Master‘s thesis

Local knowledge and perceptions of change in spatial and abundance trends of fish species in the Westfjords of Iceland between 1992 and 2012

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Declaration

I hereby confirm that I am the sole author of this thesis and it is a product of my own academic research.

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Abstract

Non-scientific information (local knowledge) in increasingly utilized together with more typical scientific data to understand the abundance dynamics and stock structure, migration patterns and species behavior variability in fish stock regimes. This thesis investigates local perceived changes in spatial and abundance trends of fish species over the study period 1992-2012, and the sensitivity and adaptability of the fisheries sector of the Westfjords of Iceland concerning these changes.

Twenty-two qualitative, semi-directive interviews were completed with fishers and individuals working in the Westfjords' fish processing and selling industry. Data of the annual groundfish survey of the Icelandic Marine Research Institute was used to compare perceived changes of the five most frequently cited species by individual interviewees to spatial and abundance trends obtained from the scientific data.

The investigation indicates that interviewed individuals working in the fishing industry possessed detailed local knowledge regarding fish species occurrence in the Westfjords on a fine geographical scale. Five out of nine perceived changes seemed generally consistent with the findings of the scientific data; four perceptions at a minimal or marginal level and one perception at a high level. Changes in national fishery regulations and local social conditions were perceived to be of a bigger threat to the fishing industry than changes in the environment. Possible adaptation strategies included an increased focus to niche products, investment in knowledge and gear in order to adapt to potential new commercial species and a shift to different fishing grounds.

This studies shows that local knowledge is highly complex: data is not standardized in spatial or temporal terms. However, data gathered by interviewing individuals working in the fishing industry combined with scientific data can contribute to the detection of short-term changes and increase the potential for more accepted stock assessments and decision making.

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Acronyms

ACIA: Arctic Climate Impact Assessment

CPUE: Catch Per Unit Effort

EEZ: Exclusive Economic Zone

FSRS: Fishermen and Scientists Research Society

GDP: Gross Domestic Product

GRT: Gross Registered Tonnage

ICES: International Council for the Exploration of the Sea

IGFS: Iceland Groundfish Survey

IPCC: Intergovernmental Panel on Climate Change

ITQ: Individual Transferable Quota

LK: Local knowledge

MRI: Marine Research Institute

NAO: North Atlantic Oscillation

SES: Social-Ecological System

SPSS: Statistical Package for the Social Sciences

TAC: Total Allowable Catch

UNESCO: United Nations Educational, Scientific and Cultural Organization

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1. Introduction

Seasonal migratory patterns of fish stocks are observed by both scientists and fishermen, yet sudden unexpected changes in fish stock distribution and abundance can lead to uncertainties about causes and development of these changes (Lehodey, et al., 2006). Since 2006, 22 southern fish species not previously recorded within the Icelandic 200 mile Exclusive Economic Zone (EEZ) were recorded in Icelandic waters (Ástþórsson & Pálsson, 2006). In addition, increased abundance and spatial distribution of southern species at more northern locations was found (Björnsson & Pálsson, 2004). Because Iceland is highly dependent on its commercial fish stocks (Eythorsson, 2000; Pálsson, 1990), understanding variability in fish stock abundance and distribution is important, as it will contribute to the socioeconomic abilities of fishing communities to adapt to changes in fish stocks (Vilhjálmsson & Hoe, 2004). Fishermen are at sea for periods of days to weeks, increasing their practical and applied environmental knowledge every year (Mackinson, 2001). This is a potentially valuable source of knowledge, and the importance of local fishers' perceptions as a contribution to scientific research is increasingly recognized and encouraged for use in research (IPCC, 2007; Næss, 2007; ACIA, 2005). Combining scientific findings with local knowledge (LK) leads to collaborative forms of assessment and management of fish stocks, and improves decision quality and acceptance (e.g. Hoefnagel, et al., 2006; Neis, et al., 1999; Johannes & Neis, 2007).

1.1 Purpose of the research

The purpose of this research is to compare local knowledge to scientific knowledge, and to discuss methods in the context of integration local knowledge in fisheries management. This was done through the analysis of locally perceived changes in fish stock distribution and abundance, the impact of these changes on the industry and the strategies to adapt, and through the comparison of perceptions of locals working it the Westfjords' fishing industry to the data of the Iceland Groundfish Surveys (IGFS) conducted by the Marine Research Institute.

1.2 Research questions

This research uses a qualitative approach to pose a set of questions examining local perceptions of changes in fish species abundance and distribution in the Westfjords. The main questions are as follows:

- What are the main spatial and abundance changes, if any, of fish species perceived by fishermen and stakeholders in the fishing-industry over the past two decades (1992-2012) in the fishing grounds used by the Westfjords fishing industry?
- What is the perceived sensitivity of the industry to changes in fish stock abundance and distribution?
- What kind of strategies do the stakeholders working the fishing industry have in mind to adapt to changes?
- Which spatial and abundance trends for the five most cited species by participants can be identified in the data of the IGFS over the period 1992-2012?
- How do the perceptions of changes in distribution and abundance of the five most cited species correspond with the spatial and abundance trends identified in the data of the IGFS over the period 1992-2012?

1.3 Data and Methods

In the current study, local perceptions of change in fish species' abundance and distribution in the Westfjords were collected through semi-structured, qualitative interviewing of individuals working in the fishing industry. This provides the structure for capturing ecological and social-economic information and offers a process for active participation in the research. Perceptions of change of the five most frequently cited species by individual interviewees were compared to linear regression models obtained from the data of the IGFS over the period 1992-2012. Furthermore, participants were questioned about their perception of the impacts of these changes on the fishing industry, as well as what strategies were adopted to adapt to these changes.

1.4 Scope and expectation of the research

The investigation was intended to show a method of collecting local knowledge and combining this with scientific data. It was expected that interviewees perceive southern marine fish species to have shifted north, and that more or less abundant species occurring in the Westfjords have extended their distribution further north. Overall, strong similarities between local and scientific knowledge were expected. It was hypothesized that local knowledge would be generally consistent with the results reported in the IGFS (H_0 = fishermen's perceptions of change are consistent with changes observed in IGFS). The fishing industry was hypothesized not to be particularly vulnerable to changes in fish species abundance and distribution, because the industry should be able to adapt to these changes with adjustments in gear, fishing grounds and target species.

1.5 Structure of thesis

After this introductory chapter, the thesis is organized in five further chapters. Chapter two provides the theoretical framework of abundance and distribution variability in fish stock regimes, as well as the use of local knowledge together with scientific data and the approach of co-management. Chapter three describes the methods used for the qualitative interviewing and the linear regression models obtained from the scientific data. Chapter four describes the results of the investigation, including a summary of the main perceptions of interviewees and the findings of the IGFS. Chapter five compares the observations of interviewees to the linear regression models and related scientific documentation and discusses the main shortcomings of the methods used. Finally, conclusions of the research are presented in chapter six, which contains a summary of the main observations as well as the role and integration of traditional knowledge in fisheries management in Iceland.

2 Literature review

2.1 Fluctuations in fish stock abundance and distribution

2.1.1 Fish population dynamics

Seasonal patterns in fish distribution are generally well known to scientists and direct resource users (e.g. MacDonald, et al. 1984; Lutcavage et al., 1999; Lehodey, et al., 2006; Pálsson & Thorsteinsson, 2003; Comeau, et al., 2002).

Fish species migrate because of feeding, spawning, juvenile, recruitment or seasonal reasons (Northcote, 1998). Capelin, for example, follow a large scale migration pattern, as it spawns along the south coast of Iceland and migrates up north and west to feed. When reaching maturity, the capelin shoal and migrate back south to spawn. Other species, such as Greenland halibut, migrate to Greenland and to the Faeroe Islands while feeding and spawning at the same time (Sævaldsson & Valtýsson, n.d.). These migration patterns are generally consistent and usually predictable from year to year (Northcote, 1998).

Systematic searches for relationships between the physical environment and fish stock dynamics in the North Atlantic Ocean were made at least since early 20th century (e.g. Helland-Hansen & Nansen 1909; Sæmundsson, 1934; Fridriksson, 1948). It is now understood that marine ecosystems change on a variety of time scales, from seasonal to decadal and longer (Lehodey, et al., 2006). Large-scale ocean climate variability are identified by climate indices like the North Atlantic Oscillation (NAO) (Stige, et al., 2006). During the twentieth century, the NAO went through significant decadal variation and reflected fluctuations in the air and sea temperatures and ice conditions throughout the North Atlantic (Lehodey, et al., 2006). Through these environmental fluctuations the NAO showed to have an impact on plankton, fish and shellfish in the North Atlantic (e.g. Parsons & Lear, 2001; Drinkwater et al., 2003; Lehodey, et al., 2006).

However, because species are dynamic and interact on multiple ways with the environment, it is not surprising that empirical correlations are not always satisfactory (Myers 1998). Abrupt changes in fish species abundance and distribution present more difficult questions about the reasons for and development of this observed change. The fish could have moved away or the stock collapsed, either as a consequence of environmental or anthropogenically-driven processes (Lehodey, et al., 2006).

Large scale redistribution of fish species are increasingly reported worldwide (Scheffer and Carpenter, 2003) and could possible represent a regime shift, which is defined by deYoung, et al., (2008) as abrupt changes between contrasting, persistent states of any complex system. Drivers of regime shifts can be of natural origin or driven by anthropogenic activities, or by a combination of the two. Human impacts on ecosystems may lower the resilience of an ecosystem, which increases the chance of regime shifts (Kraberg, et al., 2011; Folke, et al., 2004).

2.1.2 Significant changes in fish species abundance and distribution in Icelandic waters

Small changes in the properties and distribution of water masses can have significant effects on the distribution and abundance of marine animals (Ástþórsson, 2007). A major warming event between 1920 and 1940 was extensively documented and associated with distributional changes of fish stocks inhabiting Icelandic waters. Sæmundsson (1934) and Fridriksson (1948) reported large distributional and abundance changes of marine fish species, such as an increase in abundance of the species cod (*Gadus morhua*), capelin (*Mallotus villosus*) and herring (*Clupea harengus*) (Sæmundsson, 1934). Species which were recorded more frequently in Icelandic waters during that period included the mackerel (*Scomber scombrus*), tunny (*Orcynus thynnus*), horse-mackerel (*Trachurus trachurus*), basking shark (*Cetorhinus maximus*), ocean sunfish (*Mola mola*) and saury pike (*Scomberesox saurus*). Species including cod, witch (*Glyptocephalus cynoglossus)*, turbot (*Psetta maxima*), great silver smelt (*Argentina silus*), and capelin were reported to have extended their distribution further north and east over the study period (Sæmundsson, 1934; Fridriksson, 1948).

Recently, a stronger flow of Atlantic Waters have prevailed of the north coast since the middle of the 1990s. This positive hydrographic anomaly (Malmberg & Jónsson, 2002; Ástþórsson & Pálsson, 2006), was associated with marked changes in fish distribution and abundance (Ástþórsson & Pálsson, 2006; Ástþórsson, et al., 2012; Ástþórsson, et al., 2007). Certain southern commercial species were reported to have extended their habitat farther north, such as haddock (*Melanogrammus aeglefinus*), monkfish (*Lophius piscatorius)*, saithe (*Pollachius virens*) and whiting (*Merlangius merlangus*) and showed an increase in abundance (Valdimarrson, 2005). Northeast Atlantic mackerel extended its summer feeding distribution and appeared almost every year since 2006 in large numbers in many areas around Iceland (Astthorsson, et al., 2012). A total of 31 species were recorded for the first time since 1996 in the Icelandic EEZ (Valdimarsson, et al., 2012) including species such as greater fork beard (*Phycis* *blennoides*), snake pipefish (*Entelurus aequoreus*), and sea lamprey (*Petromyzon marinus*) (Valdimarsson, et al., 2012; Astthorsson & Pálsson, 2006). According to Jónsson and Valdimarsson (2005), recent favorable conditions with stronger flow of Atlantic Waters has probably provided favorable conditions for the growth and drift of cod larvae from the spawning grounds south of Iceland to the nursery grounds of the north coast Jónsson and Valdimarsson (2005). Other species, such as capelin showed a more northerly distribution and later arrival of adult capelin to the north Icelandic shelf (Astthorsson, Gislason, & Jonsson, 2007).

2.1.3 Social-ecological systems

Holling introduced in 1973 the term 'resilience' in ecological literature, to increase understanding of non-linear dynamics observed in ecosystems. Resilience was referred to as the endurance of relationships within a system and a measure of the ability of these systems to absorb changes and still persist (Holling, 1973). In a practical sense, resilience is the maintenance of a capacity, which enables the renewal of a system in a dynamic environment, as an ecological buffer in order to protect the environment from disturbance (Gunderson, 2000). Social resilience is the ability of a system to cope with external stresses and disturbances as a result of social or political change (Adger, 2000). Ecological and social resilience are believed to be linked, for example through synergistic and co-evolutionary relationships (Adger, 2000; Norgaard 1994).

Fish species, fishermen and the natural and social environments represent a social–ecological system (SES). This system consists of many components, which are closely and functionally linked (Tyler, et al., 2007; Berkes, et al., 2003); fisherman's income depends on the productivity of fish stock, and production of fish stock depends on the state of the natural population and the environmental conditions. Changes in fish stocks can significantly influence socio-economic vulnerability (Adger, 2000). The vulnerability of any coupled social-ecological system depends on the local conditions and the identification of the factors that influence the vulnerability (Tyler, et al., 2007, Berkes, 2005).

The restoration of the resilience of a system in dealing with uncertainties and surprises can be achieved through adaptive management processes (Gunderson 1999; Berkes, 2005), which requires knowledge of the priorities and perspectives of local people. Involvement of local people in the design, implementation and the distribution of research results is therefore of fundamental importance (Tyler, et al., 2007; Olsson & Folke, 2001).

2.2 Local knowledge

2.2.1 Value of local knowledge

There is a growing interest in direct resource users' knowledge, partly because of the growing recognition of its contribution to the understanding, monitoring, conservation and sustainable use of resources (e.g. Berkes, et al., 2000; Hoefnagel, et al., 2006; Gadgil, et al., 1993; Mazzocchi, 2006). Fishermen's practical and applied knowledge can add to the pool of information on abundance dynamics and stock structure, migration patterns and species behavior (Neis, et al., 1996; Johannes & Neis, 2007).

