ecosystems are highly unpredictable, with constant fluctuations in interactions between species and habitats making governance more effective on a finer spatial scale. In consensus, a paper by Johannes in 1998 highlighted that fisher LEK can fill knowledge gaps that science cannot, such as to gain these finer spatial scales.

While fishers historically remained in isolation in terms of relying on local learning, today taking part in different types of research has led to a changing vocabulary and appreciation of scientific methods. Considering a variety of research projects, this section highlights the influence upon fisher LEK at a local scale, and bi-directionally, the influence of fisher LEK upon scientific research (Engestrom, 1987). In relation to how involvement in research has changed, the following fisher brings insight from how the recording of the benthos and navigation has developed. The effort required to learn the grounds and knowledge of these benthic ecosystems have historically been very difficult, as this younger static gear skipper Jowan explained:

> Prior to Decca everyone used landmarks, the information of where to fish was actually handed down to me by an old fisherman in Mousehole, take Paul Church on a particular hill, steam off on that mark, Praas Sands hotel on a particular headland, those two transacts would put you exactly where you wanted to be (Jowan).

The recordings used to be typically shared only with the crews of the boats and apprentices. This capacity to hold secrets was accompanied by the historic difficulty in recording LEK. With knowledge now being easier to record on computers, and habitats easy to return to, there is more sharing. This new openness about bathymetric knowledge of the benthos has led to this fisher providing input into scientific surveying. The same fisher gave a clear presentation of water circulation flow and its relationship with bathymetry to the benthos on Jones' Bank:

> We carried out fisheries science with Cefas, some of our boats did benthic and pelagic surveys around Jones's Bank about four years ago for Aberdeen University. We were looking at the whole ecosystem from the bank to the surface and were really interested in the way that the banks affect water circulation and flow, and how that affects biomass right from the planktonic level, right up from there up the food chain (Jowan).

The above quote shows the detailed level of bathymetric and benthic knowledge recently available. Thirty years ago, there was not the same type of accurate technology or the scientific attempts to assess the inshore habitat dynamics or to involve fishers in doing this. The following example of researchers from Aberdeen involving fishers shows how much this has changed, technologically and in terms of involvement of fishers.

The extent to which this fisher was able to understand and describe this research to those in fisheries governance influenced the extent to which he is taken seriously, and in turn, the influence he has on the Cornish Fish Producer Organisation. As a younger fisher and public representative of Newlyn's fishing community he is unusually open, and more used to interacting with research than some of the older fishers. As someone who works with NGOs, governance and scientists and others he is unusual. Nevertheless, while only a part-time fisher, he encourages other fishers in the community to take part in such projects. As an industry knowledge bridge, he shares research knowledge in the wider community and seems to be positively encouraging both conservation research and fishing. As a static gear fisher, he seems more open to scientific research, as recent reports have emphasised the damage caused by towed gear. In 2016, the Cornish port of Newlyn landed 4,008 tons of fish, second in England to Brixham during the January to April period. Newlyn is an ancient fishing harbour currently dominated by one family and one business. This has led to a consolidation of fishing quota rights within a large beam trawler fleet, and subsequent larger impact on the benthos. It has left the local economy more vulnerable and more dependent on the successes of one company.

The following fisher Derrick from Great Yarmouth as chair of the fishing association was put forward by other fishers in the community as particularly knowledgeable and interested in research. Demographically he is part of the older generation (being over 50). Great Yarmouth's fishing fleet is thought to have decreased significantly, with over 20 boats in 1980, now down to four. By leaving fishers out of planning, its new harbour development has marginalised fishing. In a different way to the only other independent fisher, who is part-time, this fisher has managed to buy a second whelk potting boat as well as a third trawler and has even expanded to work that supports wind farm developments.

> I’ve done work on little terns, on sandwich terns, in regard to collision risk. Cetacean and Pinniped surveys for wind farms. Used to carry out aging surveys with Cefas, cutting out otoliths of cod, we would age them then estimate of weight and length (sic) (Derrick).

Through interactions with different quantitative surveys over the years, this fisher has developed a sophisticated understanding of different population recording methods. This scientific assessment of population accumulated experience has influenced his understanding of populations in regard to scarcity and abundance. He was keen to share the interview with his son Dean, who also had been working on the family fishing boat, to encourage his continuing interest in the profession, as well as to enhance both of their wider knowledge. The benefits of scientific learning through intergenerational transmission are apparent here (in a similar way to Moncrieffe’s intergenerational transmission when considering poverty, 2009).

Due to their interest in contesting the development of offshore wind farms, which remove access to prime fishing grounds, they had developed what they call a new theory with the Great Yarmouth Fisherman’s Association. Regarding the damage caused by tyre reefs, this new theory is intended to understand the environmental pollutant impact of tyres protecting the scouring effect upon wind farm pilings.

> 60000 tyres came loose, Michelin tyres off Florida, they had them tied together to create an artificial reef. They’re now proposing to use them on Scroby Sands, the wind farm to stop the scour at the base of the turbine. I don’t think it’s ethical. They’ve got a trial at the moment. They’ll have decomposed, partly broken down, and the blackening agent and the stuff in them. I’m waiting for an email from [XX] University. I’m worried about the carcinogens. And when that break down the gravity of tyre is 1.02 and that’s just in the water course, nearly buoyant but not buoyant. That’s a cumulative chemical in shellfish that gets passed on to fish. I don’t think that's right; I don't think there have been enough studies done on this. They reckon where they go along they can see bits of dead coral and dead seabed. When tyres do break down, they fluff up, and all the Rayon on them and entrap little creatures. And when they die other creatures go in. The rayon comes out. They roll on the bottom. (Dean).

It appears that Dean, having fully understood the interrelated pressures on the marine environment from artificial tyre reef research, is now working to develop knowledge to improve the health of the system, having enjoyed the interaction with research scientists. He contests the use of tyres for scour protection with the risk of the tyres coming loose. Similarly, the following older skipper Mike from Dartmouth is concerned with intergenerational transmission and sees scientific evidence as an important part of it.

> As I said I’ve got a son who’s 18 who works with me on the boat so it’s not just for me to get another 20 years out of it, we’re looking at the longer picture of the next 40 years for a sustainable fishery which we know we’ve got and hopefully the scientific evidence will come through that it’s a sustainable fishery (Mike).

In previous generations, fishing communities were insular, with knowledge passed down within families, and close kinships. Today, research science among certain fishers is seen as being an important part of this intergenerational transmission. While Sumner et al. (2009) suggest intergenerational transmission with regard to poverty needs consideration beyond material assets; intergenerational transmission of concern for ecosystems is beginning to emerge and would also need to consider different. While this remains unusual, it is part of a growing trend. Next, the chapter examines areas where fisher LEK is compatible with research but is not yet interacting formally. It shows where stochastic interaction is beginning to take place and the ramifications. These examples give a flavour of where fisher LEK is developing and could develop further in future co-production. This helps to understand further what benthic LEK local learning is changing.

5.1.2 Fisher LEK signals, seasons, temperature and the changing interaction with research

Fisher LEK of the environmental patterns that influence fish behaviour is an area which can potentially interact with scientific research. By eliciting LEK, this investigation's questioning has triggered reflection in fishers. When fishers have the opportunity for training to develop methodologies and thus comprehensively record aspects of marine ecosystems, these patterns can be developed further. In Brittany, France, Le Blond et al. (2010) innovatively developed temperature sensors that could be used with fishers to detect patterns. This relates to understandings of the dynamic balance of ecosystem's populations of species, predator, and prey. With the recent discovery that oceans are warmer by 13% through climate change than previously thought, fishers' familiarity with fluctuations is important for population assessments (Cheng et al. 2017).

The following older fisher, Eric, from Plymouth, has been influenced by his leadership role in NUTFA and the emerging Coastal Coop. Being a static gear fisher, he is more open to science which describes towed gear as more damaging. Longer-term fishers have both developed their own patterns of gear choice at different times of the year. Environmental signals such as these are important for fisher learning:

> When it comes up to May we look out for the mayweed, plankton algae growth. It gets all over the nets, all over your fingers (Eric).

The presence of mayweed demonstrates that the algae are reproducing normally and in balanced coordination with the phytoplankton cycle. The temperature is typical for that time of year and that the typical pattern of fish arriving, breeding, and reproducing in different specific localities of the known seabed can be predicted by fishers. This pattern of mayweed was found commonly up and down the south coast. Eric from Plymouth was seen to be particularly knowledgeable by other fishers, because of his long-term experience. The inshore fleet in Plymouth is relatively large being the third biggest in the study area. While the MMO has recorded 117 inshore boats, as detailed in table 6 below, fishers suggest the number to be closer to 35.

Table 6 showing the discrepancy between the recorded totals of fishers in home ports and the observed number of fishing boats

Port	No. <10m MMO data	Observed number
King's Lynn	6	17
Great Yarmouth	22	3
Lowestoft	29	6
Southend	7	5
Ramsgate	23	12
Dungeness	0	3
Rye	14	12
Hastings	71	6
Eastbourne	30	16
Newhaven	30	18
Brighton	24	12
Shoreham	5	16
Itchenor	1	4
Portsmouth	40	25
Lymington	11	8
Poole	70	30
Weymouth	42	20
West Bay	8	12
Lyme Regis	11	12
Axmouth	0	4
Brixham	71	12
Dartmouth	25	24
Plymouth	184	40
Cawsand	0	4
Looe	24	24
Mevagissey	63	42
Falmouth	23	16
Newlyn	170	60

Similarly, an older skipper from Eastbourne, Alan, was recognised as a wise fisher in the local community, and also recommended by others in Hastings. Eastbourne supports a successful fishing community of around 15 operational boats. Over 10m boats are noticeably absent, making it a cohesive community of fishers.

Many of those involved in scientific research programs have been skippers. As they have control and ownership of the vessel they gain more access to knowledge sharing in the wheel-house. This older skipper Alan from Eastbourne explained:

> The migration is triggered by the temperature change; the fish comes in when it gets warmer in the summer from the deeper water (Alan).

The ability to link ecosystem and environmental patterns are important when choosing when and how to fish on the benthos. This LEK interlinks to the knowledge of benthic, demersal and pelagic species' arrival in the water column and denotes climate change. Understanding whether climate change is influencing local environmental conditions beyond normal patterns could be improved by fishers becoming more involved in research programmes. LEK can be instructive in identifying these patterns, given the long-time frames. This is firstly relevant to pelagic species as described by this static gear crewmate from Hastings:

> The mackerel and herring have been coming later, the sea has become exceedingly warm (Sean).

The food chain supporting cod is particularly influenced by the biomass geography of phytoplankton, with southern plankton species thought to be moving north. Unusually for a non-skipper, this crew-mate from Hastings was highly knowledgeable about ecological patterns. Many of the fishers who were forthcoming about their scientific research involvement were skippers, being in a more privileged and empowered position. Hastings, an ancient beach-launched fishing community has according to the MMO database 70 boats, but in reality, 8 are operating. Fishers identified temperature change as significant ecologically across the coasts. A crew of fishers from King's Lynn argued that climate change has influenced cod populations, making them more prevalent in the north of England. A younger part skipper, part crew-mate Kieran explained in King's Lynn:

> There are different species of plankton and different species becoming prevalent, causing the cod to drop off in the south. Southern plankton coming up with the temperature rises, so it's not all the impacts of fishing (Kieran).

The following fishers supported investigations with a BBC research science programme. Phytoplankton biomass is thought to be shifting from climate changing induced temperature change. This experience led to increased understanding developing their fisher LEK:

> We did a programme with scientists measuring plankton for Springwatch, near Minsmere nature reserve. Different species of plankton are becoming prevalent through the temperature change. It's influencing species all the way up the food chain so the cod's dropping off. Southern plankton coming up with the temperature rises, so it's not all the impacts of fishing (Kieran).

The complexities of the population shift of phytoplankton lead to the abundance that in turn influences cod stocks. This was clearly explained by this fisher through his participation in a research study that showed how the local scale is now becoming understood. Kieran was interviewed with his father. Being both crew and skipper, responsibility was shared between father and son, and this younger fisher was enthusiastic about the research programme and more eloquent about the subject. Interestingly he highlighted his feelings that alternative anthropogenic processes beyond fishing are also negatively affecting the marine environment. Similarly, the group of fishers interviewed from Selby raised the natural forces responsible for disturbance to ecosystems. This relates to the fishers attempting to suggest that fishing has less impact than storms. Storm frequency on a local scale can also influence the fecundity and prevalence of keynote species, providing shelter and breeding habitat, such as kelp on rocky reefs, discussed by this older potting gear skipper, Anthony, from Selsey Bill:

> A significant amount of weed ripped off the bottom never seen anything like it. Ripped the entire weed off there from the storms this winter (Anthony).

This loss of seaweed habitat after the shear bed stress acceleration arose from a storm. This older fisher was also keen to involve his son in research. Another older skipper Dominic, who changed over to static gear from trawling, had a similar ecological experience saying:

> A Huge amount of sludge inshore building up, coming from the storms, in the water column. This business of silt, the sunlight can't penetrate. The weed is not growing. You've shallow water here and rocks, and it normally grows like buggery (Dominic).

Fishers from other parts of the country, such as the southwest, also described record high temperatures and unusually stormy conditions leading to similar siltation results.

The following older fisher, Paul, from Portsmouth, also related recordings of population change to temperature change. Scientific co-production of temperature assessments, oyster and clam size and population, and E. coli readings have apparently left this fisher well respected by public health bodies. Again, fishers in the Portsmouth community recommended the older skipper concerned was knowledgeable, trustworthy and wise. He is one of the few remaining independent fishers, the majority of the others employed by one company. Additionally, his temperature assessments, alongside species assessment have allowed him able to make his own hypothesis relating to climate-induced temperature change:

> I think that the temperatures gone down, over the last 8 years got cooler, and that's influenced the breeding of the oyster, they like the warmer water at least 20 degrees. I've been doing temperature surveys for public health now for 15 years, to measure how the oyster stocks collapsed. It's influenced the way I've recorded the data, long-term recording for changing temperatures. We sent old clams used for climate change records, to the University of [ ], they've got a 507-year-old ocean quahog apparently. I think that the temperatures gone down, got cooler, and that's influenced the breeding of the oyster, they like the warmer water. But with the E. coli, that's what the clams eat anyway, silly to close it off for that (Paul).

Unusual patterns of species arriving through climate change can be validated over long time periods; fishers can provide baselines where no others exist, triangulating with unusual weather patterns on a local scale. With the increase in storms and milder winters, the changing influence of the Atlantic Multi-decadal Oscillation and the Gulf Steam is affecting abundance and scarcity of different species (Mieszowska, 2014). Fishers from across the communities reported similarly unusual levels of storms resulting in increased siltation from the 2014 winter. In comparison, Paul from Portsmouth, quoted above, has been recording these temperatures and has created an oyster breeding cycle conclusion. Broad-scale averages of weather and species patterns are not necessarily significant at the local level, and fisher LEK can bring insights to the local spatio-temporal context of climate change impacts. Nevertheless, this needs coordination with a wider scale programme. This is addressed in regard to biodiversity in the next section.

5.1.3 Biodiversity, invasive species and how LEK is changing

While marine biodiversity is thought to be under threat, how inshore fishers comprehend biodiversity through fishing is not well understood. Marine biodiversity was recently mapped globally through the largest historic species survey, the 'Census of Marine Life (2000–2010)' (Costello et al. 2010). While this showed internationally where species and diversity are under threat, fine-scale knowledge of where biodiversity and habitats are changing can be elicited through local scientific research involving fishers. This section shows a bi-directional feedback effect. In recent times the overwhelming influence of the market has influenced the fisher classification system of the perceived value of species. Nevertheless, the interviews show that LEK comprehension of the value of biodiversity varies among different fishers. It is influenced by gear usage and fisher interaction with research. Generally, among those fishers interviewed, biodiversity is seen to be a positive consideration in regard to increased biomass, however, fishers' fluency with the term was limited. Jago an older static gear skipper from Looe attempted to define the term:

> Biodiversity? It's got to be good, hasn't it? It all concentrates on feed, whiting, and mackerel together, if you find one sort of fish you'll generally find others. If there's a mixture of feed, it's got to be good. (Jago).

This positive conception of biodiversity was broadly expressed across different locations. While there was a wide consensus that local conservation research is needed to maintain biodiversity, it has also been shown that fishers can over-exploit the biodiversity, for example of Sabellaria reefs through trawling causing collapse (Riesen, and Reise, 1982). Awareness of gear impacts to habitats, such as Sabellaria, was generally limited, as demonstrated by this older towed gear skipper from Southend, Richard.

> All sorts of funny creepy crawlies, better biodiversity. If you tow into it, you'll break the nets up. You'll fill the nets up once it's grown up (Richard).

This quote shows a somewhat anthropocentric approach to biodiversity, focusing on the damage caused to nets. This is a typical example of fishers' approach to biodiversity from towed or industrial gear, more commonly found associated with larger fishing businesses. When questioning fishers about the biodiversity impact from trawling during participant observation, the conversation became heated and argumentative. Fishers would often deny impacts to biodiversity. With regard to the impacts of industrial fishing, from the researcher's observations, it appears that techniques of beam trawling and scallop dredging are designed to move into new areas and this causes negative impacts. There is an established critique of the ecological impact of trawling and dredging in the literature (Grieve 2014). Thrush and Dayton (2002) identified that the unselective targeting of seabed species by towed gear reduces biodiversity, with recovery taking decades in biogenic reefs (Kaiser et al. 2006). Within sublittoral muds where the majority of organisms are below the surface, bioturbators such as burrowing shrimps and echinoids are damaged, which are important in maintaining infauna diversity. In reef and cobbled benthos and mixed sub-strata, towed gear can reduce the spatial complexity of the habitat by destroying epifaunal structural species including anemones, bryozoans, and sponges (Widdacombe et al. 2004). From the researcher's own participant observations, static gear is more selective, and its impacts can be more easily assessed and predicted. Further participatory research with fishers using static gear is needed to explore these interactions in more depth.

Unsurprisingly in the towed gear sector, the impacts of trawling and dredging on biodiversity are contested, particularly if fishers have not been involved in research. Involvement in research with these fishers can produce increased reflection upon their practice. The following is my reflection on the process:

> My first group experience of this saw a cacophony of fisher voices arguing with government conservation scientists, over the methods used to determine impact assessment upon the benthos. It demonstrated to me quickly how important socioeconomics would be in influencing how they would accept research and integrate it with their LEK. It was evident that how they were looking to learn to gain power and influence.

Similarly, a middle-aged trawler skipper, Scott, from Portsmouth, protested during an MPA workshop that the trawling method is an appropriate method for testing the existence and location of sessile species, including the peacock worm Sabella pavonina.

> If there'd been any peacock's worm there, then they would have come up in my trawl (Scott).

While this is unlikely to be a serious attempt of justifying trawling in an area being discussed for conservation designation, it does relate to the fishers' misunderstanding of the scientific method of assessment. Through lack of interaction with scientific research, this fisher and others interviewed who used the trawling method for fishing, gained influence by arguing that there is no impact from disturbance. Lack of understanding may represent a lack of reflection of praxis in action (Friere, 1970). It also relates to the underlying socio economics influencing the deployment of knowledge. This was a typical response found with trawler and dredger skippers to conservation science across the coasts.

The following older static gear skipper, Edgar, from Hastings, has been experiencing a skin rash from contact with the sessile juju weed species, also known as Sea Chervil, Alcyonidium diaphanum, a sessile bryozoan.

> When I pick out the fish from the nets I would get the Juju Weed on my hands. Nothing seemed to happen with it. It's affecting more and more people. I've seen several people about it up in London. Had a patch test for 36 hours, and it burnt a hole in my back and I could put my thumb in it like that (Edgar).

Although fisher LEK may attempt to be objective, all knowledge originates within the body, vulnerable to its subjective sensory limitations. Connectedly, Lewontin and Levin (2007: 31) wrote, "Your body knows your class position no matter how well you have been taught to deny it". Where fishers' interactions with these slippery species are biased by pain caused by rashes, they are more likely to see them only as pests, limiting their curiosity about how they support other species scientifically in the food chain. This, alongside the limitation of the everyday fishing practices, makes additional learning even less likely. Helping fishers get over these biases needs explanation while fishing or at least visually at sea, as fishers primarily validate new understanding through experience. While Pieraccini (2015), suggested that that benefits of ecosystem services should have been made clearer to fishers to explain conservation, describing ecosystem services in a classroom with fishers is unlikely to make any difference on practice or valuation. Co-production methods assessing biodiversity would be successful in developing fishers understanding as learning through experience is easier to comprehend than abstracted knowledge. Biodiversity benefits and considerations are also linked to changing environmental conditions, such as rising temperatures in the sea. These were particularly identified by a group of fishers from the south-east, including Hastings, Ramsgate, Eastbourne, and Portsmouth, as noted by this older skipper, Mark, from Newhaven.

> Only occasionally see now wrasse, thresher sharks, red mullet perhaps due to temperature change, we're seeing a lot less cod every year (Mark).

This older skipper from Newhaven switched over to static gear from towed gear, and critically reflects on the potential impacts to biodiversity, such as fewer species and numbers of sharks. The Newhaven fishing community sees a greater variety of trawling and towed gear fishing than other ports in Sussex. Mark links the changes in species biodiversity to temperature change. This can be generalised across the region and appears to be a shared ecological experience as this older static gear skipper, Ben, from Hastings, who reported:

> Angel sharks used to be quite common, but we haven't seen any for years, we used to have a strong population of angler fish or kettlemars, most people call them a monk. When I started in the 1970s I found I caught lots of Mediterranean species like ray bream come up, we used to have a lot of triggerfish, a lot of octopus. Now you associate those with warm water. Now you'd think with warmer water you'd get more of the species like ray bream. Now sunfish, we used to see sunfish maybe quite rare but we used to see maybe one or two a year. I haven't seen one for about 15 years. I'm actually seeing less unusual species now than I did 15 years ago (Ben).

Reflections on the gradual change of biodiversity are broadly noted, with species under threat or less commonly occurring, including wolfish, angel sharks and other larger species, such as sunfish and sharks. Fishers typically link conceptions of changing biodiversity to increasing temperatures and often link this to climate change. This historical approach is useful and the fishers concerned kept records of these species fluctuations over time in their log books. They are also linked temperature change to the unusual arrivals of species, such as invasive species. This is described by this well-educated potting older skipper, Phil, from Shoreham:

> We've been having some invasive species lately. Had non-native lobsters (Canadian Homarus americanus) and crabs (Metacarcinus magister) Load of those mad Buddhists released them down the marina. Marine Management Organisation wanted us to bring them in, check on the Cefas website. Could be temperature but we've been catching more of them (Phil).

This fisher has been influenced by scientific approaches from a young age as, unusually, his father was a medical doctor specialising in back research. Nevertheless, his legitimisation of marine research seemed to help validate it for other fishers. Molnar et al. (2008), note that marine invasive species affecting biodiversity are predominantly caused globally by aquaculture and shipping. This is an important local ecological management issue as the quote above from Phil demonstrates the need for fisher involvement in scientific research. Such interactions, including this project on discarding, bycatch, and landings, are successfully combining local and scientific knowledge. Research into discarding in relation to trawling has been explored by Cefas with inshore fishers from Eastbourne, as this older static gear skipper, Alan, explained:

> We did the small fish survey with Cefas, concentrating on gobi, gurnard, skates, flatfish, and squid, it's not going to produce the same when it's smashed up. We also did a discard survey with Cefas; the trawl catches all the different fish. We do netting mainly (Alan).

The fisher highlights in regard to the small fish survey, how bottom trawling in the reefs, can decrease biodiversity and fecundity if 'smashed up'. Unusually he linked this to the discard survey, working with those using trawling gear. This technique decreases biodiversity by catching all fish simultaneously, as well as debilitating the habitats and this is different to rod, line and set fishing. This can be seen in the context of changing awareness of discarding, explained by the following towed gear skipper, Tom, from Bangor.

> Fishermen have lied about discarding for years and years, pushed it under the carpet. They were doing the high grading, throwing the low-value fish over. FPOs built a track record high grading fish lemon soles (Tom).

This fisher originally from Bangor claims to have skippered multiple boats, in multiple seas, from Norway to New Zealand. He is unusual that he has been involved in a pan Europe 'slow fish', or slow food campaign. He suggests that there has been a wider shift in approach to research in terms of discarding and landings investigations, where previously fishers were widely more dishonest about the amount of discarding they would carry out. Today fishers are positive about taking part in discarding and bycatch research, predominantly led by Cefas. He mentions a system of high grading, where trawling would catch much fish, and throw back those that have lower perceived value. In Southern England, the need to keep high-grade stock has led to a classification system based on market prices and values. Increased research is beginning to change this as the whole ecosystem is starting to be taken into account. Nevertheless, he alleges that Cefas maintains an imbalance of power relations in terms of experimental design and participation that he would like to develop.

> You want to speak to [XX] (Cefas scientist). The trawl is more conducive to survivability for returning species. I asked them to do an experiment, but they just wanted to carry on doing their own thing. I asked to use a twin rig trial, in order to look at indicators of stress in different species. All the fish were subject to abrasion and fatigue stresses. But the trawl is more humane, gently caressing them (Tom).

While biased about the extent of damage to fish and biodiversity through trawling catch techniques, this quote is interesting in regard to the fisher's involvement in the 'discard trial'. His involvement led to his recommendation of a scientific method to minimalise survivability and abrasion of species returned to the sea. In previous generations, trawling techniques were taken to be a normal approach to fishing and not critiqued. Over the last 10 years, growing pressure from conservation research has led to trawling being banned from many areas. Today fishers are not only involved in such research on impacts but critiquing the scientific methodology. It is also noteworthy how he highlights the imbalance in power relations in terms of research design.

More generally these findings show fishers do value biodiversity positively but do not necessarily understand it in relation to the conservation of habitats and their governance. However, poor historical management inshore has led to what Pauly et al. (1998: 860) called 'fishing down marine food webs', where once long-lived, high trophic level piscivorous species where the average landed, changing to lower average trophic level species such shellfish for markets. More demographically senior fishers list which species have declined over time and their records could be shared in greater detail. LEK is changing, however, by becoming more aware of terms such as biodiversity, and the benefits of species richness. While there is an underlying understanding of biodiversity, it needs interaction with scientific research on biodiversity to develop and become explicit, such as through cooperative self-sampling approaches (Kraan, 2013). Indeed 15 under 10m vessels fishing in ICES area VIId in the south-east, and another 15 Under 10m vessels fishing in south-west areas VIIe, f, g, and h took part in a discarding trial in 2012. Unfortunately, none of the fishers from the communities interviewed were able to link their learning to these experiences. A Cefas fisheries scientist Neville from Plymouth explained more about the SESAMI project:

> In the absence of robust information on discard levels, there is no evidence to support the preferred management options of different fishing sectors or to dispute the assumptions driving unsuitable proposals. Scientific Observer programmes often suffer from low coverage relative to the total level of fishing activity, and therefore self-sampling will supplement the data collected by Observers (Neville).

This project shows that the government is becoming increasingly aware of the need to develop self-sampling and improve knowledge gaps in inshore fisheries. It has demonstrated the willingness to accept as feasible and support the practicalities of data collection by skippers, including fishing patterns and catch composition by inshore fishers. Nevertheless, the lack of consideration of how fisher LEK can be positively influenced by research meant that the benefits were lower than they could have potentially have been.

In summary, responses regarding biodiversity represent action without reflection or action for action's sake (Friere 1970). The questions about biodiversity made the fishers think more holistically about biodiversity, increasing rarity, and the different influences of different techniques. While Leonard et al. (2006) describe the benefits of a simple taxonomic index to assess anthropogenic impacts on the biodiversity of marine ecosystems; those working in the sea on a daily basis such as fishers, do not use formal taxonomy. Indeed authors, including Silvano and Begossi (2002), highlight that different fisher classifications can be rarefied by economic importance or cultural prestige. In Southern England, fishers normally record catch according to market value, such as with ‘high grading’, which has led to discarding. Research is starting to influence fishers away from this approach. The next section will examine further how involvement in different research programmes has influenced fishers in other ways. In terms of gear, forms of trawling are most debilitating to biodiversity, through their non-selective methods. While the discard ban has been implemented, it does not link well to how fishers comprehend biodiversity. This needs further research through participatory and self-sampling methods (Mangi et al. 2014). How this relates to changing fishers’ benthic LEK through knowledge sharing with scientific research is considered further in the next section.

5.2 LEK scientific research involvement in co-production and potential for adaptive co-management

This section examines how fisher LEK is influenced by research, and how this influence can create a more democratic form of fisheries management - that of adaptive co-management., such as with the IFCAs, Cefas and the Coastal Producers' Organisation. Significantly while the over 10m fleet have been often involved in programmes such as the Fisheries Science Partnership (FSP) it has been harder for inshore fishing to attract funding for research with relatively small landings per vessel, and varying market demand (Seafish, 2015). While inshore fishing in the UK has historically been data poor, this is changing with related programmes for product certification such as by the Marine Stewardship Council and Project Inshore, which mapped commercial species, value and seasonality of landings, alongside habitats (Project Inshore, 2015), and the recent publication of the 2007-10 fisher effort maps (Enever et al. 2017). Although authors including Azurro et al. (2011) underline the potential contribution of LEK for the monitoring of coastal ecosystems as data, this is a typical example of the subject/object ontology of scientific epistemology identified by the critical realism of Sayer (1984).

Inshore fishers record LEK on a much smaller scale than the regulator or scientist. It is this consideration of the local that is of particular importance and is different to researchers who seek universal generalisability. This relates to the influence on LEK from research as it develops. Similar to this thesis's conception of fisher LEK, Astorkiza et al. (2006), characterise experience-based knowledge as qualitative and recorded empirically over long periods of time. Concerns, however, about utilizing fisher knowledge have been raised regarding the unreliability of the data, whether local or scientific, and it is suggested that this can then result in overexploitation or damage to natural resources (Ludwig et al., 1993 and Walters and Hilborn, 1978).

If fisher LEK of populations is recorded in a manner similar to scientific knowledge, (such as using the codified records noted by Brehme (2007), then Agrawal's (1995:2) questioning of the dichotomy between Western and Traditional knowledge is pertinent. Through the focus upon the benthos, this section draws out the local relationship with space and place, different to Hoefnagel et al. (2006)'s experience-based knowledge, which considered nomadic fishers and pelagic stocks. Nevertheless, this positive interaction with scientific research is a modern phenomenon. Certain inshore fishers notoriously subverted the assessments of landings for the CFP during the 80s. A younger static gear skipper from Looe, Luke, explained:

> All the fishers lied about the landings back in the 80s when they first started assessing the CFP. They thought that if they hid all the fish then they would get the entire quota. That's why the French got more. It turned out that the French declared more fish and were given

> more quota. That's why so many fishermen voted for Brexit. Yes, we would do it differently now (Luke).

While certain populations of inshore fishers in England misunderstood the benefits of declaring fisheries data, their mendacious declarations left them more bereft of access to the resource. This younger fisher from Looe is critically reflective on a previous generations' mistrust of science, something shared across Looe. Having been brought up on static gear, he is now set to inherit a family boat. Across Southern England, it is apparent that there is a changing, more positive perception towards having more scientifically accurate assessments. This critical appreciation for scientific method was also revealed by another Hastings fisher and connected to his research experience of Hippocampus hippocampus or seahorses. The reputation of fisher LEK through assessment was demonstrated when fishers supported attempts to ascertain actual population levels, which were higher than scientific research had previously realised. As St. Martin et al. (2001) demonstrated it is the challenge of combining the different spatial languages and comprehensions of fishers and scientists, not that fishers have no valid knowledge. Sean a static and towed gear crew mate discussed.

> 10 years ago, I was fishing out of Rye, we starting catching an of lot seahorses, hundreds of them, and each had to be logged. We took a researcher out, and she was doing a Ph.D. on seahorses at the time the Short Snouted Seahorse was endangered. I said to look under your own noses, they're all the way to the Wash, upwards (Sean).

This interaction between fishers and scientists - collecting data to support a hypothesis, which was not evidence-based and related more too popular misconceptions of conservationists - demonstrates the importance of fisher LEK. Given the perception that Hippocampus hippocampus was endangered, fishers' active experience allowed them to validate their knowledge to the scientists in the study. They increased their social capital in the local fishing community and to a wider audience. Additionally, this episode demonstrates that where a potential threat to fishing exists and perceptions have historically related to fishers depopulating Hippocampus hippocampus populations, fishers are likely to share their knowledge with scientists to demonstrate a positive reflection on their practice. The next older static gear skipper Phil, who owns two boats and a shop, describes his experience with cuttlefish research, and how co-management needs to consider seasonal closures for eggs. His involvement in assessing cuttlefish spawning fishing grounds led to better surveying and scoping for by law implementation.

> [XX] Did that cuttlefish research, both sides of the channel, particularly regarding juvenile recruitment, not just the amount of fish you catch. The French said that you are not allowed to bring your traps in until the eggs have hatched and that you are not allowed to bring them in and scrub them, you will leave them in the sea until that time. During cuttlefish season you are not allowed to trawl where they lay their eggs. Zoning is needed seasonally for cuttlefish effort, to avoid the breeding grounds. (Phil).

The application of LEK also involved surveying with scientists in regard to the impacts of drift nets on cetaceans and tortoises. The following older static gear skipper, Ronald, from Eastbourne owns and coordinates three boats, whose design have been called 'super 10s' in their capacity to go further out to sea than average, in all weathers.

> We took the scientists out several times to show that there weren't any dolphins or tortoises in the drift nets. They've gotten a bad name because of what they do in the Mediterranean, but it's stupid to think they do the same thing up here (sic) (Ronald).

Ronald invited scientists to reconsider the perception of damage to tortoises and cetaceans through drift nets. Attempts to introduce a drift net ban across the EU relate to drift net impacts in the Mediterranean. However, the fisher tactically deploys his LEK in this case by evidencing the lack of cetaceans affected in this way in this local ecosystem in the Atlantic.

Ronald was keen to emphasise the benefits of local assessment, involving himself in the science of the IFCA. Using fisher LEK to argue that marine biological understandings of fishing gear are not always generalisable across different geographies for legislation demonstrates the need for adaptive co-management, adopting rules to local conditions integrating fisher LEK (Armitage, 2009). Likewise, Edgar the static gear skipper from Hastings relates this lack of appreciation of the differences between localised benthic environments and the lack of local understanding in centralised EU decision making in regard to ecosystems:

> It's too big a group isn't it, (The EU) it needs to be more localised. It's like the drift netting they were (sic) on about banning. I was at the meeting at Brussels and when you go there and start listening to what the problems are, I mean one of them was talking about a lesser spotted turtle. There was a bloke there who came over from Yorkshire, he's been drifting for salmon, his family has records of it for 150 years, as well as for a certain species of sturgeon. What's it all about? (Edgar).

Where fisheries management decisions are abstracted from localities, the fishers feel decisions may not take into account the local differences between fishing practices, and the consequent varied effects on ecosystems. The following older static gear skipper, Anthony, takes this logic and understanding of the potential use of his LEK, to the issue of the access to new target species:

> It's like the undulate rays, there are hundreds of them coming up but we're not allowed to fish for them, we've had to throw them back. We've been going up to lobby at Brussels. We had Cefas down to demonstrate that the populations were viable for fishing (Anthony).

By involving himself with Cefas to co-produce new knowledge of undulate ray stocks, Anthony has been deploying fisher LEK for economic advantage. Using his networks through the NFFO, he has been able to bring his message to Brussels in a way that most inshore fishers would find impossible and increase undulate ray quota. Schafer and Reis (2008) highlight that fisher LEK is often not used, due to researchers' inability to include it in management systems, because information is very specific to the region where it originates and it may not apparently be useful enough to derive wider lessons from. The IUCN listed Raja undulata as an endangered species, and the European Union since 2009 has established regulations to outlaw commercial fishing of the species (Ellis et al. 2012).

Nevertheless, as the undulate ray does not migrate, it may be possible that the local breeding population of the ray is strong, even if other populations identified as declining, such as in the Irish Sea, are not as strong. The confusion may also relate to the different spatial languages of fishers and scientists, comprehending fish populations at different spatial scales, rather than one or the other being more accurate (St. Martin, 2001). It can be argued that while there are economic drivers in this knowledge deployment, this case shows how easily LEK and catch records can be integrated into fisheries management.

The following older netting skipper, Ben, argues that the scientific validity of the quota system for species access shows the system needs general reform. He further argues that the quota system does not assess the local ecological differences of Dover sole, Solea solea, and cod Gadhus morhua populations. This demonstrates the importance again of benthic LEK records, as neoliberal policy has led to cuts in the Cefas assessment budget. The fisher attempts to link population assessment and the habitus of fishing:

> No quota even when there has been good (sic) stock of cod in the sea, because of no quota assessment. Stock-recruitment is done by survival rates of the biomass of the first-year class of sole, that's been done for generations with Cefas laboratories. Recognized tows, recognized time of the year, wind logs, and whether it was easterly or southwest winds. They said they should only be reducing the Total Allowable Catch in line with stock populations, but if you don't do the work on stock populations how do you know the strength of the stock? Especially with sole because the sole is endemic. You've got an Isle of Wight stock, you've got a Boulogne stock, and you've got a Hastings and Rye stock. Breeding populations in a local area. So, if you deplete stock from a certain area, it won't be made up of the population from another area (Ben).