The United Nations Educational, Scientific and Cultural Organization (UNESCO) defined local knowledge as the cumulative and complex knowledge bodies, practices and representations, maintained and evolved by peoples with wide-ranging histories of interactions with the natural environment. These complex systems may include language, place-attachment, spirituality and worldviews (UNESCO, 2003). Fishers acquire ecological knowledge through observation, experience, and interaction with the local environment (Berkes and Folke 2002), which is based on long-term observations of the behavior of fish and their interaction with the environment within a particular area, generated through active participation in the fishing process (Berkes and Folke, 2002; Gosse, et al., 2001). Additionally, knowledge of fishers is based on accumulation of knowledge of that of their parents, grandparents and other resources users with whom they have fished (Mackinson & Nøttestad, 1998).

One of the benefits of utilizing local knowledge combined with scientific data is reduced knowledge gaps through easier accomplishment of data gathering. Additionally, it would enhance mutual respect and foster co-operative responsibility through information sharing and enforcement of regulation, and thus likely avoid errors in management that have resulted in conflicts in the past (Hoefnagel, et al., 2006; Mackinson, 2001; Pinkerton, 1989; Mackinson & Nøttestad, 1998; Neis, et al., 1999; Pálsson, 1995).

2.2.2 Case studies

The Fishermen and Scientists Research Society (FSRS) is a non-profit organization and a partnership between fishermen and scientists established in 1994 in the Atlantic Canada region. This partnership was developed to promote communication between fishermen, scientists and the general public, and to establish and maintain a network of fishermen and scientists capable of conducting collaborative research and collecting information relevant and necessary to the long-term sustainability of marine fisheries. The fishers participated in fisheries research and made information available to scientists that only fishermen can obtain on a daily basis, and by educating fisheries managers by practical experience. In turn, fishermen gained an increased understanding of the scientific methodologies and processes involved in managing the fisheries resource (Fishermen and Scientists Research Society, 2012). The FSRS illustrates the management of marine resources through the sharing of knowledge, responsibilities, rights and authority between the primary stakeholders, in particular the community of local fishers and the government. This approach is termed co-management (Pomeroy and Berkes, 1997).

Management of the Canadian 4WX herring fishery has undergone some major developments starting in 1995, when an ‘‘in-season management approach’’ was implemented. This approach allowed decision-making regarding the distribution and rate of fishing by a team consisting of participants in the herring fisheries and members of the Canadian government. Decision-making was based on the best available information during the season, and observations were discussed regularly, allowing an adaptive management style (Stephenson, et al., 1999).

A more recent example provided by Drew (2005), describes the use of local knowledge during the establishment of protected areas to Gladden Spit in Belize (Drew, 2005). Gladden Spit is an area which was known for a long time by local fishermen, because of its importance to mutton snappers’ (*Lutjanus analis*) spawning practices, as well as the seasonal aggregation of the whale shark (*Rhinocodon typus*). This was known by locals since at least the 1920’s, and told to a group of marine biologists. The biologists discovered that this aggregation was due to feeding of the whale sharks on the mutton snappers their spawn (Heyman, et al., 2001). Currently, because of the commitment of national and international conservation organizations, the area has a protected status. However, this special concern resulted from the knowledge of local fishermen (Drew, 2005).

Rochet, et al., (2008) compared the results of a survey on fishermen’s perception of changes in the English Channel with scientific survey data in that area, testing the null hypothesis that fishermen perceptions were similar to the changes observed in the survey. They found strong similarities between the perception of change of fishermen and the scientific data (Huntington, 2000).

These case studies provide some evidence that local knowledge represents multiple bodies of accumulated information on species and their interaction with the environment (Drew, 2005).

2.2.3 Differences between local and scientific knowledge

Local knowledge and Western conceptions of sciences are both based on the accumulation of observation (Berkes, 2007) and on creating order out of disorder (Berkes, 1993). However, a number of substantive differences can be found. Western science is quantitative, follows prescribed approaches and favors rational and reductionist approaches, as opposed to LK, which is qualitative and favors an intuitive and holistic approach. Western science uses mechanistic methods, based on experimentation of systematic deliberate accumulation of facts, whereas LK is based on empirical observations and accumulation of facts by trial and error (Nakashima & Roué, 2002; Berkes, 1993). Western science is mainly based on short time-series observations over a larger area, as opposed to LK, which is based on the practices and beliefs of resource users themselves, obtained by long time series on information from one location (Berkes, 1993). Western science is based on academic documentation, while local knowledge is often passed on orally. There are many exceptions to the above generalizations and the different knowledge systems have overlapping characteristics, however, it indicates how challenging it is to combine these two types of knowledge systems (Mazzocchi, 2006).

Collection and use of local knowledge in fish stock assessments can be problematic because of several reasons. A general resistance against the use of local knowledge may exist, based upon concerns regarding priorities, power over management decisions, and an unwillingness to work with non-scientific data (Huntington, 2000, Casimirri, 2003). There is a risk of bias through either the way of phrasing questions or the wrong interpretation of answers. Therefore, researchers must be well equipped to determine what kind of data obtained from locals is new, important, well-known or doubtful. (Nadasdy, 1999). The quality of the data depends on the communication skills of the interviewer as well as the contextual understanding (Johannes, 1993).

2.2.4 Collection of local knowledge through semi-structured interviewing

In this research, local knowledge was collected through the use of semi-structured interviews. Semi-structured interviews are recognized as a powerful tool in collecting local knowledge, because it allows the interviewer to cover topics thoroughly and in detail. (Huntington, 2000). The format was similar to the semi-directive method used by Nakashima & Murray (1988); Huntington (1998); Mallory, et al. (2005); Johnson (1992); Ferguson, et al. (1998).

Selection of the right participants is an important part in the investigation and validation process. Knowledge is not uniformly distributed among fishermen, depending on age, position and years of employment in the industry (Neis, 1999). Additionally, fishermen's knowledge of fish stocks is largely based on their observation during fishing, which generally takes places in certain seasons (Huntington, 2000). A sampling strategy that spreads sampling over a larger area and across different sectors, using different fishing methods and gears, can bring all this local knowledge together and represent a larger area (Neis, et al., 1999).

In the absence of personal experience with the potential sample of a community, selection of the most knowledgeable participants is done through peer selection (Huntington, 2000). Another method would be to select the most knowledgeable participants by chain referrals, also called the 'snowballing' sampling technique, which in practice means that one participant refers to one or more possible participants (Huntington, 2000, Johnson, 1992).

Researchers can require extended periods of time to collect local knowledge through qualitative interviewing. For example, research done by Ferguson and Messier (1997) on Inuit observations of historical changes in a caribou population on southern Baffin Island, took a substantial amount of time. During 1983 – 1995, knowledge of 43 Inuit informants was collected. This took over 200 hours of interviewing, 700 – 800 hours in translating and transcribing interviews, and at least a year work for one person in data analysis and interpretation (Ferguson, et al., 1998). The make-up of the sample interviewed was mainly dependent on the accessibility of the interviewees and the willingness of the targeted audience to respond.

2.2.5 Coding

Coding is the process of assigning a word or short phrases to words, phrases, sentences or paragraphs from the raw qualitative data. Codes symbolically represents a summative, essence-capturing, and/or suggestive essence. The data can consist of interview transcripts, field notes, journals, documents, literature, artifacts, photographs, video, and so on. Dependent on the size and the type of document, the same codes can be assigned throughout the coding process, in order to find repetitive patterns, as documented in the data (Saldana, 2009).

Open coding and axial coding can be distinguished in the coding process. Open coding refers to the circling and highlighting of sections of the texts. Axial coding refers to the sorting of the codes, assigned during the open coding process into categories (Strauss & Corbin, 1999).

In this research, the Open Code 3.6 software program (2009) was used as a tool to analyze and quantify the derived data from the qualitative interviews. The software program has been developed as a tool for classifying and sorting the qualitative text information (ICT Services and System Development and Division of Epidemiology and Global Health, 2012).

2.3 Study Area

Iceland is located in the North Atlantic Ocean at the intersection of the Mid-Atlantic Ridge and the Greenland-Scotland Ridge (e.g. Ástþórsson, et al., 2007; Ogilvie & Jónsdóttir, 2000). The country is surrounded by a system of ocean currents, of which the warm and saline Atlantic water and the relatively fresh, cold Polar water are the two primary water masses (Ogilvie, 2005; Ástþórsson, et al., 2007; Malmberg & Jónsson, 2002). In this investigation, the regional focus was the Westfjords, a peninsula in the north-west of Iceland (Figure 1). Small and relatively isolated coastal communities share their dependence on marine resources (Skaptadóttir, 2007). The percentage of the total income in the peninsula acquired from the fishing industry (32%) is higher compared to Iceland as a whole (8%) (Ministry of Fisheries and Agriculture, 2008).

In the nineteenth century, the fisheries industry expanded significantly in the Westfjords. The growing international market for salted fish and the prospect of a 'better life' was reason for a migration from farming areas to the coastal areas throughout Iceland (Skaptadottir, 2007). The fishing industry provides a large share of jobs and income to the Westfjords, even though the processing facilities have decreased considerably over the past decade. The tourism industry has grown over the past years, and is rapidly becoming one of the pillars of the local economy (Skaptadottir & Johanesson, 2004). Still, municipal demographic data shows a steady annual decline of the population in villages of the Westfjords since mid-1980's. Currently, 6,955 people inhabit the region, compared to 9,798 in 1990, which is a decline of nearly 29% (City Population, 2012).

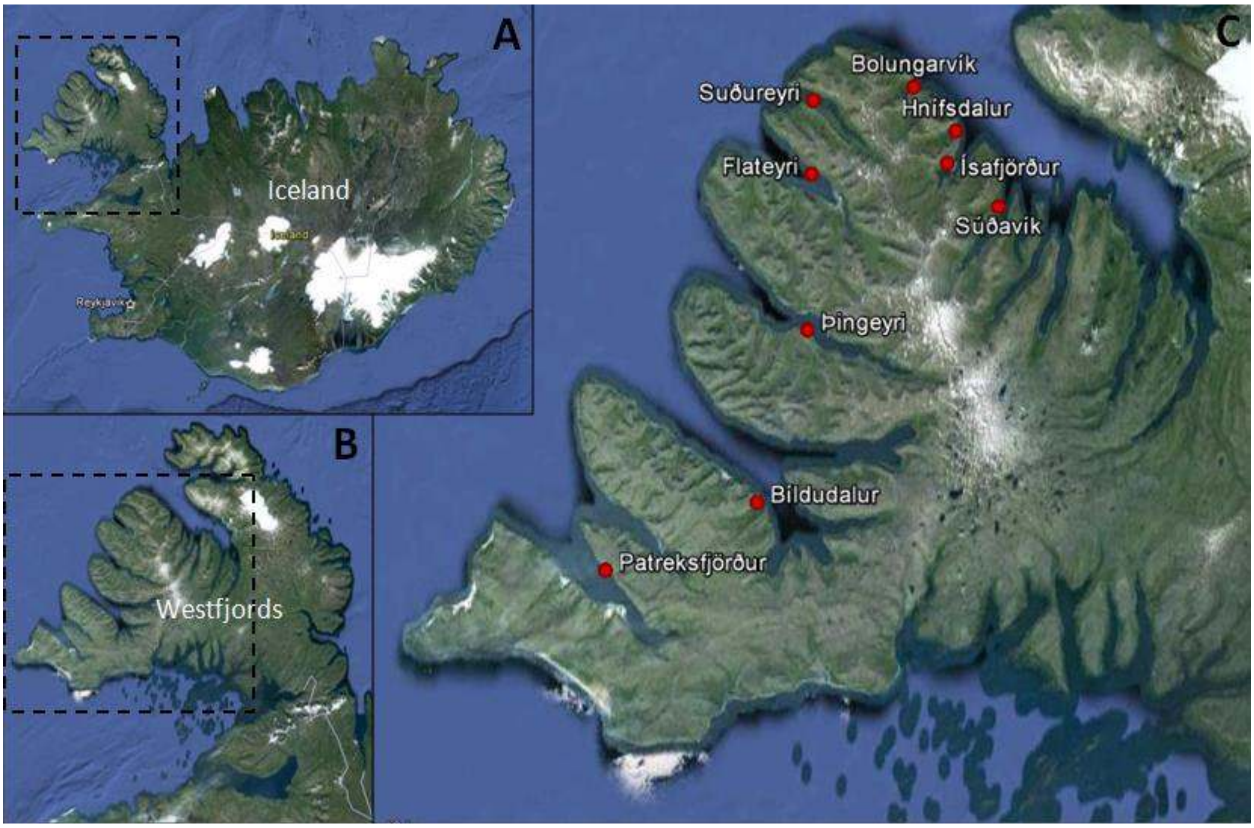

Figure 1. Westfjords peninsula, north-west Iceland. The figure shows the geographical location: A) in Iceland, B) representing the Westfjords peninsula, C) representing towns in the Westfjords where fieldwork was conducted (Image retrieved from Google Earth).

2.3.1 Fishing grounds and ecology

The Icelandic exclusive fisheries zone consists of an area of 760,000 square kilometers, which is around seven times the area of Iceland itself. The boundaries of the EEZ defines the extent of 200 nautical miles exclusive fishing zone (Knútsson, et al., 2011). Productivity of Icelandic ecosystems is relatively high, as a result of the mixing of surface waters with the colder, nutrient rich deeper waters, as well as the mixing of the colder Polar- and the warmer Atlantic currents (ICES, 2012; Ástþórsson, et al., 2007). The temperature of the waters to the south and west of Iceland is usually 6-10 ºC. The Atlantic and Arctic waters on the north Icelandic shelf mix and cool down from west (~4-6 ºC) to east (<4 ºC) (ICES, 2012). Ecosystem productivity is higher in the southwest region than in the northeast region, and higher on the shelf areas than in oceanic regions (ICES, 2012; Ástþórsson, et al., 2007). Fish spawning mainly occurs in the south and southwestern coastal areas of Iceland, during the phyto- and zooplankton bloom in the early spring (ICES, 2012).

2.3.2 Fishing vessels and gear

Icelandic marine fisheries can be divided into the fishing of demersal fish, pelagic fish and the fishing of crustacean and mollusks (The Ministry for the Environment in Iceland, 2002). A variety of gears is used for each fishery and some vessels switch from one gear to another within a year, depending on target species, amount of quota and fish availability (ICES, 2012). The total number of fishing vessels registered in Iceland and in the Westfjords in 2011 can be found in Figure 2.

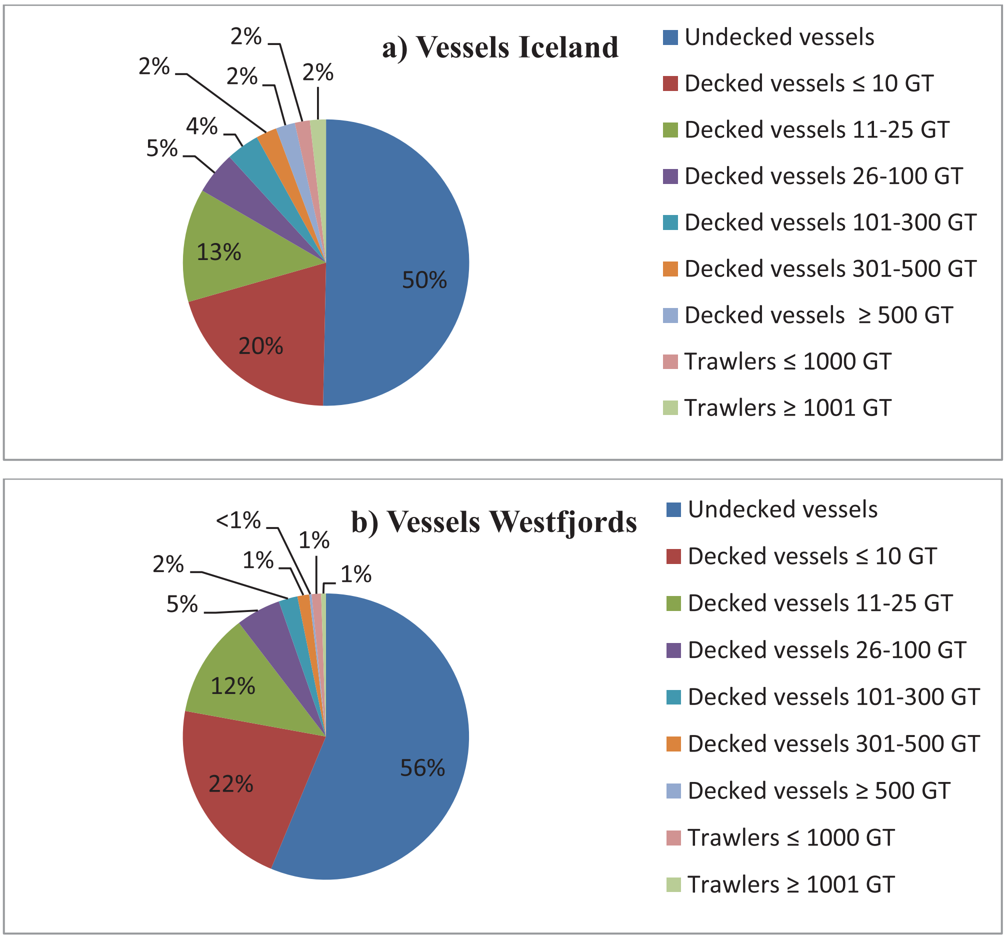

Figure 2. The Icelandic motor fishing fleet has traditionally been split into 3 groups; trawlers, decked boats, and undecked boats. The decked boat category the most diverse category and ranges from small vessels to large purse-seiners and multipurpose vessels. The separation of decked boats and trawlers is not very clear since many decked boats can also operate trawls. This classification originates from the times when trawling was much larger than all other boats, however, this classification is still used in Icelandic data sources (Knútsson, et al., 2011). Figure 2a shows the amount of registered vessels in each category in Iceland in 2011, Figure 2b shows the amount of registered vessels in each category in the Westfjords in 2011 (Statistics Iceland, 2012).

Demersal fisheries are the most valuable type of fisheries in Iceland (Arnason, 1993; Eythorsson, 2000; Gissurarson, 2000). Most demersal fisheries are conducted over the Icelandic continental shelf with a range of fishing gear, including bottom trawl, gillnet, longline, handline and Danish seine (ICES, 2012).

Purse seiners and pelagic trawlers target pelagic species. The vessels target few, but abundant species and therefore catch the highest quantities of fish. Pelagic fisheries are seasonal, and switch from one species to the other depending on the season. Trawls are used to catch invertebrates (Valtýsson & Sævaldsson, n.d.). Invertebrate landings are quite low in value and quantity, with exception of the lobster, which is a valuable species. Bottom trawlers have the highest share in the value of the total catch, followed by longliners (Knútsson, et al., 2011).

2.3.3 Target species

Some of the most abundant fish stocks in the North Atlantic Ocean can be found in Icelandic waters, such as the Atlantic cod and the capelin (Ólafsdóttir & Rose, 2012). Other stocks migrate seasonally into the area, such as the Atlantic herring, blue whiting *(Micromesistius poutassou),* and the Atlantic mackerel (Sævaldsson & Valtýsson, n.d.). A total of 30 commercially exploited fish and marine invertebrate species inhabit Icelandic waters. The most important commercial species include cod, haddock, saithe, redfish (*Sebastes marinus*), catfish (*Anarhichas lupus),* Atlantic herring, Atlantic mackerel, capelin and blue whiting (ICES, 2012). The economically most important fish species in the Westfjords area are the cod, haddock, catfish, northern shrimp (*Pandalus borealis*), and saithe. Figure 3 shows the total catch per species landed in 2012 in the Westfjords.

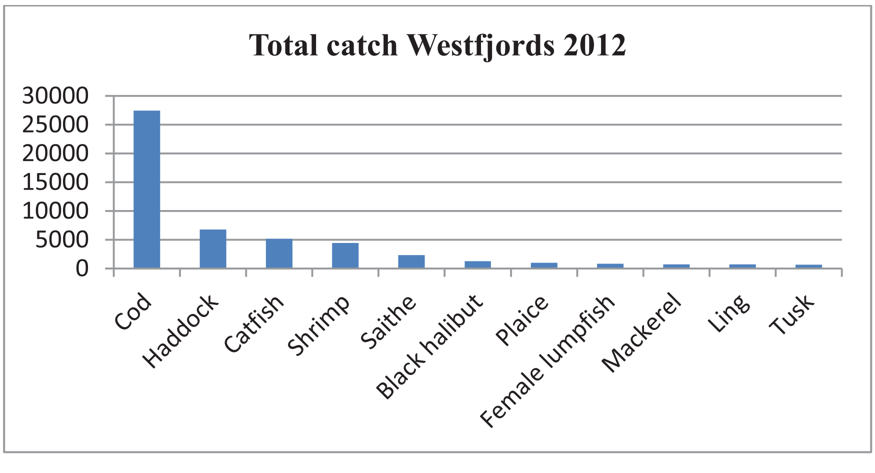

Figure 3. Figure shows the catch in tonnes in the Westfjords in 2012 of the main caught species (Directorate of Fisheries, 2012).

2.3.4 Fisheries management

The Ministry of Industries and Innovation is responsible for the implementation of fisheries management and the monitoring of fish stocks (ICES, 2012). A quota system was implemented in the Icelandic fisheries in 1984. Each vessel over ten gross tonnes (GT) was allocated a fixed proportion of future total allowable catch of cod, haddock, saithe, redfish, Greenland halibut (*Reinhardtius hippoglossoides*), plaice (*Pleuronectes platessa*) and catfish (Ministry of Fisheries and Agriculture, n.d.). Catch quotas were fixed on an annual basis for each species (Pálsson & Helgason, 1995). The allocation of vessel quota was to be based on catch history of the vessel over the previous three years, however, boat owners could also choose a system of effort quota, based on a limited days at sea system. Quotas were transferable to a certain extent: transferring from one vessel to the other meant an exclusion of the system of the vessel which transferred the quota, and exchanging and leasing of catch quota within the year was only allowed within the same community or between vessels owned by the same company (Pálsson & Helgason, 1995; Eythorsson, 2000).

In 1990, the Fisheries Management Act established a system of individual transferable quotas (ITQ's). Total allowable catch (TAC) shares were still allocated to boat owners; however, the resources would remain national property. The effort quota was eliminated, except for small boats up to 6 gross registered tonnages (GRT). Another important change was the divisibility of TAC-shares: quota became transferable between owners of Icelandic fishing vessels, without consulting the Ministry of Fisheries or the involved communities and unions (Pálsson & Helgason, 1995; Eythorsson, 2000). The exchange of quotas, either temporary or permanent, among individual quota holders or companies and the possibilities of changing the allowable catches from one species to another allowed some flexibility in the system and is a mean to minimize the amount of discard and misreporting (ICES, 2012).

The total allowable catches (TACs) are determined annually by the Minister of Fisheries for most of the commercially valuable species of fish in Icelandic waters. These amounts are set on the basis of recommendations given by the Marine Research Institute (MRI) and the International Council for the Exploration of the Sea (ICES), as well as the landings of the previous year (Gissurarson, 2000). Because vessels are required by law to land all species, no minimum landing size of the species is set. In order to reduce fishing pressure on small fish, various measures are in place, such as a set mesh size and temporary or permanent area closures (ICES, 2012). Catches brought ashore must be weighed. The Directorate of Fisheries is responsible for the enforcement and monitoring of catches. Fish quota was assigned to those who owned a boat at the time of establishing the quota system (Skaptadóttir, 2007; Arnason, 2008). If the boat owner trades its permits to either a company or an individual in another region, the local fish processing industry loses its supply of fish. As a consequence of the quota system, fisheries villages lost a control over locally-based access to resources (Skaptadottir, 2007).

3 Methods

3.1 Local knowledge

3.1.1 Selection of the participants

Initial contact with the first interviewees was made through the municipal mayors and harbor masters, who provided names, email addresses and phone numbers of most knowledgeable individuals working in the Westfjords' fishing industry. Additional names of participants were suggested by participants during the interviews, using the snowballing sampling technique.

In some villages, no names of possible participants were suggested. In order to maintain the maximum geographical distribution of interviewees, participants in these villages were approached directly at the harbor to insure that fishers throughout the entirety of the Westfjords were included in the sample. If contact details were provided, informants were contacted through phone or email and asked to participate. When they agreed, a time and place of meeting was arranged, according to the participant preference.

3.1.2 Conducting the interviews

Data collection took place through qualitative, in-depth semi-structured interviews with individuals working in the fishing industry, conducted during August, September and October of 2012. All interviews were conducted by the author. The questions were open-ended, and interviews were carried out individually and in the English language. During one interview session, three participants were interviewed at the same time. They were all equally questioned about the topic, however, answered according to their experience and position in the fishing industry.

The majority of the interviews were carried out during night time, when individuals had concluded their work for the day. Interviews were most often conducted in interviewees fishing boats, but in some cases at their homes, offices or in cars or cafés. Due to the sensitivity of some topics and the position of some of the interviewees, names were protected and all respondents were assigned a pseudonym. This was designed to allow the respondents to speak freely about their experiences and opinions. All the interviews were digitally recorded, after receiving oral permission from the respondent, and lasted between 20 and 60 minutes. A table with images of the most common fish species and the English and Icelandic names was used to avoid misidentification.

In two cases, an interpreter was willing to assist in translating the questions into Icelandic, and answers into English. This was only done when an interviewee requested an interpreter. During the interview, a guide was used with previously formulated questions. These questions contained topics such as interviewee's background, observations and experience on sea, adaptation measures and opinions concerning the current way of fisheries management (Appendix 1). The analytical concept of vulnerability, adaptive capacity and resilience were not mentioned during any of the interviews. This was done in order to prevent misinterpretation between interviewees and interviewer. No other concepts were used as interviewees provided their own concepts and terms.

3.1.3 Data analysis

Each interview was transcribed verbatim by the author. The recorded audio files were played several times in order to make sure the interviewer had correctly documented the responses. All interviews were loaded into the Open Code 3.6 software program to group similar content, through certain keywords or key phrases manually (Figure 4). After all relevant lines were assigned a code; codes were grouped together in certain categories by the author of this thesis. Assigned codes and categories can be found in Appendix 2.

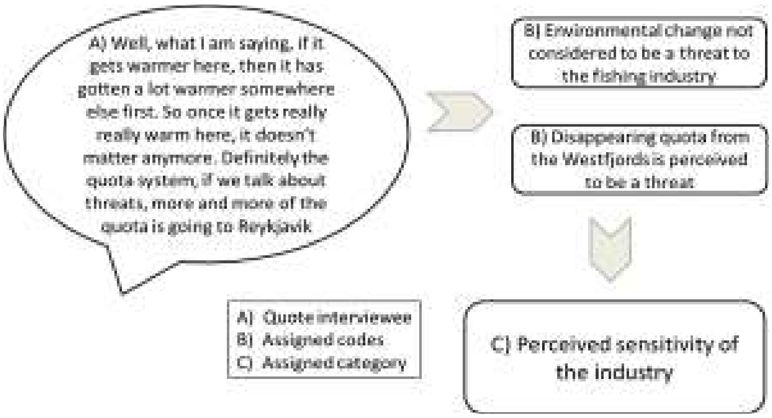

Figure 4. Figure illustrates the coding process to group similar content (based on Furberg, et al., 2011).

3.2 Scientific knowledge

3.2.1 Annual groundfish surveys

Interviewees´ perception of changes in fish species' abundance and distribution were compared with data of the IGFS conducted between 1992 and 2012 by the Marine Research Institute. Five commercial species were selected for analysis, namely cod, haddock, catfish, mackerel and monkfish. These particular species were selected based on the frequency of their mention by interviewees during the interviews. Selected stations for the species cod, haddock and catfish from the spring survey were located all around the Westfjords North of 65.4° and West of -21° (Figure 5).