The fishing quota is decided at an EU level through the International Council for the Exploration of the Sea, (ICES) where measures are designated to regions thousands of miles wide and has been critiqued as neither scientific or sustainable (Daw and Gray, 2006). Future research can work together with fishing communities to develop a more regional approach to the CFP through greater integration of fisher sampling. Given the amount of expertise and associated involvement in the NUTFA social movement of this fisher, his expert use of fisher knowledge using scientific terminology is relevant to his position as an opinion leader in the local fishing community and in the NUTFA social network. Previous research does not specifically address opinion leaders or how their different levels of power affect the development of fisher LEK. Ben's increased power through scientific fluency means he is taken more seriously by other fishers. As older trammel net skipped Edgar provided insight:

> Some of the other fishers get jealous of him, because of the respect he gets for the work with the scientists, with NUTFA, with the media attention (Edgar).

Through his increased social capital, other fishers in the local community of practice are more likely to be motivated to be involved in research, increasing both their general scientific knowledge and scientific knowledge specific to the fishery. Additionally, his increased social capital means he is more likely to be supported by other fishers outside the community. His increased reputation through scientific research may mean new fishers join such organisations as NUTFA and the Coastal Producers Organisation, strengthening his economic position by controlling inshore quota. The community's personality dependence is a risk to this community, as the fisher's relations with politicians and the media allow him to have a major influence on local learning development. This can affect perception and realities of expertise relative to other fishers. Varying concentrations of power, personality dependence and relations to the state affect perceptions and realities of expertise (Crona, 2006). Those with the greatest access to governance and power are often perceived to be more expert. Further, those with greater fishing experience over time are both seen and likely to have deeper more expert levels of fisher LEK. (Knudsen, 2008, Crona, and Bodin, 2010, and Lauer and Aswani, 2010). This was particularly apparent in the Hastings, Plymouth and Looe fleets, as well as to a lesser extent in Ramsgate and Whitstable. IFCA officers agree that securing these individuals' agreement with a research programme is essential for realising its success Tim from Southern IFCA explained more.

> We always seem to get [XX] to support us. There's always one or two people we seem to go to, makes it more successful to have them on board (Tim).

After discussing the reputation of the following fisher from Eastbourne with other researchers and fishers, he was found to be well respected by both the fishing community and the scientific community. A Natural England Officer, Erica, described:

> He's very good, he's always interested in being involved in research, and he's positive on conservation issues. He seems to be getting the others involved by explaining the research (Erica).

His efforts with research seem to legitimate the findings for others. The points made by this fisher were also made by the majority of the fishers that participated from Eastbourne, suggesting his influence. To summarise, access to power seems to be increased through interaction with scientific co-production, both in regard to resource access, as well as the perception of expertise and social capital. It demonstrates that the power of fisher LEK can increase when elicited for research, whether as oral or as discursive knowledge (Hoefnagel, 2006). Although fishers who have been involved in research projects have been positive, there remain many fishers who have not been involved in the research process. There is a barrier that exists relating to the 'framework of knowing' of natural scientists, as they are biased about fishers' knowledge as non-scientists and their methods of knowledge creation. Indeed, this is highlighted in comparison to local farmers by the emerging 'Fishing for the Future' project which highlights that:

> Fishers are asked to abide by legislation and policies for sustainability, yet there is no imperative for them to understand the science behind these theories. A direct comparison can be made with the land-based agricultural training that farmers receive – they need to know about yields, land-use, conservation theories and other issues that place them as stewards of the land they manage. There is no equivalent at sea (Fishing into the Future).

The importance of increasing fishers' knowledge of sustainability in a more explicit way is highlighted here. The project Fishing into the Future includes a mechanism for developing protocols to make fishers' LEK more accessible to research and governance through regional collaborative workshops. Nevertheless, the majority of research remains in a positivist epistemology, such as the recent publication by Enever et al. (2017). An example with the IFCAs is that while they do involve fishers in conservation research on an ad-hoc basis, there is no explicit high-level objective to explain the programme and their involvement within it. An IFCA officer from Cornwall explained:

> We don't tend to integrate fishers' knowledge into mapping. We use scientific research from universities. They never turn up to meetings. We get one update from a fisher about biodiversity; it's just a random list of species (IFCA 1).

There is a lack of understanding in IFCAs of how to increase participation of fishers in conservation and conduct research on shellfisheries permits, lobster sizes, and their other research programmes. While certain individuals may be positive about including fishers in research, explicit guidance is needed to overcome the domination of research and governance by a scientific epistemology. Similarly, other governmental bodies are primarily concerned with how fisher knowledge can be converted into valid data for marine ecosystem management purposes. The positivist epistemic framework tends to lack an understanding of the underlying social processes and structures shaping and developing knowledge (Sayer, 1984). Nevertheless, this may be beginning to change. This researcher from Cefas, Neville, explained more:

> There's a lot of effort now to combine the top down bottom up approach, historically it's been very top-down, scientists, then it comes down to policy makers, then to government then to fishermen, there are so many issues with the trust, you take the data from a skipper and the analysis gets done somewhere else. But it's really improved now, there are so many skippers who are coming to say I want to do this and this and then we can apply the scientific vigour. It's not been great, but it's been steadily improving (Neville).

It is certainly apparent that more research than in any other period of history has involved inshore fishers. This has had a generally positive influence on both knowledge systems. Nevertheless, concerning Cefas research, the programmes are not necessarily joined up and do not have the explicit goal of supporting the ZPD between fishers LEK and scientific research (Engestrom, 1987). Reflecting on the potential of the project of Fishing for the Future, which aims to develop learning for sustainability through a two-way interactive engagement model, there is potential for developing explicit interaction with research and governance on a regular basis. Supporting the development of regional knowledge exchange workshops can break down these hierarchies of knowledge (Sayer, 1984). Alongside an ethical right to see marine resources sustainably, managed between coastal communities, fishing spatial access rights could be protected more effectively if the fuller scientific understanding of limits could be developed among fishers as under the 'Pescastemic Rights' framework. The question of what Allison et al. (2012) called spatial access rights and the knowledge sharing dynamics around their governance will be more fully developed in Chapter 7. Pescastemic rights relate to critical realism in that it is an emancipatory approach to knowledge. It builds upon the right to a way of knowing, or an epistemic right, as well as the Cornish word for fisher; 'Pescador'. This thesis develops a new 'Pescastemic Rights' approach. Based on human rights and epistemic rights, it is the right to know in an environmentally and socially just way, relating to what Agyeman, (2003) called environmental justice. Indeed, Pescastemic Rights mean the right to access fishing as a common resource, if full knowledge of the socio-ecological system can be developed and shared by those using it. The paper by Tsosie et al. (2012) examines the historic epistemic injustice of indigenous people placed as objects of science during colonisation and contemporary capitalism. If the educational and research benefits of fishers, as full participants of investigative programmes in subject-subject research relationships, can be recognised, then Pescastemic Rights are more likely to be realised. To achieve this, marine governance will also have to go beyond the epistemic or testimonial injustice current in the prejudice against fishers' ways of knowing (Fricker, 2007).

This section shows the real properties and causal powers of the social structures of inshore fishing. To create an emancipatory science, that commits to supporting bodies of knowledge that have the best long-term interests of the environment and humanity at heart, requires moving from reductionism, and positivist approaches.

5.3 Conclusion

Knowledge which has not been validated is considered to be nothing more than a person's belief under a positivist epistemology. While in previous decades LEK could be justified by a person's experience, knowledge validation is now more complicated than ever historically. Nevertheless, while not everything that is believed is known, nothing can be known without first being believed, and the requirements for justification are not necessarily emancipatory under the rationale of the market. While fishers historically remained in isolated learning communities, today taking part in research of different forms has led to a changing vocabulary and appreciation of scientific methods and their systems of justification. To make the system of validation both participatory and emancipatory means taking this critical realist approach. Certain fishers involved in research processes have now been trained to autonomously continue without the scientists. Considering a variety of research projects, this chapter has highlighted the influence upon fisher LEK at a local scale, and bi-directionally, upon scientific research (Engestrom, 1987). Critical realism (as described in Chapter 4 on methodology) supports analysis of how LEK's development is implicitly connected to its interaction with scientific knowledge, supporting a new theorization and definition of it.

Authors such as Schafer and Reis, (2008) highlight that fisher LEK is often not used because this information is very specific to the region it originates from. In a related way, an assessment of whether this local versus global aspect of LEK is a strength will be considered further in the next chapters. A school of thought from Canada including Murray et al. (2006), argued that fisher LEK has universally become GHK. In western industrialised countries, fishers who are under pressure from rising costs for operating, and static prices for their commodity means fisher understanding of ecosystems is primarily guided by the rationale of the market. Fishers then find it difficult to balance long-term interests in preserving habitats and ecosystems with short-term profits. (Making livelihoods secure through enhancing sustainable practice and environmentally just fishing opportunities will be discussed in chapter 7). This is contrasted with the celebration of TEK as a different way of knowing about nature in regards to indigenous communities in the developing south by Berkes et al. (2000), Davidson Hunt (2006) and Leff, (2012). It is apparent that in these contrasting local geographies and demographics, the fisher classification system is predominantly influenced by the market rationale. Through involvement in research questioning about biodiversity change, fishers are reflecting on change, species richness and the influence of climate change. Sporadic involvement in species and quota assessment is, however, also adapting fishers understanding. Fishers are increasingly critical of historical discarding and involved programmes in reducing discarding.

Indeed, increasing amounts of involvement in scientific research and conservation assessment means that their learning is developing beyond short-termism. The chapter consciously shows that where

LEK is used as evidence for science, greater ecological understanding is achieved. Through collaboration, fishers' can gain power, as well as reputational expertise. Furthermore, by accessing new research through co-production and independent research, fishers are changing their own scientific understandings of new environmental problems, such as plastics, car tyre reefs, and climate change. By involving themselves in population studies of species such as seahorses and cetaceans, fishers attempt to build legitimacy and confidence in their practice within local ecosystems and to validate their LEK. By demonstrating expertise of population location and aggregation, certain fishers demonstrate accurate scientific knowledge as highlighted by authors such as Astorkiza et al. (2006). Moreover, this chapter has developed a definition of LEK with regard to power relations and economics, as well as the feedback on conservation. Different to Murray et al.'s (2006) theorisation fisher LEK is being used to bring attention to changing environmental conditions which, with a more participatory form of governance can support greater integration of LEK.

Fisher LEK can demonstrate how local ecosystems are subtly different. This application of fisher LEK, therefore, critiques a system that is over-centralised and unable to account for local differences in fisher practice and different ecological conditions on a fine scale inshore. As Espinoza-Tenorio et al. (2013) point out, fisher LEK and scientific knowledge are not incommensurable, rather LEK can add to and complement scientific knowledge on the local scale, in particular when quantitative data is lacking. Indeed, this demonstrates the need for more formalised training for self-sampling, where fishermen report, collect or process biological samples themselves, allowing for research with a higher coverage in time and space (Mangi et al. 2014).

This research has highlighted the importance of fisher involvement in scientific and conservation assessment, supporting worldview changes beyond market-driven norms. The analysis also shows that the generation of Hoefnagel's (2006) community science needs to move beyond co-stock assessment, to include assessment of habitats, biodiversity water quality, contamination, temperature, ecosystem services and other areas. The beneficial pedagogic influence of the research is apparent in influencing changing epistemic frameworks. Regrettably, the various research programmes from Cefas, the MMO and others do not fully consider this. Records of research involving fishers over the last ten years show the stochastic stop-start involvement of perhaps only 1% of the fishing population in England and Wales. Where there are knowledge gaps, such as in the benefits of marine conservation, considerations of population overspill, increased biomass and biodiversity and ecosystem services can be made available through a course.

New research is needed to strategically plan ways in which LEK and governance can evolve to develop a marine democracy. This will see a system where local ecological knowledge can contribute to decision making through highlighting risks to ecosystems through participatory mechanisms Relevant to what Agyeman, (2003) called environmental justice. These participatory mechanisms are based on Pescastemic Rights. These are founded upon human rights and epistemic rights, the right to know in an environmentally and socially just way.

This means that an explicit policy supporting training and integration of LEK is needed to create a marine democracy. Whether this can move fishers towards being participants in participatory policy-making remains to be seen. Moreover, the socio-economic benefits of developing a comprehensive framework for not only involving fishers in research but ensuring there is mutual learning beyond the rationale of the market, needs to be valued as a cultural ecosystem service (Church et al. 2011). Authors including Martinez-Alier, (2002), Kaime, (2013), and Kronenburg and Hubacek, (2013), critiqued the ecosystem services approach, referring to research showing commodification of ecosystem services is ill-advised. Mangi et al. (2014) estimated that fishers may have been more motivated as they were paid to take part in SESAMI research. Nevertheless, my conclusive position is that to take marine life for profit means there is a moral and ethical right to share fisher LEK (Singer, 2011).

6. How Technology is Changing and Influencing the Development of Fisher LEK of the Benthos

6.1 Changing fishing technologies, techniques and fisher LEK of the benthos

Fishing technology has changed rapidly since the 1950sleading to overexploitation of stocks (Cullis-Suzuki and Pauly 2010), and as this chapter shows, these changes have been relevant to new forms of conservation. The introduction of new industrial fishing technologies has seen over two-thirds of the high seas now exploited (Swartz et al. 2010: 1). How technology is changing and influencing the development of fisher LEK in Southern England is yet to be investigated. This chapter first demonstrates that through the use of new technologies, fisher LEK has a richer understanding of the benthos and the bathymetric phenomena that influence it. The interviews interrogated areas relating to technology codified according to what Braun and Clarke (2014) call thematic analysis. While most of the those interviewed in this doctoral research were in terms of age senior fishers continuing in the fleet, the interviews did target different ages and included some younger fishers, and also specifically explored the use of different gear types across different geographies and forms of social organisation.

Inevitably, the simultaneous development of new technologies and the pressure of international markets has significantly influenced the fishing distribution, organisation, and technology (Reed et al. 2013). Considering that the majority of learning develops through the physical interaction with the sea via the use of fishing gear, the way in which fishing techniques are changing must be intimately understood to comprehend the research question of how technology influences the development of fisher LEK. Understanding the way in which LEK is changing needs reference to the shift from tacit knowledge to discursive. While fisher LEK was previously more often tacit and unspoken (Palsson, 1998), the fishing recording has developed quickly through the late 20th century and early 21st century through new technologies, making the results of learning more explicit.

Different techniques and technologies of fishing create different ways of learning. The extent to which different methods understand the seabed will be addressed, with consideration of different benthic conditions (Golding, 2006). If different techniques of understanding the seabed are emerging through new technologies, the extent to which this is influencing knowledge generation needs consideration. Importantly, the chapter will reflect on how far Murray et al.'s (2006) paper describing LEK's transformation into GHK is relevant in southern England. Through an examination of new technologies of conservation, the chapter will demonstrate that LEK remains local, in relation to the under 10m inshore fleet. In dialectic to this technological change is organisational change, influencing LEK as described by Johnsen et al. (2009). How different forms of technology and organisation are influencing how knowledge is guarded, released and shared will be examined, alongside the relevant social dynamics.

Fisher LEK of underwater features interacts with other environmental knowledge of the ecosystem. Knowledge of water quality, temperature, seasons, tidal changes, day and night time changes in fish behaviour patterns develop and inform understanding of the benthos. An introduction of fishers' LEK of bathymetry, substrates, and habitats in relation to technological change follows in the next section.

6.1.2 The Core elements of benthic LEK in relation to technological change

With different types of fishing requiring different grounds or benthic habitats, knowledge of the seabed is a key consideration for inshore fishing. Given the difficulty in accessing detailed understanding of the geological and geomorphological aspects of habitats, this knowledge is contested (Steinburg, 1999; Eastwood, 2007). Johnsen (2014) highlights fisher LEK's importance as a way of understanding three-dimensional, coastal spaces. Given this, survey work led by the Joint Nature Conservation Committee (JNCC) has resulted in only 10% of marine UK habitats being mapped to 'high-quality' and is an indicator of just one area of research that fisher LEK can complement (JNCC, 2014). Despite the contemporary knowledge gap of the benthos, British waters fishers have always developed knowledge of the grounds to supplement their decision-making. This younger static gear skipper pointed out that:

> It's amazing how much the bottom topography affects what's above in the water column. You go back generations and fishermen recognise that even though they didn't know the bottom topography, they would go to certain areas and shoot nets and catch certain species in certain banks, to catch turbot or whatever (Jowan).

This Newlyn fisher has trained with different generations of fishers in a community which has a mixture of inshore and large-scale industrial boats, and Newlyn remains the largest fishing fleet in Cornwall. His experiences have been shaped by accessing fishing as a youngster with fairly primitive static gear technology, to experiencing the most sophisticated equipment whilst supporting larger vessels as a Cornish FPO representative. While historically the benthos and bathymetry were not always known, this quote demonstrates that historical knowledge of banks and other features supporting habitats could be gleaned by fishers via their observations. Today, technologies including the echo sounder, GPS, and Olex 3D imaging software, have changed this, making bathymetry and the benthos more accessible. How this relates to the social dynamics in boats will be investigated. Different sorts of fishing technique seek out different geomorphological features or habitats to increase success. Given the need for continuing success, developing accurate fisher LEK of the benthos is vital for continued business survival among fishers as this exert from my participant observation notes reflects:

> During the long night of my first participant observation of the Ph.D. research, it quickly became apparent how secretive fishers could be. While sleep deprivation and the ever-present stench of decaying fish threatened distraction, I continuously observed how the particular skipper attempted to avoid other vessels and the forms of surveillance he employed. Additionally, he showed me and the crew on the ‘plotter’ how bathymetric underwater features, such as the substrate, reefs, rocks, ledges, gullies, depressions, holes, and banks, are the first elements of consideration in choosing grounds to fish. The choice of grounds soon emerged as a seasonal pattern, as the blue glow of the chart plotter reflected in the gloaming.

Being static, the features of the benthos are easy to identify, recordable on charts, digital and paper, as also seen with lobster fishers in Western Australia and New England (Brehme, 2007). These static seabed features and elements are memorised and mapped by fishers, but if recorded are not necessarily shared or made available in the public domain. This is described further in relation to the social dynamics of LEK of the benthos.

6.1.3 The development of fisher LEK beyond trial and error to Olex chart plotters

This section explores different gears and their influence on the development of fisher LEK. It then goes on to look at how safety concerns influence learning, and how codification and new technologies influence understanding. While there are differences between the mobile towed gear sector and the static gear sector, systemic understanding is most appreciable where fishers experience and test a greater variety of gears in different seasons as explained by this older static gear skipper from Looe:

> The fact that I’ve been long-lining, trawling, netting, and scalloping gives me a wide vocabulary of what the seabed is like, especially in this area (Jago).

This particular skipper chairs the local Fisherman’s Association, making him a core part of his village’s community of practice. For some fishers, awareness of the topography may first be developed through concern for reducing the risk of damage to gear. Further awareness of the seabed features, such as underwater reefs, ledges, and stacks, will additionally act as a spatial deterrent to spatial conflicts as described by this older static netting captain Eric revisited:

> You look for features you can fish safely. One of the biggest risks is having your gear towed away so you look for features that will prohibit trawling, scalloping. Tend to get close to reefs and fish over them and around them. Similarly, you get close into the wrecks for soles (Eric).

This senior fisher started his career unusually as a submariner, making him particularly aware of the spatial challenges underwater that support habitats. Spatial conflicts between towed gears, such as when trawls and dredges drag away pots and nets on the seabed, are a tactical consideration. By looking for reef or other habitats that prohibit trawling static gear fishers can avoid this occurring.

Fishers traditionally have had to develop knowledge of the seabed through testing and recording with their gear. As one older static gear skipper Edgar from Hastings discussed:

> It's trial and error. We just know it's there, you see what was on it by what comes up, and you'd adjust to that, wouldn't you? Rock bungs in the nets will tell you (Edgar).

In this understanding of the substrate of the habitat, the fisher is more able to target suitable grounds. However, fishing is no longer trial and error for all fishers, and the validity of fisher knowledge through its changing methods of experience, memory, and sensing can be more easily codified using contemporary technologies. Whilst taking part in participant observation, I observed how fishers bring up different types of sediment in the nets and pots, which are recorded and mapped according to habitats, such as on the Decca chart or Olex. Variations in different geologies influence the distribution of habitat development. The following nomadic scallop dredge skipper Dougal, from Mylor Bridge near Falmouth, particularly relies on his echo sounder for detecting certain habitats.

> Came across a bit of shelly, culchy (sic) ground but this was affected by the storms. We just keep going back year by year to the same places, towing as you go, have a look. You can tell by your metre as well, dark red for hard ground for scallops. Gullies for contours for the right ground (Dougal).

This quote demonstrates the need to target hard ground for scallops, showing that a certain density of substrate is needed, identified as red upon the echo sounder. As this individual crew member was not the vessel owner, being part of a larger corporation his disinterest in species beyond scallops was noteworthy. The rationale of the market has been influential in his classification of species through new technology, and through the pressure of the market. While taking part in the fishing process at the wheelhouse, the skipper showed how they observed the different colours on the echo sounder whilst inspecting their notes. They shared their knowledge openly with the crew. Scallop dredger skippers were, however, particularly guarded about their knowledge of suitable rocky grounds for scallops. Nevertheless, technological methods of understanding the seabed's depth and substrate have rapidly changed in the late 20th and early 21st centuries. Historically after WW2, fishers would develop knowledge of the seabed using waxed leaded weights or tallows.

In the 1950s, this more traditional way of developing knowledge of the benthos was supplemented by the wet sounder and the dry sounder. The Decca system was supplemented by the colour sounder, and today sees 3D imaging with the Olex system connected to the echo sounder. The following older trawler skipper Tim from Ramsgate has been involved in trawling throughout his career. He explained:

> It was local knowledge when I started. We worked on landmarks and working between the buoys and that sort of thing. If you couldn't see it you couldn't fish, you'd take your bearing on a buoy, and then you'd put a 'Dan' (a little buoy with a flag and a stick with an anchor) in and work backward and forwards to your Dan. Work on a compass bearing all the time with your Dan. You'd get a cross bearing if you've got a clear tow. The area called south grounds,

> and the seabed runs off then it drops down at 30 fathoms, and then it slowly runs out the falls, probably chalk, but at the bottom is sand and mud. We know it's there because the old boys used have tallow on the end of a lead and then they'd sound it. The old boy he showed me and he worked it with the lead. If you hit chalk, then you knew you'd have to come off. Whatever's on the bottom would stick to the tallow. That's the only way you knew what the bottom was (Tim).

He then went on to show his son how to use Decca charts and echo sounders. Knowing the condition of where the bottom lies is important to consider in ensuring a clear tow with a trawl. There have been significant changes over the past 50 years with fishing sensory technology changing from testing the seabed depth and substrate with a wax tallow to 3D imaging. Typically, a younger fisher would be apprenticed to an older fisher to learn these techniques. Whilst netting and potting, this can increase the success of fishing success as a trammel net specialist Edgar from Hastings detailed:

> Yeah, we do look for where the contours are, where it gets deeper. Depth changes important because they're sheltered. Where it drops off it's quite good, where it goes deeper, like at the Fish's Tail (Edgar).

Places, such the Fish's tail (mentioned by Edgar above) were particularly guarded, shared with crew only, particular details about how habitat diversity varied with depth difference. Changing methods of understanding the bottom substrate are key to understanding which gear to deploy on the seabed. Certain vessels are equipped with trawls, pots, nets, and dredges, while alternatively, some crews select the equipment on the quayside prior to launch. These substrate geomorphologies are significant alongside other features of local environmental knowledge. For example, different types of fishing can be possible in different seasons and at different temperatures and substrates. Accuracy in understanding seabed habitats and substrates are important for success as explained by first crewmate Tony from Whitstable below:

> In the summer the ground goes soft, in the winter it goes hard. You get to June, July and the water gets clear, it's all the plankton, it drops down to the seabed. If you're a trawler and if the ground's too soft, you'll fill up with mud (Tony).

Contemporarily fishing techniques are moving beyond trial and error, as static gear skipper Ronald from Eastbourne explained:

> It's that thing of trial and error in the past; it's easier to reach those more difficult places. We have the echo sounders that are connected to Olex and Mac C, that re-map the bottom along for you. Now definitely a lot more accurate in the way you would go fishing. You used to go fishing your nets out in lines, 8 fleets of nets, two lines of four. Now you see them all dotted about because you see all the different lines of ground on the mapping system. When soling we fish on depths so it's just off the contour (Ronald).

The gill netting technique described on the seabed in the quote above demonstrates how new technology is moving static gear netting away from trial and error. While in the past fishers built up bathymetric and benthic knowledge through the more traditional techniques described above as trial and error, today new sensory technologies allow for bathymetric imaging. These are particularly interesting in the fishing business as some skippers own and coordinate several boats, potentially allowing for greater pressure on the grounds. Fishers now look at where depths increase and choose to fish based on where contours appear on the map. Benthic diversity is increased by having a greater variety of slopes and depths. Greater vertical variety allows for ecotones, those transition points between biomes to accumulate biodiversity in different niches. Ronald above mentions fishing off the contour, as this is how it appears on Olex. An older trawler skipper Richard from Southend elucidated his own subjective Olex experience:

> Olex is awesome, you put in your wrecks, your fars (measurement of space) you learn and draw every day. I can see a warship, and I've even got a submarine. The hardness of the ground becomes a dark brown; over disturbed seabed, it looks like fire (Richard).

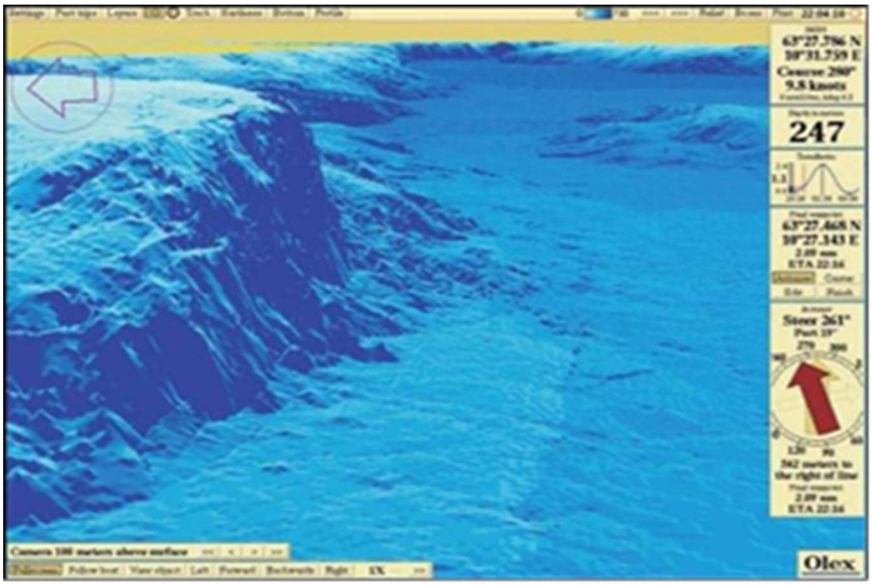


Figure 10 Olex 3D Chart plotter image of bathymetry off Carrick roads. Example shows the sophistication of the bathymetric profiling which can allow for more targeted fishing.

The increasing accuracy of targeting the best gear, using digitised technology alongside the automation of the fishing techniques such as the net flaker which helps pull the net up and pull the fish out of the net, allowing for quicker access to fishing catch. Static gear skipper from Plymouth Eric highlighted:

> Your 3D plotters make it easier to come back to the ground and concentrate on the ground, increasing the fishing effort. Fishing is far easier than it was. You've had a technological creep for years, which obviously has put far greater pressure on the stocks (Eric).

While the expensive Olex system providing 3D bathymetry remains rare in inshore fisheries, for those that can afford it, it provides a highly detailed pictured of bathymetry allowing for increasingly accurate fishing according to habitats, as seen in Figure 10. This means, however, that nomadic industrial fishers can also increase the likelihood of catching in new areas, by scanning the bathymetry. Christopher an over 10m beam trawl skipper explained:

> While you do have certain regular areas, with Olex you can get a picture of the seabed to let you trawl where you want. You're more likely to catch fish wherever you go. I could go fishing right around the coast to Liverpool Bay and know I'd catch. Yes, I'd need to buy in different quota (Christopher).

Olex allows the offshore sectors, who buy, sell and loan quota between FPOs, to fish in areas without having to rely on their LEK. This is similar to the GHK of some fishers, as described by Murray et al. (2006). The different management regime for inshore fishing's CFP quota by the MMO prevent their regular migration, as well as their smaller engine and overall size unless done in association with a larger business or FPO, who can lease them quota (this issue is discussed further in Chapter 7). Those boats equipped with Olex software, fishing inshore areas, can develop their LEK with their catch, substrate and habitat records. While species are not necessarily discernible using Olex, the latest generation of echo sounders has the capacity to see seagrass meadows and other living features. However, this has not manifested widely in inshore fleets so far due to cost, and software such as Olex WASSP is only found on survey vessels and perhaps a few of the richer offshore over 10m vessels. The Olex global bathymetric database also contributes to the ongoing mapping of the 44 marinescapes earlier described by Connor et al. (2006) (discussed in Chapter 2 about context). The limitations posed by conventional seabed survey methods means that only 5-10% of the seafloor is mapped with a resolution of similar studies on land (Wright and Heyman, 2008). Given access to conservation training and the next generation of Olex, such as WASSP multibeam echo sounders, fishers can make an increasing contribution to mapping habitats and rare species, whilst producing an updated understanding of fishing pressures. These combinations of habitats over a larger spatial scale experience different levels of sensitivity, species aggregations, and substrates. Authors, such as Buhl-Mortensen et al. (2014), describe marine landscapes as having major features delimiting different substrates that can be subdivided into smaller biotopes with specific fauna community composition, production, and functionality. Nevertheless, it could be argued that this term is 'terrestrial-centric' not being a landscape in the sea. Therefore, the term 'marinescape' is used here.

Historically, learning about the geomorphology of the marinescape through physically interacting with the gear took many years. Contemporarily, this is more easily and rapidly understood with technology, allowing fishers to return to the same spaces more quickly. These technologies have moved fishing techniques from trial and error towards increasingly rapid learning about the seabed bathymetry and associated benthic ecosystems. Given this increased accessibility to elements of the benthos, the efficiency of catch per unit effort per boat per hour has historically increased (Kennelly and Broadhurst, 2002). This means there is increasing dependence on technology, creating a form of deskilling, particularly apparent in the few larger fishing boats migrating into deeper water that can digitally view marine life through multibeam echo sounders. Nevertheless, this increased accuracy means that there is increased potential for developing and sharing fisher LEK gained through tested technology. An evolution of fisheries governance would be required for inshore fishers to successfully contribute to the European Nature Information System (EUNIS) that establishes a marine European habitats inventory to increase the collective understanding of the benthos. Its hierarchical classification is defined and relies on environmental variables which primarily constrain biological communities (e.g. substrate types, sea energy level, depth and light penetration). The following section considers how changing technology interacts with social organisation and fisher LEK learning.

6.2 Social organisation and technology

6.2.1 Intergenerational Transmission of fisher LEK

While inshore fishing crews can gain an appreciation of species, habitats, ecosystems, and bathymetry over time, deep learning of these aspects comes from skippering or piloting the vessel. While this is not always formalised, typically the vessel owner is the skipper and is often the spatial decision maker. Being able to know where to navigate to is not an important element of being a crew member for new fishers. However, inshore crew members do accrue knowledge of habitats locations as the small crew sizes require job sharing. As this quote from Arthur, a crewmate on a trawler shows, the knowledge is often shared between skippers and crew openly, particularly as this crew includes his son:

> Yeah, XXXX would show me how to work the plotter, where the grounds are and what they're called, whatever we're fishing for. When it drops off, or over the rocks or a wreck (Arthur).

This quote shows that knowledge is shared down the generations in relation to new technologies, from father to son. This is the typical method of intergenerational transmission of LEK. This is an example of technological development, as the plotter is connected to an echo sounder and computer, requiring complicated explanation and installation. Although this younger crew member had no plans to take over the trawling vessel preferring to pursue skateboarding in Australia, his older brother had an explicit interest. Since the Brexit vote in the East Cornwall area, at least three young fishers interviewed have been inspired to take on their fathers' boats, under the assumption that fishing opportunities will change for inshore fishers. Nevertheless, the demographic of inshore fishers' remains generally senior, with over 80% of skippers interviewed being over 50. This younger static gear skipper Luke described how intergenerational transmission has developed.

> Yeah me old man taught me the old ways, like to never say rabbit as it's bad luck, and having certain seagulls follow your boat. But when the echo sounder came in and Olex, I helped him out. I had older fishermen on the phone to asking me questions…. Started going out when I was about 8 (Luke).

Intergenerational transmission of LEK is apparent with a range of technological and ecological knowledge, both traditional and old for this fisher. This quote shows younger fishers are more adaptable to new technologies, with some teaching of older fishers. Many of the older fishers interviewed were less keen to use new technologies and were more critically reflective. New technologies allow access to the techniques of fishing from an early age. While there is some division of labour as described by Braverman, (1974), and as the crews are small in inshore boats, crew members' experience develops. For example, crews are allowed into the control systems of the wheelhouse, even if they do not necessarily become decision makers. The influence on LEK of the division of labour is more apparent in the larger fishing boats, as described by older crewman Jim who worked on offshore over 10m fishing vessels:

> You start off as a 'decky' learner and then as you want to be better, then you become an engineer or a cook, then you come up to the shed, and the man on the wheel teaches you about the fishing grounds and you take it on. He just takes you to the grounds, and when you're hauling the gear whether it's fishing better (Jim).

The majority of less than 10 m fishing vessels inshore remain independent of corporate organisations, although this is changing as, discussed in the next chapter. Division of labour also remains significantly lower within the inshore fleet, leaving more fishers reproducing LEK. Nevertheless, where successful intergenerational transmission is occurring, new technologies have affected the extent of benthic fisher LEK. Cyril, an older towed gear skipper, summarised his concerns regarding his son's reliance on codified records of where they had previously trawled successfully:

> Compared to when I started when all you had was Decca and an echo sounder, you could almost teach a monkey to do it now. When XXX came out with me, I tend to wipe the plotter, because he'd been brought up on the technology. He said you've taken all the bloody lines off, you know video game generation it's like stick to the lines, whereas I tend to do it all in my head (Cyril).

The lines described by Cyril are apparent in Figure 10 above. While this fisher may have originally learned using methods including physical trial and error, testing different waters at different times of the year, the codified records of activity of fishing effort were replicated by his son. This skipper was also involved as the chair of the local fishing association and had taken a progressive approach to appropriate technology partly through debates with his son. This concerns what Strathern (2002: 1) called 'virtualism' where every day learning through physical experience with the environment is lessened. Where given access to these sensors, skill, and knowledge are argued by some fishers to have decreased as the emphasis on physical environmental signals is lessened. Derrick an older towed gear skipper from Great Yarmouth explained how relevant this is to the ground discrimination using the Olex 3D chart plotter:

> Knowledge sharing, that's not to do with how clever you are at fishing, it's about how much technology you can afford. Big prawn trawlers up in Scotland, uses ground discrimination,

> little soft bits, a bit like pheasant shooting. If you had a tool that goes beep beep beep, that's exactly what fishing has become. But that's technology, isn't it? (Derrick).

Dependence on technology for decision making is making fishing knowledge less tacit, as newer fishers become dependent on digital equipment. The researcher observed through participant observation that fishers that are less able to note and integrate environmental and ecological systems when they only base their conclusions on computer-based catch focused equipment. How technological change is influencing the sharing of knowledge is considered next.

6.2.2 Knowledge sharing technology and local learning

The following section examines how technologies are influencing the sharing within local learning communities. Computer equipment such as Olex, echo sounders, and digital charts allow for three-dimensional visualisation of the bathymetry of the benthos. Whilst this might not immediately appear to be fisher LEK, basic fisher understandings of bathymetry can bring insight to the benthos and its habitats. The effort required to learn the grounds, knowledge of these benthic ecosystems have been historically a closed secret, typically shared only with the crews of the boats and apprentices, as younger static gear skipper Jowan explained:

> The older fishermen are more stuck in their ways and protective of their knowledge. But there's no doubt the new tech has helped them as well (Jowan).

This capacity to hold secrets was supported by the historic difficulty in recording fisher LEK. With knowledge now easy to record on computers, there are ramifications for sharing, such as being able to return to fishing grounds more accurately. Increasing digitisation means spatial knowledge can be transferred from computer to computer as older towed gear skipper Richard from Southend explained:

> I share knowledge with the cousins. However, they target pelagic fish, I target 'groundfish' we complement each other, help out where we can. We would share knowledge of Olex maps with a memory stick (Richard).

Digital knowledge sharing of 'the grounds' between family members and friends is now making the comprehension of the grounds increasingly more accessible. This is important for the sharing of intergenerational knowledge. The particular skipper above comes from an old successful fishing family in Southend. He bridges the offshore and inshore fleets as he owns both, predominantly using towed gear. Unusually, he has cousins who skipper boats in Southend as well as in Whitstable across the mouth of the Thames. Being family members, they support the sharing and access to knowledge between fishing boat computers. This research has also shown that friendship networks can also support knowledge sharing between boat computers, especially when belonging to the same association.

Sharing spatial knowledge of grounds is not, however, typical in the competitive markets of inshore fishing, unless fishers are related, friends or involved in the organic associations, described earlier in the literature review. While fishers would not always share valuable activity information of the seabed with other boat crews, they might share knowledge of safety risks, known as 'fastenings' in the east and 'hitchings' in the west, through concern for others in the community. Fastenings can be anything from old wrecks to hazards such as unexpectedly deep mud, as this middle-aged towed gear skipper Cyril from Whitstable described:

> We all talk in "Decca" the whole time. If I say I was in the Queen's channel between the 35 8, between the 16 and the 20, they'd know exactly what I was talking about. Also, you'd say this time of the year the ground goes really soft, really muddy; you'd have a job to tow it. So, you tell them that so they keep an eye on the revs and that so they don't get stuck in there. If you mud up bad, you can be stuck there for hours. Fastenings, there are always new ones coming out the ground, you'd share that with pretty much everybody (Cyril).

This particular mid-career fisherman spoke eloquently about releasing knowledge between fellow trawler skippers on the phone. While these aspects of knowledge may not be explicitly about habitats and species, shared knowledge of banks, wrecks and other risks may be pieced together to form ecological knowledge of an area, as bathymetry form indicates habitat and wrecks as evasion spaces more likely to hold fish. Additional benthic knowledge in all forms is pieced together to inform future decisions about where to fish in other fishing communities as Cedric a trawler skipper from Weymouth described:

> Share a bit of knowledge with a few people about hitching sites. Been sharing knowledge of where the trawling is going and has been phoning up with the crabbers, giving them a block point or something and we've been organising it. You need to bring down the intensity for a few nights, leave it for a couple nights; it seems to be the way to do it (Cedric).

Using mobile phones between fishing boats is now increasingly common. While steaming or relaxing between trawls, mobile phones can be useful in strategically planning activity. While previously using the radio was possible, having each other's phone numbers creates more personal relations in the community. This fisher from Weymouth above reminisced that he was one of the last trawler-men in the area, the others moving to static gear. More fishers have moved onto static gear only or become seasonally polyvalent as new conservation regulations have been approved. The technological recording of LEK through digital means has consequences for scarcity and abundance as this younger static gear skipper Jowan summarised:

> Now with 3D bottom mapping that memorises where boats have been, you can go straight back to where you were, even on small boats. That has definitely made catching fish easier and potentially has a higher impact on the environment (Jowan).

Furthermore, in some circumstances, the combined technologies of echo sounders and Olex 3D plotters allow for return and detection of shellfish beds such as scallops as this older towed gear skipper summarised:

> Now with modern echo sounders. With a double echo, you could tell you had a hard bottom or a soft bottom; you get to read your sounder. When you get the mussel beds you lose the echo, when it's soft you lose the echo (Tim).

Given that this Thames estuary area marine space is unmapped, and open access beyond the network of MPAs, LEK is still kept secret. Habitats beyond MPAs predominantly remain unmapped, alongside the fishing activity upon them. Nevertheless, with new technology, the benthos is being mapped by individual fishers more accurately than ever before. This older rod and line skipper Gulvar from Weymouth continued to explain more regarding the Portland Ledge and his bass fishing:

> You know when it's abundant when all the boats are on it. Better off if you find it on your own, then you can catch a load the next day, but if the whole fleet is (sic) on it, then you fish it out (Gulvar).

Being sessile, scallop beds are easy to dredge out quickly, and fishers need to be careful that others are not following them to their local habitat as Paul an older potter skipper explained:

> I've got a nice bit of scallop ground there, over by the island. But I keep it to myself (sic), only fish it at night, as all the other fishers will follow me. I take a little at Christmas just a little, leaving some for next year (Paul).

This comment from Portsmouth 2 highlights the race to fish with valuable but static seabed resources such as scallop beds. That the majority of habitats remain unmapped and open access means such valuable shellfish beds are being degraded. Whilst the IFCAs can issue shellfish permits, in such areas habitat mapping technologies for conservation should be less problematic. However, where power is explicitly formalised in corporate hierarchy or where a corporate body dominates the local boat fleet, as in Portsmouth, conflict resolution and knowledge sharing is a major problem, as explained by younger towed gear skipper Tristan:

> We need somewhere where we can sort out our arguments, somewhere where we can plan a bit better like at the Fisheries Mission in Newlyn. There's (sic) too many fights here, trawlers going through pots (Tristan).

This younger skipper was open to developing new forms of cooperation for knowledge sharing. His fishing connections on the Isle of Wight have seen over-competition lead to both deaths through accident and imprisonment in his family through the pressure of the market, making him open to new social solutions. This position was shared across fishers from Portsmouth. Knowledge sharing typically relates then to concerns of safety, which is more often shared in stronger communities or organic associations, typically in networks of friends and families. Older fishers were found in this research to share knowledge less readily. This is, however, changing with technology. Additionally, fishers share knowledge with each other of their future and recent activity to enhance safety between static and mobile gear users. However, the 'race to fish' means many fishers will keep knowledge activity and good grounds secret. Innovative forms of social organisation, such as cooperatives, are likely to be needed to change this Deacon, (2012). To participate in the fisheries planning of the seabed between gear users, as seen in Japan, (Matsuda et al., 2009), requires increased knowledge sharing. Cooperatives are known to ameliorate competition through profit sharing, and spatial organisation (Gaspart and Seki, 2003). New social media technologies, such as web-based apps to facilitate knowledge sharing could be developed to support those willing to start fishing cooperatives. Cooperatives, such as the new Coastal Producers' Organisation, would see open access areas better managed than individual interests. How social media technologies have influenced LEK will be considered more deeply in the following section.

6.3 Fisher LEK and learning through non-fishing technologies

6.3.1 Social media technologies, access, and sharing

Social organisation and sharing of fisher LEK are influenced by increasing access to social media technology. Digital mapping of the seabed leads to a decreasing need for continued use of physical testing of knowledge through physical experience. Indeed, the codification of knowledge in digital form has positive ramifications, including increasing access to knowledge through the community of fishers. An older crew mate from Hastings Sean summarized the shift:

> Through the last 10 years, because of the internet, because of the complicated electronics, once people have had to start reading the manual, the education level has gone up (Sean).

This fisher had worked both in the Puget Sound in Canada, as well as off the Cornish coast giving him more experience than many in how increased use of the internet has led to greater technological and ecological comprehension. In Dorset, through participatory mapping of the seabed with C - Scope, a non-statutory marine plan, the knowledge that previously would have taken generations to accumulate is now available on the internet. Gulvar, the rod and line skipper from Weymouth, explained his experience:

> Been on the internet to look at the C-scope mapping - if you look at St Alban's ledge you can see it's similar to Portland ledge, you've got to keep running over ground (Gulvar).

This quote demonstrates that their access to digital mapping knowledge has confirmed the fisher's assumptions about their bathymetric knowledge, which supports spatial ecological knowledge, and estimations of the available fish stocks. This adds a layer of ecological knowledge of conservation to local maps which can be accessed for further reflection. This access to bathymetry and conservation logic through the internet from outside of the traditional fisher knowledge system was accessed easily by the bass angler above. Differently, Cedric, an older trawler skipper was less positive about its value:

> It's nice but we know the grounds locations already (Cedric).

Knowledge of sustainable practice is not necessarily part of fisher learning system. Given additional restrictions, fishers are likely to critique negative comments of their practice. For example, social media brings critical consideration of fisher practice into the mainstream debate, and consequently many fishers from the towed gear sector feel under threat, such as this older scallop dredge skipper Dougal:

> That TV chef, Hugh Fernley Whittingstall. Spreading his nonsense about fishing, about scalloping. It really makes me furious I just want to get on with fishing (Dougal).

The influence of Hugh Fernley Whittingstall's social media movement, 'The Big Fish Fight', alongside the growth of MPAs, and the growing mainstream critique of trawlers is influencing how fishers select and reproduce LEK as explained by older static gear skipper, Ben:

> We had that Hugh Fernley Whittingstall down had to put him right about a few things about the marine conservation zones, particularly about Hythe Bay (Ben).

Given the opportunity for social media to influence the policy agenda of marine conservation zones, this older towed gear skipper Louie engaged critically, with regard to the local contestation of the proposed Hythe Bay MCZ.

> Had my son do all the website stuff for the Hythe Bay MCZ. It's a traditional area; we've been fishing there for generations. We've been doing it there for hundreds of years, and they've still got the peacock's tail. Really got the campaign going getting it online, built a lot of momentum. It's on YouTube as well (Louie).

This demonstrates that by initiating their own campaign against the Hythe Bay MCZ designation, fishers are aware of the value of their knowledge and are ready to deploy it to defend against external threats to practice. After interaction with the MCZ consultation, the fisher demonstrated knowledge of species of conservation interest. Nevertheless, this was added to the argument for continuing fishing in the area. Later reflections were more positive when it became apparent that fixed gear fishing could coexist with rare species in the area. This is a shift to online activism. Fishers, such as this older static gear skipper John, deploying their power and influence by getting the general public involved in fishing policy:

> We share knowledge on the Facebook group, the 'Real Fish Fight', countering all that nonsense from that TV chef, share videos, and links about what it's really like (John).

This work established with the 'Real Fish Fight' Facebook group attempts to influence and bring the narrative about fishing back under the control of the fishing community. An excerpt from the introduction that he has co-written reads:

> Have you had enough of Anti-fishing campaigners having their say and not having yours? Well, now you have your own platform to share your experiences and opinions, post your pictures etc. and stand united and make a difference for our future! (John).

Given the critique of fishing (and trawling in particular) in the media and the resulting public discussion around the policy of bycatch and discarding, the fishing industry as a whole felt targeted, and acted together beyond the internal divisions in the industry of static gear and towed gear. Fishers' Facebook pages are designed to question the critique of fishing and feature links to articles regarding ecological processes, as in the following introduced by this older gill netting skipper John from Ramsgate:

> Marine ecosystems are dynamic and cyclic, we need better food web monitoring as to where and when, and who is eating whom... (John).

This fisher also made specific reference to research on fisher LEK he obtained online via Facebook, which he described during the following interview excerpt:

> Universities have documented fishermen's knowledge in India. Eight hours before the tsunami hit the shores in 2004, fishermen in the coastal areas sent a message that the sea would come flooding in. It was the elderly fishermen in the area who gave the warning - listening to the sounds the sea and the behaviour of animals in the water and on the land. But, for want of any scientific explanation, the warning fell on deaf ears (John).

The article John mentions is linked to the GAP2 Facebook page and project where scientists in Britain have been working with offshore skippers to use fisher knowledge for assessment of water column species stocks. That the original Big Fish Fight group, started by Hugh Fernley Whittingstall, was perceived to be critical of fishing and is being responded to by fishers, but in a way that opens up the debate to scientific knowledge, as suggested by the fisher above. Other fishers in Devon and Dorset responded to the influences of the social movement of the Big Fish Fight in positive ways, for example, the Blue Marine Foundation has created the Lyme Bay Reserve Group. Their website compares fishing to farming, highlighting the benefits that farmers gain from leaving land fallow – as supported by EU regulations "British farmers are paid to conserve on land. Our project will try to find ways in which fishermen can derive similar benefits from conservation at sea" (Blue Marine Foundation. 2015).

However, while farmers are subsidised, fishers lack the property rights of farmers that are concrete and spatially based. This demonstrates how the NGO sector is now working with fishers to campaign for conservation on a spatial scientific basis. In a related but separate campaign for quota, fishers from New Under Ten-metre Fisheries Association (NUTFA) encourage greater engagement with scientists for co-production of knowledge, as indicated below on the NUTFA website - nutfa.org:

> What is vital and only now beginning to be recognised and accepted by fisheries scientists, managers and ICES itself is that the observations of fishermen are valid and could make a significant contribution to their knowledge and understanding. NUTFA actively encourage members to make a positive contribution to data collection and to assist fisheries scientists through practical means to more clearly understand marine processes (NUTFA, 2015).

Relating to this, an umbrella group has begun to campaign for special access rights for the low impact fishers of Europe (LIFE):

> The aim of LIFE is to provide a clear and coherent voice at EU level for the previously mainly silent majority of European fishermen, who are smaller scale and who use low impact fishing gears and methods but have historically lacked dedicated and effective representation in Brussels and at Member State level (LIFE, 2016).

The low impact fishers of Europe are now aiming to change perceptions about the differences that different techniques of fishing have on the benthos, on their LIFE website (LIFE, 2017). Working across the EU, having begun with NUTFA members, LIFE's work reflects the changes in the industry, away from towed gear. From the 2014 reform of the CFP, Article 17's definition of special access criteria for low impact and socially sustainable fishers, has given LIFE impetus as a social movement. Nevertheless, its website lacks clarification on what exactly low impact fishing is, such as any reference to the different environmental impacts made explicit by the earlier quoted fishers. While described to some extent in this chapter, the impacts of social media and websites on fishing requires more research in the different inshore areas of the EU's member states. The social network LIFE and the Coastal Producers' Organisation would need support from researchers to consolidate collaborative governance and the diffusion of new knowledge about fishing techniques. This links to the analysis in Chapter 7 of the influence of quota governance and the effects of corporate forms of social organisation.

This section has demonstrated how fishers are beginning to deploy their LEK online in order to defend their reputation, as well as aiming to increase their power by influencing the general public and authorities. This is influencing their LEK as they gain a greater understanding of ecological learning and programmes. As the next section shows, fishers are also increasingly engaged with the logic of conservation where new technology is making different ecological knowledge accessible. In cases where fishers have been included in underwater habitat visualization methods, such as with cameras and diving, their understanding of the need for marine conservation of habitats is becoming more developed. This is more easily accepted by fishers whose gear is less likely to interfere with the conservation objectives.

6.3.2 Conservation, validation, use of low impact gear and the relationship to NGOs

Where gear use is less at odds with ecological overexploitation, such as with static users like netters, potters, and divers (Grieve, 2015 and Coleman, 2013), it is easier for fishers to integrate conservation science with their LEK. In the case of Lyme Bay Reserve, the working group, facilitated by the Blue Marine Foundation NGO, has been successful with these challenges. When the mobile gear was banned from the MCZ, local fishers became concerned at the significant growth of potting gear in the locality, and the Lyme Bay voluntary agreement facilitated cooperation on potting between fishers, conservation, and government. An elderly potting captain discussed how the project evolved.

> There was way too much potting going on, so we got the voluntary agreement together. It has been helped a lot with the underwater camera work with the University so we could show them where the habitats are, like the grey Lias rocky reefs, and the species like the sea fans were (sic) (Reggie).

Given the potential for management measures to restrict bottom towed gear types of fishing in historic grounds, fishers were keen to understand better the methods of scientific assessment to find and designate the interest features. Where the banning of towed gear did occur and over-potting subsequently became an issue, an NGO and fisher led co-management group successfully evolved in Lyme Bay. However, this was underpinned by ongoing visual bathymetric and benthic research, to better understand potting impacts. Interestingly, where visualization of the benthos does take place, it appears to encourage fishers to access, value and engage with scientific conservation knowledge. Given the above exchange, with regard to the contestation of accessing benthic scientific knowledge in designating marine conservation zones, the fishers felt motivated to help more accurately zone their local habitats and ecosystems. This demonstrates the potential of co-produced conservation science and its ramifications for fisher LEK. An older potting skipper from Selsey explained his experience and justifies his input:

> As usual, the data was crap. We towed a sledge around (sic) here. With a video camera and a still camera. It was nowhere near where they thought it was. We knew where the stuff was, showed it to them. Got my son involved. Showed them where the hounds were, Mixon hole and the other rocky sublittoral habitats (Anthony).

Enabling visualization of the seabed, using a towed sled camera around the rocky reef habitats of Selsey Bill, allowed fishers to validate and confirm their benthic LEK with Natural England. These efforts allowed for the visual identification of habitats around the local fishing community to be shared. While helping to map this area did not create limitations on potting, it did allow for greater influence by the fisher concerned in the running of the local Inshore Fisheries and Conservation Authority (IFCA). Subsequently, he achieved influence on the designation and management of MCZs in the region. The following younger skipper from Portsmouth, who used to fish in Cornwall, also found video surveying of habitats significant.

> Seeing all the maerl down the Fal was good, we attached cameras to the dredge and other gear to see what the impacts were like. Obviously dredging over maerl is going to cause damage to other species which live off it (Tristan).

This fisher’s experiences of making films using towed gear were positive, particularly in regard to the rare species of maerl, which creates a habitat and feeding ground for other species. It was helped by his girlfriend who wanted to research towing impacts on the seabed. This led to ideas about the importance of conservation of habitats to become integrated into fisher LEK, both in Falmouth and

Portsmouth. Similarly, the older static gear skipper Alan, who had been involved in scientific surveying with video cameras, was able to explain where habitats were and emphasise their importance.

> We did the video survey to show them where the different rocky reefs and stacks were, for the balanced seas project. It identified Sabellaria reefs, blue mussel beds, oyster beds and piddock beds (Alan).

Given this motivation to protect these scarce habitats, the fisher concerned was keen to demonstrate their existence with scientific validity. This has led to a changing practice in regard to the recording of habitats by fishers:

> Sabellaria - we try and mark them out and avoid them. (Alan).

The way in which Alan now codifies certain habitats for conservation interest is novel. While most fishers are codifying their personal fisher knowledge with regard to good fishing grounds, such as closely guarded locations of scallop beds, it is a new phenomenon that this fisher is voluntarily recording data for conservation purposes. It demonstrates the way benthic LEK of some fishers is now changing - creating a mapped recording of the habitats on this fisher's computer. It also demonstrates that in future attempts to help conservation, local IFCAs could create GIS layers of vulnerable habitats and features to help educate fishers of their value. This learning has been spreading through this fisher's local community, changing the perception of the scarcity of habitats among other fishers locally, and creating more consensus regarding MCZs. Furthermore, those fishers who have been diving and actually physically surveyed the benthos have a particularly well-developed comprehension of benthic habitats such as this older static gear skipper Ben from Hastings:

> I think diving did make a difference, cameras are good too. I think diving gives you the knowledge, and of substrates, how it affects the life on the seabed better. It's brilliant, how the fish hide and adapt how the fish live in certain sea bed types, structures, and rock forms. What I've been diving is mainly caves and tunnels and rock forms (Ben).

Accessing this hidden marine landscape through diving allows fishers to visualise it in a way that is not possible through traditional fishing techniques on the surface, nor through emerging technologies, such as Olex chart plotters and echo sounders. This visualization through the fishers' own eyes has helped piece together a sensory understanding, regarding how different substrates influence the development of different habitats. This younger static gear skipper from Newlyn elucidated:

> Most familiar with habitats at diving depth because I've done a lot of diving. I go fishing in places where I've been diving. Certain rare habitats, such as the Isles of Scilly where they have these scoured narrow channels, where you get eelgrass and such things, quite a rare habitat apparently. Mainly the offshore reefs that create (sic) a habitat, such as for sessile species like kelp which brings in species like pollock (Jowan).

Given this development of LEK of scarce habitats, and how reefs allow for sessile species to develop through the rocky substrate, this quote demonstrates the benefit of diving as a source of LEK for fishers. Given the opportunity to participate in the marine conservation zone network south-west assessment group 'Finding Sanctuary', it appears that this fisher's diving experiences have helped open his mind to the benefits of conservation and given him the experiential enjoyment of the species and habitats of the benthos. This has made him more likely to learn about habitats and species than those fishers that do not dive. It is this barrier of the sea surface that if penetrated, can yield illuminating insights into phenomena and events efflorescing in the deep. Other fishers in Devon, such as this younger scallop diving skipper, have been increasingly diving for scallops and echo this.

> With no dredging the seabed's come alive, two years does make a difference. Primrose and jewel anemones on rock faces, with sea fans starting to come back. The seagrass is doing really well, not getting dredge silt on it. Never seen as many cuttlefish eggs, or the Spiridius orange sponge, white sea squirts and small fan corals, as well as bright orange starfish. (Neil).

This fisher, working on boats as well as dive scalloping, brings detailed knowledge of locations of habitat recovery after scallop dredging, as seen in Figure 12, and shares it with other fishers in the Brixham community.

This LEK is further shared photographically through a local diver group. Work by Kenter et al. (2013) simplifies MCZs according to monetary value. Further research could examine the non-monetary understanding of the intrinsic and instrumental value of these habitats. This can consolidate a non-monetary theorisation of LEK of biodiversity and its value. Given this visual access to scarce habitats and species, fishers and others are more likely to value this as external life (as suggested by Butler, (2006) when referring to life taken during the war). This is because if fishers see the benthos living in full production, they are more likely to go home and research it through aesthetic enjoyment. The framing of the benthos is then dependent on whether it is analogue or digital, the research shows both physical experience with LEK needs to be complimented by technologies which draw attention to habitats that need to be conserved. Viewed through a video camera or through a diver's mask, rather than observed through a digital interface, to target single species makes biodiversity benefits more explicit through their living aesthetics and physicality. The commodification of species rarefied only according to exchange value can leave them undervalued by fishers. The next generation of Olex 3D plotters may provide increased visualization of habitats and species in the future to support conservation learning. These adaptations of the process through diving demonstrate the potential for more fishers to develop a greater understanding of biodiversity and conservation through different techniques of underwater fishing. Regular surveys of marinescapes by fishers using video cameras, Olex chart plotting, and diving could provide invaluable evidence to the IFCAs and other conservation bodies of habitat recovery if this was increasingly encouraged through zoning and adaptive co-management. Emancipatory knowledge creation through praxis can produce an increased reflection on how different types of fishing practice have different impacts on ecosystem services and biodiversity. Involvement in such research can overcome the neoclassical economic focus on single species for markets.

6.4 Conclusion

This chapter demonstrates how fisher LEK of the benthos is changing and developing through evolving technology, through codification, organisation, social media and different forms of visualisation. These aspects relate to the key research question of how technology is influencing fisher LEK of the benthos. It begins by highlighting that the key elements of the benthic knowledge system across gear types focusing on bathymetric features that support habitat development, including rocky reefs, gullies, ledges, and substrate differences. Considerations of the tide, shear bed stress, temperatures, and seasons are also used to understand changes in fishing grounds. Fishers' comprehensions of marinescapes give insight into the environmental signals that interlink regularly with LEK of ecological systems, multiple species, and abiotic factors that influence fish species' biology (Drew, 2005). Different fishers use these signals to determine what gives rise to nursery grounds, breeding grounds and feeding grounds for different species across their local marinescapes. The usage of this term makes it clear that the marine landscape is not 'terrestrial-centric' and that it is not 'a landscape'.

Fisher LEK has also changed with the growth of different types of fishing techniques. Fishing effort has notably increased over approximately the last 40 years through increasingly efficient, automated gear such as net stackers, winches and new types of nets. Neis and Kean (2003) underline how spatial, temporal, and ecological intensification and interrelated expansion was also noted for inshore fishing. This acceleration in spatial fishing effort due to technological advances has increasingly blurred the boundaries between the inshore and offshore sectors in Newfoundland. Where new digital technologies allow rapid sensing of bathymetry, vessels can more easily explore new areas, with a greater chance of fishing success, and thus cause new damage to previously untouched habitats. This relates to competition, the differences between static gear and towed gear, and how this has been changing. In Newfoundland, Canada, the local ecology, and customs have changed through the influence of the market, shift towards GHK (Murray et al. 2006). In southern England new technologies are allowing the sharing of knowledge in new ways, improving understanding of conservation that means fisher LEK is not just becoming GHK. Therefore, some inshore fishers have switched over to static gear to reduce their impact and ensure that they can continue to fish in some areas of MCZs.

New technology and seabed sensing methods are moving fishing from a trial-and-error approach to a more accurate way of knowing. While towed gear and static gear sectors remain different, they are both changing in regard to benthic sensing with technologies, such as Olex plotters and echo-sounders, making targeting more efficient. Furthermore, this greater accuracy means LEK can increasingly contribute to the widespread mapping of the benthos and improved governance. Certain fishers are deploying ground sensory techniques and mapping new bathymetry more accurately than ever before using Olex chart plotters around England. While this codification occurs over the local benthos, it is not necessary for it to be recorded fully for it to be useful to fishers. Contrastingly natural scientific knowledge requires knowledge to be codified for it to be analysed to become a product for it to be fully realised (Sayer, 1984). The natural science vision of knowledge only becomes fully realised when abstracted and codified and is therefore often not as important to fishers or to conservation initiatives as fisher local learning.

Fishers highlight that other fishermen are increasingly less reliant in physically experiencing the benthos because of new sensory technology. Fisher LEK of species biotics, environmental signals, and ecosystem pattern learning is apparently being disrupted. These new technologies mean that fishers are increasingly aware of the potential for overexploitation of fisheries. Where these characteristics are occurring, the potential for adaptive co-management and spatial use rotation in collaboration with the IFCA is more apparent.

With regard to shared learning, LEK is increasingly reliant on technological sensing. It is now possible to share the results of fishing activity digitally, such as which gear was used and when, alongside records of catch spatially recorded, thus allowing for self-sampling (as suggested by Kraan et al. 2013). The new methods in which fishers are recording their activity make their knowledge easier to discuss so that LEK becomes discursive knowledge. Activity which was once tacit is now explainable; supported through codification. While fishers historically would not share this knowledge, except through intergenerational transmission or their own crews, fisher LEK sharing is shown in this research to take place, particularly in regard to how underwater features shape risks. In local communities around Southern England, fishers attempt to avoid fishing in the same places. New technology now facilitates this process between different vessels' crews which is, in turn, significant for the organisation of the commons.

Fishers are deploying new social media to gain and share knowledge. Understandings of the different layers of ecosystems – such as the vertical changes of ecotones are expressed. Furthermore, the participatory mapping work of Dorset's C-Scope has added layers of comprehension of features of conservation interest, whilst additionally confirming pre-existing understandings of LEK. Internet based social media has led to contestations of conservation, as well as defence of the reputation of the fishing industry. With fishers concerned about the impact of the Facebook group, The Real Fish Fight, this chapter has analysed how fishers' learning is changing by attempting to gain control of the marine environmental narrative from Hugh Fearnley Whittingstall's Big Fish Fight social movement. By using social media, LEK is being shared among fishers electronically, outside the NUTFA group. By this means other fishers have defended access rights to the marine resource by campaigning to maintain fishing without bylaws in the proposed Hythe Bay MCZ.

The benefits of Pescastemic rights, as defined in the conclusion of Chapter 5, can be glimpsed through the shared learning of conservation, made possible through new technologies. Using critical realism has helped identify this emancipatory mechanism, benefiting from co-produced scientific knowledge for conservation. It is manifest in locations such as Lyme Bay and is significant in shifting epistemic frameworks through LEK. Visualization of the benthos through the use of technology has brought to life marinescapes normally invisible and lifeless at the surface. The use of underwater cameras and diving has allowed those fishers to become more interested in species of conservation interest, as well as the integrity of the associated habitats. For example, fishers in this research have highlighted the importance of maerl in contrast to rocky reefs and discuss the value of protecting sublittoral mud in proximity to an MCZ. While bathymetric data is increasingly accessible through Olex plotters, this does not provide an appreciation of living habitat differences. Olex and similar technologies can bring a reductionist bathymetry, without the actual colour and biodiversity of the benthos. Given this increased access to visual methods and more learning about underwater habitats, fisher LEK is more likely to be validated and shared within the local fishing community. Furthermore, now that an increasing number of fishers are supporting the protection of these areas with visual data gathering, this research demonstrates that their epistemic framework exists beyond the pursuit of single stocks and an explicit policy supporting the integration of LEK could support the growth of marine democracy. The concept of 'Pescastemic Rights' could help to provide a framework where both digital and analogue forms of technology visualising the benthos would see educational feedback between fishers and scientists, rather than simply focusing on single species for the market.

The next chapter will examine the interaction with quota governance, property rights and how social organisation influences fisher LEK. It will examine these LEK issues in reflection of whether UK marine quota governance delivers environmental justice, the contribution of fisher social movements and how marine democracy can be enhanced.

7. The Interaction of Quota Governance and Social Organisation and Fisher LEK of the Benthos

7. Introduction

The changing tides surrounding Brexit discussions present an opportunity to reform fisheries in the UK (Anbleyth-Evans and Williams, 2018). It potentially could allow for greater participation and integration of fisher LEK of the benthos. Inshore fisheries in England can be viewed through a lens of environmental injustice. Integrating fisher LEK of the benthos would allow for a spatialised, geographical approach. Currently as Total Allowable Catch (TAC) considers demersal stocks, rather than those of the benthos an ecosystem-based management approach is not taking place (Carpenter et al. 2016). Further, the EU's Common Fisheries Policy (CFP) has developed at such a high spatial scale that it has left small-scale fishers feeling excluded in ecological assessment (Anbleyth-Evans and Williams, 2018). Compounding this, for the last 40 years, the UK Government gave less than 2% of the right to fish ('quota') to the 78% of the UK fleet that's made up of boats under ten metres (NEF, 2015). What is less well understood is that once the overall share of the TAC at EU level has been split among the Member States, the proportion of quota for each species distributed to the UK fishing industry is a UK government competence, rather than (as often claimed) the choice of Brussels (Appleby et al. 2013). This confusion around responsibility and sense of injustice are the inequality in terms of allocation to particular fleet segments has led to many inshore fishers to campaign to leave the EU. It is the role of the UK government to develop a just system of allocation and assessment. If integrating fisher LEK of the benthos, a spatially just rights approach for different inshore fishing communities would be needed. Nevertheless, the UK government has sought to expand further the non-spatial, private property approach to the under 10m fleet, which it is suggested will result in greater concentration of access for bigger fishing businesses (Sumalia, 2010).

A concomitant pressure for England's inshore fisheries, limiting the development of fisher LEK of the benthos, has been top-down governance. In order to counteract the influence of this historically open-access fisheries, an assumption developed that an external, 'Hobbesian' state administrative Leviathan was necessary to bring over fishing under control and prevent the tragedy of the commons (Larkin 1977). In England, there remains an ecological and democratic imbalance with the 0-6nm inshore area being managed top down without fisher participation in quota or other ecological assessment, by the Marine Management Organisation (MMO). There has also been stakeholder-led by-law development with the IFCAs for fisheries activities in MPAs. In contrast, the 6-12nm offshore and 12+ 'Exclusive Economic Zone' (EEZ) is market or private-property led, and the scallop-dredging fleet is open-access managed by days at sea effort regimes (Imperial and Yandle 2006). It is worth noting that the

6-12nm fishing area incorporates boats in UK FPOs including different EU boats. Also, there are specific EU boats with historic grandfather rights to access waters 0-12nm through the London Convention. Offshore beyond 12nm (this is more Scotland and the North Sea and Celtic than the Channel), pelagic fisheries are dominated by massive high capacity trawlers. This chapter examines how fisher LEK has been deployed to the problems arising from these arrangements and, using a critical realist approach, how a mechanism could be developed to address what Agyeman (2003) refers to as environmental justice and fisheries democracy.

The goal of this chapter is to demonstrate, through interviews, how changing forms of governance and social organisation are influencing the development of fisher LEK of the benthos. An equal spread of quotes were taken from static and towed gear operators, including different geographies, age, different types of organisations and crew types. The quota system has evolved to benefit those in the over 10m FPOs, who hold more than 98% of the quota quasi-property rights. Confusingly, the quasi-property rights are legally ambiguous, not being fully defendable in court (Appleby et al. 2016). The complex negotiations needed between states for fisheries management and quota through the CFP has evolved to suit fishers with greater industrial scale and ecological impact (Sissenwine and Symes 2007). Accumulation through the market enclosure is seeing fisheries rights concentrated with big business around the world through 'blue/ocean-grabbing' (Benjaminsen and Bryceson 2012). Incentivizing those that are most economically efficient can often mean supporting those who are more environmentally destructive (Sumalia, 2010). The fleet register of UK fisheries shows that the over 10m fleet features over 90% towed gear, compared to 22% under 10m, (Fleet Register, 2016), which is more ecologically damaging (Kaiser et al. 2006 and Grieve, 2014).

The introduction of the Register of Buyers' and Sellers' legislation in 1986 showed the UK government that the inshore fleet was landing much more than they first assumed when originally allocating. By the time they realised the inshore fleet was having a notable impact on stocks they had already given the majority of fishing opportunity to the over 10m fleet. The mid-80s also saw the introduction of the FPOs. The overwhelming majority of fishing companies in FPOs manage multiple over 10m vessels. While some still relate to the original regions they were conceived for such as the Shetland and Cornwall, the majority now allow for boats to migrate around the coast by buying and renting / leasing quota, with transnational rather than community ownership. The FPO system has allowed for 'quota hopping' (the practice of obtaining the right to catch a part of a country's national quota for fish in European waters (by buying quota attached to vessel licenses). It has seen more foreign business ownership of quota in the UK than in any other EU member state (Hatcher 2002 and MSEP 2015). The economic link study by DEFRA in (2009) underlined that a high percentage of quota is controlled by foreign-owned vessels with non-indigenous fishers, landing fish in Europe, who do not ripple benefits through local economies and communities (NEF, 2017).

It was the London Convention of 1964 that formalised rights of access for EU nations to fish in UK waters, between 6 and 12 miles. The rights of access to fish in the 12-200 nm zones of all EU Member States as a common pool is enshrined in the CFP first signed in 1973. For UK waters between 12 and 200 nautical miles, this means other EU fleets can fish. Ending this situation has been one of the primary objectives of the Fishing for Leave / Brexit lobby, with the aim of an exclusive UK fishing zone within 12nm. The UK quota system also allows the over 10m FPO sector to be nomadic around the coasts. The government has allowed a competitive race to fish to develop by making quota a tradable commodity (Appleby 2013), and by not formalising the relationship between fishers and a coastal region (Appleby et al. 2016).

The socio-ecological system in which these fishers are embedded has changed from organic associations to corporations or cybernetic organisations. This has impacted upon the knowledge and orientation of these fishers to each other, the fish and their work (Murray and Neis, 2004, and Johnsen, 2009). Within this context, different forms of social organisation are active and influential in the development of today's fisher LEK of the benthos. How certain forms of organisation and governance support and act against intergenerational transmission of fisher LEK through demographic impact is examined. With larger businesses owning more than one boat in one area, intergenerational transmission is being impacted, alongside the potential for the forms of cooperative behaviour necessary to share knowledge, resources, and power with the government. Forms of cooperative behaviour, identified by Deacon, (2012) relate to the social organisation identified here. Allison et al. (2012) theorised fishing spatial access rights as a human right. The knowledge sharing dynamics around fishers' governance can inform the discussion of the total number of boats and fishing effort spatially on the benthos under a Pescastemic Rights approach.

Nevertheless, as Appleby and Jones (2012) point out in the legislation in the MCAA there is no reference to the ecosystem approach and therefore no objective to see the participation and integration of fisher LEK of the benthos. How this situation and the role of fisher LEK relates to the tensions of growing private property relations introduced will be investigated. This leads to reflections upon which forms of governance could evolve to develop democracy in fisheries. This chapter also considers how fisher LEK is responding to the politics of access and the use of space caused by the quota market. While the quota system has the effect of limiting the effort of inshore fishing upon single species, it demonstrates that quota does not relate to the spatial areas of breeding grounds, habitats or biodiversity from the benthos upward.

In 2009 Elinor Ostrom observed that while scientific knowledge and the social sciences are both needed to support socio-ecological systems, they do not combine easily. This chapter shows the importance of taking a critical realist approach to bring together both the natural and the social sciences to identify regimes where fisher LEK of the benthos can contribute to new democratic processes of quota governance (Bhaskar, 1975). This chapter demonstrates how fisher LEK is developing at the locus of marine knowledge spatial contestation, going beyond the market- led, short-term epistemic approach. It aligns with research that shows that in the future, fishing cooperatives can share fisher LEK with each other to decrease excess capacity and slow the race to fish, whilst planning how, where and with what gear fishing is carried out over habitats and space (Deacon, 2012). The following section will examine how fisher LEK is changing in response to social organisation, intergenerational transmission and the politics of quota governance.

7.1 The new politics of LEK: quota governance open access and intergenerational transmission

The following section explains the core challenges of fisheries governance for inshore fishers' LEK of the benthos. It explores their responses to these issues of participation and also collates insights from key informant interviews to understand how fisher LEK is interacting and responding. Politically, many inshore fishers claim that the EU CFP has been the obstacle to participation, being too remote from local seas and the people fishing in them. The political movement of United Kingdom Independence Party harnessed fishermen's anger as a vehicle to gain momentum to make people in the UK vote to leave the EU (BBC, 2016). This is in tandem with claims by the 'Fishing For Leave' social movement that a 'Days at Sea' open access regime would be the best approach, led by large-scale industrial fishing boat owners, as well as certain inshore skippers outside of the New Under Ten metre Fisheries Association (NUTFA). Historically, as negotiation for the total allowable catch (TAC) is completed in political competition with other nation states, scientific evidence has been ignored through attempts to placate large-scale fisheries. It has been highlighted that stakeholders from the fisheries industry feel that scientific advice also suffers from low legitimacy and a lack of transparency (O'Leary et al. 2011). Scientific accuracy has been better integrated with the 2014 changes to the CFP (Carpenter et al. 2016).