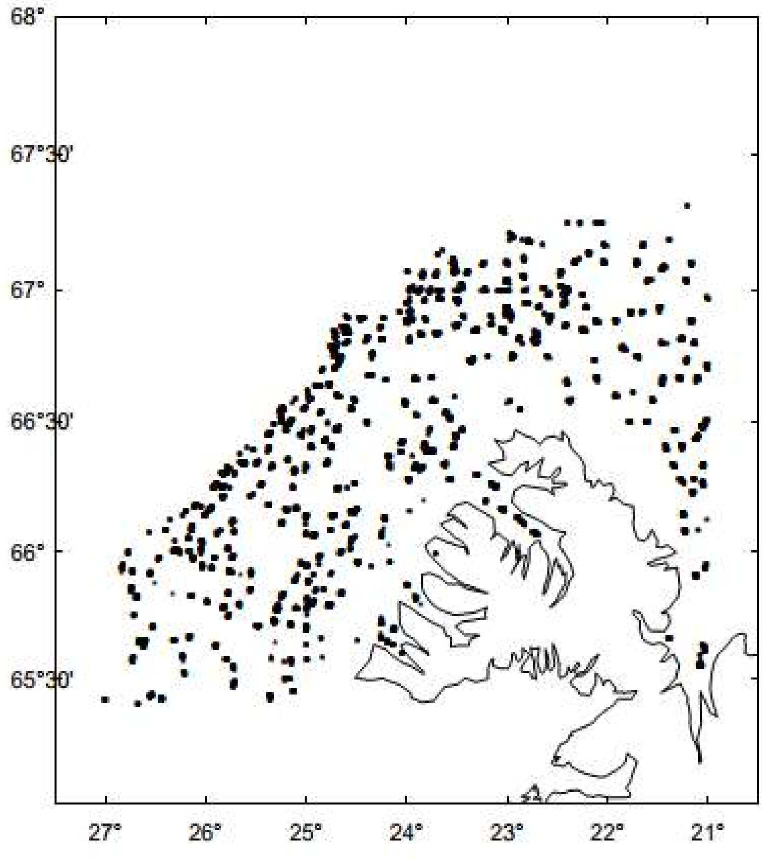

Figure 5. Figure shows the location of official survey stations in the Westfjords used in this investigation for the species cod, haddock and catfish. Thanks to Jacob Kasper for providing this figure.

Selected stations used in this analysis for the monkfish were located all around Iceland from the spring survey between 1992 and 2012. This was done because they are far less abundant in the Westfjords compared to cod, haddock and catfish. Selected stations used in this analysis for the mackerel were located all around Iceland and derived from the autumn survey since 2005, when the species re-appeared in great abundance in Icelandic waters.

Standardized bottom trawls were used for the IGFS. The towing distance of the trawl was approximately four nautical miles, but varied between 1.00 and 4.00 nautical miles, and was towed over the bottom at a speed of 3.8 knots (Pálsson, et al., 1989). Compared to commercial trawlers, the mesh size of the trawls were relatively small, with 135 mm mesh sizes in the front part of the net, 80 mm in the belly of the trawl and 40 mm netting at the cod-end (Pálsson, et al., 1989). Data collected during the survey, and relevant to this study, included the position of the stations, time, tow length, frequency of species, depth and bottom temperature. Bottom temperature was recorded by means of a Scanmar Sonde with an expected accuracy of 0.5 degrees (Pálsson, et al., 1989). There are various reasons why the stations were not sampled each year, such as gear failure, weather conditions or obstacles in the way (J.M.C. Kasper, 2012, personal communication).

3.2.2 Statistical analysis

The data collected in the IGFS was used to study the depth and temperature preference, abundance and spatial trends of the fish species cod, haddock, catfish, monkfish and mackerel. Temperature measurements were missing from several stations over the survey years. It was decided to ignore missing values and temperatures below -2.0°C. Obvious errors in depth measurements (<0m, >900m) were replaced with the mean of the same station in different years. Subsequent analysis was performed using Excel 2007 and Statistical Package for the Social Sciences (SPSS) Advanced Statistics number 17. The methods were used after an investigation of spatial and temporal trends of fifteen noncommercial fin-fish species in Iceland between 1985 and 2009 (Kasper, 2010).

Catch per unit effort (CPUE) was calculated by dividing the number of individuals caught at a station in a given species by the tow length:

$$CPUE = \frac{I}{L}$$

where I is the number of individuals caught at a particular station and L is the length of the tow at that station. To standardize the variance, CPUE was log transformed:

$$CPUE = \ln(CPUE+1)$$

Weighted mean latitude, longitude, temperature and depth over the years were calculated by using the following formula in excel:

$$\text{weighted average } X = \text{Sum product } (X,CPUE) / \text{sum } CPUE$$

Where X is the value of interest at a given year and CPUE is the number of individuals per unit of effort at a given year. Linear models were used to calculate trend lines, with P values indicating significance of the model and r^2 indicating the level of correlations. Abundance trends were calculated based on linear regression models, to indicate change in abundance over time.

4 Results

4.1 Results - perception of interviewees

4.1.1 Population sample

The interviewees were 22 male fishermen employed in eight different villages in the Westfjords of Iceland, namely Ísafjörður, Bolungarvík, Hnifsdalur, Patreksfjörður, Bíldudalur, Súðavík, Þingeyri and Suðureyri. The geographical distribution of interviewees is shown (Figure 1C). Interviewees' total years of employment in the fishing industry ranged from 3 to 52 years, with an average of 26 years (standard deviation 11.8).

The positions of participants in the industry varied from fisherman (15 skippers, 1 mate), either self-employed or working for the fish factory, second engineer on a bottom trawler (1), quality manager at a shrimp plant (1), production manager at a fish processing plant (1), development manager at a fishing-, processing- and sales company (1), employee at an international fish exports company (1) and finally the owner of a fish and seafood shop (1).

A variety of fishing gear was used by interviewed fisherman throughout the year including: bottom longline (12), bottom trawl (3), shrimp trawl (3), Danish seine (3), jig (2), hand line (1) and gillnet (1). Appendix 3 summarizes the population sample. The different target species of the interviewees included cod, catfish, haddock, lumpfish (*Cyclopterus lumpus*), shrimp and mackerel. The main bycatch species of the interviewees included American plaice, blue ling (*Molva dypterygia*), ling (*Molva molva*), dab (*Limanda limanda*), haddock, flounder (*Platichthys flesus),* halibut, monkfish, redfish, saithe, tusk (*Brosme brosme*), skate (*Dipturus batis*) and starry ray (*Amblyraja radiata*).

4.1.2 Perceived environmental changes

Interviewees identified an increase in seawater temperature as one of the main environmental changes over the study period (50%[1]).

Additionally, warmer summers (32%), milder winters with less snow and ice cover (27%) and more rain instead of snow during winter time (9%) were reported. Of the interviewees, 55% reported of a change in wind direction over the study period with a perceived stronger force (14%), possibly coming more from the south west (5%) instead of coming from the north (5%).

[1] Please note: percentages indicate the quantity of perceptions by individual interviewees.

Of the interviewees, 5% mentioned less accumulation of ice on the vessels. According to fishermen's perceptions, ocean temperature influenced distribution, abundance and behavior of species (45%).

4.1.3 Perceived changes in abundance and distribution

Table 1 summarizes the main perceived changes in abundance and distribution of fish species in the Westfjords.

Species	**Perceived increase in abundance**	**Perceived decrease in abundance**	**Perceived change in distribution**
Monkfish	Increased (86%)		Closer to mainland (9%)
Mackerel	Increased (77%)		
Cod	Increased (32%)		Deeper in water column (23%) More north of mainland (27%)
Haddock	Increased (32%)	Decreased (5%)	Closer to mainland (23%)
Ling	Increased (27%)		Closer to mainland (14%)
Catfish			Closer to mainland (14%)
Capelin		Decrease (18%)	
Shellfish		Decrease: (18%)	
Shrimp	Increased since 2011 (9%)	Decreased over study period (18%)	Deeper in water column (18%) More north of mainland (18%)
Sandeel		Decreased (14%)	
Redfish	Increased (9%)		
Whiting	Increased (9%)		
Blue ling	Increased (9%)		
Tusk	Increased (9%)		Closer to mainland (5%)
Witch flounder	Increased (9%)		
Blue whiting	Increased (5%)		

Table 1. Table illustrating perceived changes in species abundance and/or distribution over the study period. Percentages indicate the quantity of perceptions by individual interviewees.

Some of the perceived changes by interviewees were contradicting, such as the reported increase in haddock (32%), in contrast to the reported decrease in the population size of the haddock (5%). Interviewees shared their perceptions of change referring to different spatial and temporal scales; 18% of the interviewees reported of a decreasing shrimp population over the study period whereas 9% of the interviewees reported of an increasing population since 2011. Additionally, 5% of the interviewees reported of a change in species occurrence specifically in Arnarfjordur, referring to the catfish as: “Just coming back into Arnarfjordur.” Interviewees of other regions in the Westfjords had not reported specific changes in catfish population in the entire Westfjords region, which illustrate the differences in spatial scale at which changes were reported. Furthermore, interviewees reported of an increase of juvenile fish in the fjords (18%), and these juvenile species were thought to stay longer in the fjords during autumn (14%). The haddock (27%) and catfish (14%) appeared to stay in the fjords for a longer period of time in each season.

Speculations concerning the distributional change of the cod population more north of the mainland (27%) included the expectation that cod follows the capelin and the shrimp (14%). The movement of cod deeper into the water column was observed (23%) and explained by 5% of the interviewees as avoiding the increasing temperatures of the water surfaces and going after the shrimp.

4.1.4 Perceived sensitivity of the fishing industry to stock changes

Of the interviewees, 64% did not perceive changes in fish stocks as a threat to the fishing industry. The variation in temperature was perceived as a historically continuous phenomena (23%). Fishing is an occupation tied to a naturally varying resource, and therefore, the industry is by necessity flexible and adaptive. Of the interviewees, 55% were convinced the currently higher temperatures will decrease again, as opposed to 14%, who considered the current temperature increase as likely to be permanent. The current warming phenomenon was perceived by 32% of the interviewees as affecting the occurring species, either positively or negatively, however, they knew that there will always be commercially exploitable species to catch (32%).

Mackerel was perceived to be a commercial opportunity for the Westfjords by 27% of the interviewees. However, 41% of the interviewees perceived the mackerel to be a threat to the traditionally occurring species through the increased competition for local food sources. The perceived decrease in lumpfish population was thought to be the result of monkfish predation (23%). Of the interviewed fishermen, 18% felt the need to catch the monkfish in order to protect the lumpfish.

> Participant G: “What is happening, like when they are coming, it is like what is happening here, when the haddock comes and the cod disappears. That happens overnight, and of course this can happen also when these new species are coming in, they can just disappear. And, it is like the monkfish, he is like a

really fast one, like he is attacking the lumpfish, that is a really slow fish, and they have lots of fear that the lumpfish is disappearing, and the monkfish is coming in instead."

Five percent of the interviewees noticed that the lumpfish season started earlier; a phenomenon fishermen needed to adapt to regardless of what time of the year it is.

> Participant E: "The seawater is getting hotter, and this brings differences to the species. For example the lumpfish. Usually we started fishing the lumpfish on the 20th of April. Now we start fishing the 15th of March. So the season for lumpfish is actually one month earlier than it used to be."

Nine percent of the interviewed skippers perceived the shift of haddock closer to shore as having negative consequences for the bigger bottom trawlers, as these vessels were not allowed to fish in shallow waters. The skipper of a smaller bottom trawler described the fatal conditions for cod, when caught and pulled to the surface. The difference between the bottom temperature and the surface temperature of the seawater were too great in the summer months, potentially causing fatal conditions for the cod.

> Participant G: "For example over the summer now, we have not been able to fish here [points at screen] where we used to fish. Everybody is able to fish there, but we are not because the fish die on the way up. Because on the bottom, where the fish is, and then the heat is about five degrees, and on the way up, it is about eleven degrees. And that is just too warm for the fish. He just dies."

As a consequence of changes in stock distribution, fishermen needed to go out further to catch the target species, which meant an increase in fuel costs (18%).

> Participant A: "We are trying to find cod now, where the haddock is not there, and that's why we try those weird places. So there is cod everywhere, there is haddock everywhere, and we are just trying to find places without haddock and with cod. It is terrible, because we could just go straight out, and catch tonnes and tonnes and tonnes of both."

4.1.5 Perceived sensitivity of the industry to institutional and social factors

The quota system itself was perceived by 27% of the interviewees to be an efficient system to regulate fishing. However, changes in national fisheries policies and regulations were perceived as a threat to the fishing industry. Interviewees felt like the Westfjords communities have lost their access to the local resources (41%). The selling and renting of quota is considered to be unprofitable and a threat to the existence of the fishing industry in the Westfjords (23%). In addition, the quota was regarded to be expensive (9%), and it was considered to be impossible for a beginner to start his or her own business (14%). The adaptability of the system to new species was perceived to be too slow, and therefore, interviewees recommended a more flexible and adaptive system (27%). Of the interviewees, 5% referred to the historical fishing of mackerel in Arnarfjordur, and how this has changed with the changes in fisheries management.

> Participant I: "And the mackerel is coming, started about three years ago. Long before I was born, a boat from this town fished a lot of this species. And now it is coming back. But now there is the quota system, and we cannot fish it."

Interviewees referred to environmental changes, which can happen overnight and can have significant impacts on species dynamics. Changes in species distribution can make it harder for a fisherman to land the species for which they possess quota, and interviewees perceived it as expensive to obtain quota for new species in the area (9%).

> Participant V: "It has to be, in my opinion, it has to be more flexible and adapt to changing situations that we do not know beforehand. So for example if we take the monkfish, there were mainly three companies, in the south, that had the quota for nearly all the monkfish. Then the monkfish moved here north, and the people who did not had the license to fish it, they came across very strange options. They were not allowed to throw it away, and they were not allowed to land it. So then the government stepped in and made some flexible government quota for the monkfish. That has helped a bit. But still, the stronghold of a few companies in Iceland on this natural resource is very much disputed. That is for sure."

Fishermen did not noticed the government's direct attention to the observations and problems of the fishing industry. The government was not seen as being objective enough, but rather influenced and run by powerful organization such as LIU (The Federation of Icelandic Fishing Vessel Owners) (9%). The interviewees referred to the mackerel dispute (32%). Of the interviewees, 5% described the allocation of mackerel quota from the government to the bigger trawler owners, which was perceived to be unfair.

> Participant G: "For example the monkfish, when he started to come here, they put a quota on it. And they sell the quota from the government, they do the right thing. So you send a letter to the government, I want to have this much quota for the monk fish, and they send you a letter back pay this and then you get the quota. But mackerel, also a new species, they do not sell that. Only the big boots get it. And do not have to pay for it. Why do not they rent out the mackerel quota just as they did with the monkfish quota. That is a political question"

Several participants perceived the methods of the MRI in determining stock size as outdated and do not anticipate changes in fish species distributions (27%). Fishermen showed their concerns regarding the quota advices of the MRI towards the ministry, in particular the recommendations to cut down the haddock quota (32%).

> Participant D: "They always go themselves. To the same spot, same time of the year, fish on the same spot, same trawler they have been using since 70 something, so, all their data is corrupt. They never listen to the fishermen."

> Participant L: "Hafró goes once every year with a trawler around Iceland, on the same places every year. If it isn't there if we are there, it is not there. But that is wrong. […] They say: the haddock is not there, you have to cut it down. But haddock is in other place as where it was 20 years ago. The catfish is getting in very shallow water now. Like twenty, fifteen meters deep. And they are not trawling there. They say: there is no catfish, you have to cut it down. But the experiences of the fishermen is another, you see. […] If the water is getting warmer, the fish are moving away. And we have to follow them. And Hafró is not doing that."

The depopulation in the area was seen as one consequence of the disappearing quota in the Westfjords and a problem for the fishing communities (23%). One of the interviewees mentioned a decrease of inhabitants by 23% in Þingeyri. Younger interviewees indicated that they would not want to stay in the area, and that not many young adolescents are attracted to jobs in the fishing industry (9%).

4.1.6 Adaptation strategies

Adaptation strategies included investment in knowledge and gear, in order to adapt to potential new commercial species. Three of the interviewees commented that gear, knowledge and factories are present in the Westfjords to adapt to changes (14%), however, 23% of the interviewees commented that the factories are not set up for mackerel yet, and that there is insufficient equipment to catch mackerel in the Westfjords. Adaptation in gear included jigging, which can be used to catch mackerel (32%), and to avoid haddock as bycatch (9%). Additional advantage of jigging is the lowered cost rate because less employees are needed to haul the fish lines and the gear does not use live bait (5%). Fisherman adapted through choosing different fishing grounds because cod is perceived to be more north of the mainland (18%) as well as deeper into the water column (23%). Other adaptation strategies derived from interviewees included a changed focus in fish processing: from frozen products to more valuable niche products, such as fresh and smoked fish (9%).

Nine percent of the interviewees practiced a diversified livelihood (9%). These interviewees were, besides fisherman, active in the tourism industry through the management of a hostel, as well as through offering sea angling tours to tourists. Their rationale to diversify their income was not only to adapt to the environmental variability (one of the interviewees with a diversified livelihood was a shrimp fisher, with very low catch quota over the past years) but also to adapt to market variability and changes in allocated catch quota.

The investment in gear and knowledge by one of the fish factories to set up fish farming, after the decrease and closure of the in-fjord shrimp fisheries, was perceived to be a successful strategy to adapt to changing population' abundance and distribution (5%). A 'total days per year fishing system' was recommended by 18% of the interviewees in order to get the access to the local fishing grounds back, especially for the species monkfish and mackerel.

4.1.7 Summary interviewees perceptions

Fishermen reported increased abundances of monkfish (86%), mackerel (77%), cod (32%), haddock (32%), ling (27%), redfish (9%), whiting (9%), blue ling (9%), tusk (9%), blue whiting

(5%), and the witch flounder (5%). Species that were recognized to have decreased in population size in the Westfjords included the capelin (18%), shrimp (14%), shellfish (14%), sandeel (9%) and the haddock (5%). Cod was perceived to be moving more north of the mainland (27%) as well as a movement deeper into the water column was observed (23%). Shrimps were reported to migrate in northern direction of the mainland and deeper in the water column (18%). The haddock appeared to be closer to shore (23%). The catfish was reported as reallocated to shallower waters (14%) as well as the species ling (14%), monkfish (9%) and tusk (5%).

The majority of the interviewees did not consider the changes in fish to be a particular threat to their businesses. The major determinants to response to fish stock changes included fishery regulations and management. Interviewees perceived the quota system insufficiently flexible, and the adaptation of the system to new species was perceived to be too slow. The depopulation in the area was seen as a threat to the adaptive capacity of the fishing industry. Flexibility in the industry under environmental uncertainty included fishing at different fishing grounds, for different species or with different gear. These adaptation strategies are tied to regulations, and flexible fisheries management was perceived to be the feature of successful fishing activities.

4.2 Results - bottom surveys data

4.2.1 Cod (Gadus morhua)

The number of stations where cod was caught varied between 93-155 (average ±122, standard deviation 18.8) The ln(CPUE+1) trend for cod decreased over the course of this study as confirmed by the linear model ($P = <0.001$, $r^2 = 0.583$). No significant trends in latitude, longitude or temperature change were detected. However, an increase in average depth preference was found as confirmed by the linear model ($P = 0.049$, $r^2 = 0.189$) (Appendix 4).

Earlier spring migration and later fall return of *G. morhua*, as a response to the increasing water temperatures, could affect the annual survey findings (Drinkwater, 2005) and explain the decreasing trend of species abundance. Another reason of the decreasing trend could be because of decreased prey availability. The main prey species of cod, capelin, may be affected by the warming conditions north of Iceland, resulting in a northward shift in migrations and spawning locations of the species. Additionally, increased fishing effort over the past decades could be the cause of the continuous reduction of cod stocks (ICES, 2012).

4.2.2 Haddock (Melanogrammus aeglefinus)

The number of stations where haddock was caught between 87-143 (average ±113, standard deviation 17.0). The (lnCPUE+1) trend of haddock did not significantly change. The latitudinal position of the haddock did not change over the study period, however, the species showed an eastern trend in longitude (P=<0. 001, r^2 =0.629). The average depth preference of the species decreased (P=<0. 001, r^2 =0.680) and the average bottom temperature indicated a positive trend (P=0.032, r^2=0.219) over the study period (Appendix 5).

With increasing bottom temperature, it is expected that the species changes position to maintain their optimum habitat conditions. This is confirmed by Valdimarsson, et al., (2005), who found that southern gadoids, including haddock, are amongst the species that have shown the largest distribution extension. An increased recruitment and more northward and eastward distribution of haddock was found in the Icelandic groundfish survey during 1985 – 2005, based on ca. 600 stations covering the shelf area around Iceland (Ástþórsson, et al., 2007).

4.2.3 Catfish (Anarhichas lupus)

The number of stations where catfish was caught varied between 94-142 (average ±117, standard deviation 15.5). The ln(CPUE+1) trend for catfish decreased over the course of this study, as confirmed by the abundance linear model (P = <0.001, r^2 = 0.654). Catfish latitudinal position has not changed over the study period, however, the species is found more easterly (P = <0.046, r^2 = 0.139).

The temperature preference of the species increased (P = 0.022, r^2 = 0.246), and no significant changes were found in the depth preference of the species (Appendix 6). Since 1992, the total catch of catfish has gone down. Fishable stock in the coming years is expected to be low as recruitment to the fishable stock will be low in the coming years (Marine Research Institute, 2012a).

4.2.4 Monkfish (Lophius piscatorius)

The number of stations where monkfish was caught varied between 2-138 (average ±60, standard deviation 42.1). The (lnCPUE+1) trend of monkfish has increased over the study period (P = <0.001, r^2 = 0.690).

Both latitude (P = <0.001, r^2 = 0.839) and longitude (P = <0.001, r^2 = 0.545) preference showed a positive trend, meaning a north western distributional shift. In addition, the temperature preference of the species decreased (P = 0.013, r^2 = 0.286) and the species is found in shallower waters (P = <0.001, r^2 = 0.491) (Appendix 7).

Monkfish is distributed in the temperature northern Atlantic and observed more frequently in Icelandic water since 1992 (Solmundsson, et al., 2007). The species has shifted its habitat over the years and can increasingly be found at the grounds west off Iceland, where it formerly almost was non-existent (Thangstad, et al., 2006; Solmundsson, et al., 2007). Furthermore, the total area of Icelandic waters above 400 meters where the bottom temperature is higher than 5°C, doubled in size between 1985 and 2007 (Solmundsson, et al., 2007), which increased the total area of suitable grounds for the species. They are rarely observed deeper than 500 meters, which is likely related to the temperature preference of the species (Solmundsson, et al., 2007).

4.2.5 Mackerel (Scomber scombrus)

The number of stations where mackerel was caught varied between 2-44 (average ±18, standard deviation 20). No significant positive or negative trends were found for the species abundance and temperature preference, eastern and western geographical distribution or average depth preference (Appendix 8). However, this is most likely due to the fact that the mackerel is a pelagic fish, whereas bottom trawling targets groundfish and semi-pelagic species. In addition, mackerel is mostly out of the region by the autumn, which means that they are only caught in warmer years (J.M.C. Kasper, personal communication, January 2013).

Since around 2006, mackerel extended its summer feeding distribution towards north and west, and was therefore increasingly observed in Icelandic waters (Óskarsson, et al., 2012). The reason for this extension into Icelandic waters is unknown, but is thought to be linked to increased sea water temperatures (Óskarsson, et al., 2012). It could also be because of poor feeding condition on traditional feeding grounds. In 2011, the total catch in tonnes in Iceland was 159,000 tonnes. Spawning stock increased between 2003-2009, and has decreased since then. Spawning stock in 2012 was estimated to be approximately 2.7 million tonnes (Marine Research Institute, 2012b).

4.3 Results - comparison perceptions and linear regression models

Table 2 summarizes interviewees perceptions and regression models. Five out of nine of the perceptions potentially suggested correspondence with the scientific data, however, four perceptions corresponded at a minimal or marginal level with the scientific date. The perceived increase in monkfish showed a high level of agreement with the regression model. No significant trends were found in mackerel abundance and distribution, however, literature of the MRI reported of increasing mackerel abundances in Icelandic waters since 2005.

Species	Participants perception	Bottom-trawl survey data MRI	Agreement/ disagreement
Cod			
Abundance	Increase in cod population (32%)	Decreased (r^2 = 0.596, P = <0.001)	No agreement
Distribution	Cod is moving further north of the mainland (27%)	No significant change	No agreement
Depth preference	Cod is moving deeper in the water column (23%)	Increased (r^2 = 0.189, P = 0.049)	Marginal agreement
Haddock			
Abundance	Local increases in haddock density (32%) Decrease in haddock population (5%)	No significant change No significant change	No agreement
Distribution	Haddock is found closer to the mainland (23%)	Eastern trend longitude (r^2 = 0.629, P = <0.001)	Marginal agreement
Catfish			
Distribution	Catfish moving closer to shore (14%)	East (r^2 = 0.193, P = 0.036)	Minimal agreement
Monkfish			
Abundance	Increase in monkfish abundance in the Westfjords (86%)	Increased (r^2 = 0.690, P = <0.001)	high agreement
Distribution	Monkfish is migrating closer to shore (9%)	Northwest (r^2 = 0.839, P = <0.001) (r^2 = 0.545, P = <0.001)	No agreement
Depth preference	Monkfish is found in shallower waters (9%)	Decreased (r^2 = 0.491, P = <0.001)	Minimal agreement
Mackerel			
Abundance	Increase in mackerel abundance in the Westfjords (77%)	No significant changes found in data of the MRI survey	Scientific literature: Agree

Table 2. Participant perceptions regarding changes in abundance, distribution and depth preference of the species cod, haddock, catfish, monkfish and mackerel over the study period (second column). Third column presents the results of linear regression models of the bottom trawl surveys. Last column presents the level of agreement or disagreement between the two types of data: <20%: "Minimal agreement", 20-40%: "Marginal agreement", 40-60%: "Moderate agreement", 60-80%: "Significant agreement", > 80%: "High agreement".

5 Discussion

5.1 Research limitations and inconsistencies

The main disadvantage of the use of semi-structured interviewing in this research was the wide-range of topics discussed by relatively few of the interviewees which were partly linked to the subject of investigation. From the reported responses, many were not essential to the key question. The success of the interview was dependent on the experience of the interviewer, and the more interviews were conducted, the easier it was to maintain a relaxed and efficient dialogue. This has affected the outcomes of the interviews in a way that the last interviews were much more relevant to the topic than the first interviews conducted, as interview-skills, confidence and knowledge on the topic of the interviewer increased.

A larger sample size makes the data more reliable and potentially more representative of the larger group the sample was selected to represent. To increase the validity of findings drawn from the current population sample, a greater cohort of respondents covering all villages of the Westfjords is needed. This would potentially provide the opportunity to represent the variability in gender, age, total years of experience in the fishing industry, function and employment status. Added thereto, a considerable amount of time is required to collect the data properly and thoroughly.

The interviews were conducted in the English language. The interviewer’s inability to speak Icelandic probably posed – to some extent or even considerably in some cases – certain limitations to participants as well as the interviewer. Some individuals were not unwilling to participate, but their insecurity in their English abilities created an obstacle preventing them from being ready to participate. In addition, interviewing in a foreign language is not ideal, as you may lose valuable information drawn from nuances in language in the translation.

Five of the interviewees in the population sample had less than 20 years of experience in the fishing industry, respectively only 3, 6, 16 and two times 15 years of experience. The older generation was a better source of knowledge; however, a few younger people were purposely interviewed, because they spent a significant proportion of their life in the fishing communities in the Westfjords, and have therefore likely accumulated valuable knowledge concerning the industry.

One group interview was conducted. This was efficient, because it was less time-consuming and the interviewees complemented each other. On the other hand, it tended to be less controllable, and harder to address all relevant topics. Importantly, interviewees were more likely to have influenced each other's responses.

Assigning codes to cover perceptions of different interviewees can be a risk because of the subjective character of the process. Assigned codes were carefully evaluated to make sure that they referred to the same aspects, however, a second round of coding conducted by another researcher to ensure concordance in the interpretations would have increased reliability of the allocated corresponding perceptions of interviewees in this study (Furberg, et al., 2011).