Curiously, interviews with key informants from NUTFA, civil servants and NGOs suggest that it was the UK government that played a central role in the creation and the allocation of fishing opportunities under the Ministry of Agriculture, Fisheries and Food (now Defra). Under 10m fishers report that, as track records were not taken for their fishing, but only taken for the large scale over 10m FPO sector, they were given an environmentally unjust portion of the quota. Originally quota swapping began as a form of adaptive management to changing conditions (Appleby, 2013). It evolved into a shadow trading market for EU assessed overall quota then allocated by the UK Government, disproportionately to over 10m FPOs. With quota in effect for sale, it allowed for those with the greatest financial resources to invest, such as transnational corporations from different countries (Greenpeace, 2016). This has taken access to fishing out of communities and local ecologies. The continued consolidation and aggregation of fishing rights outside of the local fishery community area to larger corporate entities has decreased the potential for trust in the system and between fishers (Crosson et al. 2013). It has also led to businesses making more money leasing out fishing rights, whilst not doing any fishing or the rise of 'Slipper Skippers'. A leading activist fisher from Plymouth, an older static gear skipper explained:

> There's one Dutch vessel that has 23% of the entire (English) quota, it's called the Cornelius Vrolijk, and it's a factory ship. Yes, it's employing 60 people, but there's (sic) 60 people fishing in this port, but we don't have 60% of the quota. The quota in this port is less than 1%. That vessel has more than the whole Cornish fleet (Eric).

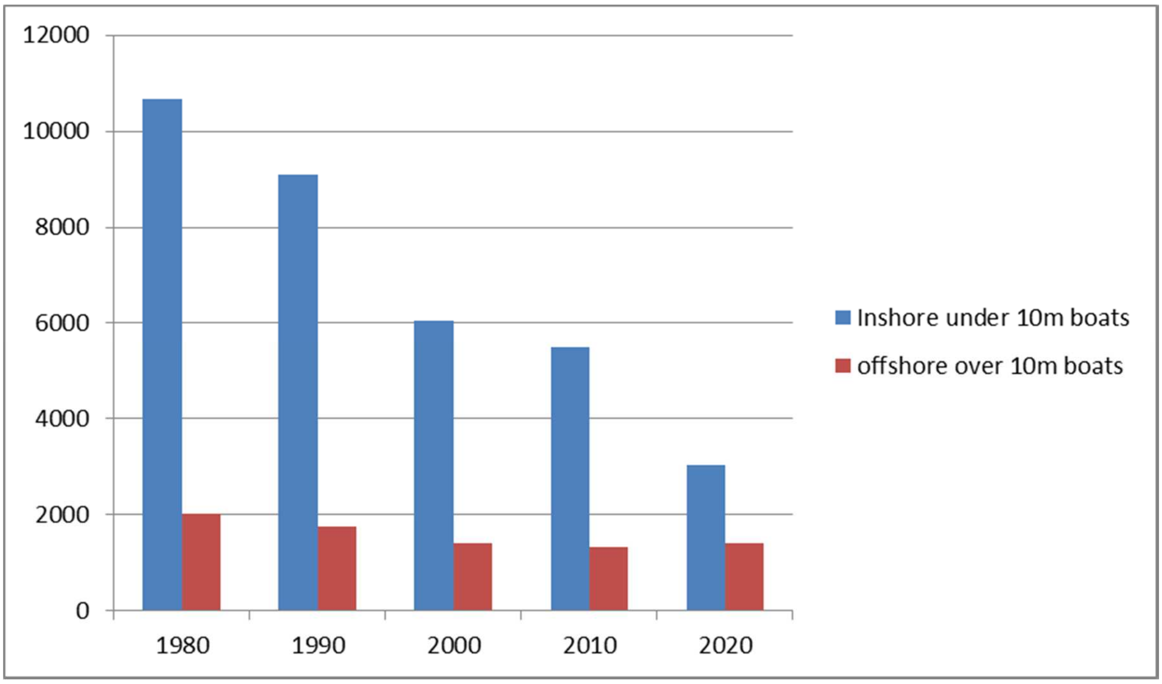
The quota market has led to 23% of all pelagic species quota in England being attached to one fishing boat the Cornelius Vrolijk, a Dutch-owned company as shown in the figure below. The consolidation has been possible under the EU freedom of establishment, rather than the CFP. By taking ownership of so much of the quota, this single fishing factory trawler reduces access to smaller vessels, supporting local fishing communities. As a result, fishing populations tied to local communities are declining. This has caused a form of elite stratification with declining numbers of skippers and crew throughout the inshore fleet in Southern England.

Figure 9 The Cornelius Vrolijk owned factory trawler. This fishing ship is important in the imaginations of inshore fishers as a symbol of the inequality of the system, between those classed as under 10m operating inshore and those over 10m.

The Cornelius Vrolijk's quota ownership distorts the market by monopolising ownership. Large business structures are only dominant in certain local geographies in England's inshore area. These companies are not legally obliged to make quota available to inshore boats. The combination of FPOs, the quota market and corporate forms of ownership has led to a reduction in the size of local fleets (Fleet Register, 2016). This combination has also influenced the age profile of fishers, as lack of access to quota is a barrier to entry for young fishermen, who also have vessel and gear costs to contend with. An older towed gear crew mate from West Mersea concluded:

> There's your knowledge problem, there's no one to pass the knowledge on to! Ask Kent and Essex IFCA how many fishers there are under 50. Ask how many there were in the 90s compared to now (Stuart).

This part-time crewman, who previously had the capacity to pay for a two-man crew, had to sell his static gear boat and his house through lack of quota access. He now has to work part-time on a Chinese owned dredger in the east Essex area. The devastation wrought by the quota system on this fisher was apparent in this emotionally charged interview. While these thoughts from the fisher reflect a specific demographic problem in their locality, the overall decrease in inshore UK fishing boats is around 4500 since 1980, when it was a fleet of more than 10000 boats (Fleet Register, 2016). This trend is demonstrated in the graph below:



Graph 1 Population of fishers over time and predicted a decrease in the inshore population under current quota regime (Statistics from Seafish, 2016).

This coincides with the gradual introduction of FQA system allowing quota trading from 1986. Indeed, the continued transformation of many small into few large companies has continued, seeing the quota concentration with fewer fishing businesses and less allocation to support coastal communities in the UK (Anbleyth-Evans and Williams, 2018). Research work by Greenpeace has shown that the existing quasi-quota property rights system has resulted in just over 66% of quota as property belonging to three companies; Andrew Marr Inc, Interfish and Cornilieus Vrolijk (Undercurrent, 2016). While FQAs were introduced for efficiency to reduce the fleet size via economic means, the result is consolidation by fewer boats, an aim not made explicit by DEFRA at the time. Nevertheless, the logic of neoliberal growth has seen the metaphoric enclosure and sell-off of public property as quota, which does not support the intergenerational transmission of fishing and LEK (Mansfield, 2004). Indeed, the quota system creates hidden social costs, such as the cost of getting a fishing boat without family backing (Pinkerton and Edwards, 2009).

It was reported by the fisherman during an interview that the cost for a tonne of cod varies from £300 to £800. The resulting catch might bring just £1100 at the market, leaving a profit margin of between £300 and £500 before staff and equipment costs. While this is problematic, interviews with fishers suggest the majority of inshore fishers cannot even lease quota across England. Leasing quota is essential if a fisher does not have the quota for what he has caught that month to earn a living. Fishing effort is limited by those who dominate the market, with no regard to the spatial assessment of ecosystems. Tom an older towed gear skipper from Bangor explained further.

> The UK quota system is perverse, there's quite a few quota selling companies. You can ring up XXXX XXXXX buying and selling in Newlyn. There's another one in Aberdeen. You've got quota agents making money. You don't want consolidation, private property rights. It's like with the Adam Smith libertarian think tank, they're advocating more privatisation for quota. In 2005 we had a bioethics of the sea. It was all about privatisation, had a debate with Hannerson (A reported academic) who was pro-privatisation. They've only got 6 or so companies operating in Iceland now who own the entire quota (Tom).

Tom is critical of the expansion of private property rights for quota. He warned of the UK following the lead of a system such as Iceland's. It is already emerging with a number of businesses vying for control of quota, thus reducing access and the overall number of fishers involved. Fishing effort is limited by those who dominate the market, with no regard to the spatial assessment of ecosystems (Dengbol, 2003). Despite the major decrease in the population of active fishers since the 80s, certain communities are more successfully intergenerational as Wurzel an older over 10m ring netting skipper explained:

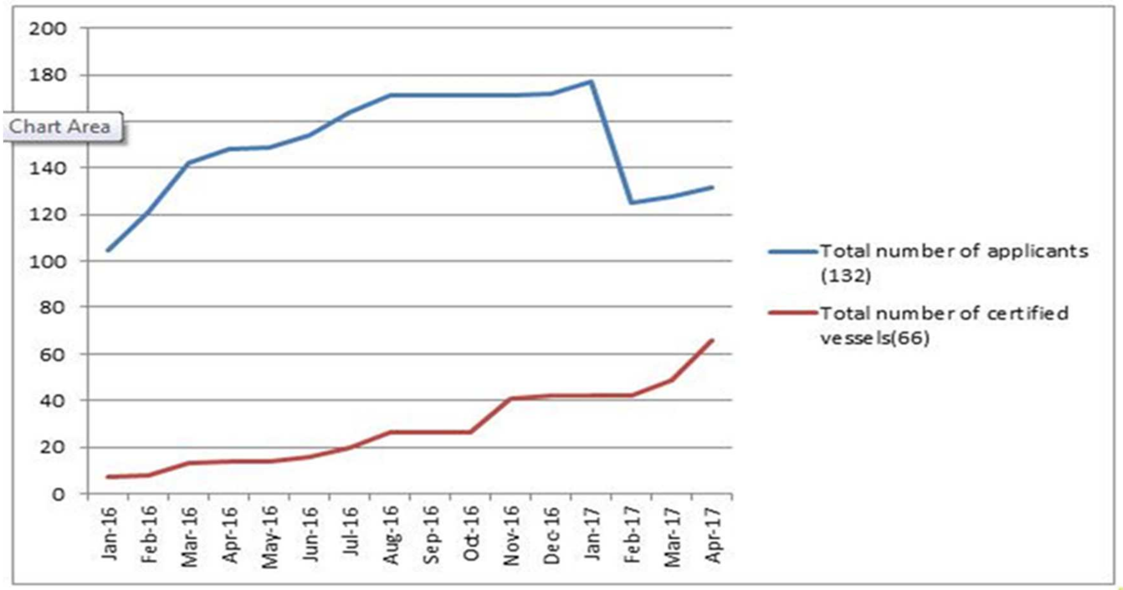
> We've got plenty of kids coming through. They'll come down to the quay wall and help pull all the pots and things up (Wurzel).

This fisher formed part of a successful father and son team, the most common and successful form of intergenerational transmission (Mckenna et al. 2008). This is partly because he owns his own quota and operates in Cornwall which maintains the largest inshore fleet in England. This may be because Cornwall sees more access to quota through the Duchy Quota Company, which aims to return the entire fish quota held in Cornwall back into the hands of the community. This initiative has been important in maintaining fishing in Cornwall by providing in effect a common quota pool.

Intergenerational transmission is also challenged by the capacity to get cheap crew through passing fishers at sea beyond the EEZ. An older static gear crew mate Eddie observed from Shoreham:

> They get a load of Africans and Filipinos on the boats, transfer them over at sea. They confiscate their passports, make them work hard. It's cheaper labour as long as they don't step ashore. No, they wouldn't allow them to go up to the wheelhouse to learn where the habitats are (Eddie).

This quote demonstrates the internationalization of the crew in the over 10m labour pool. It is another factor in reducing intergenerational knowledge sharing, as well as local recruitment from the community. While a responsible fishing scheme has emerged in response from Seafish in 2016, this is industry-led (Seafish, 2016). It follows from the 2016 International Labour Organisation Report Fishers First – Good practices to end Labour Exploitation at Sea and Environmental Justice Foundation' s 2015 report Pirates and Slaves (ILO, 2016 and Environmental Justice Foundation, 2015). Nevertheless, this has not resolved the governance problem of workers' rights if fishers are prevented from coming ashore. With labour exploitation based on researcher observation and fisher reporting, there needs greater exploration into attempts to address this problem in in New Zealand described by Stringer, (2016) and in Thai fisheries (Derks, 2010). The additional bureaucratic burden of reporting labour use has not been well received by inshore fishers who do not have the organisational capacity. Take up has been surprisingly low and ineffective across the fleets, as seen below in graph 2 leaving a research gap in fishers' LEK of the extent of coerced labour. Currently, since January 2016, only 66 vessels have been certified as can be seen in graph 2 below:



Graph 2 showing graph of applicants to the responsible fishing programme (Seafish, 2016).

Generalising across the study area, intergenerational transmission of benthic LEK is challenged geographically both by physical and corporate organisational obstacles. With interviewees reporting that access for fishing boats is increasingly difficult in certain areas such as Lowestoft and Shoreham where corporate port and marina take-over is blamed for this situation. Traditional harbours are denying public access in new ways, with some fishers such as this older static gear skipper Todd from Shoreham claiming it affects their communication with the wider community:

> We don’t get anyone down there. It’s all gated off past the security. We used to chat to them but we don’t get any kids down anymore, all the health safety nonsense too (Todd).

The area around the fishing wharf is cornered off on one side with access to an aggregate dredging wharf and on the other side by barbed wire fences. Fishers in such areas feel the lack of access to the fishing harbour area limit public interest, and curiosity reduces interaction with the fishers in the local community with the next generation. This is seen in such harbours as Shoreham in Brighton, where access is limited to those with digital keys to the gates. Similarly, in Lowestoft ABP Ports provides stringent security checks to anyone attempting to access the area, as this older trawler skipper Ronny passionately explained:

> They’re trying to kick us out they don’t want the likes of us around in the port. They’ve given us a year to leave (Ronny).

This problem of intergenerational knowledge sharing also relates to a number of fishers purposefully encouraging their sons to look beyond fishing for their future employment as this older trawler skipper explained:

> Told my sons not to get into it, there's no future in fishing anymore (Angus).

Nevertheless, where there remains visible access to the fishing harbour in places such as Newhaven, Portsmouth, Mevagissey, and Hastings there is apparent intergenerational recruitment if perhaps being less frequent than before the formalisation of inshore fishing with the introduction of current quota market. With 80% of eastern and south-eastern fishers being over 50 years old, it seems likely that the populations of inshore fishers in these areas are likely to reduce as this demographic group retires, taking their LEK of the benthos with them (Seafish, 2016). The private self-management of the over 10m fleet, allowing for quota trading across regions and internationally, ignores considerations of port location and historic fishing effort (Sanchirico and Wilen, 1999). Furthermore, the quota market forces attention on individual species as entities, rather than considering the whole ecosystem and its different species interactions and impacts from gear (Anbleyth-Evans and Williams, 2018). The system lacks consideration of the mixed nature of inshore fisheries species, creating discarding, with 'choke species'. This occurs when fishing for cod, plaice has to be discarded as a choke species, but with the CFP landing obligation, inshore fishing has to land and count all species caught which are taken off of the monthly quota (Mangi et al. 2014).

A problem of overfishing developed with the MMO's piloted quota management groups failed through the same structural weaknesses. John, an older towed gear skipper from Ramsgate explained further:

> With the quota management group, it was a load of nonsense because we had to loan the entire quota off the Producer Organisations. The fish would still be caught near to the Ramsgate coast, but they had ownership because of the track records. It wasn't locally assessed. Some people weren't allowed to participate as they had bought new under 10m boats (John).

While it is commendable that a local quota management scheme was attempted in Ramsgate, West Mersea, and Lowestoft, it failed as it did not take into account that the license is attached to the boat, not the fisherman. Second, to enter the pool, vessels were assessed on historical catch records, which meant those who had bought new boats, were left out. This has been a big issue in the bass industry (Fishing News, 2017). Only three remained in the pool. Another ecological issue was that the assessment of quota was not related to local ecosystems, and some were leased in from other areas. This reflects the situation elsewhere with the majority of quota awarded to the over 10m sector because track records were only recorded for over 10m vessels from 1986 onwards, while under 10m vessels were under no legal obligation to do so and therefore still do not have track records (log books) (Anbleyth-Evans and Williams, 2018).

Given the decrease in the number of vessels, licenses, and quota, the associated demographic decrease in active fishers, and increasing age of fishers appears likely to continue and consequently will affect how knowledge is shared. It is hoped by many of the inshore fishers interviewed in this research that the Coastal Producers Organisation CPO, formally incorporated as a Producer Organisation in July 2017, can replace the MMO management of the under 10m quota pool. Emerging from New Under Ten-metre Fisheries Association social movement, the CPO can develop what the EU's 2014 CFP called 'Special Access Rights for Socially Sustainable and Low Impact Fishers'. A fisher representative Denzil from the CPO explained their developing strategy.

> We want to protect the existing pools of quota for inshore boats and the non-sector boats. If they want to trade it, increase the value of it, it's not the FPO for them. We want to use only what we need. To have quota as a commonwealth; fishermen would fish in those ICES sea areas where and when they have that allocation and take part in the assessment (Representative from CPO).

It is important to solve this spatial problem as trading between FPOs can put additional pressure on regional stocks beyond biophysical limits. While CFP stocks are wide-ranging, benthic impacts from fishing ports and from aggregate dredging influence how nursery grounds/feeding grounds inshore needs to be adaptively co-managed (Elliot et al 2017). It appears that the CPO would align access to inshore fishers according to their existing geography and ICES areas. The CPO would support a move towards regional quota pools in the future whilst beginning centrally, with fisher LEK involved in co-production of ecosystem assessment supported by ICES assessments (Anbleyth-Evans and Williams, 2018). This has the benefit of making the Total Allowable Catch quota system of the EU more legitimate in the eyes of inshore fishermen and more scientifically rigorous for scientists. To be able to adaptively co-manage ecosystems requires fishers to integrate their knowledge into fishing plans, both for reasons of trust and increased accuracy. It can take into account the variations of species and habitats that are occurring under ocean acidification processes such as to shellfish. To be able to do this, the quota pool made available to inshore fishers needs to stay consistent without fluctuations of fishing pressure and other interactions which drive variability in fisheries (Dengbol, 2003).

Nevertheless, the fishers will need to remain self-conscious of power relations in the organisation in order to ensure 'Little Kings' are not created in certain geographic communities (Chambers et al. 2017). Equality of fishermen's associations' representation in the organisation will be necessary to achieve this going forward. Scientifically Succofish's Catchapp would see the number of species caught immediately recorded on mobiles, which can then evolve over time to match the quota (Succorfish, 2017). It can add data for baseline monitoring of population over time which can after being tested, be incorporated into ICES predictions. It is more scientifically rigorous as currently; the only data is the weight of catch over 2kg landed at the market. Indeed, this is more flexible than a monthly number which does not reflect seasonality or species mix over the year (Anbleyth-Evans and Williams, 2018). As trust is built over time scientists can incorporate the data. To overcome perceived bias concerns, sampling prompts can be randomly generated to get fishers to record, whilst being supported by training. Furthermore, support can be given to fishers recording invasive species and rare species to gain more data on biodiversity (Anbleyth-Evans and Williams, 2018). However, it would need to be combined with a commitment to a Vessel Monitoring System to be effective. Nevertheless, the processes which led fisher LEK to be marginalised by large businesses buying up fixed quota allocations have had serious consequences, such as the collapse of the fishery in North Devon. In the North Devon Biosphere, the local government want to encourage a quota pool with the North Devon Fishermen's Association. Currently, there is no access to quota species, as the static gear skipper, Ian from Appledore explained.

> 'Not one English boat here now. There were about 80 to 100 in these parts in 2002. The Bristol Channel is very much a ray fishery and Appledore was the single most important port in the country to handle ray. We've had gradual quota reductions in sole, other demersal flatfish species through the CFP. We've been dedicated to conserving a sustainable fishery, helping to set up the Lundy No Take Zone and introducing closed areas for spawning. But the Belgians have got all the quota. We need our own quota here; we're working with Pioneers and the Biosphere' (Ian).

The North Devon fishing industry has recently collapsed, through a combination of the selloff of quota rights to Belgian businesses, alongside reductions of species access made available on a national level. This has led to these former fishers campaigning hard to leave the EU. It is hoped that the CPO can complement their objectives through a local quota sub group through the North Devon Fishermen's Association.

The lack of participatory processes also relates to the MMO and the IFCAs not having accurate records of all the fishing boats, a starting point for their gear use and activity in the different regional areas (See Table 6 in chapter 5). The inaccuracy of vessel records means that successful adaptive co-management is less likely, as the first stage is to know how many boats are fishing actively, where and with what type of gear. Currently, there is no limitation of nomadic fishing up and down the coast between MMO office districts, ICES areas and IFCA districts. This is further confused as these jurisdictions and those of FPOs do not overlap. Indeed, interrogation of the MMO issued vessel lists monthly showed that it was out of date and is nationally inaccurate with regard to the number of vessels operating and their geographical locations as shown in table 6. It would facilitate understanding the ecological implications of fishing activities if the pool of fishers active in the respective local areas was recorded comprehensively.

Having fisher LEK of the benthos involved in adaptive co-management is important and could be situated within the Territorial Use Rights Framework (TURF) (Gelcich et al. 2010). This can ensure a fairer distribution of quota, that isn't disrupted by nomadic vessels swapping quota around the country. An example is the nomadic beam trawling fleet with different damaging benthic impacts in different geographies (Thurstan et al. 2010). Given that trawling activity is nomadic it expands into new areas. An older static gear skipper Ben from Hastings explained the problematic effects of nomadic fishing:

> It was infralittoral rock, it's all rocky outcrops, reefs, and ledges, and if you towed over them, with beam trawls, with a stone matrix, then you devastate juvenile mussel because you could squash it with your fingers. That would have a knock on effect because if the juvenile mussel beds were destroyed, you would have the fish coming into feed on the juvenile mussel beds and then we can't catch the fish. So, it would have a knock-on effect to the ecosystem in general. We were picking up giant chunks of blue Claystone, with all the smashed up Piddock shells which were a protected species, all decimated.

This quote is interesting as it highlights the different approach of nomadic fishers who are more likely to cause benthic cascading as discussed by Pinnegar et al. (2000), depleting stocks and moving on. Fishers' LEK can draw attention to nomadic fishing, and through TURFs, fishermen's associations can limit this type of fishing and the number of boats fishing from the area. The researcher's experience of participant observation of beam trawling demonstrated how difficult it was to tell what species would be recovered using a trawl. More damaging forms of fishing, such as beam trawling, are more common with the over 10m corporations who, with the additional quota rights, can legally land a greater range of by-caught fish in the trawl (Kaiser et al. 2006). The 'days at sea' was suggested as a mechanism by the Fishing for Leave Campaign to control effort, rather than quota. This would allow such beam trawlers to fish as they pleased for limited periods of time. The Fishing for Leave Campaign, associated with UKIP, organised the Thames flotilla which captured many under 10m inshore imaginations to campaign for Brexit (Anbleyth-Evans and Williams, 2018). Importantly, it was the UK government which assigned unequal fishing opportunities. Simultaneous to the influence of the quota system on fisher LEK of the benthos is the changing type of organisation. The influence of hierarchical command and control 'cybernetic organisations' or larger corporations' limits flexibility and adaptiveness to local conditions by ignoring fisher LEK of the benthos (Johnsen, 2009). A younger clam boat skipper from Portsmouth described how management pressure is influencing his behaviour working for a large fishing business:

> Well, we didn't really get much more clams but Eric's (the boat owner) on me to fish them out. Going to go back with a dredge with longer teeth tomorrow (Tristan).

After the discovery of clam beds in the Langstone Harbour, the fisher was encouraged to complete the harvesting by the boat owner until the resource was depleted of a particular size. Despite knowing the bio-physical limitations, the skipper became involved in the race to fish enforced by the boat owner. Through the corporate management hierarchy, the skipper's LEK of environmental limits was ignored. The capacity to adapt to ecological changes needs independence from market pressure and managerial influence for reflection. If the fishers were able to evidence these ecological limits, such as through a benthic survey he would be able to limit his activity under a TURF system where cooperative exploitation rules are established.

Certain fishers then have found themselves in cybernetic organisations. In contrast to the adaptability and autonomous decision making of fishermen's associations, formalised power relations enforce hierarchies of procedures and control (Holm and Nielsen, 2007). Whether to start or stop fishing is not based on tradition or experience but guided by the profit motive of the vessel owner, rather than the fishers' LEK (Johnsen et al. 2009). Greater adaptive co-management is needed to enable the sharing of knowledge among stakeholders (Armitage, 2009). Where organic associations and fishermen's associations are active, the results of the interviews discussed in earlier chapters suggest the sharing of knowledge cooperatively does still occur. These fishermen's associations are those driving the new Coastal Producers' Organisation. Fishers in other traditional associations, including Mevagissey and Ramsgate, demonstrate aspects of what Gaspart and Seki (2003) call cooperative behaviour sharing fisher LEK of the benthos through trust relations and mutual dependency in the fishing community. In Hastings where there is no harbour, common ownership and access rights to the beach have helped to consolidate this. This older static gear skipper from Hastings routinely shares with other fishers' LEK of the benthos where he has recently been active:

> You've got your circles, haven't you? The community share that, Ben told me where he'd been trawling, and not to bother going there as I'd find no fish (Edgar).

While these traditional fisheries associations exhibit cooperative characteristics, they contrast with the larger corporation in the Portsmouth case study above. If fishing effort plans were to be created between gear groups, this shows fishing associations have the best social cooperative relations in terms of knowledge sharing.

With the Hastings Fisherman's Protection Society being particularly active, this appears to support a sense of local solidarity less obvious elsewhere, seeing continued knowledge sharing. Comparably, the historically successful Devon Inshore Potting Agreement which started in 1978 is another example where the local social structure allowed for the development of cooperative behaviour. Originally covering 527.3 km2 with 291 km2 reserved for static gear exclusively, the remaining areas allowing mobile gear either seasonally or with other limitations. It is explained below in figure 15 (Hart et al, 2002).

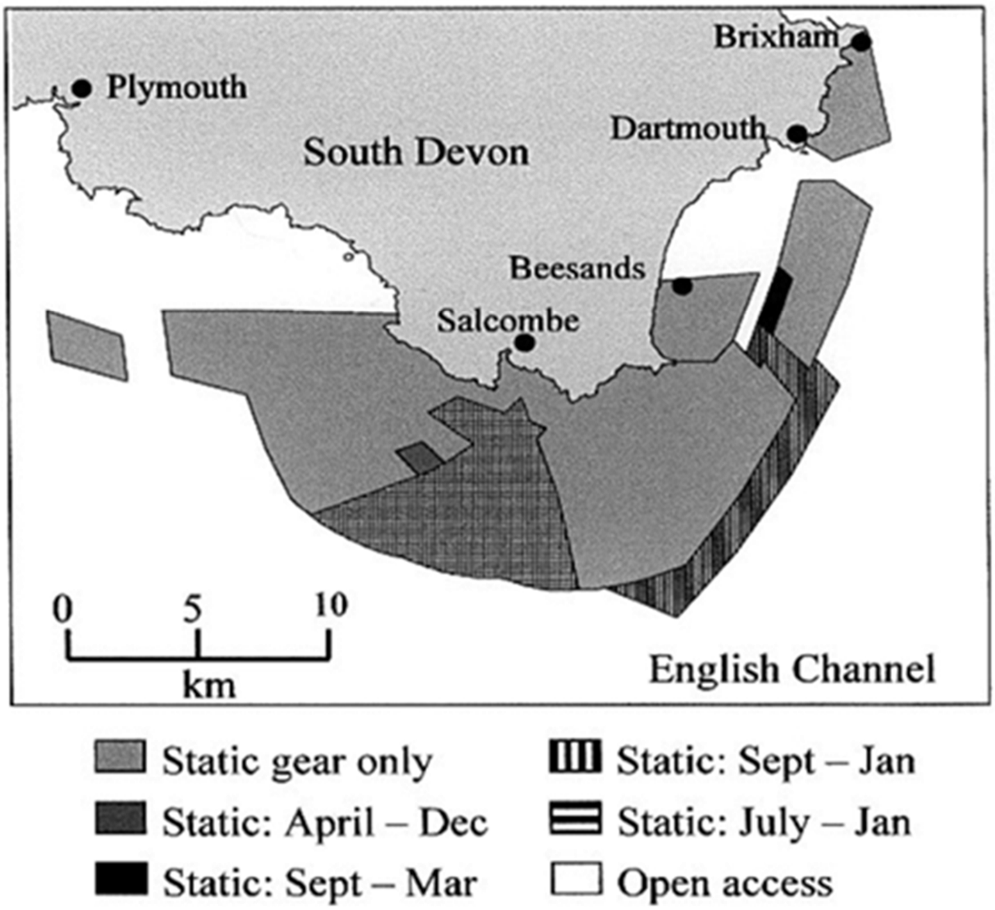


Figure 10: The area covered by the Inshore Potting Agreement off the south coast of Devon. The boundaries were agreed and remain from 2003. The key shows the times when the areas are open seasonally (Hart et al. 2002).

Unusual in that it started autonomously, the Devon potting agreement is an example of the model of the 'Prisoners Dilemma' or game theory in action, seeing benthic LEK sharing between fishers to define the territories (Axelrod 1984). In the case of the Devon fishers, cooperation would be abiding by the regulations, whilst defection would be breaking the rules. In this sense, the closed areas have set a ceiling to the amount of fishing effort that can be deployed on the crab stocks, as there is a physical constraint on the amount of gear that can be deployed at any one time, reducing the race to fish. Importantly the potters and towed gear fishers in the area exhibit characteristics similar to other historic fishermen's associations who have long-term interests in their mutual relationships. An older potting skipper from Beesands, Irvine explained:

> Yeah, there are a lot of families potting who go back through the generations. We all know each other, around this part of the coast. The trawler's still come through at nights sometimes though, lost a few pots. It's better than it would be without it; we know the habitats are healthier than they would be (Irvine).

The community solidarity in the area and ongoing relationships meant they were happy to continue to share knowledge with the Sea Fisheries Committee and later the IFCA as governance became formalised in 2003. This has led to further scientific research on potting impact assessment involving the fishers. While the IFCAs have a reasonable knowledge base of the total number of static gear fishers in the area, this still leaves out the total number of towed gear users in the wider area as this includes nomadic boats and is assessed under the CFP. It shows how other communities could move forward, combining a spatial rights approach for communities with evolving community co-assessment. However, this is not standard practice in most fleets and locations, such as Shoreham, Portsmouth, Newlyn, Brixham, and Plymouth. Where knowledge sharing spatially is formally organised, such as in Japanese fishing associations, and under the Chilean Territorial User Rights Framework (Gelcich, 2010), knowledge of the potential for overexploitation is increasingly known among fishers, though not always shared, due to the often-rampant competition. Given that cooperative initiatives (Deacon, 2012) are more adaptive to ecosystem fluctuations, (Holling, 1973), cooperative LEK can be enhanced. It has been argued that the older organic associations are resilient and more adaptive within dynamic environments than cybernetic organisations (Cadigan 2003). According to interviewees organic associations or fishermen's associations show cooperative attributes sharing knowledge and this demonstrates their value. However, this is not standard practice in fleets and locations where corporations are beginning to dominate the area. Associations such as in Portsmouth or Plymouth are fragmenting. These communities see bigger corporations buying up quota, boats, and licenses from independent fishers, eroding the traditions of social-ecological resilience (Kinzig, 2006). Without support for groups such as the CPO, the dominance of larger businesses means this is likely to continue, with commensurate reductions in associations and independent boats. While the IFCAs might support cooperatives and cooperative behaviour, their resources are overstretched and their priorities are focused on mapping ecosystems for marine protected areas, rather than the sort of social organisation which would best support the development and sharing of fisher LEK of the benthos.

Further, IFCAs and the MMO do not have an up to date record of how many boats are in the area, how many are full time, and the type of gear used. The recording focuses on the size and engine power, not the gear. A spatial rights approach for these communities would end the problems of nomadic fishing. This section also shows that additional quota support for fishing associations, rather than individuals/corporations would be environmentally just. Intergenerational transmission of LEK would be supported by transfer of quota to the CPO and local associations who can develop co-assessment with scientists. They provide a way of realising the participatory assessment of ecosystems as members are required to go beyond simply recording their landings by using Catchapp. Further research is needed to develop Mangi et al.'s (2014) self-sampling to ensure the mechanism is both democratic and scientific. With climate change impacts developing and impacting the marine environment, it will be vital for fisheries adaptive co-management plans to feed in observed changes to species, habitats, spawning and breeding grounds. Further research is needed, therefore, to develop and harness fisher LEK of biodiversity in a way that contributes to conservation and sustainable fishing.

7.2 Conclusion

This chapter shows how the conditions of neoliberalism both prevent and allow for fisher LEK of the benthos to support governance and ecological sustainability with regard to fisheries governance. The Devon Inshore Potting Agreement was illustrative as a mechanism where benthic fisher LEK successfully informed and improved fisheries governance. The lessons of the territorial user rights framework indicate the need to limit the number of boats, traps, and quota for species in a local territory. Currently, however, the IFCA and MMO do not calculate this. The Devon IPA shows that adaptive co-management can develop, integrating non-quota species shellfish assessment through fisher LEK, as well as pelagic fishing effort and involvement in the assessment of CFP quota species. This approach has the potential to decrease the democratic deficit whilst increasing scientific accuracy. Hart et al. (2002) argue because it is a home-grown system rather than top-down approach with inherent integrated knowledge of the fishers' behaviour through their own design, fishers LEK of habitats has been the driving force in determining livelihood decisions. While Ostrom et al. (2001) emphasise that resource management linked to the social structure of the exploiters can be problematic; this research shows that cooperative fishermen's associations are more adaptable to conservation governance. Outside of designated MPAs, the system is open access. To support the continued development of fisher LEK and its contribution to the benthos, territorial user rights are necessary to develop the areas managed by IFCAs. As ancillary instruments for conservation, they can allow other stakeholder negotiations to take place whilst interacting with fishers and research programmes (Gelcich, 2010). This is a human rights approach for the community to access the resource (Allison et al. 2012). This is preferable to private spatial or other individual quota rights without guarantee of transparency.

Fishers' interaction with quota governance, alongside increased access to research and NGOs, is leading to a greater critical analysis of the quota system. Quota governance is also arguably influencing conservation behaviour by accelerating the race to fish. Nevertheless, the influence of corporate led social organisation upon governance threatens the intergenerational transmission of benthic fisher LEK (Moncrieffe, 2009). With populations of inshore and other independent fishers being at record lows, fishermen link this decline to the social injustice of current quota access. In Iceland, Chambers et al. (2017) described how the transferable quota system has led to large business owners in cities buying up rights, while traditional fishery communities collapsed on the coast. In England, the enclosure of the market by a small number of large businesses and a simultaneous lack of participation in assessments has combined with significant consequences for the size and nature of inshore fleets. Other fishers relate how changing corporate port architecture is removing involvement from local communities. Nevertheless, certain ports continue to recruit. This reduction of fishers also relates to the technological expansion of fishing effort, seeing less need for the crew as well as overexploitation of populations of species through damage to habitats. Fisher LEK of the benthos evidences how certain over 10m vessel owners are able to maintain their monopolies of quota; without involvement in local communities or ecological assessment. In response the social movement NUTFA has evolved into the Coastal PO, bringing hope for fairer access to coastal communities and providing a vision towards realising the participatory assessment of ecosystems. The Coastal PO and NUTFA have been working with Greenpeace and the New Economics Foundation; which showed civil society is a sphere of political struggle challenging the property-owning establishment and the state (Heywood, 1994). These social movements are moving to find a solution beyond neoliberalism, in identifying the need for a transfer of quota from individuals to a collective commonwealth (Brown, 2015). The earlier injustice of quota distribution could be ended by supporting the Coastal PO. The Coastal PO suggests that leaving 98% of quota with the over 10m sector is environmentally unjust. They are campaigning to adaptively co-manage the remaining 2% of quota which is currently managed by the MMO. They argue that by demonstrating a more flexible participatory approach than the MMO in the future, they should be awarded a greater slice of the overall CFP quota pool, to allow members to make a living, and allow the next generation of fishers to come through.

Total Allowable Catch for Quota can be distributed to regional fishermen's associations based on the continued assessments of International Council of the Exploration of the Sea (ICES) blocks. In order to support the cooperation and sharing of knowledge between fishers, what Johnsen (2009) called organic associations such traditional fishermen's associations need support through increased quota access and representation on local decision making and management institutions.