Because of the qualitative character of the research design, quantification of the data was never intended to provide definite or statistically valuable comparison. The quantification of the data therefore serve as an indication of the central subjects in this research. Observations of a change by only one or two of the interviewees or contradictions in interviewees responses does not say that the observation is not reliable. Low scores are rather the consequence of the heterogeneous character of a small population sample, and indicates the different opinions within the category. However, low scores of responses may also reflect a low level of quality and depth of the local knowledge. A second round of interviewing was outside the scope of this study, but would be an appropriate measure to test the consistency of individual interviewees answers.

In the recent study, linear regression models were used to investigate the trends in species' ln(CPUE), depth preference, temperature preference and geographical shifts shown in either longitude and/or latitude change. Linear regression models are a rather simple tool to investigate ln(CPUE) trends in dynamic populations, because it uses the number of individual fish species only as indication for the condition of the fish stock. More complex methods take age, sex and the fish stock's composition into account and are recommended for use in subsequent research (Machiels, 1996).

The time frame of the interviews was 20 years, which defined the study period and allowed for comparison with the scientific data. This was partly because it is known that scientific data has a stronger power to detect changes over a longer time frame (Nicholson & Jennings, 2004). However, it should be noted that only one or two of the interviewees referred to the study time frame, when indicating a specific change in species' abundance or distribution. This is partly the consequence of an unspecified way of questioning, and interviewees were not asked to indicate the specific years when recalling events. However, many respondents provided information by recounting a specific event related to a change in the environment, such as the increasing seawater temperatures, or milder winters, as a time indicator. In addition, most perceived changes were related to the last few years.

Interviewees working at processing factories possess different knowledge of the fish species in the Westfjords than fishermen, and presented different problems and adaptation strategies. In the current study, the linkage between perceptions of interviewees and interviewees' background and experience in the fishing industry was not analyzed. This was beyond the scope and time-frame of the research. However, assigning higher confidence scores to interviewees with greater experience in the fishing industry could be an appropriate measure to increase the validity of the perception (Neis, et al., 1999). For instance, Ferguson, et al., (1998) ranked the reliability of each informant's observation on caribou distribution according to the source of each observation with (1) firsthand observations by the informant; (2) secondhand knowledge from family members, (3) secondhand information from other hunters and (4) speculative information from observations (Ferguson, et al., 1998).

5.2 Environmental change

5.2.1 Species abundance

Over the study period, monkfish was perceived as having increased in abundance by 86% of the interviewees, which was in high agreement with the linear regression model obtained from the groundfish survey ($P=<0.001$, $r^2=0.690$). The r^2 value for ln(CPUE+1) indicated that 69% of change in abundance was positively correlated with time. The perceived increase in mackerel (77%) did not correspond with the linear model. However, the mackerel is a pelagic fish, whereas the survey was conducted with bottom trawls, which only targets groundfish and semi-pelagic fish. Publications showed an increase in abundance of mackerel in the Icelandic EEZ (e.g. Óskarsson, et al., 2012, Ástþórsson & Pálsson, 2006), which is in accordance with interviewees observations. Of the interviewees, 32% reported a locally increased density of haddock, and 32% interviewees reported an increase in cod abundance over the study period, whereas the scientific data did not show significant abundance trends for haddock, and a strong correlated decreasing trend for cod ($P=<0.001$, $r^2=0.583$) over time. One explanation of this difference can be a biased position of fishermen towards the state of commercial fish stocks on their fishing grounds. Haddock and cod are both important species for the Westfjords' fishing industry.

A study done by Rose & Kulka (1999) during the late 1980s, showed that cod may aggregate differently according to their abundance and distribution range. It was found that northern cod hyper-aggregated (local densities increased with decreasing biomass) at the northeast Newfoundland shelf, which is the most southerly cross-shelf migration of northern cod.

The CPUE increased over this period (Rose & Kulka, 1999). Even though the linear regression models in the current study did not show significant increases of the species cod, haddock or catfish, observations of local fishermen may indicate aggregation of species on a local scale. Local densities can not only remain relatively stable as total biomass changes, but even increase: if there is a high abundance of species in southern waters, and they shift north, an increase in population abundance in the north is observed. This does not say anything about the population's total abundance.

Other fish species, observed by interviewees in greater quantities included tusk (5%), redfish (9%), blue ling (9%), blue whiting (5%), witch flounder (5%), whiting (9%) and ling (27%). No analyses were made to compare interviewees' perceptions of these species to scientific data, mainly due to the limited time frame of the research. However, variability in species abundance and distribution is documented for several species inhabiting Icelandic waters. Several documentations reported of an increase of southern commercial species in Icelandic waters, including haddock, monkfish, and whiting (e.g. Valdimarrson, 2005; Björnsson & Pálsson, 2004; Solmundsson, et al., 2009). In addition, greater quantities of blue whiting (Björnsson and Pálsson, 2004) and witch flounder (ICES, 2012) to the north of Iceland were documented, which was in accordance with interviewees' perceptions. Landings of ling have increased steadily since 2001. Survey indices of harvestable biomass have remained high since 2007, however fishing mortality increased substantially from 2007-2010. Increased fishing mortality was likely caused by a fish effort above the recommendations and allocated TAC, as a consequence of landings of foreign vessels and species conversion within the management system (Marine Research Institute, 2012c).

Very few interviewees observed a decrease in abundance of shrimp (9%), capelin (18%), scallop (14%) and sandeel (9%). According to documentation, capelin showed a northward distribution trend, and adult capelin arrived later to the north Icelandic shelf (Ástþórsson, et al., 2007). In addition, the northern shrimps harvesting decreased rapidly since 1997, and reached a minimum in 2006. There is an reported increase in the landings since 2011 (ICES, 2012).

5.2.2 Geographical distribution

The perceived distributional changes of haddock (23%) closer to shore potentially suggested a marginal correspondence with the scientific findings. The change in longitude of haddock ($P=<0.001$, $r^2=0.629$) was strong and corresponded to an eastern shifts in the geographic centre of the species. Monkfish showed a strong north-western distribution (latitude: $P=<0.001$, $r^2=0.839$, longitude: $P=<0.001$, $r^2=0.545$), which did not correspond with the perception of monkfish migrating closer to shore (9%). Northeast Atlantic mackerel extended its summer feeding distribution and appeared almost every year since 2006 in large numbers in many areas around Iceland (Ástþórsson & Pálsson, 2006; Ástþórsson, et al., 2012), which was in accordance with interviewees perceptions (77%). Cod was perceived to show a northwards migration pattern (27%), which did not correlate with the scientific data in this investigation. However, documentation suggested earlier spring migration and later fall return of cod, as well as an extension of the species' habitat towards the north of Iceland as a response to the increasing water temperatures. This could have significantly affected IGFS results and could possibly explain the different findings (Drinkwater, 2005).

Linear models of haddock ($P=<0.001$, $r^2=0.680$) and monkfish ($P=<0.001$, $r^2= 0.491$) showed a strong significant decrease in depth preferences. Haddock (23%) and monkfish (9%) were both observed closer to shore in shallower waters and suggested a marginal and minimal correspondence with the scientific findings. The total area of Icelandic shelf above 400 meters where the mean bottom temperature is higher than 5°C, has doubled in size since 1985 (Solmundsson, et al., 2007), which can be reason for these changes. Cod was observed in deeper waters (23%), which was in accordance with the linear regression model of cod's increased depth preference ($P=0.049$, $r^2=0.189$), even though its significance is not very strong. However, no significant trend in latitudinal change were found. The non-correlating variables in this study can be due to limitations of the research design or because of a small (not significant) change in latitude or longitude.

Perception of distributional change of species is based on local fishing activities. Fishing practices do not necessarily cover the total area of the Westfjords. Therefore, use of charts during a similar investigation could be an added value to specify local differences in perception of species abundance and distribution (Huntington, 2000).

According to research by Mackinson (2001) on integrating local and scientific knowledge on herring distribution and behavior, all conflicting information obtained from fishermen, scientists, and literature could be explained by observations at different scales (Mackinson, 2001). The importance of scale was also documented by Finlayson and McCay (1998), who showed how the Canadian government scientists were not able to predict the collapse of the inshore cod stocks in Newfoundland, partly because the stock was managed as a unit stock at a very large spatial scale (Finlayson & McCay, 1998). However, focusing only at the local level can also be misleading (Nenadovic, et al., 2012). Wilson (2003) pointed out the logistic problems in his study regarding a participant observation of scientific decision making, with a discourse analysis of debates around the management of Atlantic bluefish (*Pomatomus saltatrix*) from 1996 till 1998. The study described the difficulties of processing detailed information and translating local observations from across the breadth of the Northeast Region into meaningful information at a larger scale (Wilson, 2003). Interviewees in the current study gave detailed description of observations at small spatial scales, for instances "in the fjord", but less informative description at the larger study area. The local knowledge may therefore provide more detailed information at the finer geographical scales.

5.2.3 Temperature

Mean temperature at which haddock (P=0.032, r^2=0.219), catfish (P=0.022, R^2=0.246) and monkfish (P=0,013, r^2=0.286) were caught in the groundfish survey increased according to the linear model. The correlation was somewhat weak, because data points were scattered. Environmental conditions during the current period in Iceland showed a rise in both temperature and salinity levels in the Atlantic waters south and west of Iceland since 1996. A similar trend was observed in the waters off north Iceland, although with greater inter-annual fluctuations (ICES, 2012). Belkin (2009) documented on a temperature increase of 0.86 °C between 1982 and 2006 for the Icelandic shelf. Temperature and salinity have remained at high levels, with an average increase of approximately 1˚C in water temperature, and by one unit of the salinity level (ICES, 2012).

Of the interviewees, 45% claimed that changes in water temperature are the main cause of distributional, abundance and behavior changes of species. In addition, the increasing temperatures are perceived to have a significant impact on species which are dependent on live bait, such as cod (5%). The correlation between temperature increase and changes in fish stock is arguable, because temperature is only one environmental factor influencing behavior of fish stocks (ICES, 2012). In addition, it is uncertain to what extent changes in fish stock are caused by changes in the environment or by factors such as overfishing (Björnsson & Pálsson, 2004).

5.3 Sensitivity of the industry to changes in fish stocks

Changes in national fishery policies and regulations are perceived to be a bigger threat to the fishing industry than environmental changes, because of the perceived lack of control over the risk. An investigation of risk perception amongst fishermen in four European countries including Iceland, the United Kingdom, Greece and the Faroe Islands corresponded with the findings in this study, as the study concludes that risks related to policy, management and control are most frequently cited by fishermen in the case study countries, followed by economic factors and fishing impact on environment and resource (Edvardsson, et al., 2011). An estimation by

Arnason (2003), attempting to assess the economic impact of fish stock alteration on the Icelandic Gross Domestic Product (GDP), concluded that changes in fish stock availability, that now seem most likely to be induced by warming, over the next 50-100 years are unlikely to have a significant long term impact on the Icelandic economy. If sudden changes occur, the short time impact on the Icelandic GDP and economic growth rates may be quite significant. However, the impact seems very unlikely to be dramatic (Arnason, 2003).

New species in the Westfjords, including mackerel and monkfish, are perceived to be both an opportunity (27%) and a threat to the fishing industry, because mackerel was seen as a scavenger by 41% of the interviewees and monkfish as a threat to the lumpfish (14%). Mackerels feeding in Icelandic water gain around 43% of their body weight during the summer months. The invasion of mackerel has negative impacts on the native fish species, caused by competition for food and predation on other fish stocks (Óskarsson, et al., 2012). The Westfjords' processing factories are not set up for mackerel yet, which is a problem if fishers want to target mackerel, and which requires capital and permits.

Science is perceived as a significant risk factor, as the reduction in quotas is based on scientific advice of the MRI. Of the interviewees, 32% perceived the methods of the MRI to be outdated and not adapting to environmental change. This is supported by Delaney, et al., (2007), who documented decision management of European Union fisheries management. According to interviewed fishermen, scientists' methods to assess cod stock size and condition were considered to be unreliable and unsuitable, when it comes to gear, fishing methods and area sampled. They complained about the lack of recognition for their knowledge and experience (Delaney, et al., 2007). It should be noted that fishermen, mainly the captains of the research trawlers, were involved in planning the establishing the IGFS in 1985. They advised on aspects such as gear standardization and stratification of the survey area with respect to fish abundance. This was done to increase precision and reliability of stock size estimates of relevant fish stocks, through the integration of fishermen's knowledge of fish behavior, migrations and topography of the fishing grounds (Pálsson, 1989). This discrepancy between fishermen's experience and scientific knowledge is likely based on the disagreement within the research community and the perception of sustainable management of the fishing stocks.

In addition to institutional boundaries, the declining population in the Westfjords is perceived to be a social threat to the industry by 23% of the interviewees. A study by Bjarnason & Thorlindsson (2006) showed that the majority of adolescents living in farming and fishing communities in Iceland expected to live somewhere else in future. The main reason interviewees gave for this expected migration is their perceived limited job opportunities in the rural community, although young adults with a strong community-based identity were more likely to stay (Bjarnason & Thorlindsson, 2006).

5.4 Adaptation

Adaptation and flexibility in the fishing industry range from a change of fishing gear, fishing grounds, use of different kinds of knowledge, diversification of income or new or altered fishing regulations (West & Hovelsrud, 2010). Most of these listed adaptation measures corresponded to adaptation measures adopted in the Westfjords' fishing industry, including investment in knowledge and gear (36%), development of the tourism industry in combination with the fishing industry (5%) and development of more valuable niche products, such as fresh or smoked fish products (9%).

However, adaptations to changes in fish stock migration and new species were also seen within the context of a governance system in which the quota system and regulations are restricted. Because the TACs in Iceland are estimated on a yearly basis on the advice of the Icelandic MRI, the current fisheries management system allows flexibility and adaptive capacity. Fisheries management is based on these permanent harvest shares in the form of ITQs, and is therefore forward-looking to changes in the availability of fish (ACIA, 2004). Because the Icelandic demersal fisheries is a mixed-stock fisheries, the ITQs or TAC-shares are denominated in cod equivalent terms, as cod is the most important species in the Icelandic fisheries (Christensen, et al., 2009). This provides flexibility to the vessels, because they can subtract bycatch from their quota as fixed values up to 5% of the total value of the demersal quota. Excess of catch of each demersal species may not exceed 2% of the total value of the demersal quota (The Fisheries Management Act, article 8, No.116 2006).