The London convention notice was served in July, there remains a two-year wait to leave the CFP and the London Convention. The end of this agreement will mean the right to exclude non-national vessels up to the 12nm limit. While fair allocation could already have happened, there is an opportunity to make environmental justice in fishing opportunity allocation access a reality. Leaving the CFP may bring an opportunity to change this and integrate legislation in the MCAA (2009) ensuring environmentally just access rights to inshore fishers. The right to participate in the assessment of quota species, such as through the mechanism of Catchapp can allow integration of LEK and build trust between scientists and fishers. Recent research by Elliot et al. (2017) suggests that a spatially managed approach is needed to protect nursery and feeding grounds on the benthos of cod, whiting, and haddock. TURFs can add another dimension to IFCA co-management. Fisher LEK can identify areas suitable for seasonal closure, and if carried out within associations, trust over common adherence to bylaws is more likely. Developing a fisheries democracy means making livelihoods more secure through environmental and distributive justice. Considering that inshore fishers consist of over 78% of the fishing population and receive less than 2% of the EU TAC quota a re-evaluation is needed by DEFRA. By supporting the development of the Coastal Producer Organisation and the use of Catchapp, there is a way forward in integrating fisher LEK of the benthos scientifically. Nevertheless, this would need a paradigm shift from top down marine fisheries management to an adaptive co-management approach. It would also need recognition on an EU level that an ecosystem-based management approach needs to acknowledge the species of the benthos and fishers' interaction with them, not simply calculating the maximum sustainable yield of demersal stocks.

8. Marine Licensing, Conservation, Spatial Planning Governance and fisher LEK of the Benthos

8.1 Introduction

Fisher LEK of the benthos is adapting and responding to the challenges of many different forms of governance. The last chapter identified the importance of participation in quota governance, and the influence on benthic fisher LEK. Through the benthic emphasis, it recognised that defined space for fisheries quota governance can allow adaptive co-management to evolve. While marine conservation interaction with fisheries is well documented including Blyth et al. (2002), how it is changing benthic fisher LEK less well known. Furthermore, the extent that marine spatial planning has interacted with and influenced fisher LEK is not discussed in the literature. How these two threads of governance interact and allow for the development of fisher LEK of the benthos are explored in this chapter but as an introduction the remainder of this section summarises the changing context of fisher benthic LEK. The rest of the chapter provides insights into how fishers believe changing governance affects fisher LEK of the benthos.

While the Marine Management Organisation (MMO) has attempted to use a ‘core fishing grounds’ approach to fisheries management, this has not involved the participation of the inshore fleet (MMO, 2014). Also, in the UK and EU, it is reported that economic demands for fishing under the Directive Establishing a Framework for Maritime Spatial Planning (MSP) remain in tension with objectives for improving marine ecological health by 2020 under the Marine Strategy Framework Directive (MSFD) (Qiu and Jones, 2013). While the MSP directive began as a mechanism for conserving, understanding and improving marine ecosystems, this has now been overtaken by the growth agenda (Qiu and Jones, 2013). In addition, Jones et al. (2016) report that marine plans appear disconnected from other governance devices in England and across the EU and others suggest that a lack of participation in marine spatial planning breaches the ‘public participation in decision-making’ obligations of the Aarhus Convention (De Santo, 2016). It creates a double disconnect for inshore fishers, first from planning and decision-making, and second with certain types of scientific knowledge dominating decisions. It is leaving fisher LEK of the benthos out of the process when it can as this chapter and the previous ones show beneficially draw attention to ecologically damaging processes such as the destruction of habitats. Indeed, a return to ecosystem-based planning is needed; one that “considers the entire ecosystem, including humans” in this case fishers and their understanding of impacts (Douvere 2008: 764).

Further, the lack of policies for preventing significant benthic habitat loss by development outside of MPAs also could affect inshore fishers. Under the Habitats Directive, impacts are not considered if they are 2km outside of Marine Protected Areas (92/43/EEC). Nevertheless, if port, wind farm, and aggregate cases have been judged as having met the 'Imperative Reasons of Overriding Public Interest' (IROPI) test contained in Article 6(4) of the EU's Habitats Directive then they can proceed despite adversely impacting on the benthic ecosystem (Morris and Gibson, 2007). The IROPI test identifies that if a project is of significance to economic growth, then an alternative ecosystem elsewhere can be created as compensation (See figure 16 below). These aspects of the Habitats Directive and IROPI test make marine spatial planning problematic for socio-ecological resilience, as the priority for governance is to increase blue growth without specific limitations to environmental externalities (Douglas, 2006).

Warnings by Jones et al. (2016: 256) raised concern that contemporary marine spatial planning involves top-down processes dominating and that more participative platforms are found to be 'disconnected by design' from actual decision-making. Indeed, this is thought to relate to the prioritisation of blue growth and is in tension with conservation and fisheries. This chapter examines the extent fisher LEK of the benthos can participate in decisions in marine developments and conservation, and how the system can move towards a marine democracy.

Findings from the fisher carried out in this research is presented in the first section of this chapter and reveal how increasing levels of aggregate extraction, development of offshore wind farms, the need for dredge channels for large ships from ports and associated dumping create an ecological disturbance of the benthos. Fishers feel such disturbance needs to be locally and nationally addressed through the conservation objectives of marine spatial planning. These risks to the marine environment also provide a threat to local fishing in a way that is imperceptible except to those who work every day in that environment. The second section of the chapter examines how fisher LEK is interacting with marine conservation governance and NGOs. The chapter concludes on how fisher LEK and conservation governance can be drawn more closely together through the emancipatory mechanism of the Territorial Use Rights Framework, which can complement marine spatial planning legislation. This refers back to the theorisation of 'Pescastemic Rights' in Chapter 5. The goal of this chapter is to demonstrate through interviews, how changing forms of marine governance and conservation are influencing the development of fisher LEK of the benthos.

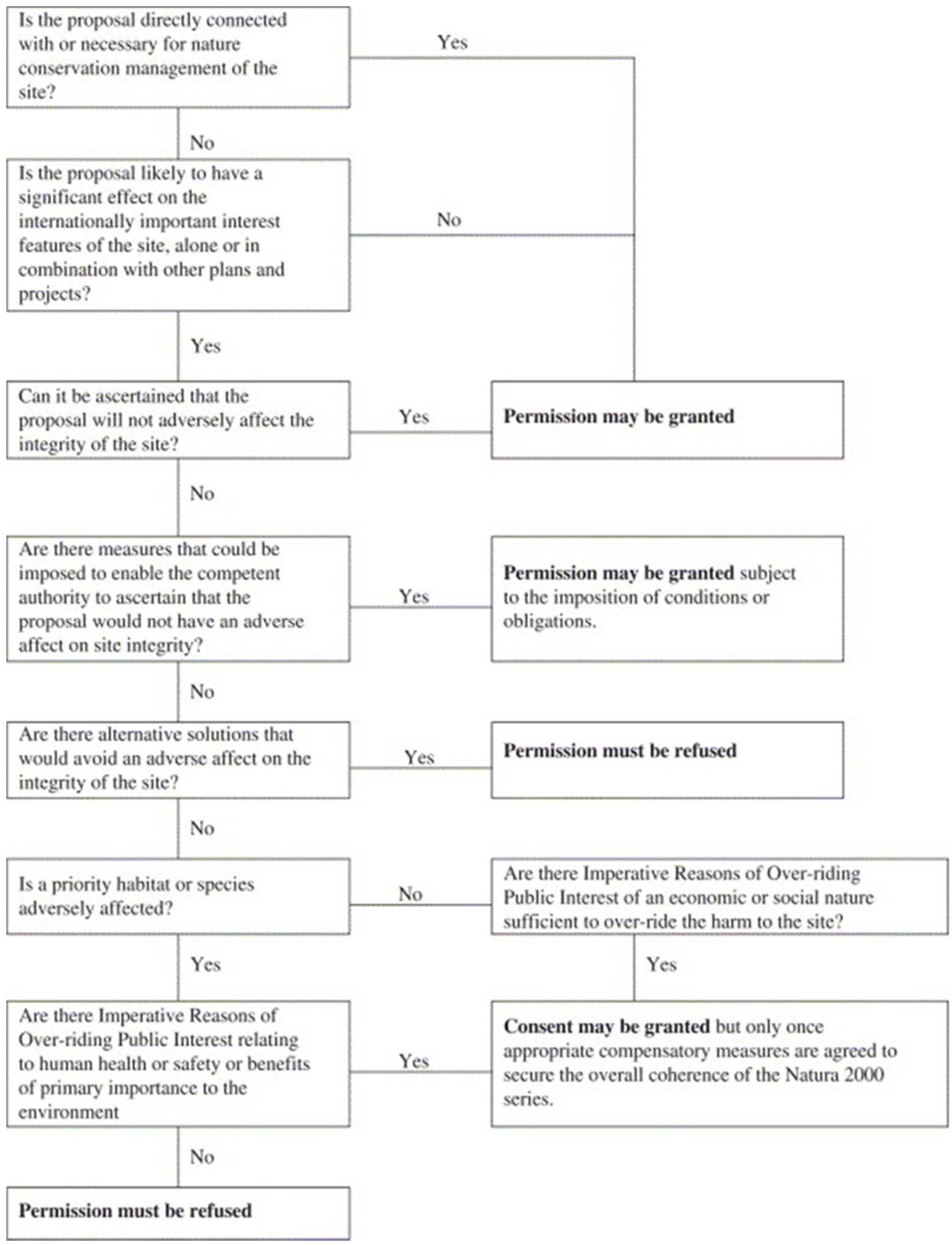


Figure 11 Pathway of the Imperative Reasons for Overwhelming Public Interest decision making process according to the Habitats regulations

8.1.2 Fisher LEK of disturbance and the governance of port development dredging and wind farms

How the underlying structures of power counteract participation of benthic fisher LEK in the governance of marine development is investigated in this section. Importantly, the findings that follow show that fisher risk assessment could support initiatives to protect the health of the marine environment. Whether that this type of local risk assessment, should only be validated when co-produced with scientists will be reflected upon. Applying a Critical Realist approach identifies why marine governance might position fisher LEK as less valid than science. One school of thought may consider LEK to be anecdotal knowledge, through its lack of mainstream science method (Sayer, 1984). Nevertheless, processes which facilitate deliberation between England's marine management and coastal communities can improve disturbance identification and parity of participation as Frazer (2001) suggested. Enhancing participation in marine decision making through fisher LEK can support adaptive co-management. While the Marine and Coastal Access Act (2009) identified marine planning as an approach to ensure sustainable seas, it has been challenging to integrate fisheries because there is no legislative responsibility for the UK to assess the social distribution and scientific assessment of quota. The excessive complexity of different public bodies having responsibility for different domains was highlighted by Boyes and Elliot (2015). The importance of fisher LEK in understanding coastal space was highlighted by Johnsen (2014) and also how the influence of fisher LEK relates to power relations. A literature gap emerges around how the structures of power in England have created different classes of marine stakeholders caused by the socioeconomic drivers of neoliberal marine governance.

This is an issue of participation and democracy, as inshore fisher LEK currently has no influence and fishers no way to participate in local or national decision-making, particularly with large projects judged to have Imperative Reasons of Overriding Public Importance (IROPI). The following examples show LEK can illuminate impacts of development that are changing marine ecosystems in the proximity of their local ports. An area over 2000 km2, about the size of East Sussex, has been affected by the dredging of the London Gateway for the Port of London as detailed in the map of Figure 17 below. The following older towed gear skipper from Southend, Richard, highlighted how the seabed has been changing through the action of capital dredging for the new London Gateway:

> Lots of pebbles now exposed from being drawn down the bank. Cockle beds used to be prevalent can't now grow on the stony ground. There used to be lots of lugworms, though now no longer present. There has been a decrease of 3 to 5 inches of mud. Now featuring only crows and crabs. I have the photographs by the pier of what it was like before and after (Richard).

The fisher highlights ecological change and that the shore level has been reduced by the dredging. This has stopped a large area of traditional cockle beds from continuing to grow which is significant.

In addition, there is exposure of stony ground from a previously muddy substrate for annelids, such as lugworms. The fisher presented photographic evidence to demonstrate this over time. This was further confirmed by an older towed gear skipper from Whitstable:

> Talk about the seabed: it’s all changed. Out to the low water mark, it's gone all clay and clitey, over 30 years. It's what a lot of fishermen think now. It used to be a nursery area for sole, plaice, dabs, and with the dredging where they used to spawn, there’s no small stuff. Queens Channel used to be quite a clean area, now it’s become a lot dirtier. There’s (sic) sandstone slabs exposed (Ted).

The substrate geology has changed and the spawning ground has now disappeared in Whitstable. This suggests that the impacts of the capital dredging are not only related to small areas but the whole estuary. Other fishers from Whitstable also explained similar geophysical impacts on the benthos. An older towed gear skipper, Tim from Ramsgate, based closer to the mouth of the Thames explained more:

> All the cumulative impacts have pushed the fish out of the Thames. [   ] was saying they were having phenomenal catches. Fish smell the silt in the water and they’re gone, pushed into the deeper water (Tim).

The quote explains that there is less fish left to catch in the local water through the disturbance and fish stocks have migrated elsewhere. This more politicised fisherman, also involved in the setup of the NUTFA network, deploys his understanding of ‘cumulative impacts’, a scientific environmental impact assessment term demonstrating the accumulation of effect over time. Secondly, the way he reports how fish smelt the silt in the water, which relates to how marine life sense through chemoreceptors. Increased catches have been reported by Tim above, through fish moving away from the contaminated area in the mouth of the estuary which relates to the resuspension of spoil. This expertise in water quality assessment demonstrates the significance of fisher LEK, and how fisher LEK vocabularies are changing in response to development.

Further, changing fisher LEK is linked to a critique of the governmental methodology of marine environmental impact assessment, which is perceived to be flawed and influenced by financial power, as critiqued by the older towed gear skipper, Tim from Ramsgate:

> South falls fishing grounds, sand eels now moved in, from maintenance dredging and disposal, no EIA on the impacts. No reference no benchmark. Cefas research discontinued through cutbacks; London gateway said they were going to do the survey. We would of rather of seen the independent Cefas survey continued, 30 years’ worth of knowledge. They say there’s an awful lot of little fish, but it’s not there on the ground. Money shouts all of the time. They’re biased should be carried out independently. […] boat same spot same gear. Had only two fish, couldn't accept it (sic) (Tim).

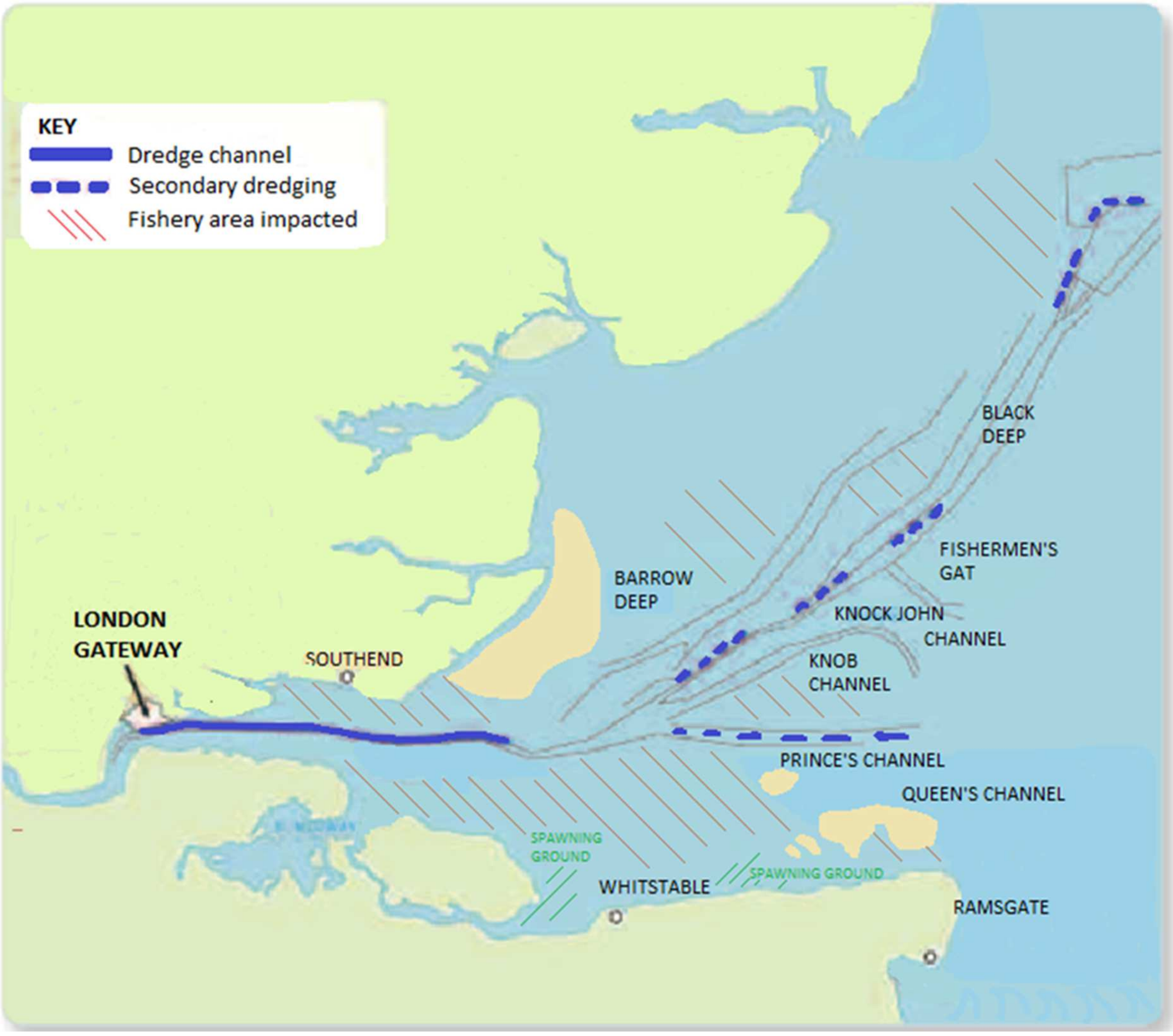


Figure 12 Thames estuary map showing fishing grounds impacted by new dredging channel in brown. Spawning ground areas impacted in green. Adapted from London Gateway map. Map created by author combining Ordnance survey, London Gateway plans and fisher LEK.

The quote above highlights the lack of a benchmark for the environmental impact assessment, and that historic benchmarks have not been used from the historic Centre for Environmental, Fisheries and Aquaculture Sciences (Cefas) case. It is interesting to note the fisher's comprehension of the environmental impact assessment system and its flaws. Fisher LEK is being shaped by changing scientific knowledge, which is increasingly influencing terminology and fisher approaches to the understanding of water quality and marine biology in the Thames. However, as the quote above shows fishers believe that scientific knowledge is being influenced by the market, with consultants organising the planning applications for ports known to be awarded bonuses for getting decisions about licenses quickly. The Marine Management Organisation produces a Maintenance Dredging Baseline Protocol for continuous dredging impacts, in this case on the Thames Estuary and Marshes

SPA (Special Protection Area) and 3 other MPAs. Nevertheless, this fails to consider the ecosystems on the benthos and in the water column, shown by the capital dredger in figure 18 at work.

As benthic ecosystems were not considered by the MMO in this case despite earlier benthic records being available through Cefas, the importance of fishers' LEK becomes apparent. Nevertheless, marine governance places barriers on the consideration of fisher LEK by considering it inexpert. Given the lack of university education of fishers, fisher LEK is portrayed as inexpert, as highlighted by a towed gear skipper, Richard from Southend, after reporting the decrease in water quality and the impact upon benthic ecosystems:

> Fisher knowledge dismissed as anecdotal, someone from the EA dismissed it saying you can't say these things; you don't have the qualifications (Richard).

The catch landings for the Thames Estuary since the London Gateway port dredging campaign began in 2010 are shown in Table 7 and demonstrate the fall in species biodiversity landed over time in the dredged area. While fishers' everyday experience of the marine environment brings them into continual contact with ecological processes, the non-formalised methodology means that often their fisher LEK is described as anecdotal. Nevertheless, after an information request lodged with the MMO, the researcher received an email of the records of quantified data which is presented in Table 7 and aligns with the qualitative knowledge of the fisher interviewees concerning falling fish stocks.

Table 7 showing the fall in biodiversity over time since the beginning of the dredging campaign in the Thames estuary (From information request email to MMO in 2016).

Number of species landed by Thames estuary fishers	Year	Area
17	2010	31F0
6	2011	31F0
4	2012	31F0
5	2013	31F0
2	2014	31F0
2	2015	31F0

While previous generations of fishers assessed the marine environment in isolation, fishers now access scientific reports - changing their assessments, vocabulary, and therefore, their LEK. This is reflected in regard to areas now designated for large wind farms. Ted, an older towed gear skipper described the ecological impacts and the effect of lack of access caused by wind farms.

> They've got a lot of Sabellaria where they're planning to put the wind farm; they're just going to build all over it, while they limit us from fishing around it. It's good feeding ground on the Sabellaria, a lot of worms for the fish (Ted).

Fisher LEK is used to draw attention to damaged ecosystems habitats, such as Sabellaria spinulosa in the wind farm development, referred to above. Supporting what marine planners call co-existence between usages may be possible (Jentoft and Knol, 2014). However, as the quotes presented below suggest this has not been fully realised with wind farms. While fishing will be limited by an MPA to protect species such as Sabellaria, the fisher argues the same Sabellaria will be built on by the wind farm. Currently, there is no independent pre-development assessment or post-development monitoring of wind farm impacts by the MMO, something which could be supported by fisher LEK.

Earlier research in relation to marine developments, such as ports, has argued that the influence of neoliberalism in prioritising activities that encourage economic growth is apparent in that only the private interests of the planning applicant appear to be represented (Mansfield, 2004). There have been significant increases in marine disturbance caused by port dredging and wind farms, but these port development and wind farm cases have been judged as having met the 'Imperative Reasons of Overriding Public Interest' (IROPI) test contained in Article 6(4) of the EU's Habitats Directive (Morris and Gibson, 2007), producing greater economic significance. While the fishers' collection of evidence allows them to contest the original conclusions of planning enquiries, so far, they have not influenced the process maintaining the existing hierarchy of knowledge (Sayer, 1984). While other cases of port dredging and dumping brought to attention through fisher LEK have not faced the IROPI test, they have gone ahead as local MPAs have not been present. The Thames estuary example demonstrates why fisher LEK has value and can be integrated with scientific research to highlight ecological risk. The following section examines how similar issues have arisen in relation to aggregate dredging.

8.1.3 Aggregate Dredging, and fisher LEK in the English Channel

This section addresses how fisher LEK is deployed to draw attention to perceived benthic ecosystem impacts on the seabed from aggregate-dredging. It is an example that examines how the neoliberal paradigm has led to support for a more profitable activity over a more ecologically sustainable one. Fishing rights, in contrast to sovereign rights to aggregates, oil, and marine constructions, is not defined spatially. In the legal case of R vs Minister of Agriculture, Fisheries and Foods Ex p. Hamble (Offshore) Fisheries Limited, fishermen fought to claim a right to fish in aggregate vessel license areas on the basis of established practice but, this case failed in court as the aggregate-dredging license was held to be an overriding public interest (Appleby, 2013). With aggregate-dredging, large amounts of aggregate stone and shingle are removed (see figure 19), resulting in a sustained different bathymetric form, disturbing benthic habitats and the abundance of species (Hitchcock, 2002, Robinson et al. 2005). In common with dredging and disposal for ports, aggregate-dredging is a particular problem for biodiversity and habitats (Newell et al 1998). In interviews, fishers reported that after aggregate-dredging was licensed close to their local grounds, their catches decreased.

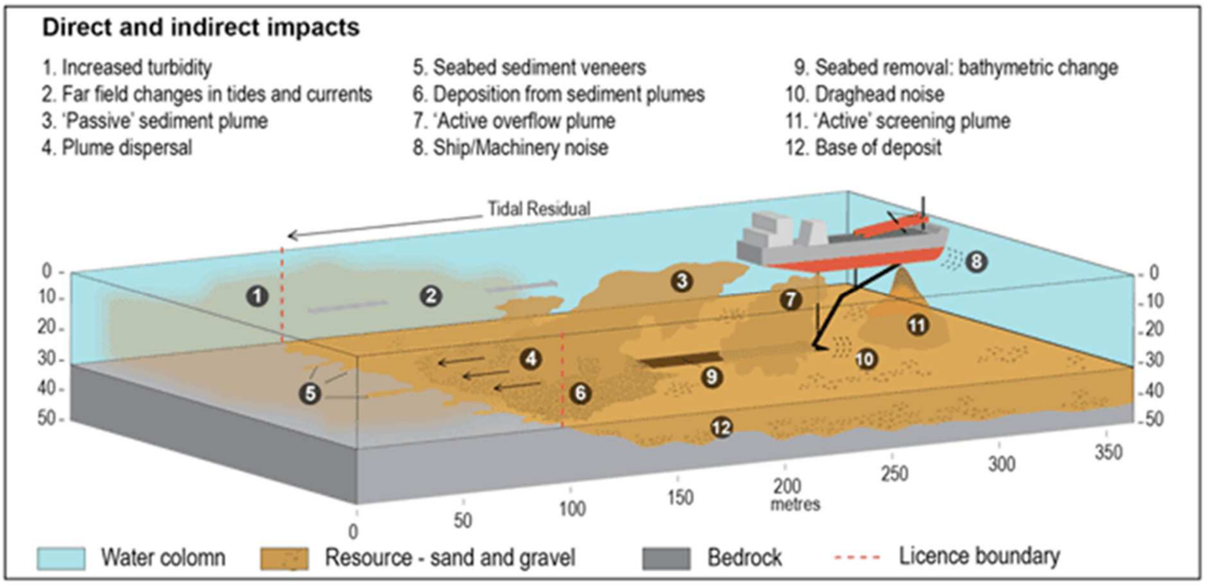


Figure 13 Diagram explaining the impacts of aggregate dredging (From Tillin et al. 2011).

Fishers' consideration of aggregates relates to the associated loss of fishing space, as well as the perceived and actual loss of fishing-ground habitats where larger populations of fish can normally be caught. Describing the impact of dredging on the south coast near Eastbourne upon the grounds of target crab species an older potting skipper reiterated.

> We've been having a lot of problems with the shingle bank. We've been having all the sediment fines getting into the crabs' gills, making them all move away from the grounds. We've been catching them and have records close to the site and they've gone (Leonard).

Re-suspended fines rejected from the aggregate dredging process can impact upon the breathing habits and habitats of crabs, relevant as a bio indicator of a healthy ecosystem. Given the continual recording of edible crab (Cancer pagurus) population dynamics in local sites, static-gear fishermen have kept a continuous recording of species. These can provide an indication of the activities of the aggregates industry, described in the fisher map of Figure 20 below which shows the potting sites near Eastbourne from which crabs had disappeared. In a different way, an older static gear skipper from Hastings to the east of Eastbourne elucidated how flatfish species have been affected by acoustic pollution impacts from dredging:

> We have the shingle bank area, that's an Ice Age deposit, our major problem with aggregate-dredging was the loss of habitat to fish on. We found out that it had a more detrimental effect: the noise pollution to the sole migration. We managed to prove that over a period time the sole migrated differently due to the activity of the dredgers, so we managed to incorporate a cessation in the dredging during the period of the migration of the sole, that's been implemented by ourselves when we know the sole are migrating on the right temperatures. We got the environmental groups employed by the dredging companies to do scientific analyses; they became very abundant to the west of us and the east of us but in the centre in the area of Hastings and Bexhill which was anyway south of the dredging area. After that period, it doesn't have a detrimental effect because the soles have migrated in because they come in SW to NE, every generation we met the sole at the same place at the same time (Ben).

While authors such as Johnsen et al. (2014) argue that LEK of coastal space is important to governance, the underlying socio-economic aspects outlined here demonstrate why fisher LEK is not made use of by the government in England. As inshore fishing is comparatively low revenue in comparison to port development or resource extraction, it appears not to be a priority for economic planning. As they felt the MMO did not take their representations seriously, the Hastings fishers commissioned an environmental consultancy to produce further scientific evidence for acoustic pollution impacts on benthic species, an example of knowledge co-production, between LEK and scientific knowledge. Fishers supplied the provisional evidence for possible impacts to their benthic habitats from catch recordings and observation. This confirmed how the aggregate-dredging acoustic impacts were forcing populations of Dover sole away from the area. In this case, the fishers' recordings of temperature at the time of seasonal sole migration was important in relation to the dynamics of the dredging activity. Furthermore, the change in flatfish migration accords with the collapse of the crab populations reported by fishers in Eastbourne as described in Figure 20 below. While an EIA assessor was hired by the Hastings fishers with the aggregates case, this supported a seasonal closure of dredging only; meaning the crab-fishing sites of the Eastbourne fishers could not be continued. While Hastings fishers were able to change the conditions of the aggregate-dredging regime, the crab fishers from Eastbourne were still affected. The rationale of neoliberalism is apparent again in prioritising aggregate dredging, which is more profitable than fishing. These decisions ultimately relate to spatial rights, aggregates and wind-farms impacts which are approved ground by the Crown Estate via the MMO. Territorial user rights would allow for equal legal representation of fisher LEK of the benthos.

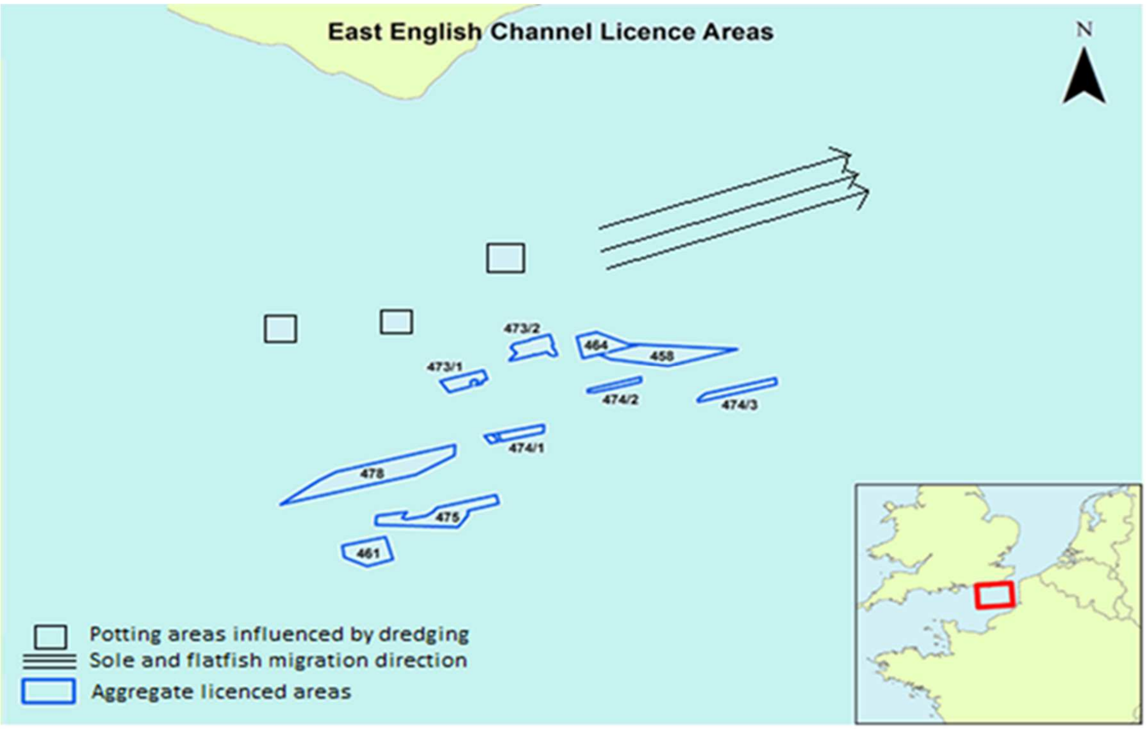


Figure 14 East Channel aggregate license areas. Conflict has developed in proximity to sole migration and crab potting areas of Eastbourne and Hastings, as traditional fishing grounds lack spatial rights in England (Adapted from MMO map).

These concerns of fishers regarding aggregate dredging relate to smothering, resuspension, siltation, and the related effects on the benthos, with differing negative influences on local benthic ecosystems. The discussions above based on local interviews and documentation of the legal case, demonstrate how fisher LEK is changing, incorporating scientific knowledge from environmental impact assessments, which is in turn, influencing fishers' deployment and interpretation of their own fish population recordings. However, as discussed in Chapter 5, fisher LEK encompasses both elements of scientific assessment and assessment through fishing. But the pressure of political austerity has encouraged marine governance to reduce spending through cutbacks. It has encouraged a system where environmental impact assessment and water quality samples can be determined by private rather than public interests through the presentation of evidence by consultants at planning enquiries.

In the current form, marine environment planning is driven forward by demands for blue growth (Qiu and Jones, 2013). It is surprising then that there is currently no independent pre-development assessment or post-development monitoring by the MMO of the benthos. The cost of hiring marine consultants to assess environmental impacts is prohibitive to inshore fishers; nevertheless, their reports from the core evidence base upon which decisions are made. While an EIA assessor was hired by the Hastings fishers with the aggregates case, the prohibitive cost of reassessing the London

Gateway development means the system privileges a hierarchy of knowledge, something which Mikalsen and Jentoft (2001) called corporatist, where a particular stakeholder group is selected over others. This ultimately relates to spatial rights, as the impacts of aggregates and wind farms are approved ground by the Crown Estate via the MMO.

Although fishers are also subject to bias, their commercial interest is based on an ecosystem that maintains the reproduction of populations of fish. Contrastingly arguments of Bennett and Dearden (2014) suggested local people are always against conserving resources for livelihoods. In this research, however, fishers on either side of the Thames Estuary have tried to conserve ecosystems if only to maintain their fisheries. While Murray et al. (2006) argue that fisher LEK has universally become GHK; these case studies show how local knowledge is changing to draw attention to local environmental challenges. Using critical realism brings attention to sets of knowledge which contest the context of dominant governance led by capital. For instance, dredging in its various forms can be lucrative for business and government, but can lead to overexploitation of and damage to the commons. Bhaskar (1975: 24) underlined that '…science is a social activity whose aim is the production of the knowledge of the kinds and ways of acting of independently existing and acting things…', thus, as a social activity, science can be influenced by socioeconomic considerations, such as contrasting assessments of the impacts of dredging from the perspective of business compared with members of the fishing industry. While scientific marine assessment is potentially a social activity, the involvement of citizen science to take advantage of what Shirky (2010) calls a cogitative surplus is something yet to be realised in UK marine governance. The following section now considers the extent to which fisher LEK has been integrated into conservation governance, and marine spatial planning, through the development of MPAs, and how this has also been influencing fisher LEK.

8.2 Fisher LEK interactions with conservation governance

This section demonstrates how fisher LEK is evolving through collaboration with conservation NGOs and governance. It relates to the role fisher LEK can potentially play in organising MPA governance as common properties, that is democratically and with participation (Ostrom, 2010). While Jones et al. (2016) posits that marine planning in Europe seems disconnected from participation by design, this section shows how a balance between top-down and bottom processes can support conservation through LEK participation. The first part of this chapter showed examples of the lack of recognition of fishers' spatial areas due to a lack of participation that recognises territorial user rights. This section, by contrast, examines fisher involvement in common properties of conservation or MPAs. MPAs are the only form of governance mechanism that is not open access to fishing. How conservation is influencing fisher LEK and how this subsequently interacts with the evolution of governance is investigated. As Shiva (2016) highlighted, the very existence of common property demonstrated the historical capacity of societies to cooperatively organise resources sustainably. While collective action is more difficult to arrange, the resulting forms of common property see resource access controlled and more equally distributed (Shiva, 2016). The section begins by reflecting on how conservation focused NGOs have been influencing fisher LEK through collaboration. Moving beyond the epistemic framework of markets and single species, working with NGOs, such as Finding Sanctuary, has shifted fishers' ideas about conservation. This older static gear skipper's participation with the MCZ assessment network made him encourage further collaborative work:

> And I found out with Finding Sanctuary, they have a bit of your opinion, and you of theirs and hopefully you have something sensible (Eric).

As the above quotes indicate, when fishers associate themselves with such conservationists, it can lead to a shift in fisher attitudes towards changing knowledge. Similarly, working with the Blue Marine Foundation in Lyme Bay has had a similar influence with regard to conservation as described by this fisher-activist and older potting skipper.

> We had a talk about those Territorial User Rights at the Lyme Bay Reserve group. They brought in someone from the Environmental Defence Fund come and talk about it. Common property rights are the way forward, how else are you going to motivate fishermen to be involved in conservation? (Ned).

Understanding common property from a talk hosted by the Lyme Bay Reserve Conservation Group led this fisher to a different way of thinking about ecological conservation governance emerging as a shared common space, rather than a private individual space. Long-term appreciation amongst fishers of the need for shared responsibility through common property might represent an example of changing epistemic framework, an approach that can mend the epistemic rift described by Schneider and McMichael (2010). Furthermore, as the quote above suggests, engagement with ideas of common property can make fishers more open-minded about the mutual cooperative benefits of conservation, as well as improve knowledge of habitats and science of species. A younger static gear skipper from Newlyn explained at greater depth his experiences with MPAs working with the NGO Finding Sanctuary.

> Finding Sanctuary, they had species of conservation importance, foci identified as being vulnerable, like stalk jellyfish, the obvious sea fans. I was involved, shared my knowledge from diving. New Special Areas of Conservation on the Lizard and the Cape Cornwall bank. Because they are all now protected under European regulation, there's no doubt that trawling will be banned in those areas (Jowan).