Still, investigation of interviewees perspectives in the current study showed fishermen concerns regarding the MRI's annual adjusted quota recommendations. Interviewees perceived that large changes in species availability can happen overnight and the possibilities to respond to these changes are limited (23%). In addition, interviewees perceived that it is hard to obtain quota for new species which migrate into the local fishing grounds because of the high quota prices (9%). Economic benefits or disadvantages of renting or buying quota depend to a great extent on the market value of TAC-share. Quota values of the Icelandic fisheries have risen quite dramatically since 1984 (Arnason, 2008).

Fishing vessels are sometimes forced to go to different fishing grounds, further offshore, for different reasons. The target species could have moved away, or the increased abundance of non-target species makes it hard to catch certain target species. For example, the increased density of haddock makes it hard for bottom longliners to target cod without catching haddock (23%). Some fishermen were used to extensive travelling to fishing grounds. This may be lower-cost adaptation strategy, particularly because switching to new species can be expensive and often requires new knowledge, skills and gear. In addition, switching to new species may be difficult given existing landing, processing facilities and infrastructures. However, for smaller vessels which usually do not travel extensively, this might be a costly operation, and may force them to switch to different species or leave the fisheries industry entirely (Pinsky & Fogarty, 2012).

5.5 Use of local knowledge in scientific studies: management recommendations

If fishery productivity and stock distribution in Iceland changes dramatically, distribution of costs and benefits among different stakeholders, on a local, national and international scale will eventually happen. The increased abundance of mackerel in the Icelandic EEZ for example has created around 1000 new jobs in Iceland and the export of mackerel was worth around 25 billion Iceland kronor in 2011 (Ministry of Fisheries and Agriculture, 2011). If local fishing communities want to adapt to changes in marine resource availability, adaptation strategies are often connected to institutional rules, which can be beyond the stakeholder’s direct influence and control. Through a holistic management approach, local fishing communities can be directly involved in the monitoring and management process of resources. Their knowledge can be connected with scientific findings, and increased participation in the identification and evaluation of management strategies will lead to an increased support of management decisions (Casimirri, 2003).

Spatial and temporal scales at which fishers and fisheries scientists observe and study marine ecosystems differ significantly (Nenadovic, 2012). Resource users are likely to develop a small-scale understanding of population, while scientific management typically aims at a larger scale estimate of the entire stock (Neis, et al., 1996). This leads to different perceptions of the status of a stock: resource users are unlikely to agree to a stock status statement if they have different experiences based on a smaller scale. Therefore, local and larger scale perceptions may indicate the need of assessments based at different spatial scales and multiple methodologies (Neis, et al., 1996). It is recommended to the research institutes to focus on the contradicting findings between the two types of data. Conflicting information in future research could be handled by questioning subsequent interviewees specifically on the conflicting subject in an attempt to clear up potential inconsistencies. This could potentially lead to new insights and greater understanding towards both knowledge bases.

One should wonder how much knowledge people working in the fishing industry have when it comes to scientific methodologies and processes involved in managing the fisheries resource. It is recommended to examine the knowledge and understanding of the fishing industry with regards to the IGFS conducted by the MRI. If knowledge of the fish industry about methodology of the IGFS turns out to be limited, it is recommended to inform individuals working in the fishing industry about scientific practices of the MRI. This will potentially increase understanding and create support towards the methodology of the MRI.

While conducting the interviews, it became clear that a well-structured interviewing method is of great importance to interpret and compare results between different participants and prevent from responses including speculations instead of observations. Further investigations are recommended to use a clear questioning format, in order to save time and make the analysis easier. This includes the development of a standardized annual survey addressed to all Icelandic fishermen, containing questions about the main perceptional change in species abundance, distribution and behavior over that particular year.

6 Main conclusions

The current study provides insight into the perception of changes in fish species distribution and abundance of individuals working in the fishing industry. The main question posed in this research was to identify the major spatial and distributional changes of fish species in the Westfjords, over the past two decades 1992-2012, identified by individuals working in the fishing industry. In addition, this investigation aimed to analyze the sensitivity of the local fishing industry to these changes, as well as to identify the local adaptation strategies to these changes.

The investigation indicates that individuals working in the local fishing industry possessed specific, albeit limited knowledge, regarding fish species abundance and distribution in the Westfjords of Iceland. Ten species were perceived to have increased in abundance, three species were reported to have decreased in abundance and six species were reported to have shifted their habitat. Nine perceptions were compared to findings of scientific data. Five out of nine of the interviewees' perceptions potentially shows a correspondence with the scientific data; four at a minimal or marginal level and one at a high level.

The majority of the interviewees did not consider themselves as being particularly vulnerable to changes in the environment. The main factors identified by interviewees as influencing the adaptive capacity and strategies of the local fishing industry included the depopulation of the area, as well as changes in national fishery politics and regulations, which in turn have implications for the resilience of the fishing industry.

Possible adaptation strategies to fish stock alterations derived from interviewees included a shift to more valuable processed products, a shift to different fishing grounds and investment in knowledge and gear, in order to adapt to potential new commercial species.

This studies shows that local knowledge is highly complex: data is not standardized in terms of spatial, temporal or territorial coverage. However, data gathered interviewing individuals working in the fishing industry, combined with scientific data can contribute to (1) specific knowledge of species abundance, distribution and behavior at the finer geographical scales; (2) the detection of short-term changes; (3) the opportunity to not only discuss observations, but also theories regarding decision-making and management goals, which can be a contribution to fisheries management to draw upon these concerns.

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Appendix 1. Interview guide

Fish species occurrence and distribution in the Westfjords of Iceland

Thank you for taking the time to complete this survey. The results of this survey will contribute to my master's thesis research at the University Centre of the Westfjords, Ísafjörður. The central focus of this research is on the changes in fish species distribution in the Westfjords over the past 20 years. This survey should only take about 15 minutes of your time, and your answers will be processed anonymously.

Clasina Jansen
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Part 1: background questions

1. Where do you live?
2. Where do you originate from?
3. What is your position on the vessel?
4. Are you self employed?
5. Where do you land your catch?
6. How long have you been working in the fishing industry for?
7. What type of registered vessel do you mainly work on?
8. What kind of fishing techniques/ gear(s) do you normally use during fishing activities?
9. What are your main target species and associated bycatch species?
10. Please estimate your total annual landing size (tonnage) in 2011:
11. Where is your main fishing ground located?

Part 2: Observed changes in fish species occurrence and distribution over time

12. Did the landing size of your main target species increase or decrease over the past 20 years?
13. What kind of changes, if any, did you notice in fish species abundance and distribution over the past 20 years? (species list)
14. What do you consider as the most probable cause for changes in fish species distribution?

Part 3 - Perceived sensitivity of the industry to variations in fish species occurrence and distribution over time

15. Would you consider the fishing industry to be vulnerable to changes in fish species abundance and distribution?

16. What do you currently consider to be a threat to the fishing industry in the Westfjords? E.g. changes in policies/ environment etc.

Part 4 – Adaptation

17. Do you consider the current way of fisheries management to be limiting for the fishing industry to adapt to changes in fish species abundance? If yes, why?

18. Do you know of any national/ local policies or strategies in place to prepare the Icelandic fisheries sector to the variations in fish species abundance?

19. Do you take changes in fish species occurrence and distribution into account when starting the new fishing season?

20. Do you think of or adapt to changes in fish species distribution and abundance? E.g. by change in gear/ fishing grounds etc.

Appendix 2. Assigned codes and categories

Category	Code	Counts
Perceived changes abiotic	Climate is undergoing major changes	1
	Recently a strong stability of the water	1
	Increase in seawater temperature	11
	Warmer summers	7
	Milder winters	6
	No ice-accumulation on vessels	1
	Wind comes more from southwest	1
	Used to be weather from the north	1
	Direction of wind has changed	12
	Stronger wind force	3
	More rain instead of snow	2
	Increase of seawater temperature as cause distribution, abundance and behavior changes	10
Past events	Warming event 1940-1960 same as now	2
	During 1960-1980 water temperature decreased	1
	Used to fish mackerel Arnarfjordur long time ago	1
	Used to be a lot of halibut 1880-1900	1
	Used to be squid 1986-1988	2
Sensitivity of the industry neutral	Variation in temperature has always happened	5
	Changes are challenging but not a threat	1
	Changes in fish stocks not a threat to the industry	14
	No economic benefits or disadvantages to stock changes	1
	Target species respond to changes in the season	3
	Some species will benefit and some species won’t	7
	There is always going to be fish in the sea	7
	Like any other job sometimes favorable and sometimes bad	1
Sensitivity of the industry positive	Change in fish stock gives opportunities	3
	Gear is present in the Westfjords	3
	Factories are present in the Westfjords	3
	Knowledge is present in the Westfjords	3
	Jigging is low in price	1
	Mackerel is an opportunity for business	6
	Monkfish is caught with nets lump suckers	1
	More days to go out fishing	1
Sensitivity of the industry Negative	Current changes in fish stocks is a threat	3
	Decrease lumpfish population through monkfish	5
	Lumpfish market is currently bad	1
	Increase in juvenile fish is bad for shrimp stocks	1
	Mackerel is a scavenger	9
	Increase in temperature is a threat to cod	1
	Increase in fuel costs because of different fishing ground	3
	Mainly threat to deep water species	1
	Haddock closer to shore is negative for trawlers	2
	Market is not asking for big but for small cod	2

	Insufficient equipment to catch and process mackerel	5
Government	Government is not looking ahead enough	1
	Redistribution of quota is politically seen to complicated	4
	LIU goes after own economical benefits	2
	Government does not listen to fisherman	2
	Mention of international conflict ownership of mackerel	7
	Government does not sell mackerel quota to small vessels	1
	EU might be the chance to stop corruption	1
Depopulation	Small towns are dying	1
	Depopulation is a threat to the fishing industry	5
Fisheries management	Quota system limits the mackerel fisheries	1
	Strong need of more groundfish quota Westfjords	1
	Quota for new species in the area too expensive	2
	Renting of quota is unprofitable	5
	Impossible for a beginner to start business	3
	Numbers of quota-owners in the Westfjords has dropped	6
	Westfjords lost access to local fishing resource	9
	Quota is expensive	2
	Quota system is a threat to business	4
	50 families in Iceland own about 80% of the quota	1
	Quota system must be made more flexible and adaptive	6
	Quota system is a efficient system to regulate fishing	6
	Disappearing quota Westfjords is threat	3
	Salaries has been cut down	2
	Decreased haddock quota considered to be tough	5
	Day system might be better for industry	4
MRI	Negative attitude towards practices Hafró	6
	Lack of middle sized haddock according to haddock	7
Speculations	Seawater temperature will decrease again	12
	Temperature increase is likely permanent	3
	Some species might move away	2
	Possible lobster in the area if temperature stays high	1
	Possible squid in the area if temperature stays high	1
	Tuna might come back to the Westfjords	1
	Capelin might move away from the Westfjords	3
Adaptation strategies	Target cod at different fishing grounds to avoid haddock	4
	Jigging to avoid haddock	2
	Jigging to catch mackerel	3
	Investment in new gear to catch mackerel	5
	Fish farming after decline shrimp stock	1
	Focus on niche products	2
	Fishing further out on sea because cod is in deeper waters	5
	Towns adapt through focusing on different sectors	1
Increased Abundance	Increase of tusk	2
	Increase of monkfish	19
	Increase of redfish	2
	Increase of blue ling	2

	Increase in mackerel	17
	Increase of cod	7
	Increase of blue whiting	1
	Increase of haddock	7
	Increase of witch	2
	Increase of whiting	2
	Increase of blue whiting	1
	Increase of ling	6
	Increase of juvenile fish species in the fjords	2
	Increase of ribbon fish	1
	Increase of shrimp over 2011	2
	Increase of juvenile fish in the fjords	1
Decreased abundance	Amount of jellyfish decreased	1
	Decrease of shellfish	4
	No significant changes in haddock' abundance	2
	Decrease of sandeel	3
	Decrease of shrimp over study period	4
	Decrease in haddock	1
	Increase in temperature makes scallop move away	2
	Decrease in big skate	1
	Decrease in capelin	4
Distribution	Catfish is staying longer in the fjords	1
	Catfish is closer to mainland	3
	Haddock is staying all year long	1
	Haddock is closer to the mainland	5
	Cod is moving more north of the mainland	6
	Cod deeper in water column	5
	Shrimps are now deeper in water column	4
	Shrimp more north of mainland	4
	Monkfish migrates closer to shore	2
	Ling migrates closer to shore	3
	Tusk migrates closer to shore	1
	Fish is moving more and more north	2
	Juvenile fish are staying longer in the fjords	1
Behavior	Cod lies down if seawater temperature is too warm	1
	Cod does not bite hooks if environment is too warm	2
	Live bait more dependent on temperatures	1
	Haddock is getting smaller	2
	Size of cod is increasing	2
	Fish is staying year around in the fjords	1

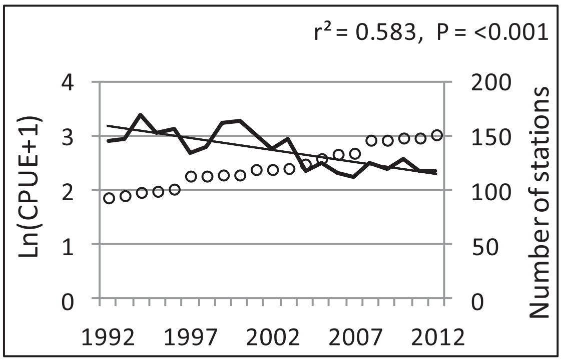
Appendix 3. Population sample

	Gender	Town of employment	Origin	Employment status
Respondent A	M	Suðureyri	Suðureyri	Works for fish factory
Respondent B	M	Ísafjörður	Ísafjörður	Works for fish factory
Respondent C	M	Bíldudalur	Bíldudalur	Self-employed
Respondent D	M	Bolungarvík	Bolungarvík	Works for fish industry
Respondent E	M	Patreksfjörður	Patreksfjörður	Self-employed
Respondent F	M	Bolungarvík	Bolungarvík	Self-employed
Respondent G	M	Ísafjörður	Suðureyri	Self-employed
Respondent I	M	Bíldudalur	Bíldudalur	Self-employed
Respondent J	M	Súðavík	Súðavík	Self-employed
Respondent K	M	Bolungarvík	Bolungarvík	Self-employed
Respondent L	M	Ísafjörður	Ísafjörður	Self-employed
Respondent M	M	Suðureyri	South of Iceland	Works for fish factory
Respondent N	M	Ísafjörður	Patreksfjörður	Works for fish factory
Respondent O	M	Þingeyri		Self-employed
Respondent P	M	Þingeyri		Self-employed
Respondent Q	M	Þingeyri		Fishing, processing and sales company
Respondent R	M	Patreksfjörður	Patreksfjörður	Self-employed
Respondent S	M	Ísafjörður	Ísafjörður	Shrimp processing plant
Respondent T	M	Ísafjörður	Flateyri	Self-employed
Respondent U	M	Hnifsdalur		Fish processing plant
Respondent V	M	Ísafjörður	Ísafjörður	International fish exports company
Respondent W	M	Ísafjörður	Ísafjörður	Fish and seashop