As the quote shows the influence of interacting with different levels of marine governance and NGOs is significant in the evolution of fisher LEK and LEK is also elucidated by fishers' motivation to draw attention to the impacts of competing sports fishermen, who might take away access to their resource as explained by this older static gear skipper:

> The fishermen proposed Kingmere for the Black Sea Bream nesting. Too many anglers on it, but they are supposed to breed on the bottom, on the sandstone reefs (Anthony).

This fisherman made the link between the need to conserve the sandstone reefs of Kingmere as a breeding site of the Black Sea Bream. This fisher also argued that the fishing industry does consider conservation interests, while the sports fishing industry does not. These quotes also demonstrate the importance of bathymetry, reefs substrates, tides and currents for determining feeding and breeding grounds, all important for improving the governance of the commons. Fisher LEK of these marine features also leads them to identify habitats where trawling can continue as shown in the quote below. It is interesting to note here that over time gear use has slowly shifted towards more low impact forms of fishing. In 1980, there were 2169, towed gear vessels (Fleet Register, 2015), or 35% of the fleet. Unregulated inshore trawler fishing normally encourages ecological overexploitation and towed gear is more likely to be limited in MCZs. This is explained by an older static gear skipper Ronald from Eastbourne:

> On the MCZs it's good to look after the grounds, might be breeding areas. I think to save a certain species of fish it's not so effective, but to save the ground, which in turn, I do agree there is some big hard ground, rocky ground, which you shouldn't have your trawlers going over. Totally agree with that, because once the ground's been destroyed, it's been destroyed. So that looks after the species in a sense (Ronald).

Importantly Ronald, (whose actions were discussed in the previous chapter section on conservation technology) reported back to the fisher community the success of his towed camera work. This led to further LEK sharing among fishers. Despite these sorts of fisher involvement in MPA initiatives with the IFCAs, in the South East, fishers as the quote below indicates still feel this has not led to government bodies such as the Marine Management Organisation accrediting fisher LEK or their expertise. An older static gear fisher from Hastings explained:

> The MMO doesn't take our knowledge seriously. They see us like criminals really (Ben).

This may relate to a joint distrust between the MMO and local fishers, through the MMO's enforcement of a multitude of new rules the fishers do not fully understand. Indeed, an interview with a key informant from Cefas explained:

> There is a lot of recruitment from the Navy and the Police, and that influences the way they think about the fishers. At Cefas, we try to recruit some fishers as observers. At the MMO and the IFCAs, they really don't get the participation issue. They think that more enforcement and CCTV will be enough, so it can be frustrating (Cefas, 1).

That this Cefas key informant reports significant recruitment from the Royal Navy and the Police into the MMO and IFCAs, driving non-participatory approaches to marine governance would be useful to reflect upon in further research. It is reported by fishers and the key informant that these more hierarchical organisations do not encourage an emancipatory approach to knowledge sharing, as they are trained to react to defence and crime situations, rather than develop educative, participatory research with fishers. This can be described as another example of testimonial injustice in that the perceived MMO's negative attitudes to fisher LEK is an example of limiting the potential credibility and validation of inshore fishers (Fricker, 2007). This further relates to the potential epistemic rights of fishers to be able to access fully the detail of the conservation science programme (Tsosie et al. 2012). The lack of participatory processes also relates to how the MMO and the IFCAs do not have an accurate record of all the fishing boats in the different local areas (See table 6 shown in chapter 5). The inaccuracy of vessel records means there is a form of open access between fishing grounds and harbours. An IFCA officer from Sussex explained:

> No, we don't know how many boats there are really. They are not recorded by us. It's a problem. You should ask the MMO (IFCA, 2).

Currently, there is no limitation of migration up and down the coast between MMO office districts, ICES areas and IFCA districts. This is further confused as these jurisdictions and those of FPOs do not overlap. If boats wish to lease or buy quota via an FPO they may do so. Indeed, interrogation of the MMO issued vessel list issued monthly shows it is out of date and is nationally inaccurate in regard to the number of vessels operating and their geographical locations as shown in Table 6. It would be much easier for understanding the ecological implications of fishing activities if the pool of fishers active in the respective local areas was recorded comprehensively. In Chile Gelcich et al.'s (2010)'s research showed how the territorial framework protects artisanal techniques of fishing within 5 nautical miles. These territorial rights designate access for fisher associations, coops and unions based in communities, and further lead to a more accurate understanding of the number of boats in the group and their impacts. Others have argued in Europe that plans that integrate the different spatial needs of marine users' need the involvement of fisher LEK at different scales beyond 6nm, to the limit of the EEZ (Jentoft and Knol, 2014).

An example of how the nomadic nature of some forms of fishing affects marine conservation in England is the fleet dredging for scallops, also known as the non-sector. The nomadic boats that dock in a range of ports dredge in different habitats, with different damaging impacts. The Chalk reefs off Shoreham are thought to have been eroded by scallop dredging according to divers and fishermen, destroying geological features that may be valuable to ecosystems (Thurstan et al. 2010). Given that Scallop dredging activity is nomadic it expands into new areas, eroding such reefs which have inadequate mapping and enforcement (Kaiser et al. 2006). An older static gear skipper from Hastings explained:

> The migratory, it has a massive effect on it [the benthos]. I counted at least seven Irish boats. They're coming down all the time. They're decimating it aren't they? Trouble is these big boats they scallop all year round. …. when you've got people coming down from Ireland and Scotland it messes it up. The local 'scallopers' in Rye have a system whereby they leave the seabed to recover at certain times of the year (Edgar).

This quote is interesting in highlighting the different approach of nomadic fishers who are more likely to cause regime shifts in new ecosystems (Kinzig, 2006). In the Rye scallop fishery, there are traditional grounds left aside for the summer season. The nomadic scallop dredgers operate in an ad hoc way having a greater impact, harvesting less impacted areas. While the MMO (2016) has recently issued a report stating 'Scallop fishing is not a widely managed activity' they have not addressed the requirements to spatially manage scallop dredging. While they note TAC should be introduced in line with other fisheries, to calculate this requires scientific participation, possible through spatial zoning approaches. With a combination of vessel monitoring for effort assessment inshore and offshore, limiting migration of boats to territories, alongside participatory impact assessment, then TAC can become effectively managed. My experience of participant observation dredging for shellfish demonstrated to me how difficult it is to tell what species will be recovered. During an attempt to film the benthos using a camera attached to a clam dredging in Portsmouth, it was apparent that while the footage was not particularly clear, that significant infaunal biodiversity was being disturbed. This led to a debate about the importance of conserving the seagrass habitat in Portsmouth, its importance as a nursery for breeding, and the merits of biodiversity. Ultimately cooperative effort organisation is needed to make an MPA successful and well understood, something more likely under TURF legislation (Gelcich et al 2010).

The problem of fishing effort control has been solved in Southern IFCA in the area of Poole Harbour through a permitting by-law, limiting access to a certain amount of boat cockling in the harbour. The problem of vessel license buying and selling for quota could be solved in this way on a county scale.

Seasonal closures such as the Welsh limitation of scallop dredging during the summer months until November are progressive, but currently impossible to implement beyond 6nm (Association of IFCAs, 2011). Scalloping can be zoned, co-assessed through the IFCA through towed cameras and VMS. The co-assessment of impacts involving fishers could allow benthic LEK to incorporate further scientific knowledge. Nevertheless, the dominance of positivist epistemology as identified in chapter 5 means the IFCAs and MMO continue a subject-object research approach, with no explicit objective to involve fishers in programmes, limiting the development of what was theorised as Pescastemic Rights in chapter 5's conclusion. However, locations do exist where fisher involvement has successfully moved forward to promote conservation and management in areas having previously suffered from overexploitation from scallop dredging such as Lyme Bay (Rees et al. 2010).

Through the visual surveying of the benthos and bathymetry of Lyme Bay, there has been ongoing support for the voluntary potting agreement. Fisher LEK has been used to support a shift in marine management. Given existing knowledge of habitat locales, fishers helped the collection of data using towed and static cameras in the MCZ. Importantly in 2008 scallop dredging was banned leaving the habitats to recover. This, in turn, led to an increase of static gear such as potters and netters. Involvement of the potters in the visual survey in Lyme Bay has led to adaptive co-management according to habitat zoning and increased knowledge of the value of species. An older crab potting skipper from Axmouth explained more.

> Well, I thought it would be a load of nonsense but it's been useful for us to show where things are. We knew where everything was already, but it helped us show them where the rocky reef was, the grey lias, sand gravel and shale, and how that relates to potting intensity. The Devon and Severn IFCA don't listen to us, but they'll see this (Reggie).

Plymouth University's involvement of the fishers in the research and the habitat zoning for the Lyme Bay Reserve programme made the programme more participatory. Nevertheless, this fisher quoted above highlighted that Devon and Severn had been too top down in their approach and that the programme has only really succeeded through support from the Blue Marine Foundation. Indeed, a Southern IFCA officer suggested:

> It was really helped by having the Blue Marine Foundation on board. We couldn't offer the same kind of beer and sandwiches. It made conservation much more participatory (Marcus).

Having a knowledge bridge, in this case, a part-time fisherman working for the NGO has been effective as a boundary spanner, linking between resource managers and fisheries scientists and governance, by seeking fishers' experiential knowledge (Johnson et al, 2011). This former full-time fisherman at Lyme Regis, who is now involved in the Lyme Bay Reserve group, commented in regard to participation:

> Yes, we're getting more and more fishermen on board. Only had about 8 to start with, and now we're getting about 20. We're dynamic and we can help them with their problems, such

> as with their licenses being capped, which will move them on to single stocks, if they lose sole, it will push them on to bass and so on. We've been doing crab and lobster assessments, habitat assessments. We want adaptive management here so we're trying to fight for them in Parliament, as the capping is not in the voluntary protocol (Terrence).

This fisher is trying to generate a form of adaptive co-management to support the ecosystem approach rather than focus only on single stocks. It shows that the knowledge rift noted by Schneider and McMichael, (2010) is here being addressed. Local fishers point out important ecological processes, which can often be subsumed in the praxis of accumulating capital from natural resources. If forums such as the Lyme Bay Reserve can be more widely realised, then fisher LEK can be codified and develop in a way which is not subsumed by capital.

Nevertheless, the adaptive capacity of fishers is limited by the extent that they can access such public forums and particularly bodies involved in national marine conservation governance such as Natural England. Indeed, this quote below from a fisher who dives highlights habitat recovery but expresses that their LEK is not recognised.

> 2 years ago, like the surface of the moon. I've been telling the IFCA not to let them dredge in the corner in the silty sediments, not important under Natural England to protect sublittoral muds (Neil).

This fisher, working on boats as well as dive scalloping, brings detailed knowledge of locations of habitat recovery after scallop dredging, and shares it with other fishers in the Brixham community. Unfortunately, his efforts have not led to any closure or dredging bans as there is no participatory connection between this form of fisher LEK and Natural England. Currently, the habitat he dives in is not prioritised, and there is no mechanism for this fisher to validate his conservation knowledge. In other locations where interviews were undertaken similar problems have arisen of integrating fisher LEK with national conservation governance.

Within the Wash European Marine Site, stakeholders 'Advisory Groups' have struggled to get their fisher LEK advice heard and validated with Natural England. A representative of the Wash MPA explained:

> Natural England says they are an evidence-based organisation, how the activities impact on the features. They don't want to write in the text that these traditional activities are sustainable. They've got bigger issues than the customary rights of shellfish harvesters (Toby).

This relates to the overwhelming scientific epistemology applied to the validation of fisher LEK. While this was previously discussed in chapter 5, core to the critical realist framework is an emancipatory approach to knowledge. This means finding ways to bridge hierarchies through new structures of governance. The local council for part of the Wash area has been successful in appointing a professional to facilitate dialogue between harvesters and governance in a similar same way as discussed in Lyme Bay. He explained his own position on the theorisation of fisher LEK.

> The difference between scientific knowledge and fisher LEK is the way it is recorded. My view is that they are both monitoring observations, but fisher LEK doesn't have it written down in some way, how and what you're going to do, on that line. There is an area in The Wash which is sub-tidally trawled for shrimp. They (The IFCA) are closing it they (Natural England) are doing a habitats regulation assessment on the subtidal mixed sediments. The fishermen haven't provided any evidence that can be validated. But then you've got the cables, leveling the sand waves which can be distributed around the site and the effect it has on the mussel beds. Yes, it's less than 1% of the area, but if you've got 20 activities with less than 1% then you've got potential impacts altogether. It's about communicating it better to stakeholders and regulators and educating each other (Toby).

This quote also shows the importance of understanding fisher LEK in relation to how it is codified and recorded and the power relations over those who control the knowledge. Ultimately this facilitator takes a positivist approach to validation, critiquing fisher LEK's recording and monitoring methods. However, it is likely that this is because he is aware that fishers using shrimp trawlers have an inherent bias over their impacts. Nevertheless, while fisher LEK does not have a hypothetico – deductive framework, long-term recordings of changing patterns and fluctuations are recorded by fishers and can be more widely shared. While the Wash has 3 advisory groups, the extent that their knowledge is validated depends on the interpretations of the Wash project manager. Nevertheless, an overview is needed to facilitate dialogue between multiple users who combine to create disturbance in The Wash. Indeed, the facilitators' role will be to design mechanisms for positive educational feedback between interest groups to support local learning. If methods such as participatory impact assessment Schindler et al. (2010), self-sampling Mangi et al. (2014), can build on existing community voice initiatives Ranger et al., (2016), then local learning can progress exponentially. It is apparent that different traditional harvesters are learning in the Wash from each other and conservationists. Nevertheless, how LEK of disturbance is recognised depends on the facilitator's acknowledgment of the emancipatory potential of LEK's validation and access to methods which can be used to successfully share learning. An opportunity arises, however, in the Wash and in the Lundy island MPA area with recognition of these areas by DEFRA as 'Pioneers' of best practice. Recent research into knowledge and governance of cultural ecosystem services by Orchard Webb et al. (2016) and Fish et al. (2016) show how easy it is to transplant cultural services of ecology into a capitalist episteme. Nevertheless, it may present an opportunity to demonstrate the value of LEK of environmental and social externalities to governance in new ways, leading to new legislative requirements for their consideration.

Another location in the case area showing positive signs of proto adaptive co-management involving the interaction of fisher LEK, with conservation governance is the Chichester Harbour Oyster Partnership Initiative (Chopi). It has progressive aspects, such as including fishers in the co-production of species population assessment. A towed gear skipper from Itchenor noted:

> We've had Chopi [Chichester Harbour Oyster Partnership Initiative] going for years. Feeding in a number of oyster stocks. Working together is good for trust, but there are always those that will be against it (Samuel).

Chopi is unusual in attempting to maintain stocks of oysters in the local area by feeding in logs of populations of oysters caught per month. Young oysters (or breed stock) were relayed to closed areas of Chichester harbour in order to restock the population. As Ostrom (2009) observed, cooperation in the management of the commons will not succeed without the capacity of those involved to trust each other. Trust requires cooperative participation. Nevertheless, an IFCA officer noted that they had legal advice saying they couldn't limit boats coming to fish for oysters in the open season. This means that anyone from Portsmouth to Peterhead can come to fish during the opening if they had the initiative and the budget for the fuel costs. The pioneering author Christy (1982) whilst first defining the TURF approach emphasised the importance of the right of exclusion and the right to determine intensity and kind of use in TURFs. Without the right of exclusion, trust cannot develop between all fishers, with the need to invest time in ecological monitoring and oyster restocking. The free-rider fisher can arrive and fish for oysters from outside the community.

Nevertheless, by involving fishers' LEK in the oyster assessment process, the quotes above show that trust has improved with IFCA's governance. Stanley and Rice (2007: 403) highlight that "The process, not the concept, develops trust, which is essential for meaningful dialogue". While involving a critical mass of opinion leaders in the development of IFCA bylaws is crucial, it is important to involve those who are not opinion leaders, who may be more negative in the process where the opinion leaders are already engaged in the issue. If those with less social capital are left out of the collaboration, through repeated use of the LEK of opinion leaders, compliance and trust do not necessarily build throughout the community. Similarly, the way that the habitat is changing and being reported through fisher LEK after ending scalloping in Lyme Bay is being shared among fishers and divers. Involvement in the Lyme Bay Reserve Group has created educative feedback and increased trust.

A final example from the case study area illustrates how different interests of aggregates and conservation designation are interacting with fisher LEK in the Kingsmere MCZ located in West Sussex. As noted in the example of the Thames estuary earlier dredging can lead to acoustic pollution and electromagnetic effects on the benthos with the predominant marine animal sensory systems being acoustic sense and chemoreception. An older potting skipper from Selby Bill detailed some of the risks from aggregate dredging upon the conservation objectives of the Kingmere MCZ:

> It's the aggregate dredging you want to be thinking about on the seabed, not the trawling. It's nothing compared to what nature can do as we've seen with the storms. But the aggregate dredger takes the whole lot. And they've been licensed for the South West corner of the Kingmere reserve. What's the point in stopping fishing if the whole seabed's being sucked up, taking the shingle away? What's the black bream going to breed on? (Anthony).

This fisher highlights the lack of joined-up-thinking ongoing in the licensing of this activity in proximity to the MCZ, with the impact of aggregate dredging on the shingle reef, and the breeding site. Those fishers working with the IFCA developing bylaws for the Kingmere MCZ have been seeking to highlight the need for protection of the black bream and undulate rays' nesting. The decision in this case has been to go ahead with the aggregate dredging near to the newly protected reefs as of March 2017. While there is to be an amendment to the marine license for a summer cessation in dredging, fisher interviews correlate with such work as (Newell et al., 1998: 130), which highlights that "…aggregate dredging is commonly associated with a 30–70% reduction of species diversity, a 40–90% reduction in population density and a similar reduction in the biomass of benthic fauna." Additionally, deposition of material mobilised by dredging and transported outside the boundaries of the dredge site is also of potential significance in controlling the nature and abundance of the benthos over a wider area (Hitchcock, 2002). In the example of Kingsmere MCZ Fisher LEK analysis draws attention to the conflicts of interest. Responsibility is divided with the MMO for aggregate licensing, and the IFCA for marine enforcement. If territorial user rights were recognised under the MCAA, a democratic body would have greater democratic oversight over the activities and conservation management. Fisher LEK and other forms of LEK can identify ecological risks and be accredited, being formalised in participatory marine plans. This section shows how interactions with conservation governance and NGOs are changing fisher LEK. Fisher LEK is increasingly aware of the benefits of conservation management. It has an increasing role to play in it, to fill gaps in habitats and species knowledge, as well as to build trust between governance and fishers.

8.3 Conclusion

This chapter shows how current governance both prevents and allows for LEK to support ecological sustainability. The chapters' two sections relate to how two discrete forms of marine spatial governance interact with fisher LEK. This conclusion draws together the findings of the two sections. The first section 8.1 shows the factors limiting fisher LEK's participation in decisions over dredging developments linked to ports, aggregates, and wind farms. In 8.2 the chapter considered how marine conservation governance can benefit from LEK being involved in assessing habitats for new marine protected areas and those existing. Both sections suggest there is a need for legal recognition of democratic common property rights for fishers based in coastal communities. This is demonstrated by the lack of formal consideration of fisheries during developmental applications that involve dredging. In section 8.1 the findings from interviews illuminated how accelerating efforts to extract aggregates, dredge port channels, build offshore wind farms and dump mixed materials at sea, weaken socio-ecological resilience. Contrastingly, the second section shows how fishers are attempting to be part of the conservation solution. While fisher LEK of the benthos encompasses both elements of scientific assessment and assessment through fishing; it faces economic barriers to participation. Contemporaneous pressure for neoliberal blue growth is driving decision making and marine planning (Qiu and Jones, 2013). Indeed, public decision making appears disconnected by design from marine planning (Jones et al. 2016). The critical realist approach adopted in the thesis identifies why marine governance positions fisher LEK as less valid, considering it anecdotal, through the lack of mainstream science method (Sayer, 1984). The MCAA (2009) identified marine planning as an approach to ensure sustainable seas. Nevertheless, it has failed to integrate fisheries management and fisher LEK, which creates difficulties as shown in this chapter in achieving conservation objectives.

Fisher LEK can draw attention to developments causing pollution to marine ecology and the wider marine environment. The chapter shows the importance of power relations and socio-economic factors, which influence, shape and validate LEK and highlights how more research is needed critically evaluating the economics driving marine decision making. The monetary value of aggregate dredging and ports for the government outweighs the perceived value of inshore fishing and biodiversity under the current paradigm. Habitats and fisheries outside of dredging zones which fisher LEK presented in this chapter shows are negatively affected. Fisher LEK is not considered in dredging decisions in combination with other processes. Section 8.1.3 showed that an EIA assessor was needed by the fishers in Hastings to legitimise their LEK. The chapter evidences the testimonial injustice of marine governance prejudicing against the potential validation of inshore fishers' epistemologies (Fricker, 2007). Fishers by identifying risks to new marine conservation zones from aggregate dredging and other disturbance demonstrate how their knowledge considers values beyond impacts on their livelihoods. These environmental impacts elicited as LEK demonstrate why Murray et al.'s (2006) conclusion that inshore fisher LEK has become GHK is inaccurate in Western Europe. These narratives of potential environmental justice relate not to the celebration of the cultures of TEK holders in the developing south as described by Berkes et al. (2000) but to both the defence of livelihoods and through concern for conservation.

Previously non-scientists such as fishers evolved different local vocabularies to researchers, today begins to see these differences being reduced as the two vocabularies become more integrated that relates to the broader process of the collapse of an age-old distinction between the same and the other in areas including classification (Foucault, 1966).

Nevertheless, while authors such as Jasonoff (2003) argue that an intellectual environment needs to be encouraged where the public can bring their knowledge to common problems with the state, this does not appear to be occurring in marine planning and conservation (Jones et al. 2016). The research shows that environmental impact assessments created by dredging and development private interests are more influential than those developed by fishers. While fishers can themselves be influenced by the market, their economic interests can also align with the continuation of healthy ecosystems, such as where fishers adapt to the benefits of MPAs through research participation as discussed in chapter 5.

While this chapter showed fishers would like to participate in the discussion and decision making on issues such as aggregate dredging, port development dredging, and wind farm development, there is no such forum which facilitates this alongside the conservation objectives for MPAs. While fishers have limited access to IFCA governance, (thus supporting the development of marine conservation management), there is no direct democratic link for fishers into the governance of these external industries. Marine licensing decisions take place in the MMO headquarters in Newcastle. As there is no recommended process for officers to visit sites or those locally affected, it prevents holistic consideration of cross-sectoral impact. The potential for face to face interaction is probably needed to democratise the process. Unlike wind farms, port development and aggregate dredging, low impact fishing is one of the few sectors vocally supportive and compatible with maintaining marine habitats and biodiversity. Different to the MMO, the IFCA committees have local authorities such as Parish and County councils on board contributing to fisheries bylaws. This facilitates oversight over fisheries but not activities such as dredging. Relevantly, Pieraccini and Cardwell (2016) wrote that to ensure democratic accountability and effective deliberation, stakeholder selection for co-management groups should cover as wide a range of local interests as possible. While marine licensing for constructions and developments is logically separate from fisheries licensing, it also remains separate from marine planning. A mechanism to join the two together through a local marine planning mechanism would be beneficial for the integration of fisher LEK into decision making. To avoid circumscribing the local demos, democratic bodies should be led by decision makers aiming to ensure the integration of LEK into marine planning and licensing. To facilitate collaborative planning or co-decision making, the integration of LEK is needed to highlight questions of risk from developments such as dredging, wind farm, and aggregates extraction through a precautionary approach. Uncertainty should not be overlooked: the absence of proof of harm is not the same thing as proof of the absence of harm (De Santo, 2016). Improving marine decision making especially in inshore areas needs holistic integration of a range of different indicators of harm, suggesting where further assessment is needed. Currently as the final decision for major projects falls with the IROPI test, which overrides local considerations and has a narrow conception of economic growth rather than cultural and other ecosystem services, LEK is not considered. Fisher LEK of disturbance of the benthos demonstrates the value of knowledge as a cultural ecosystem service. It is knowledge which does not have immediate monetary value, but ecological benefits in highlighting environmental and social externalities to marine governance. If this was recognised, there is a research opportunity to develop mechanisms to support fisher LEK of biodiversity in a more strategic way across regions for marine democracy. These can be built upon the mechanisms such as Catchapp discussed in chapter 7.

This research also demonstrates that a changing fisher epistemic framework to conservation is emerging; where the influence of NGOs and governance is present. In part supported by the bi-directional interaction with scientific research, the overriding influence of the market rationale is not overwhelming the inshore fleet's appetite for conservation, biodiversity, and sustainability. Whilst adaptive co-management is limited in the case study area the examples of such management approaches in Lyme Bay, the Wash, Lundy and Chichester Harbour, highlight the potential for LEK to be used by IFCAs democratically throughout the country. Involvement of LEK can improve management decisions, for both fishing activity and marine environmental usage external to fishing. The collaborative inclusion of fisher LEK is more likely to build trust and respect for decisions made (Stanley and Rice, 2007). Fishers' are more likely to invest in jointly assessing their ecosystems baselines in partnership with IFCAs, if the area can be closed to other debilitating activities even if only for seasonal periods of time. Nevertheless, as this chapter showed the adaptive capacity of marine management for integrating LEK is limited by a lack of mechanisms for fisher LEK of the benthos to access national governing bodies such as Natural England and MMO. As a non-departmental public body, the MMO is only answerable to the secretary of state, not the local or national electorate (Appleby and Jones, 2012). This means there is no democratic mechanism to integrate LEK into MMO activities, such as through elected democratic bodies.

Historically, fishers have kept the coordinates of their fishing grounds and stocks secret. As chapter 6 showed it appears this is now beginning to change by using new technologies where it can benefit their livelihoods. A legal solution to this would be the implementation of the TURFs explicitly under democratic control. TURFs have gained attention as rights-based fisheries management, relating to existing associations of fishing communities, where territories are commonly owned and organised

(Gelcich, 2010). The framework implies a series of rights; among them are the right of exclusion, the right to determine intensity and kind of use, the right to extract benefits and the right to future returns (Christy, 1982). To maintain TURFs as democratic bodies, these need to answer to the local electorate through a locally elected body. While IFCAs co-management over MPAs has some of these characteristics, there is no right of exclusion. This is important with as this chapter showed nomadic vessels such as scallop dredgers and beam trawlers having disturbing impacts. Furthermore, there is no democratic approach whatsoever for establishing MPAs beyond the 6nm limit where IFCA responsibility ends.

Discussions of the need for different benthic based common property rights in the Lyme Bay Reserve show an appetite for shared responsibility amongst fishers using different forms of gear especially amongst those who adopted potting techniques. This NGO influenced epistemic framework shift to marine governance based on common rights is a prime example of where research science and cooperative effort are beginning to mend the knowledge rift (Schneider and McMichael, 2010). Where space is commonly owned, it is less likely there will be a culture of secrecy over sharing coordinates and knowledge of stocks. Problems induced by dredging, aggregates, and wind farms, could be mitigated using open access benthic maps which are then coordinated with landing records to support democratic sustainable fisheries especially if participatory adaptive management can develop (Matsuda et al. 2011). While Gordon (1954), argued that open access situations encourage overexploitation and that only private property rights can avoid the tragedy of the commons - the present thesis demonstrates a real possibility for a shared and democratic approach. Nevertheless, as the scallop dredging fleet is controlled by the days at sea mechanism, they can migrate to the coast in an open access form. Secondly, beam trawlers can trade quota between ports, or simply migrate to fish non-quota species. Only a full understanding of the total number of fishers and vessels in local areas will allow for trust to develop and successful participation of LEK. As fishing quota has been the responsibility of the CFP and quota rights not relating to space, the MMO, as this chapter showed, has not recorded where vessels are based according to home ports accurately. If marine plans are to be participatory and integrate LEK, then fishing boats could no longer be allowed to be nomadic without recording their activity, if their effect upon the marine environment is to be recorded and fully understood. The MCAA could be updated to ensure that marine licensing and other bodies had to follow regional marine plans and be answerable to the electorate. This can allow for democratic bodies to integrate the different spatial needs of marine users' within 6nm of the coast. Similarly leaving the CFP and the London Convention after Brexit will mean LEK could be integrated to the limit of the 200nm EEZ, alongside other users (Jentoft and Knol, 2014).

Social collaborative work can build trust between governance, industry, and science (Hoefnagel et al. 2006). Problematically, the continued dominance of the positivist epistemology of those involved in IFCA, Natural England, and MMO governance is commonplace, as mentioned in chapter 5. This means that a subject-object research approach leaves no explicit aim to examine and research the educative benefits of involving fishers in research programmes. While IFCA researchers do involve fishers on an ad-hoc basis, they often return to the same individuals as quoted in chapter 5. A more comprehensive approach would see all members of the community involved, and the objectives and benefits explained so fishers can share their long-term LEK and integrate their conservation efforts more effectively. In order to move towards 'Pescastemic Rights' the bi-directional feedback loop between fisheries and marine research and fisher LEK must be made explicit (Davydov and Markova, 1983). Importantly without the vessel lists being accurate as shown in table 6, it is difficult to achieve this without an ongoing record of who has been involved in fishing particular areas. Knowing how many fish where, can allow for an assessment of how participatory the mechanism is. A more comprehensive approach would mean the whole of the local marine area's ecosystems, species and activities considered together. This could happen by integrating fisher LEK, other community LEK such as divers, alongside the knowledge of governmental scientists, researchers and democratic decision makers. This process could inform where ports, energy, and aggregates may be biophysically compatible with conservation and fishing in a limited way.

Currently, there is no explicit reference to the ecosystem approach in marine governance and the integration of fisher LEK legally and this would require an update in the legislation of the MCAA (Appleby and Jones 2012). The transformation of private goods into commons means connecting the participatory democratic practices to the production of commons services, such as ecosystem services (Constanza et al.1997). Nevertheless, theorising cultural ecosystem services of knowledge such as LEK is challenging, requiring both participation and ensuring individual commodification through payments for ecosystem services does not occur. The final chapter concludes on these findings and those of the other chapters to show the different ways that fisher LEK of the benthos has been developing and the potential ramifications for marine democracy, according to the research questions and aims.

Chapter 9 Conclusion

9.1 Introduction to the conclusions

The previous chapters examined how LEK is developing through fishers' understandings of benthic ecosystems as it is influenced by scientific research, technology, quota governance, marine spatial planning and decision making, markets and conservation. The research question identified by the review of existing research was to understand:

1. How has fisher LEK of the benthos developed in recent times, and how could this inform re-theorisation of fisher LEK?

To answer this key research, question these sub-questions were posed as they addressed key issues identified in the previous literature of fisher LEK:

2. How does scientific research interact with fisher LEK?

3. How does technology influence the development of fisher LEK?

4. In what ways do governance and social organisation influence the development of fisher LEK?

These supported the structure and aims of chapters 5 to 9 that presented the findings.

In contrast to other research on the marine geographies of fishing, this thesis draws explores the human geographies of the benthos. In contrast to the focus of other studies on the water column or interactions with the coast, the originality of the focus of this thesis on the benthos is introduced in Chapter 1 and established in the literature of Chapter 3. Through a critical realist methodology, the findings redefine the changing nature of LEK in an advanced West European context, that is in southern England, whereas much previous research has focused on the global south. By exploring the changing nature of research science, technology and governance the findings highlight how fisher LEK can be influenced by different mechanisms or processes that combine fisher knowledge with scientific evidence. LEK is therefore reframed through the influence or combination of fisher LEK with scientific knowledge fitting with the critical realist approach taken in this thesis. Mechanisms include the right to understand and participate in marine research, the use of new technologies, as well as forms of governance that allow for the participation of fisher LEK.

Table 8 below sets out the 3 broad mechanisms relating to the research questions and chapters. These are: increased scientific interactions, increased access to technology, increasing social movement pressure on governance and changing governance and policy. On the left side the specific mechanisms are detailed, with the middle column indicating the particular section of the thesis that provides evidence of where and how these specific mechanisms affect fisher knowledge. In the third column the socio-ecological context is summarised, including the sites where the mechanism has been successful and also some of the ways in which the mechanism has changed LEK.

Going through the specific mechanisms identified on the left, the first identifies the increasing number of scientific research projects involving fishers in England. This is specifically addressed in the thesis in the sections of Chapter 5, including 5.1.1, 5.1.2 and 5.1.3 and 5.2 and is further explained in section 9.2 below. The influence of this mechanism is that fisher LEK is evolving through bi-directional feedback with scientific research. It is a mechanism which is validating fisher LEK in new ways, expanding its vocabulary as well as enhancing the holistic understanding of marine ecosystems of scientists. For example, discarding surveys with Cefas in Plymouth, self-sampling of species in trammel nets in Hastings, and shark tagging in Looe.

The second specific mechanism discussed in section 5.2 and also in section 8.2, 9.2 and 9.5 is how conservation NGOs and scientists have developed as boundary spanners to bridge epistemologies. This occurs where people have sought out fishers' participation, such as Blue Marine Foundation employment of an ex fisher to facilitate the Lyme Bay Reserve. This mechanism was also successful where NGOs researchers and governance involved fishers in habitat mapping including rocky reefs. It has influenced fisher valuation of habitats in relation to the importance of protecting the rare species living in them such as through the research in Lyme Bay, Chichester Harbour and Selsey Bill. Fishers have enhanced their marine biological knowledge of species, including sharks, seahorses and sea fans, whilst improving understanding of their geographical distribution and population through their fisher LEK, as seen in Hastings and West Bay.

The third specific mechanism, identified in chapter 6.1, and discussed further in 9.3, is the greater access to accurate technology for sensing the bathymetry of the seabed and the benthos. Using new echo sounder technology including Olex and C-Scope, there is future potential for sharing knowledge accurately through shared databases. Fishers across the case study area from Newlyn to Ramsgate to King´s Lynn are using these tools. The next specific mechanism also from chapter 6 discussed in section 6.2, is also linked to changing technology and concerns the changing use of communications, data sharing and social media. Knowledge sharing is occurring through mobile phones and computers between fishers regarding their activity at sea. If integrated with research this could help understand pressures on ecosystems more clearly from local to regional scales. The use of the internet to gain knowledge and share knowledge of campaigns has also evolved. New forms of fishing based on sharing of knowledge in community and corporate groups were also observed. New social media access allows for the development of new fishing campaigns and access to new ecological knowledge, such as in Ramsgate, Hastings and Plymouth.

A further specific mechanism, described in chapter 7, is the increased critical engagement with the fixed quota allocation system and its relationship to fisheries stock assessment. This is linked to fishers' social movements attempting to gather momentum to realise a more environmentally and socially just system. Fishers were found to be particularly active in Ramsgate, Hastings and Plymouth. In Chapter 7.1, fishers link the temporal lack of local consideration and involvement of local species assessment, to their lack of access to the quota resource. By employing specific technologies such as Catchapp, inshore fishers have found a way to integrate their LEK with research but the barrier of institutional resistance remains.

The third broad mechanism is the influence of governance and policy in chapter 8. As part of this broad mechanism the specific mechanism of increased port expansion has led to the violent disruption of ecosystems through dredging as described in section 8.1 and 9.5. It has meant the development of counter environmental impact assessments including changes in biodiversity with different levels of success. This has similarly been changing LEK in 8.1.2 in relation to the expansion of aggregate dredging. This specific mechanism has been changing terminologies and understanding of scientific methods in response to dredging impacts. In one particular case, fishers were able to demonstrate ecological change linked to dredging through a paid scientist. Similarly, fishers have contested the impacts of offshore windfarms, whilst increasing overall understanding between knowledge systems through the deployment of a scientific research vessel. A successful mechanism that integrates fisher LEK with scientific processes and evidence has been in conservation governance such as through participation in the IFCAs in Devon and King´s Lynn. Fishers in Sussex have contributed to habitat surveying and have contested the sustainability of siting aggregate dredging on the edge of an MCZ. This is explored in section 8.2 and 9.5 and introduced in 5.2. These broad and specific mechanisms are defined and clarified in table 8 below.

Specific mechanisms changing LEK	**Where addressed**	**Examples from case study area how the mechanism has changed LEK**
BROAD MECHANSISM - INCREASED SCIENITIFIC INTERACTION		
Increased number of scientific research projects involving fishers	Chapter 5. See 5.1.1, 5.1.2 and 5.1.3 and 5.2. and 9.2	Fishers are taking part in more scientific research, with mutually beneficial bi-directional feedback. Fishers are becoming more familiar with scientific methods and sharing their critiques, observed in Hastings, Chichester Harbour, Plymouth.
Conservation NGOs and research boundary spanners bridging epistemologies	Chapter 5 See explanations of 5.1.3 and 5.2, and 8.2 further clarified in 9.2	Fishers are involved in habitat mapping of rocky reefs changing their values of habitats in regard to threats such as trawling. They have also been involved in research regarding rare species such as seahorses and sea fans, changing their values of species. Boundary spanners

		between fisher epistemologies have supported video methods to record habitats including NGOs such as Blue Marine Foundation and university researchers as observed in Lyme Bay, Selsey Bill, Portsmouth.
BROAD MECHANISM - ACCESS TO TECHNOLOGY		
Increasingly accurate technology: new echo sounders for bathymetry such as Olex	Chapter 6 See 6.1 Also discussed in 9.3	There is increasing accuracy of fishing through better detection of bathymetry and benthos. There is greater potential for sharing knowledge accurately through these new technologies. While there is increasing technological access to sensory systems, there is a lack of joined up thinking preventing this from being shared with government as seen across southern England.
Use of computers to share data and mobile phones to share knowledge of activity. Social media technologies are being deployed to share knowledge and to campaign	Chapter 6, See section 6.2 and 9.3	New forms of sharing knowledge in fishing communities and corporate groups through technology. Use of mobile phones to share knowledge of activity at sea, use of memory sticks to share coordinates. New media access allowing for the development of new more successful fishing campaigns and access to new ecological knowledge from media as seen around southern England.
BROAD MECHANSISM - CHANGING GOVERNANCE AND POLICY		
Increased critical engagement with fisheries and governance through fisher social movements	Chapter 7 See 7.1 and 9.4	The political context of the CFP has created a sense of alienation from an abstract process, different to fisher LEK and fisher epistemology. Fishers are contesting the methodology of stock assessment pointing to its flaws and lack of local consideration and involvement of LEK. Increased inequality in access to the quota resource and comparative lack of participation in the FQA system has led to new social movements. NUTFA and the Coastal Producer Organisation are challenging the system sharing knowledge and solutions. Particularly explicit with fisher organisations in Plymouth and Hastings.
Changing response to intervention: increased port dredging	Chapter 8. See 8.1.2 and 9.5	Expansion of new ports means dredging campaigns are disrupting fishing grounds and ecosystems. Fishers are sharing knowledge of these impacts. Lack of

		resource to demonstrate baselines of ecosystem habitats in non-designated areas has meant ecosystems for fishing being disrupted and access lost. Fisher LEK not taken seriously by governance in Thames Estuary.
Changing response to intervention: increased aggregate dredging	Chapter 8. See 8.1.3 and 9.5	Development of existing and new aggregate concessions is disturbing fisheries. Fishers are developing knowledge of these impacts. Lack of resource to demonstrate baselines of fishing activities has meant ecosystem habitats in non-designated are being disrupted. Some fishers have used financial resources to hire scientists to validate their knowledge as described in Hastings.
Changing response to intervention: increased wind farm development	Chapter 8 See 8.1.2 and 9.5	Development of new windfarms is disturbing fisheries. Fishers are sharing knowledge and developing research into these impacts. Lack of resource to demonstrate baselines of fishing activities has meant ecosystem habitats in non-designated are being disrupted as seen in Brighton, Ramsgate.
Participation in IFCAs	Chapter 8. See 8.2 and 9.5	Fishers are increasingly involved in co-management of IFCAs and are attempting to integrate their LEK to improve governance. Certain fishers with good governmental relations have been invited to co-govern aspects of IFCA by law development as seen across southern England.
Changing mechanism new MPAs and bylaws	Chapter 8 See 8.2 and 9.5	Fishers are integrating their LEK into co-management in certain localities corresponding to specific spatial common pool resources. Boundary spanners between fisher epistemologies have supported video methods to record habitats including NGOs such as Blue Marine Foundation and university researchers. Occurring in Lyme Bay, Chichester Harbour, Selsey Bill.

Table 8 showing the specific mechanisms discussed in the broad mechanisms sections, where addressed, and the outcomes

The following sections detail the key areas of original contribution and illustrate how the sub research questions have been answered, beginning with the interaction between fisher LEK and research science.

9.2 The mechanisms associated with fisher involvement in scientific research

This section concludes on the first research question, how fisher LEK of the benthos is changing through interaction with scientific research. As summarised in table 8 above, Chapter 5 in 5.1. and 5.2 demonstrated the increasing involvement of fishers in scientific research. It has seen mutual benefits for both fishers and the scientific community, with both fishers and scientists increasing their knowledge (Engestrom, 1987). It can therefore be seen that this bi-directional feedback fits with the re-theorisation of LEK using critical realism where Sayer (1984) described the need for a subject-subject ontology. The specific mechanism described in 5.2 includes the way boundary spanners were able to bridge fisher and scientific epistemologies.

Fisher involvement in scientific research was an important theme that arose from the participant observation, further explored during the interview process This included how fisher LEK interaction with the scientific knowledge system saw knowledge shared of seabed habitats and biodiversity. This specific mechanism saw fishers taking part in self-sampling through trammel nets in Hastings and Plymouth and discard surveys across southern England for Cefas (Mangi et al. 2014).

The thesis has shown that much scientific research on inshore fisheries in the UK remains locked into a positivist epistemology, lacking consideration of the beneficial feedback from fisher LEK of the benthos to science. Furthermore, the majority of research in UK fisheries has involved over 10m vessels in FPOs. Programmes including the Fisheries Science Partnership (FSP) have been partly funded by commercial fishermen. It has, been harder for inshore fishing to attract funding for research with relatively small landings per vessel, and varying market demand (Seafish, 2015). Where research is beginning to appear, work such as by Enever et al. (2017) continues the subject/object ontology of positivism. In contrast, this doctoral research demonstrates that across southern England scientific research is significantly interacting with fisher LEK and recirculating back into research.

This thesis demonstrated the changing influence upon LEK of transmission from scientific research. Before the early 20th century, fishing communities were insular, gaining and sharing their learning within their local geography with knowledge of grounds and stocks, often kept secret by individual fishers. Fisher LEK was the ecological knowledge developed using techniques of fishing only such as potting, netting and trawling. Scientists were separate from the communities they studied, such as when Icelandic researcher Saemundsson thought of himself as a mediator between ‘foreign scientists and Icelandic fishers’ (Aegir, 1921 and Palsson, 1998). The divisions between the understandings of fishers and researchers are now much less demarcated, and researchers and scientific research are increasingly accepted in fishing communities. This research shows that in the late 20th and early 21st centuries, scientific research with fishers has increased, changing vocabularies and ways of knowing. Contemporarily, as this thesis has shown influences from research has led to certain fishers adopting the same scientific terminology to explain their conclusions on fish stocks. Through involvement in research processes, fishers are more able to advance their ideas to a wider audience and transmit this LEK to the next generation. Hoefnagel et al. (2006)'s work was significant in developing the concept of community science. Nevertheless, as Hoefnagel et al. (2006) focused on nomadic boats and pelagic stocks, this doctorate provides a contrasting view through the consideration upon the benthos and seabed geography. Chapters 7 and 8, in particular, used the findings to identify new issues regarding the problems of integrating LEK with science and policy and how knowledge can also determine spatial access rights for fishers.

The following conclusions demonstrate the beneficial feedback mechanisms of research and fisher LEK, identified through critical realism. For example, fisher LEK is evolving to identify unusual weather and environmental conditions influencing marine ecology as discussed in 5.1.2. While authors such as Brehme, (2007) and Turner et al. (2014), considered only single species of the benthos, this thesis shows that LEK is developing to consider multiple species and to identify how marinescapes are different. The familiarity with fluctuations of temperature has enabled fishers LEK to understand local to regional scale processes of stock change (Cheng et al. 2017). This thesis shows fishers have recorded multiple unusual species in different parts of the country, and they linked climate change with changes in invasive as well as indicator species. For example, climate change affects native oyster and clam spawning, and mackerel and pilchards arrive later in the season in Southern England. The range of findings from fishers highlights that larger species such as sharks and sunfish are not as common as in previous years. Due to increases in temperatures, unusual species such as yellowfin tuna are arriving in Cornwall, and invasive species are also reported such as Canadian lobsters. These species can be recorded across the coasts to assess against ongoing baselines and to understand the interplay of changing pressures on native species populations. The findings also showed how out of the ordinary species arrival patterns can be recorded by fishers over long time frames. Fishers can provide baselines where no others exist for understanding the interactions between species and unusual weather patterns on a local scale, using new technologies. Using this knowledge to develop further insights into the influence of species and the benthos of the local spatiotemporal context needs coordination with a wider scale research programme across the country. For example, milder winters in Southern England and more storms relate to changes of the Atlantic Multidecadal Oscillation and the Gulf Steam, which interact with abundance and scarcity of species (Mieszowska, 2014).

Recorded in this thesis, fisher LEK of the benthos has demonstrated the gap in understanding local biodiversity changes of the benthos (see 5.1.3 for details). Fishers across England have qualitatively observed decreased species richness. Fishers conceptualise biodiversity in terms of valuing species richness and complexity. Nevertheless, the majority of fishers continue taking an anthropocentric approach to biodiversity, linking biodiversity to fishing success. Similarly, in the towed gear sector, fishing impacts from trawling and dredging on biodiversity are highly contested by the fishers interviewed, especially where there are limitations of gear access. Poor historical management inshore has led to what Pauly and Watson (2005: 415) called 'fishing down marine food webs' where species previously not targeted are landed. In Southern England, fishers normally record according to market value, such as with 'high grading', which has led to discarding. As the findings in 5.1.3 showed, research programmes have started to influence fishers away from this approach. Some fishers interviewed elicited that the industry has concealed discarding for years but fishers are now being increasingly open and bringing attention to the problem through their interaction with research. Involvement in research by fishers produced increased reflection upon their practice.

Lack of comprehension may represent a lack of consideration of praxis whilst doing (Friere, 1970). While the discard ban has come in, it does not link to how fishers comprehend biodiversity. This needs further research into fisher attitudes to discard and other writers have suggested this needs participatory and self-sampling methods (Mangi et al. 2014). Nevertheless, where the benefits of biodiversity were discussed, fishers were critically reflective over the changing populations of different species they recorded. This 'Capitalocene' period sees marine ecosystems increasingly disturbed from fisheries and other types of human development (Costello, 2010). Local-scale observations from fishers can bring fine scale recordings of biodiversity change, something which needs to be researched further quantitatively so that a complete picture can be gained of changing marine biodiversity and especially of biodiversity in the benthos.

The research shows that LEK is evolving in ways which can facilitate a more democratic form of fisheries management - that of adaptive co-management (Armitage et al. 2009) (See section 5.2). Involvement in scientific research has allowed fishers to validate their cumulative learning. Gilchrist and Mallory (2007) highlight that there is ample evidence that communities in the Canadian Arctic have recently been empowered by this process of involvement in research, rather than marginalized, as Brook and McLachlan (2005) suggest. This thesis builds on this and the critique of authors such as Wenzel (1999), who fear the cultural risks of appropriation and dispossession of LEK by science. The research counters Drew's (2005) position that LEK research is a one-way transference of power to scientists. This is evidenced by fishers interviewed in this thesis taking part in water temperature testing, conservation research and species assessment. Concerns over utilizing fisher LEK have been continually brought up relating to the reliability of data (Walters and Hilborn, 1978). If fisher LEK of populations can be recorded in a manner similar to scientific knowledge, such as using the codified records (noted by Brehme (2007), then Agrawal's (1995:2) questioning of the dichotomy between Western and Traditional knowledge is particularly relevant. Integrating fisher LEK with governmental science is obviously challenging. Schafer and Reis (2008) highlight that fisher LEK is often not used due to researchers' inability to include it in management systems because information is very specific to the region where it originates and it may not apparently be useful enough for deriving wider lessons. As St. Martin et al. (2001) suggested fishers and scientists have different spatial languages and understandings of fish populations making the translation between them the challenge

Historically in England, fishers have been negative about research, distrusting its methods and seeing it as a barrier to their work as discussed in 5.2. Certain inshore fishers notoriously subverted the assessments of landings for the CFP during the 80s. More recently, the research in this thesis shows that this situation is changing: fishers are positive about integrating their knowledge given the opportunity and have learned from past mistakes. They realise they have to be involved to improve the system of knowledge generation and related marine governance. Taking part in seahorse, oyster, lobster, cuttlefish, rays and other species assessment have been mutually beneficial for fishers and scientists. The reputation of fisher LEK through their involvement in species assessments was demonstrated in section 5.2 when fishers supported attempts to ascertain actual population levels, which were higher than scientific research had previously realised.

The findings also show that fishers deploy their LEK to argue that the marine biological impacts of fishing gear are not always generalisable across different local geographies. The over-centralised EU assessment process means fishers argue there is a need for adaptive co-management. This means adopting gear rules to local conditions and integrating fisher LEK with all forms of knowledge of species caught, to ensure the bi-directional feedback loop of learning (Engestrom, 1987). But new forms of management need to take account of the differences between localised benthic environments. Fishing for certain demersal and pelagic quota is decided at an EU level through the ICES. Measures of stocks are designated to regions thousands of miles wide (Daw and Gray, 2006). As section 5.2. showed, many fishers emphasised the benefits of local assessment of stock levels, such as involvement with the IFCAs, Cefas, and the MMO, but fisheries management decisions are still abstracted from localities, as well as consideration of the benthos. The fishers interviewed feel decisions may not take into account the local differences between fishing practices, benthic environments and the consequent varied impact on ecosystems. Nevertheless, this is changing where successful initiatives involving fishers in research have developed such as in Chichester Harbour. The suggests future scientific research can work together with fishing communities to develop a more regional approach to the CFP through greater integration of fisher LEK with associated ICES boxes.

The findings highlight where fishers' reputations are enhanced through participation in research and expert use of fisher knowledge using scientific terminology gives fishers status as opinion leaders in local fishing communities and beyond. It can increase fishers' influence, the efficacy of their respective campaigns, and help them to achieve their economic objectives. Interviews with fishers in this thesis in section 5.2 have demonstrated the effectiveness of using LEK to increase their cultural and social capital, increase the wider expertise in the community, and to validate their type of fishing gear. For example, allowing them to demonstrate that drift nets do not have an impact on turtles and cetaceans or potting impact assessments. The usage of new tools such as echo sounders, temperature sensors, and cameras allow fishers to form their own scientific hypothesises. Access to political influence and power is increased through interaction in scientific co-production. The findings demonstrate that the power of fisher LEK can increase when elicited for research, whether as oral or as discursive knowledge as suggested by Hoefnagel (2006). Nevertheless, certain fishers are deploying fisher LEK with scientific research for economic advantage. Unlike most inshore fishers, certain fishers' networks including the NFFO, allowed their LEK to be used in Brussels. This shows that the scientific validation of fisher LEK is influenced by socioeconomic access to governance mechanisms, apparent in the Fisheries Science Partnership co-produced by the better funded over 10m FPO sector.

Although fishers interviewed who have been involved in research projects have been positive about their experiences, there remain many fishers who have not been involved in the research process. From those interviewed, it appeared that scientists had often returned to the same fishermen. This is because the benefits of the bi-directional feedback mechanism between fishers and scientists are not well understood; something this thesis highlight's especially in relation to the benthos. Similarly, there remains a barrier to interaction with fisher LEK from some natural scientists concerned about the possible role of fishers as recorders of ecological understanding. The emerging 'Fishing into the Future' project highlights the possibilities of increasing fishers' education and involvement in fisheries science development as shown in 5.2. The NGO 'Fishing into the Future' supported by Seafish, would also see a mechanism for developing protocols to make fishers' LEK more accessible to research and governance through regional collaborative workshops. Particularly pertinent is the role of the IFCAs, who while involving fishers in research programmes in an ad-hoc way, have no explicit objective to explain fully the implications of their scientific research to fishers involved.

Similarly, while certain officers from Cefas or the IFCAs may be positive about including fishers, an explicit policy is needed to go beyond the domination of a scientific epistemology in research. As section 5.2 showed, governmental bodies often can only see how fisher LEK can be applied as data, rather than the development of wisdom. The positivist epistemic framework tends to lack an understanding of the underlying social processes and structures shaping and developing knowledge (Sayer, 1984). This also means that many fishers do not understand fully the goal of the research as shown in chapter 8. Having the detail of the programme explained fully allows for the educational benefits of their participation to feed back into fisher LEK more effectively. Schneider and McMichael's (2010) theorization of repairing the knowledge rift neglects the increasingly dominant influence of research science, interacting with producers of LEK and the feedback into local learning, and into future governance. The importance of Bhaskar's (1975: 4) critical realism approach that advocates "…the triangulation of the natural and the social sciences", becomes apparent, in the findings of this thesis which reveal the underlying social processes and structures shaping and developing LEK.

Although natural scientists focus on measuring the environment using quantitative methods, they sometimes fail to reflect on how the social context impacts on research production. Similarly, the constructivists' prioritization of cultural influence means the influence of quantitative scientific recording of knowledge is not always considered. As LEK and science align, it becomes apparent that their epistemic approaches and methods are in some instances reaching consensus regarding ecological patterns such as the examples in Chapter 8 in Lyme Bay, Chichester Harbour and the Wash findings examples. This thesis has argued that the Pescastemic Rights approach is an emancipatory mechanism for fisher LEK and knowledge more widely to develop. The socio-economic benefits of developing a comprehensive framework for involving fishers in research and ensuring there is mutual learning beyond the rationale of the market can be referred to as a cultural ecosystem service (Church et al. 2011). Findings from the thesis presented in Chapter 5 showed how the properties and causal powers of the social structures that influence inshore fishing also shape LEK. To create an emancipatory science that commits to supporting knowledge of both the environment and humanity requires moving beyond reductionism and positivist approaches. Conclusively, critical realism allows for a re-theorisation of fisher LEK in its implicit interaction with scientific knowledge. Conceptually building on human rights and epistemic rights, Pescastemic Rights is offered as a new construct regarding the right to know, in this case about fishing and the wider marine ecosystem in an environmentally and socially just way. Referencing Tsosie et al. (2012) the historic epistemic injustice of indigenous people placed as objects of science subjects is reflected on and redeveloped for fishermen in contemporary Europe. Indeed, Pescastemic Rights means the right to fish sustainably given full knowledge development and sharing of learning between its users and stakeholders. As core marine stakeholders, fishers should have the right to simultaneously increase their understanding of the benthos through access to educational resources, as well as being responsible to other marine stakeholders as stewards of the sea.

9.3 The mechanisms associated with changing technology

In regards to the second research question how fisher LEK is changing through the influence of technology, chapter 6 explored the broad mechanism of how technology is influencing fisher LEK as summarised in table 8 above. Section 6.1 researched how technologies that are increasingly accurate and flexible whilst considered user-friendly by fishers described improved echo sounder technologies. This bathymetric sensing for understanding the seabed and benthos has enhanced fisher LEK. Section 6.2 analysed boat to boat mobile phone communications, computer usage to share data and new social media to share knowledge and develop campaigns. It is apparent that new technologies are an emancipatory mechanism for fishermen to understand the benthos. Simultaneously, new technologies see increased efficiency of catch rates to unsustainable levels (Cullis-Suzuki and Pauly 2010). The increasing pressure of neoliberal internationalisation of markets has undoubtedly influenced the fishing distribution, organisation and technology (Reed et al. 2013). Nevertheless, while Murray et al. (2006) based on work in Eastern Canada conceptualised fisher knowledge as homogenised understanding, becoming GHK, the reality is different in Southern England and beyond. The legal regime here limits under 10m boats fishing offshore beyond 6nm. It has led to a continuing relationship with the community and marine spaces. This research demonstrates that technologies can enhance the bi-directional feedback mechanism between fishers and researchers, enhancing collective understanding. Chapter 6 demonstrates that while fisher LEK was once tacit and unspoken as described by Palsson (1998), forms of fishing technologies have evolved the recording of activity through the late 20th century and early 21st century, making codified perspectives on fishing easier to share. Supported by technologies, fisher LEK is shifting from a tacit knowledge to discursive knowledge which is also discussed with governance agencies and researchers. This thesis demonstrates how technologies used by fishers have built and enhanced existing fisher LEK, improving the accuracy of habitats and species knowledge according to their respective geographies.

The primary data of breeding, feeding, and nursery grounds are based on comprehensions of how marinescapes relate to underwater features (discussed in section 6.11). Fishers' knowledge of underwater features layers spatially with other environmental variables influencing the ecosystem, partly gained by interaction with scientific research as discussed in chapter 5. The research demonstrated how digital technology can improve access to accurate understanding such as of bathymetry, which influences the interaction of fishers with certain habitats. This has led to a changing fisher codification of habitats, according to the challenges and demands of different technologies of fishing in different localities and ecosystems. Knowledge developed using new forms of technology for measuring water quality, temperature, seasons, tidal changes, alongside day and night time behavioural patterns inform fisher LEK of benthic structure and species activity. For a re-theorisation of fisher LEK of the benthos, it is important to reiterate that the findings of the thesis suggest nomadic fishers produce and use LEK differently to inshore fishers that do not migrate. Inshore fishers normally continue fishing for less than 24 hours before returning to the same home port (Urquhart and Acott, 2013). Furthermore, the findings showed that among those specialising with particular gear types only, inshore fishers with static gear record ecological fluctuations differently to towed gear fishers. Towed gear sees trawl-sampling over many nautical miles, making habitat and species aggregation sampling less accurate than static gear fishers who deposit gear at the same places, such as on reefs and in gullies. This relates to the collective under 10m fleet's continual relationship with local space and community, and how they use sensory technology to comprehend the seabed and the relationship with different forms of fishing gear.

The thesis has described fishers' experience with earlier technologies, going from trial and error in understanding bathymetry and the benthos, to improved habitat accuracy (See section 6.1.2 for details). Given the risks involved in deploying trawling gear, potting gear, and other gear, the interviews showed that fishers in the same community increase safety by informing each other of risks that relate to bathymetry particularly wrecks and habitats. Unintentionally, such new shared learning of safety hazards, such as reefs and wrecks, can increase understanding of habitats, if fished with static gear. While Brehme (2007), examined how the single species of lobsters and their habitats in the benthos are recorded on digital resources in Western Australia and New England, this current research highlights how learning of multiple species and habitats is shared, and how static and towed-gear groups have different approaches. Given the differing environmental impacts caused by the choice of fishing gear used, this relates to different LEK's of disturbance. Codification of knowledge of the benthos, held by fishers in this study, has changed through the evolution of Decca charts to three-dimensional imaging of bathymetry through Olex. This, in combination with echo sounders and computers, allows fishers to gain fisher LEK in new digital forms.

This research has also demonstrated how social organisation and technology interact and interface with fisher LEK. This commenced with an examination of how intergenerational transmission of fisher LEK is developing. It demonstrated that the majority of fisher technology which enhances LEK is passed down from generation to generation particularly in families and local communities. Typically, knowledge is passed from older to younger fishers generationally. Nevertheless, younger fishers appear to adapt more quickly and advise older fishers on how to use these technologies as they emerge. New technologies are also critiqued by older fishers for making fishing too easy for the next generation, leading to overexploitation. Alienation from the experiential knowledge techniques of the past was criticised by some fishers in relation to potential overexploitation. Nevertheless, new technologies are also allowing fishers to share LEK in new ways that can benefit conservation. Typically, among kinship networks and close friends, fishers are sharing mapped knowledge such as Olex via disks and other electronic media, as well as co-produced GIS maps. Knowledge of static shellfish beds remains closely guarded by older fishers, however. This thesis also showed that knowledge of these habitats and species when shared can inform adaptive co-management. Nevertheless, where corporate businesses dominate the local boat fleet, knowledge sharing using technologies is limited outside of the company, reducing cooperative behaviours. This research also examines how corporate management can create limitations to accessing knowledge, such as a division of labour to increase catch-per-unit-effort, which can limit the development of LEK. Conflict resolution is more challenging in this context, and the race to fish out limited resources may be accelerated. New social media technologies, such as web-based apps to facilitate knowledge sharing could be developed to support those willing to start fishing cooperatives. The work of NUTFA and the Coastal Producer Organisation can be central in developing this sharing of fisher LEK. As a social movement with sympathy for cooperative fishing activity, NUTFA's approach aligns with supporting communities and the sharing of fisher LEK.

New social media tools are becoming integral to fishers (as explained in 6.2.1). It has provided benthic information in much more detailed forms compared with more traditional methods. Social media has allowed for the sharing of knowledge from the internet and other media and for this to be applied to the local ecological context. Knowledge of bathymetric features which previously would take generations to accumulate is now available on the internet through the C - Scope mapping software. This would be significant for planning access equitably to common resources. While access for fishers has been coloured by perceptions that C - Scope has been primarily produced by divers, the findings of this thesis demonstrated that usage has raised fisher knowledge and interest in conservation.

Fishers have increasingly supplemented their LEK with new sources from the internet and television, through documentaries and scientific studies as well as creating their own social media in relation to LEK. This research shows that by debating documentaries such as Blue Planet, fisher LEK is perceived by fishers to be enhanced. While websites have been deployed by fishers to campaign against the creation of an MCZ in Hythe Bay, organisations such as NUTFA have encouraged interaction with fisheries science to demonstrate the validity of LEK to conservation. Further, while the Real Fish Fight Facebook group was originally set up to defend the reputation of the fishing industry, it shares scientific knowledge concerning existing and continuing research. For example, knowledge shared on this site includes the GAP2 research, fisher LEK in India, as well as articles relating to the dynamic nature of marine ecosystems and the need for better food web monitoring. The findings from interviews suggest this has influenced fisher learning of scientific limits to exploitation. Other active NGOs working with groups such as NUTFA, including Greenpeace and the Blue Marine Foundation, have also influenced LEK through their websites sharing ideas around how conservation and involvement in research science can develop.

Technologies allowing for co-production of research can produce an increased reflection on practice. These technologies have allowed for broad-scale habitat shared learning between fishers and researchers, including rocky reefs off Eastbourne, Selsey Bill, Lyme Bay and Penwith. Locating these habitats can be difficult as satellite technologies such as remote sensing cannot penetrate the sea surface. While British baselines for marine ecosystems indicate they are often overstressed, with many areas needing recovery, MPAs can support repopulation and the return of climax communities (Jones, 2014). Nevertheless, some interviews suggested that the benefits of these MPAs, such as biodiversity, biomass increase, and ecosystem services are not always clear to fishers. Particularly apparent as this thesis illustrates is the lack of understanding of the impacts of towed gear fishers. This may represent a lack of reflection during the action of trawling and dredging (Friere, 1970). Co-production of knowledge can produce an increased reflection on practice and shared learning. Nevertheless, it is apparent from the findings in this thesis that full comprehension of conservation benefits of marine governance is not apparent across all the fishing community.

Expanding sensory exploration through visualisation, the thesis demonstrates that the camera lens can be both a hunting technology and conservation tool (Butler, 2006). As Hoorweg and colleagues (2006) highlight, involvement in collecting related data can also increase fishers' motivation for marine conservation. With towed cameras being deployed in Sussex, Devon, and Cornwall, actual visualization of marinescapes has become possible. Additional social capital and respect are given to those fishers identifying habitats such as reefs with cameras by the local community, governance, and researchers, this, in turn, leads to an increased understanding and sense of supporting conservation for future generations amongst some fishers. As observations confirmed, changed fisher behaviour was apparent with the codification of habitats, such as Sabellaria reefs or rocky reefs and seagrass meadows.

Fishers used cameras alongside new technologies while taking part in potting impact assessments in Lyme Bay. While fishers were originally skeptical of the erosive influence of potting on the rocky reefs, participation in the study has led to greater reflection of substrates suitability and intensity of potting. However, for shellfish dredgers, otter-board, and beam trawlers, the potential economic loss of their fishing grounds meant they were less reflective about their own impacts upon the benthos. Static gear fishers are beginning to demonstrate an alternative epistemic framework; relating to a more specific sense of place attachment to marine habitats, as these fishers are less able to migrate to fish new grounds.

Dive fishers in the East Devon area demonstrated a developing body of knowledge showing how habitats are recovering through conservation zones. They highlighted that areas in their proximity could also have zoned use, especially for habitats not valued by Natural England assessments. This knowledge could be usefully integrated with the local IFCA's management. While Kenter et al.

(2013) highlight the economic value of MCZs to divers; more work could examine the intrinsic value of these habitats to fishers and the non-monetary value of fisher LEK of biodiversity. The learning made accessible by diving and seeing species alive in their natural habitats can make fishers more motivated to research and comprehend the intrinsic value of biodiversity. While systems such as Olex may visualise bathymetric forms, in the future layers of habitats can be identified on navigational systems for increased understanding of biodiversity. This will depend on multi-beam echo sounders becoming available across the community as the price decreases.

Habitat mapping with examples of rare species needs to be made available to fishers in order to construct electronic charts. The intrinsic value of biodiversity is currently undervalued by the intrinsic nature of the market episteme. As the technology becomes more available, collective community maps can be collated with the IFCAs under the guidance of EUNIS - The European Nature Information System. Further, the Olex global bathymetric database also promises much for the participatory mapping of the 44 marinescapes identified in the UK (Connor et al. 2006). Only 5-10% of the seafloor is mapped with a resolution of similar studies on land, (Wright and Heyman, 2008). With the policy approved nationally, access to conservation training can be made more widely available for fishers. They can make an evolving contribution to habitat and biodiversity mapping, identifying rare species, whilst updating information on the latest fishing pressures.

Fisher LEK has thus changed with the growth of different types of fishing and sensory technologies. Nevertheless, although authors such as Neis and Kean (2003) underline how spatial, temporal, and ecological intensification and interrelated catch expansion has occurred as a result of new technologies, they have also coincided with the growth of conservation technologies and participatory research. Resourced with visual codification methods and more learning about underwater habitats, fisher LEK is more likely to be validated and shared as a result of new technologies. This research demonstrates the growing rupture of an understanding limited to the pursuit of single stocks, and an evolving epistemic framework incorporating fishers' understandings of multiple species in the ecosystem. Fuller scientific understanding of limits could be developed more effectively among fishers if the 'Pescastemic Rights' framework could have full policy recognition by Defra. Alongside an ethical right to see marine resources harvested sustainably, fishers can enjoy a fuller understanding of conservation benefits through both analogue and digital technology. This can also bring a more accurate understanding of habitats, biodiversity and ecosystem services recovery through the praxis of fishers.

9.4 Governance and policy - quota and fisher social movements

In keeping with the final research question, chapter 7 explored how specific forms of governance and policy influence the development of fisher LEK. As highlighted in table 8 above, the specific mechanism of the inshore fisher social movements in 7.1 challenges the top down FQA system, and its related quota trading for over 10m boats in FPOs. This has influenced the development of fisher LEK, such as through engagement with stock assessments and impacts of different gear. It has demonstrated a mechanism for its compatibility with science in response to lack of access to the quota resource. Marine governance has been influencing the development of fisher LEK of the benthos since the first attempts at fisheries management. Nevertheless, chapter 7 indicated that in the opposite direction, fisher LEK in Southern England has not necessarily influenced management in the ways which inshore fishers would wish. With the UK as a result of Brexit leaving the London Convention of 1964 and the CFP of 1976, there is an opportunity for fisher LEK to contribute in new ways to marine democracy (Anbleyth-Evans and Williams, 2018). To do so, the system of fisheries management will need to overcome the challenges of a quota property market disembodied from space and environmental justice. While social movements campaigning for Brexit blame the CFP for inequality, the distribution of fishing opportunities has actually been the responsibility of the UK government It has resulted in the over 10m fleet consolidating 98% of CFP quota, whilst having less than 30% of the fleet (Anbleyth-Evans and Williams, 2018). Continuous and wide-ranging literature criticises the application of private property solutions to fisheries quota. Authors from Mansfield, (2004) to Appleby et al. (2013) and Campling and Havice (2014) suggest public, common and democratic rights access should be respected. Nevertheless, the dominant neoliberal logic has continued the expansion of quota as private property into the sea. Quota as a solution to the open access problems of the UK's fisheries has not so far resulted in environmental justice (Agyeman, 2003). Nor has it led to adaptive co-management, which the literature review identified as important in developing a fisheries democracy (Armitage et al. 2009). Nomadic fishing carried out by the offshore over 10m fleet lacks a relationship with local communities, as well as using the most profitable but destructive techniques (Kaiser et al. 2006).

The research in this thesis showed that ongoing research programmes involving fisheries and fishermen are not joined up, and so do not recognise the goal of supporting the ZPD between fishers LEK and research (Engestrom, 1987). There is potential for the NGO Fishing for the Future supported by Seafish to develop learning for sustainability through a two-way interactive engagement model if it can be associated with the newly recognised Coastal Producer Organisation. In tandem with the ethics overseeing marine resources equitably managed among coastal communities, spatial access rights could be more clearly defined if the fuller scientific understanding of ecological limits can be developed among fishers under the 'Pescastemic Rights' framework proposed in this thesis.

Recent research by Elliot et al. (2017) concluded that a spatially managed approach is needed to protect benthic nursery and breeding ground habitats for different species. This is more difficult under a regime that allows fishers to transfer and buy fishing rights in different parts of the country through nomadic fishing. For social sustainability, it is also problematic. Historically, the apparent crisis of inshore fishing impacts led to the development of top-down governance for under 10m vessels. Differently the over 10m vessels in FPOs have been allowed to self-manage quota and fishing effort (Larkin 1977). These two contrasting management regimes mean that a new participatory mechanism to integrate fisher LEK is needed regionally. To connect different scales of fishing with communities and participation in research an emancipatory mechanism is diagnosed in this thesis and discussed later in section 9.5, through a critical realist lens. Murray et al. (2006) demonstrated that in Newfoundland, fishers had become less concerned about local ecosystems as interactions with markets have shifted their focus from local to global export markets. Similarly, while Reed (2013) argued that fishers' behaviour is irrevocably influenced by neoliberal ideas around financial allocation to the commons, the present research demonstrates that fishers' collective epistemic framework, and furthermore their behaviour, is more complex than Reed (2013) allows for. This thesis demonstrates that where fishers, especially inshore fishers, are sharing knowledge of exploitation using new technologies in fishing, their communities are often 'protection societies' and fisheries associations, theorised by Johnsen et al. (2009) as organic associations. Quota commodification of single stocks focuses fishers' attention on single species rather than the whole ecosystem.

The findings also show how intergenerational transmission of LEK is also influenced by governance, social organisation, access to quota, alongside knowledge sharing (As demonstrated in Section 7.1). Johnsen (2009) used an organisational analysis to show how organic associations (or traditional inshore fishing communities) have become increasingly cybernetic organisations or corporate fishing businesses. Intergenerational transmission is challenged both by the distribution of quota property rights, as well as corporate managerial barriers linked to changing market arrangements. This follows Moncrieffe's (2009) analysis of intergenerational transmission in international development. Furthermore, the interviews indicated that physical access to fishing boats in the community has become increasingly difficult in certain areas. Corporate port and marina take over have seen traditional harbours enclosed from public access such as in Shoreham and Lowestoft. Fishers claim these influences change who they communicate and share knowledge with. However, chapter 8 showed that older and younger fishers share knowledge gathered using new technologies. While different across regions, inshore fishermen continue to be one of the few livelihoods that can bring the sea to life in coastal communities (Urquhart and Acott, 2013). A continued loss of their population due to a lack of access to boats or ports would further reduce this connection.

To support development and sharing of LEK, the findings of this research suggest there needs to be a common access to the fishing harbour/beach, as well as environmentally just quota for inshore fishers.

In places such as Plymouth, around Cornwall, Newhaven, Portsmouth, and Hastings, there is some noticeable intergenerational recruitment to fishing. Recruitment was particularly prevalent where fathers or family members already owned fishing boats and access to quota. The research in this thesis shows that LEK is still being reproduced and shared even if fleets and LEK are decreasing in many areas. Larger corporate organisations are becoming more dominant through centralising quota in businesses which dominate producer organisations and through vessel license buyouts. Given the decrease in the number of inshore vessels and licenses and historic overfishing, intergenerational recruitment seems likely to decrease.

The predominance of the market rationale has been developed by Defra through the encouragement of the FQA system (Anbleyth-Evans and Williams, 2018). It has made the inshore quota pool currently managed by the government a tradable right. Inshore fishers interviewed protested from the Coastal Producer Organisation that their LEK could be a better-taken account of in participatory processes and their communities would benefit from a system where they could access power and adaptive co-management. Catchapp can be a way for members to integrate their fisher LEK to form the basis for real time updates to changes on fishing grounds.

The expansion of FQAs would mean it would be easier for the better funded industrial over 10m businesses to buy them out. Reflections on how quota monopolies limit the participation of fisher LEK was powerfully rendered by social movements such as the Coastal Producer Organisation and NUTFA. Gramsci's (1992) ideas about how power as 'hegemony' and the 'manufacture of consent' is relevant to how civil society is challenging ideas and norms of the property relations of the corporate fishing organisations, through support by NGOs such as Greenpeace. These groups and others such as the Lyme Bay Reserve group were more critical of industrial techniques of fishing and disturbance of habitats. This contradicted the discourses of industrial fishers, particularly those representing offshore fishers from the NFFO.

The developing associations representing inshore fishers of NUTFA and the Coastal Producer Organisation are a sphere of political struggle challenging unjust property relations and the state (Heywood 1994) and neoliberalism, if not consciously so. They are attempting to move beyond neoliberal norms and logic by lobbying against the privatisation of the inshore quota pool, and campaigning for the redistribution of a percentage of quota for the collective ownership of the Coastal Producer Organisation (Brown, 2015). Whether the emerging consensus from Coastal Producer Organisation and LIFE (2016) documents regarding how low-impact and socially sustainable fishing can be translated into continuing fishing practices will actually be implemented may depend on whether quota redistribution can be achieved. While the prospect of Brexit is creating a policy space for change, an emphatic legal challenge to the current property relations of quota would be needed for environmental justice (Agyeman, 2003). The incorporation of CFP law after Brexit will be complex.

Nevertheless, it affords the opportunity to make quota allocation more participatory and democratic through new law recognising a participatory ecosystem approach, allocating quota to the Coastal Producer Organisation.

The market rationale which has led to the commodification of single stocks marginalises fisher LEK's potential for participation, discussed in section 7.1.1. Despite this, as findings from this research in chapter 8 showed, fisher LEK can be part of a radical new future of ecological assessment linked to conservation and the mitigation of harm from port development, wind farms and aggregate extraction. This thesis suggests that localised assessment and adaptive co-management integrating LEK of local biophysical differences can slow exploitative forces. It would require as shown in chapter 7 a new conceptualisation where community situated common properties based on traditional fishermen's associations as cooperative quota holders. The current quota trading and leasing system allow for businesses to exploit multiple ecosystems without local management (Anbleyth-Evans and Williams, 2018). Different local communities need political access to FPOs. Fisher LEK of the benthos revealed in this research draws attention to these political pressures. Being of the benthos, fisher LEK described in chapters 7 and 8 is aware of the consequences for future species populations of overexploitation and the pressures from other activities such as dredging on less migratory species such as flatfish, skates, and rays. The subtle spatial differences of habitats and their topographically shaped ecosystems can be brought into co-assessment under adaptive co-management. Currently, this adaptive capacity remains inchoate through the quota market for many species. With seasonal differences from temperature change the findings of this thesis suggest that understanding the breeding, feeding and migration patterns of species needs the participation of fisher LEK at different times of the year, not currently possible under ICES areas. Nevertheless, with the political ramifications of Brexit, there may be space for a greater use of LEK to evolve.

Command and control hierarchies of businesses (with their linkages to shareholders) are more likely to attempt to monopolise knowledge to gain greater control of the potential profit (Johnsen et al. 2009). This echoes research done on private interests and fishing organisation versus cooperatives in the developing south carried out by Deacon (2012). This thesis suggests that as knowledge becomes increasingly codified and centralised in organisations, crews are increasingly removed from different local ecosystem processes as they fish and become nomadic in their catch strategies. The nomadic skippers interviewed for the research presented in this thesis were more reductionist, their answers focused on the market of single stocks, such as the value of specific shellfish. In interviews, these nomadic fishers did not draw attention to external issues influencing their local ecologies, including conservation challenges, dredging aggregates, and marine constructions. They lacked the spatial attachment to place apparent with inshore fishers and the associated nuanced understanding of benthic ecosystems under stress but their overall influence on fisher LEK requires further research.

This thesis also shows in chapter 7 that the social organisation of inshore industrial fisheries is modernised in some associations by what Holm and Nielsen (2007) call a cybernetic system; based on the development formalised command and control hierarchy influencing the system of knowledge (Johnsen et al. 2009). Example organisations investigated in Portsmouth, Newlyn and Plymouth are noted by the IFCAs to be less likely to participate in conservation research. Questions of conservation research were less positively received by boats based in their locations. Furthermore, the larger, more corporate organisations had higher occurrences of destructive towed gear forms of fisheries. Similarly, fishermen from more corporate systems of organisation interviewed in this research highlighted the pressure they are put under by their bosses to race to fish, such as dredging out limited shellfish areas. This decreased autonomy and power led to them being less open to conservation research and arguments for ecological sustainability. Adaptive co-management is therefore limited through cultures in the industry driven by an overwhelming focus on economic gain. Gaining experience of habitats and navigation has been made more difficult for the typically younger crews in the larger organisations. Fisher LEK in migratory fleets primarily developed by skippers and navigational access is needed to understand where ecological processes are occurring underwater. Inshore, there is more informality between skippers and crews, allowing for greater access to the wheelhouse. This thesis demonstrates through interviews that where fisheries protection societies and similar organic associations of fishers still dominate inshore fishing, knowledge sharing of ecosystems and exploitation were more common. These forms of organisations were more likely to support participatory approaches to fishing and conservation with their more flexible hierarchies.

While fishers discussed as shown in chapter 7 how the power structures of government limited their agency in highlighting ecosystem limits, critical realism draws out the underlying economic mechanisms limiting their participation in governance. The application of critical realism in this research gives new insight how the structures of the market can lead to overexploitation; and why the underlying political power relations need to be understood to appreciate how LEK or governmental science knowledge develop and interact. With the territorial user rights framework, as developed by Matsuda et al. (2011) and Gelcich et al. (2010), the democratic deficit can potentially be reduced using LEK whilst increasing scientific accuracy. Indeed, having the capacity to exclude access of nomadic fishers from other areas, as well as certain forms of high-intensity fishing and gear types is essential for ecological sustainability, best developed through the inclusion of fisher LEK (Christy, 1982). In areas such as Portsmouth and Shoreham where cybernetic organisations dominate, they have been unwilling to share knowledge and reciprocate, especially with the local IFCAs. Cooperative behaviour is more apparent with fishermen's associations which seek more equality and social continuity down the generations. Recognition of these associations in developing further TURF structures around the coast will be advantageous. Limiting a certain number of vessels to regions is currently not policy, and government attempts to record vessel numbers and their effort remain inadequate, as referenced in table 6 in the appendices.

New legislation is probably needed to make the CFP assessment process more participatory and integrated with the MCAA national legislation. This could start with adopting section 3 (1) of the MCAA making the MMO under local democratic authority to ensure that participation in fishing access is cooperative, locally situated, democratic and transparent (Appleby and Jones, 2012). Implementation of the ecosystem approach would also ensure the valuing, participation and integration of fisher LEK into this process. The recognition of the Coastal Producer Organisation can lead towards greater quota access and would prevent the loss of local associations such as North Devon Fishermen's Association which has collapsed. The guiding logic of neoliberalism in encouraging the quota market from 1986 led to inequality in fishing opportunities (Brown, 2015). Mechanisms being developed with the Coastal Producer Organisation could see more small-scale fishermen fishing. Quota can be adaptively co-managed with fishermen's associations. This means more LEK can be reproduced in more local communities and take part in more research programmes.

The assessment of quota and conservation measures in a regional, participatory way, supported by the relevant IFCAs, is something which needs to be researched further especially relating to areas beyond 6nm. The majority of spawning and breeding grounds are in local geographical areas which can be co-mapped with local fishers. While these grounds can relate to migratory species, in different parts of the life cycle these species remain biophysically bound, requiring adaptive co-management processes to ensure their health. The changes in climate mean fisher LEK of changing species patterns and habitats will need to be validated through self-sampling (Mangi, 2014). If using the 'Pescastemic Rights' approach introduced in the conclusion of chapter 5, the co-produced scientific assessment could understand local regions' ecological fecundity increasing the collective understanding of marine resources and social stability.

9.5 Mechanisms associated with governance and specific policy changes

Chapter 8 considered the general mechanism of how governance is influencing fisher LEK. As discussed in table 8 above, the specific mechanisms of new and continuing development projects linked to changing governance and policy, such as port expansion, aggregate dredging and windfarms, are causing fisher LEK to engage with environmental impacts and increased shared learning. It further identifies specific mechanisms of where boundary spanners have supported work with conservation governance successfully. In the interaction of governance with fisher LEK, there needs to be consideration of how the actions of other marine space users and the ecological problems of open access are being responded to by fishers and how the system of governance could evolve. The research, especailly in chapter 8, recognised that private property interests of businesses are being prioritised over collective interests of marine commons communities especially in relation to decisions on port construction, energy, and their interactions with conservation through MPA governance. Furthermore, beyond Johnson's (2011) focus on validation of LEK, the thesis considers the beneficial consequences for fishers of taking part in governance and research linked to other marine uses, including increased social capital as well as becoming more knowledgeable about conservation. This is evidenced by fishers drawing attention to dredging and aggregates impacts for fisheries management, and fishers' involvement in conservation research. These examples demonstrate the potential for greater regular participation by fishers in marine governance. Again, this thesis expands on Johnsen's (2014) work by highlighting the potential of LEK for marine governance and also considering the underlying socioeconomics and structures of power limiting the development of this path forward. The need for legal recognition of benthic TURFs for low impact fishers was further demonstrated in this research by the lack of formal consultation with fishers during developmental applications for dredging, port, and wind energy developments. Combining, territorial user rights, (Gelcich et al. 2010, and Matsuda et al. 2011) and a human rights approach to spatial community resource access (Allison et al. 2012) can enable the bi-directional feedback of research from conservation programmes to support Pescastemic Rights. These territorial user rights can be clearly defined, and where future polluting activities are proposed, fisher LEK will have an active mechanism and method to assess risk and receive validation. This is demonstrated by this thesis which demonstrates those fishers' interactions and involvement with conservation governance is not only influencing their LEK but creating a bi-directional feedback mechanism that informs scientific research. Fisher LEK through its elicitation with research is becoming discursive knowledge, and more suitable to be shared with governance than previous generations tacit and oral knowledge forms of LEK (Hoefnagel et al. 2006). The progress made with MPAs and fisheries show how a spatial approach to recognising fisher LEK can increase participation and overall socio-ecological resilience.

A key area of everyday work where fishers face competition is through the impacts of port development and dumping, aggregate dredging and energy infrastructure (as demonstrated in section 8.1.2). Examples detailed in the research include the influence of capital dredging and habitat change in the Thames estuary and in relation to sabellaria reefs. This thesis shows that fisher LEK has often been dismissed by the Environment Agency, Natural England, IFCAs and MMO as anecdotal. With fishers contesting impacts such as the London Gateway and Port of Southampton developments, the impacts to fisheries have been denied or not considered by the government. This suggests that there is a lack of recognition of alternative ways of knowing by some of the organisations involved in marine governance. Further policy guidance is needed to refine the process of validation of fisher LEK as an evidence base. It demonstrates that LEK is not always valued by governance due to the established perceptions in the natural sciences about fisher expertise. Sayer (1984: 4), writing from a critical realist perspective, argues that technologically and scientifically rooted intellectual prejudices about the creation of knowledge are connected to misconceptions that states that "…science can be assumed to be the highest form of knowledge and that other types are displaceable in the hierarchy." Critical realism is then essential in steering towards the identification of where emancipation based on other forms of knowledge is possible, by focusing on the underlying socioeconomic factors influencing the use and development of knowledge.

In regards to aggregate dredging, the findings in this thesis show that spatial conflicts caused by physical loss of fishing space have brought debilitation of habitats to fishers' attention (See section 8.1.3). Fishers in Hastings empowered themselves in shared learning by hiring a scientist, in order to gain influence over the governance of aggregate extraction. Ongoing disruptive acoustic pollution from dredging activity influenced the seasonal behaviour of flat fish. Nevertheless, it proves that governance maintains a perceived hierarchy of knowledge with fisher LEK continuing to be perceived by decision makers as of limited value. Learning about these activities by fishers has been supplemented by online sources from NGOs such as Marinet, improving fisher confidence in their assessments of ecological disturbance. Furthermore, fishers' involvement in the organisation of the IFCA in West Sussex left them reflecting upon how aggregate dredging expansion is likely to influence Black Bream nesting areas, a habitat near to sandstone reefs. This extraction has now been approved, but the method of assessment means that a new mechanism of validation needs the involvement of fisher LEK to record pre-aggregate extraction and post-extraction impacts. By gaining access to conservation research, the fishers concerned have not only increased their intrinsic valuation of the habitats but gained influence within governmental networks. Nevertheless, it is another example of their prediction of disturbance not being integrated into decision making as the dredging was allowed to proceed as it was judged to have met the 'Imperative Reasons of Overriding Public Interest' overriding the conservation objectives of the MPA.

Milton (1996: 106) argued that through its spiritual component, TEK has been argued to be a threat to environmental assessment, "…because a rational understanding of the world is impeded by spiritualism". This thesis's theorization, however, demonstrates that fisher LEK, being situated in a wider culture, can bring attention to environmental impacts and organise them to defend marine life. Milton's (1996) position is critiqued, as cultures in the West demonstrate that societies do not remain static, moving on from primitive communalism through feudalism to capitalism; removing humans from cultural rituals which might balance processes within the ecosystem (Dickens, 2004). With the addition of citizen science (Fischer, 2000) in terms of assessing the environmental impacts of human activity, fishers are looking to highlight the importance of ecosystems beyond the market value of single stocks. While early theorisations of Local Knowledge such as by Geertz, (1983:2) related to its local history and geographical context, earlier conceptions ignore the scientific and economic influences upon LEK revealed in this thesis. Nevertheless, chapter 8 shows the difficulties inshore fishers face in integrating their knowledge in a way that can be accepted by governance.

The dominant hierarchy of knowledge can disguise underlying economic arrangements. Port developers, aggregate extractors, and wind farms are likely to meet the government's economic growth goals more than inshore fishermen. Nevertheless, despite their own underlying socio-economic reasoning to protect their livelihoods, fishers interviewed in this research communicated that they have a valid interest in keeping the marine environment healthy around their fishing grounds and beyond. Furthermore, the fishers wanted to increase understanding of the importance of the ecological health of the benthos and increase overall awareness of ecological signals to support ecosystems and associated fishers' economic livelihoods. Neverthless the thesis evidences examples of testimonial injustice prejudicing marine governance against inshore fishers' epistemologies, and their potentially valid identification of risk (Fricker, 2007). Writers including Jasonoff (2003) also suggest that formal mechanisms of participation alongside an intellectual environment where the public can bring their knowledge to common problems need clarification for marine governance.

The current pressures upon local ecosystems are shifting certain fishers' epistemic frameworks outside of capitalist markets towards socio-ecological resilience (Kinzig, 2006). Interview evidence from this research demonstrates that in specific local geographies fishers are using LEK to demand greater conservation and to limit damaging fishing techniques and other industrial developments. This relates to the arguments of place-based attachment. While fishers are involved in the defence of fisheries' spaces including the Thames estuary, the Shingle Bank near Hastings, or the Lyme Bay Reserve, the findings suggest this is place-based defence, and may also involve positive emotional connections described by Manzo and Perkins (2006). Uniquely, this work demonstrates active participation in place defence by fishers for the socio-economic benefit of their livelihoods. While Bennett and Dearden (2014), posit that local fishers are rarely in favour of conservation, this thesis shows otherwise, where conservation from environmental threats can support fisheries' livelihoods.

Fishers in the UK, differently to those in Thailand (Bennett and Dearden, 2014) have enough understanding to make these connections through fishing experience, which has been complimented through involvement in research. Fishers are more likely to invest in jointly assessing their ecosystems using scientific methods in partnership with IFCAs if the area can be protected from debilitating activities. Nevertheless, the adaptive capacity is limited by the extent that these practice-based observations will be recognised by governance. Activities which can co-exist with conservation, therefore, need to be given greater priority than those that cannot ensure future healthy seas. Additionally, there is an opportunity for leaving the CFP to make ecosystem assessment for fishing quota more participatory and democratic by updating the legal regime. Adopting Section 3 (1) of MCCA can make MMO decisions fall under the remit of democratic bodies, where face to face interactions can occur. Ensuring marine decisions follow marine plans Section 58 (3) of the MCCA will make space for LEK to be involved in the co-assessment of all species caught, adding to the fluency of decision participation. Furthermore, the development of democratic bodies that can integrate LEK and the different spatial needs of marine users' within and beyond 6nm, to the limit of the EEZ will eventually be possible (Jentoft and Knol, 2014).

This democratisation of marine management can be supported by changing fisher LEK of the benthos playing an increasing role in MPA governance through involvement in research (As demonstrated in section 8.2.). Indeed, by accessing conservation research through involvement, the epistemic rift identified by Schneider and McMichael (2010) is being mended in certain local harbours. Furthermore, by being involved in different programmes of research, there is a greater possibility of linked understanding between different marine and terrestrial ecological and environmental systems (as mentioned in chapter 5). Through the influence of conservation NGOs, research, and social media, fisher ideas for more sustainable management of inshore marine habitats and species are percolating through to the epistemic unconscious, if not yet resulting in a paradigm shift (Foucault, 1966).

Conservation focused NGOs have also been influencing fisher LEK through collaboration (See section 8.2). Moving beyond the epistemic framework of single species and markets, work with NGOs such as Finding Sanctuary and Blue Marine Foundation appears to be shifting fishers' ideas around conservation. Furthermore, this investigation highlights the importance of NUTFA's activism with Greenpeace in shifting the fisher epistemic framework towards sustainability. The dialogue between fishers and conservation groups such as Finding Sanctuary during the MCZ consultation has been influential. Latterly, the Blue Marine Foundation has been supporting a group of low-impact static gear and dive scallop fishers in the organisation of the Lyme Bay Reserve group. Similarly, the influence of the Wildlife Trust and government consultation upon under 10m fishers from Eastbourne, resulted in the East Sussex inshore fishing community recommending the MCZ Beachy Head East. This has not yet been fully legislated by DEFRA. This demonstrates an ongoing interaction with the new scientific learning of scarcity and disturbance, being developed among the fishers locally through participation in the designation process. This was reflected in other areas such as Looe, Lyme Bay, Plymouth, Newlyn, and Poole. Nevertheless, those fishers from the towed gear sector interviewed across the study area were more negative about the possible benefits of marine conservation. Fishing with trawls and dredges often is r physically incompatible with the continued health of habitats, the benthos, and biodiversity. Fishers with low-impact static gear, who face limitations such as potting and netting intensity, do not need to be spatially excluded entirely in marine conservation areas, making them more open to marine conservation learning.

Technologically, the C – Scope project in Dorset laid lessons for the application of the zoned approach of the seabed. Spatial mapping of potting intensity according to habitats is also being developed in Lyme Bay. Habitats and species of conservation interest can be mapped and made available to Olex and similar software users. Indeed, as the thesis shows fishers can be trained to co-map and assess the ecosystem more widely as technological sensing through multi beam sonars becomes cheaper and more accessible to the point where living species can be detected. Adaptive co-management is beginning to emerge in this way in Lyme Bay, but not yet explicitly linking to fisher LEK. Nevertheless, outside the Devon Inshore Potting Agreement, which uses the same zonation of use undertaken by the Great Barrier Reef National Park Authority, democratic processes of zonation of uses are not yet implemented (Olsson, 2004). Fisher LEK participation in zoning is also important where there are risks of the removal of reef habitats with towed gear. Such risks as seen with the sovereign shoals in the south-east of Sussex were highlighted and fishers outlined in interviews how they argued for MCZ protection, to maintain the reefs for future generations. Fishers highlighted the increasing conflict of interest between the spatial use of habitats by different types of fishing, and the need for innovative zoning activities such as trawling lanes and potting zones. This is relevant for the application of adaptive co-management. The local IFCA can facilitate zonation and with the addition of CFP species, total co-assessment of all species and all fishing can be understood simultaneously. Further, dive fishers in the East Devon area demonstrate a developing body of knowledge of how habitats are recovering through conservation zones. They illuminated that the areas of zones could be extended to maximise habitat recovery. While some of these habitats may not be currently valued by Natural England assessments, these habitats could be usefully integrated with the local IFCA management.

The findings demonstrate that a reorganisation of marine governance is needed so that combined understanding of all cumulative and in-combination ecological impacts can be seen by participatory local bodies. Legal recognition of territorial user rights for low-impact fisheries also needs to be more widely debated. Where space is commonly owned, it is less likely there will be a culture of secrecy over sharing coordinates of activity and fish stocks. Similarly, it must be recognised that fisher LEK has a role to play in considerations of where 'Imperative Reasons of Overriding Public Interest' should or should not override MPA protections in favour of financial interests. This creates a space for a more holistic ecological-economic assessment where ecological costs and benefits are given equal weight to mainstream economic growth costs and benefits.

Schneider and McMichael (2010) underline how the capitalist episteme works to condition social thought and valuations of nature. The research, (specifically highlighted by the interviews), demonstrates how involvement in research science, and support of conservation zone assessment, influences the long-term understanding and valuation of ecosystems and highlights fishers' motivations to protect ecosystems through this increased understanding. The use value of habitats and biodiversity are apparent in supporting species that are commodifiable in markets, such as through fishing. Nevertheless, biodiversity markets such as payments for ecosystem services are problematic because of the fluidity of marine ecosystems. The ecosystem services approach has been critiqued (for example in chapter 3) by such authors as Martinez-Alier, (2002) and Kronenburg and Hubacek, (2013). Biodiversity, ecosystem services and habitats mature and regrow from the disturbance over long periods of time, which is different to commodity markets. This shows why LEK commodification is not advised. This thesis argues against a theorization of cultural ecosystem services of knowledge which would position fisher LEK as a market commodity, moving back towards capitalist episteme of fish as single stocks through payments for ecosystem services. Sharing LEK could be rather argued to be a moral and ethical right (Singer, 2011), given the privilege of fishers to take marine life for livelihoods and profit. Fisher and other LEK can be described as a cultural ecosystem service where this commodification is impossible, such as under public and common property rights.

More research is needed to fully understand how instead of using fiscal incentives which lead to the commodification of a service, fishers could be legally bound to share knowledge and participate in research as a condition for access rights. Where fishers share LEK and at the same time demonstrate low-impact forms of fishing, special spatial access rights would build on Allison et al.'s (2012) conception of access rights of local communities to support livelihoods as a human right. Harnessing the advantages of territorial user rights (Gelcich, 2010), it allows for gear use planning and limiting new polluting activities under the hierarchy of conservation. Also building on epistemic rights, it means the right to understand fishing is occurring according to principles of social and environmental justice (Agyeman, 2003). Pescastemic rights mean the right to access fishing as a common resource, based on full knowledge of the socio-ecological system which can be developed and shared by cooperative fishermen's associations using it. Additionally, the definition of pescastemic rights needs to include intergenerational transmission. That is socially regenerative communities who comprehend how to harvest marine resources sustainably and can share conservation understanding through intergenerational transmission of LEK (Moncrieffe, 2009).

Tsosie et al. (2012) related the historic epistemic injustice of indigenous communities placed as objects of science under imperialism and modern capitalism. Further research is needed to examine how Pescastemic rights could enable the educational and research benefits of fishers as full participants of investigative programmes to develop in a subject-subject research relationship. Fishers could be supported with education provision in marine conservation, to learn about MPA benefits of population overspill, including increased biomass and biodiversity alongside ecosystem services. Local terminology and scientific approaches need to be compared and reflected upon, and research is undertaken into techniques of improving ecological health, with monitoring being shared. This would see a transformative bi-directional research praxis both reflective and action directed at transforming the structures of property and power (Freire, 1970).

This doctoral research also evidences examples of testimonial injustice, concerning the epistemic relations between inshore fishers and decision makers (Fricker, 2007). Overcoming the bias of marine governance against LEK could be transformative in unlocking the different ways in which those working in marine governance could imagine LEK being validated. Pescastemic rights also include a right not to experience testimonial injustice as knowers. Further research can be done in examining the wider testimonial injustice against different forms of LEK by governance. Further research is also needed to understand the relevance of the many different forms of LEK to marine decisions and planning.

Recognition of these epistemic or Pescastemic Rights is the first stage towards realising a marine democracy. Integration of fisher LEK is potentially an emancipatory mechanism. How these different forms of LEK can be recognised by the government can be methodologically clarified. Catchapp is the first technique to clearly show how fisher LEK can be recorded for Total Allowable Catch species under the CFP. Nevertheless, the labelling of many fish as demersal species makes this assessment incognisant of local benthic disturbance from gear. The importance of re-theorising fisher LEK of the benthos is that the ecosystem from the seabed upwards is not well understood by wider society and nor are the human activity impacts on it. New legislation is needed to make the CFP assessment process more participatory within the MCAA national legislation after leaving the London Convention and CFP. This can start with adopting section 3 (1) of the MCAA making the MMO under the democratic power of local mechanisms to ensure that participation in fishing access is cooperative, locally situated, democratic and transparent as shown in figure 21.

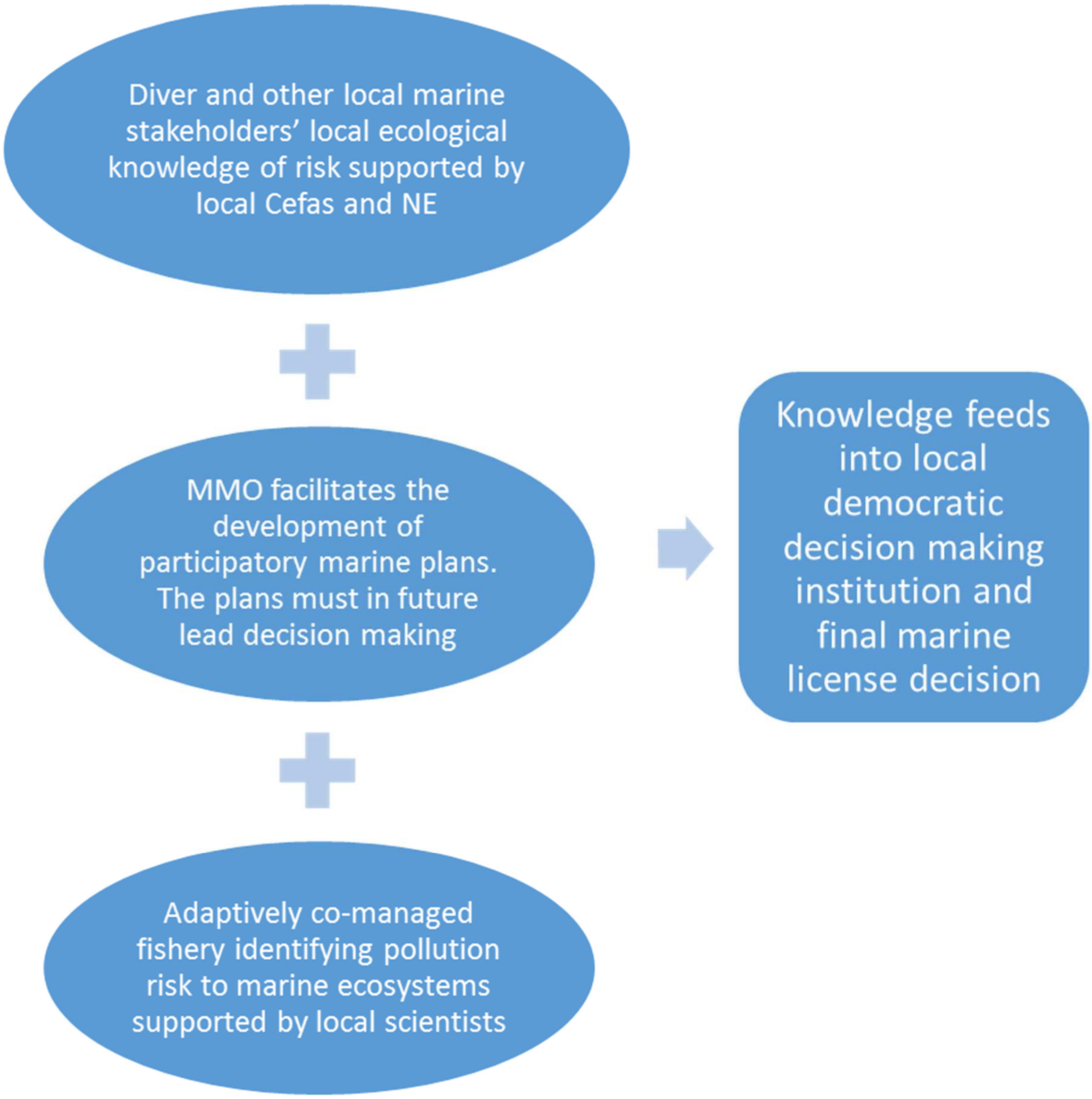


Figure 21 new participatory planning and decision-making pathway including LEK. The MMO can facilitate participatory marine plans overseen by the democratic power of local bodies to ensure that participation is real and adaptive to changing conditions.

To create marine commons under the law, the Commons Act 2006 in England and Wales could be a template which allows the marine commons to be managed sustainably by different users working together through commons councils (Linebaugh, 2014). Greater work is needed to make the science of the benthos accessible, through new sampling regimes to continue this evolution. Further research could also consider how fisher LEK of biodiversity and ecosystem services valued under marine commons legal regime could develop. The degree to which fisher LEK can support global marine governance is contingent on the differing socio-economic and political geographies that influence fishers in different regions.

Given support to move beyond neoliberal governance, cooperative networks of fishers such as LIFE could expand globally. LEK could be integrated into local science systems internationally, supporting conservation, greater food sovereignty, and democratic organisation of communities. The promise of Shiva's (2016) Earth Democracy can begin at local scales where life began, in the sea. Certain environmental governance challenges such as climate change problems and transboundary processes inevitably need to be made at a national level or global level. Where the concern is for local ecosystems, to pass up to higher scales this thesis recommends that decisions need to pass the screen of living ecological democracy and involve LEK. The democratic monitoring of multiple local scale sustenance spaces is needed. This would be possible by the globalisation of participatory mechanisms of validation that involve LEK and use forms of technology and social media. The lessons of democratic confederalism identified by Knapp et al. (2016) in Rojava could be researched further in regard to participatory governance through LEK and its integration. This thesis demonstrates an original re-theorisation of LEK of the benthos through the critical realist approach. The new politics of LEK are analysed in this thesis through fishers' understandings of fishing techniques, technology, governance, intergenerational transmission and scientific research. The thesis proves how fisher LEK undoubtedly provides important insights into ecological processes, which within a reformed system of governance could support an emancipatory approach of adaptive co-management and democratic deliberation.

Appendices

Appendix 1. Scoping the techniques of inshore fishing

2.1 Netting

Trammel netting and gill netting fishing requires an understanding of the subtleties of different habitats and geomorphologies on the seabed. When launching anchored nets, appreciation of depth, sediment type, current, as well as tide, are factors in decision making. Consisting of a net connected between two anchors with buoys, the trammel net passively catches fish which swim into its confines. After a period of two-to-four hours, this will be retrieved using a winch or flaker. Fish then are untangled from the nets, alongside seaweed debris, as well as rock 'bungs' which give an indication of the geology if not previously fished. The echo sounder and GPS are used to ascertain depth. There is a low division of labour between skipper and crew, with the crew getting the opportunity to navigate and gain knowledge of the grounds.

2.2 Potting

With lobster and crab potting, knowledge of the location of rocky reefs is key to the success of fishing as this is their main habitat. For Cuttlefish potting, it appears that weedy ground, such as seagrasses and kelp forests are also favoured habitats. Whelks, however, enjoy more variety off the rocks, preferring flat muddy ground without rocks. Given this, the echo sounder is used to determine the hardness of the rock, to mark off depths and gradients, to determine where to pot. There is a strong division of labour between the father and son and the third member of the crew, who does not navigate or control the winch. The skipper and his son, however, job swap between navigating and winching the pots. The third crewmate puts the pots in place and extracts the lobsters.

2.3 Rod and line and long lining

The rod and line fishing technique firstly require sensitivity to the different tugging sensations of different species. Given an understanding of how to deploy the rod and reel the line at speed, fish can be caught effectively given an understanding of the grounds. The fishing grounds seabed characteristics such rocky reefs are more likely to see squid feeding at certain times of the year such as September, or wrecks giving mackerel population space for evasion. Knowledge of technique is shared between skipper and crew, with the low division of labour, with crew navigating and developing seabed knowledge alongside the older fisher. Similarly, to other forms of inshore fishing, understanding of the vessels engineering is essential for all members of the crew. With the linking of the piloting to the GPS, autopilot has increasingly allowed the skipper to take part in fishing techniques such as rod and lining.

2.4 Otter board bottom Trawling

Strong division of labour between skipper and crew with skipper navigating to grounds, with crew supporting shooting the trawl door. However, there are opportunities for crew to learn of the grounds given time, friendship or familiarity with the skipper. Consideration for the conditions of the benthos is of utmost importance for this fishing approach, the ground must be relatively flat, such as sandy or muddy grounds. The effort will be made to clear small boulders and debris where possible, and attempts will be made to clear the seaweed, by digging into the ground if shooting in a new area. Increasing access to ground composition technology is changing this practice, through greater access to 3d imaging such as Olex.

2.5 Beam Trawling

Beam trawling is similar to otter board trawling, deploying a chain matrix on the seabed, alongside heavy metal rolling beam, compressing the seabed. Differently to otter board trawling, rocky ground is targeted, and the edges of reefs, though not continuous rocky reef structures. More commonly found in the over 10m industrial fisheries sector there are high levels of division of labour between skipper and crew members hauling gear, as shooting the trawl is highly automated. Beam trawling because of the heavy gear, requires a lot of fuel compared to the other gears except shellfish dredging. To make a trip cost effective, fishers have to maximise hours by deploying the gear as often as possible. Hauls are shorter than otter board trawling, being around 3 to 3 hours.

2.6 Shellfish Dredging

The key shellfish dredge target species are mussels, clams, oysters, and scallops. While there is some difference in technique, this is primarily regarding the size and scale of the fishing. The clam dredging technique firstly featured strong division of labour between the decision-making skipper, and the shellfish sorting crew. Nevertheless, the crew was given access to the controls at certain periods, allowing for the development of spatial benthic LEK. The skipper made strong use of landmarks on the coast, based on his previous experiences with the local ecology. Specific teethed dredges are used on the flinty ground, and other grounds thought to be rough. The extent of the marine life is noted for that area and used in future tows. Flinty ground deployment – introduction of gear to new unexploited closed area. Previous concerns regarding e coli left the grounds free from disturbance, perpetuating the clam population.

Appendix 2. Semi-structured interview questions regarding seabed ecosystems

Scarcity and abundance questions

a.) What signals identify seabed abundance to you?

b.) How do you identify scarcity? What is a bad catch, how do you compare this?

c.) How do changes in depth affect abundance? When it drops off are there more fish?

d.) What are the seasonal, ecosystem signals that you watch out for? Behavioural patterns that you identify with different species at different seasons?

e.) Which species have noted as having disappeared or become rare, e.g. angel shark, skate's and rays, conger eels & wolfish?

f.) Which species have you noted out of season? Any new species in last ten years?

Seabed characteristics questions

g.) Which seabed habitat characteristics would you expect to be good for fishing or bad? How did you identify them?

h) Which habitats are in your locality? Would you be able to identify their locations geographically?

i.) How can you tell what the geology of the fishing ground beneath is?

j.) What seabed features do you identify as important to your fishing, and to which species?

k.) How do you comprehend the effect of complex and mixed seabed habitats on fish and other species?

Seabed habitats and biodiversity questions

m.) What would you say is the importance of biodiversity in the places you fish in? (e.g. to biomass)

n.) How do you identify and record spawning / nursery grounds, e.g. for sole and how do you ensure you and other fishers avoid them in future?

Sessile species and biogenic reefs

o.) In regard to preferable seabed conditions, how do you ensure the seabed is kept clear for bottom trawling?

p.) How did you get your knowledge of seabed species and habitats?

p.) How do you perceive the importance of species on the surface of the seabed during fishing, and also species below the seabed.

q.) To what extent is the health of these species important for continued fishing for your target stocks?

r.) Which biogenic reefs, or interest features do you identify as having conservation interest? (E.g. blue mussel beds, oyster beds, piddock beds, anemone and sponge meadows. sea squirt mogula beds, hydroids, sea pens, Ross worm reef, erect bryozoans.

Human nature relations

s.) What species do you perceive as threats and why? E.g. Seals, Spider Crabs starfish.

t.) Are you involved in controlling their populations?

u.) Which species would you rather see extinct to benefit your fisheries?

v.) Do you perceive yourself to be the top predator in the marine ecosystem?

With the scientific knowledge system

How have you interacted with scientists and their knowledge of the seabed?

What have they learnt from you about the seabed?

What can fishers contribute to marine conservation?

The market

How has the market changed in fishing, and how has this affected your fishing practice?

Has this affected how you understand the seabed?

How has the technology of fishing changed in your career, and how has that affected your knowledge of the seabed?

Appendix 3. Consent Form

Title of Project: Local Ecological Knowledge, The Benthos, and Epistemologies of Inshore Fishing

Name of Researcher: Jeremy Evans

1. Confirm that the participant has understood the study and should briefly state what is expected of them.

I ____ agree to be involved in this research which investigates fisher knowledge. I give my permission for Jeremy Evans to use excerpts from the interviews, data and underwater filming.

2. Confirm that the participant has read and understood the information sheet for the study. Confirm that they have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

[Jeremy Evans] has explained to my satisfaction the purpose of the study. I have been informed of the nature and purposes of the study and have read the information sheet. I understand the principles and processes of the study.

3. Confirm that they know exactly what they are being asked to do

I am aware that I will be asked to [allow them on board the fishing boat to work as a fisherman].

4. Confirm confidentiality arrangements

I understand that my personal details (including my contact details) will remain confidential. Data will be stored in a secure area and destroyed after [3 years]. I understand that relevant (anonymous) sections of any of data collected during the study, may be looked at by [Andrew Church] the supervisor of this dissertation for teaching and research purposes.

5. Confirm their right to withdraw

I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my rights being affected [This will not adversely affect the project].

6. Confirm how the information will be used.

I understand that the data collected will be used as part of a dissertation project. I understand that the data will be used in writing up and disseminating [Marine Geographical research] research (including in a dissertation which will be held in the School of the Environment & Technology University of Brighton). I understand that only anonymous excerpts from the research will be used in this write up.

7. Confirm that they agree to take part

I agree to take part in the above study.

Name of Participant	Date	Signature
Name of Person taking consent (if different from researcher)	Date	Signature
Researcher	Date	Signature

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