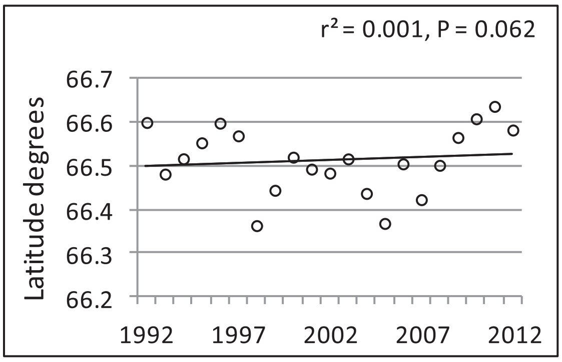
	Position in industry	Experience in industry	Vessel type	Vessel size	Total catch 2011
Respondent A	Fisherman	3 years	BL	18 GT	325 tonnes
Respondent B	Second engineer	6 years	BT	< 1000 GT	5000 tonnes
Respondent C	Skipper	22 years	ST DS	11-24 GT	100 tonnes
Respondent D	Skipper	15 years	BL	6-10 GT	1700 tonnes
Respondent E	Skipper	20 years	HL BL GN	6 GT 11-25 GT	180 tonnes
Respondent F	Skipper	22 years	BL	11-25 GT	1550 tonnes
Respondent G	Skipper	25 years	BT	11-25 GT	Unknown
Respondent I	Skipper	25 years	ST DS	34 GT	60 tonnes shrimp 10 tonnes cod
Respondent J	Skipper	40 years	ST J	6 GT 6 GT	300 tonnes combined
Respondent K	Skipper	16 years	BL	11-24 GT	200 tonnes
Respondent L	Skipper	20 years	BL DS	10 GT	300 tonnes
Respondent M	Skipper	15 years	BL	18 GT	325 tonnes
Respondent N	Skipper	40 years	BT	< 1000 GT	3000 tonnes
Respondent O	Skipper	52 years	BL J	10 GT	7-8 tonnes
Respondent P	Skipper	47 years	BL	10 GT	7-8 tonnes
Respondent Q	Development manager		-	-	-
Respondent R	Skipper	25 years	BL	26-100 GT	
Respondent S	Quality manager	Over 20 years	-	-	-
Respondent T	Skipper	20 years	BL	8 GT	220 tonnes
Respondent U	Production manager	40 years	-	-	-
Respondent V			-	-	-
Respondent W	Owner	34 years	-	-	-

Appendix 4. Cod (*Gadus morhua)*

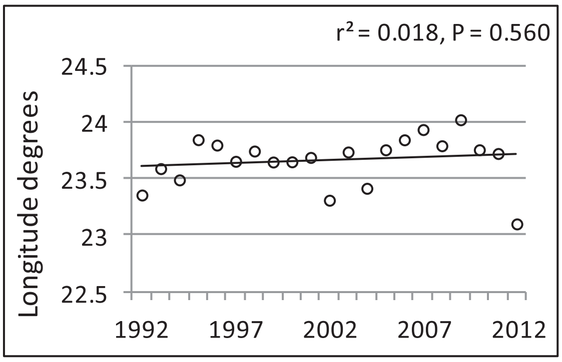
a) Average CPUE per station



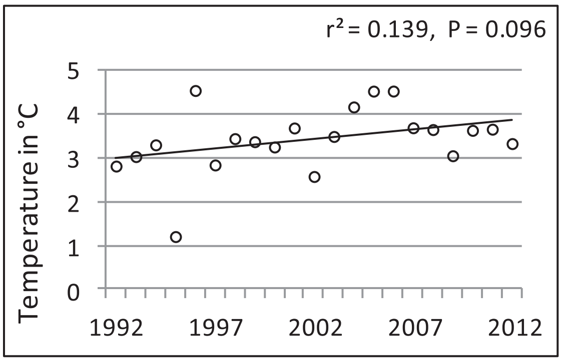
b) Average latitude



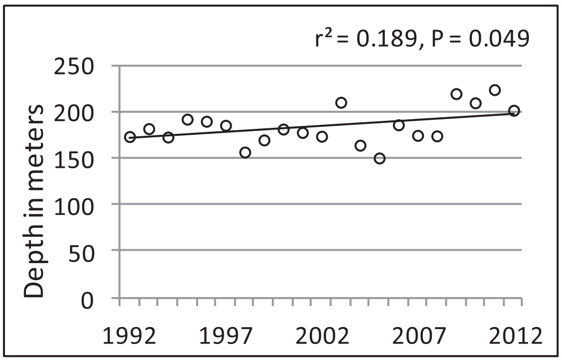
c) Average longitude



d) Average temperature

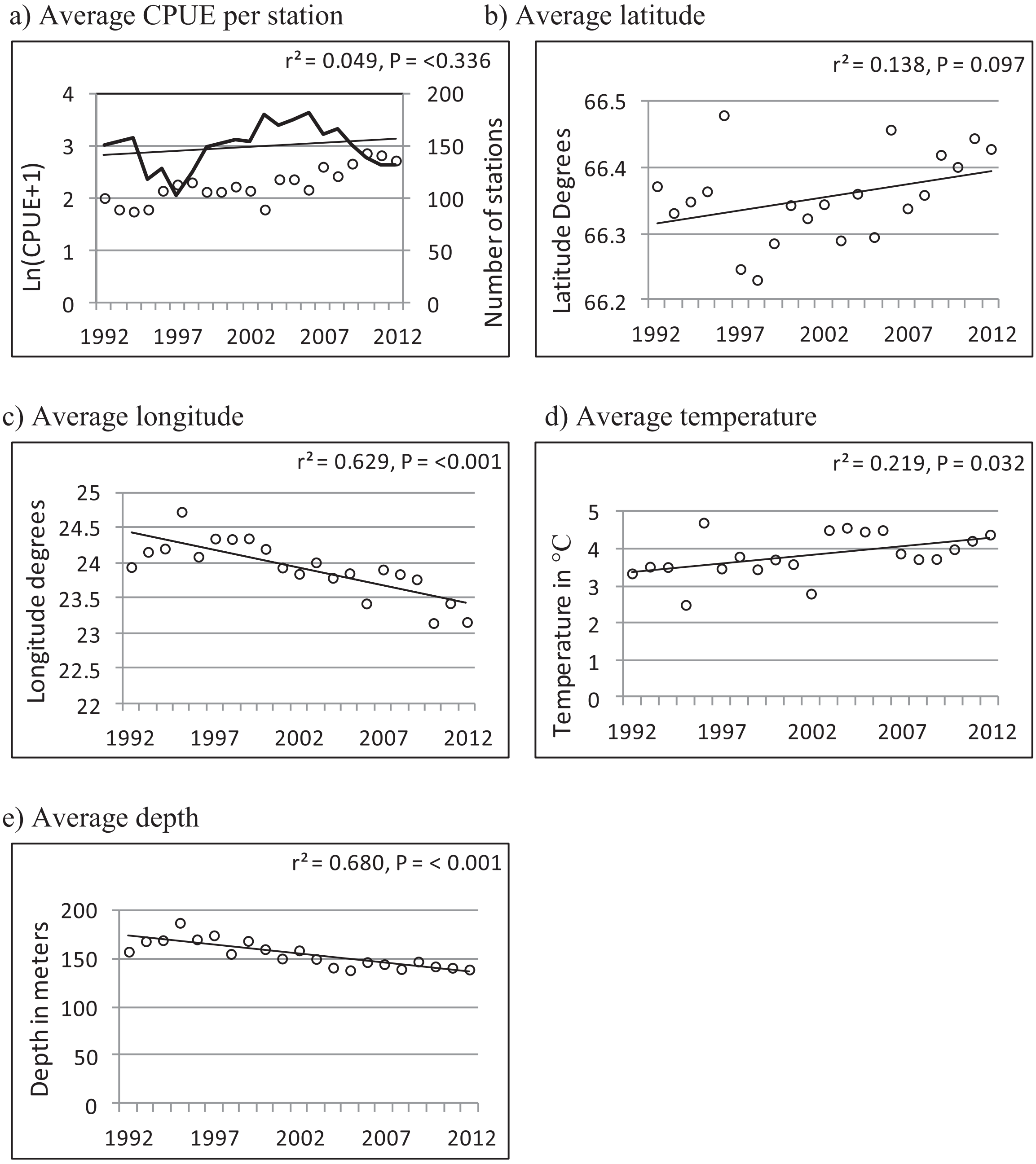


e) Average depth



Appendix 4. (a) Linear model indicating the abundance trend for cod between 1992 and 2012. Thick black line represents the ln(CPUE+1) trend, left y-axis, dots represent the number of stations the given species was caught in any year, right y-axis. X-axis represents the time. Results for linear model indicate that the population has decreased over the study period ($P = <0.001$, $r^2 = 0.583$). No significant geographic changes were found over the study period as linear models (b – c) demonstrate. (d) Linear model indicates that mean bottom temperature did not change. (e) Mean depth preference increased over the study period, as indicated by the linear model ($P = 0.049$, $r^2 = 0 .189$).

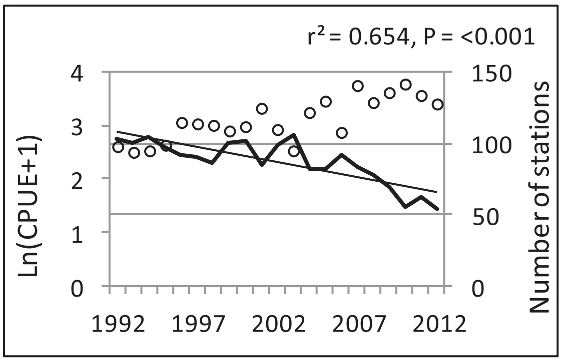
Appendix 5. Haddock (*Melanogrammus aeglefinus*)



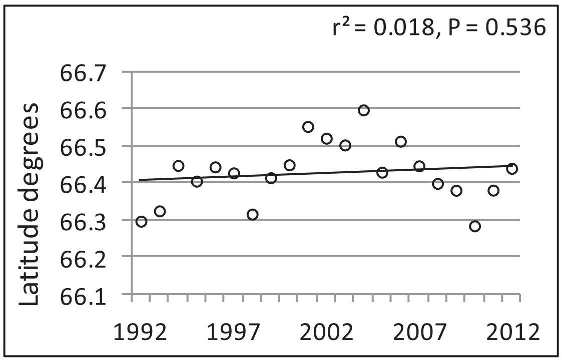
Appendix 5. (a) Linear model indicating the abundance trend for haddock between 1992 and 2012. Thick black line represents the ln(CPUE+1) trend, left y-axis, dots represent the number of stations the given species was caught in any year, right y-axis. X-axis represents the time. Results for linear model indicate no significant changes in population abundance over the study period. (b) No significant changes in latitudinal distribution were found. (c) The geographic centre of the catch moved east ($P = <0.001$, $r^2 = 0.629$). (d) Linear model indicates that mean bottom temperature increased ($P = 0.219$, $r^2 = 0.032$). (e) Mean depth preference decreased over the study period, as indicated by the linear model ($P = <0.001$, $r^2 = .680$).

Appendix 6. Catfish (*Anarhichas lupus*)

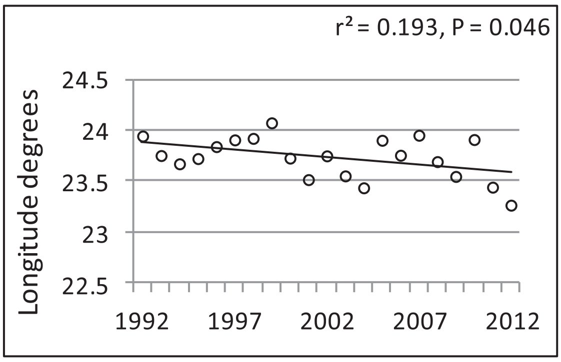
a) Average CPUE per station



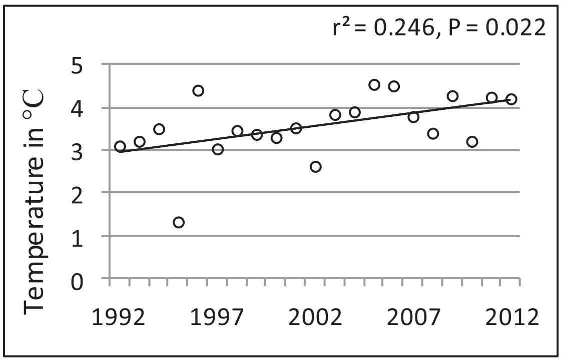
b) Average latitude



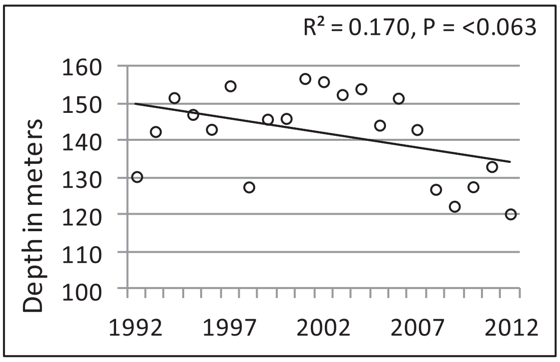
c) Average longitude



d) Average temperature



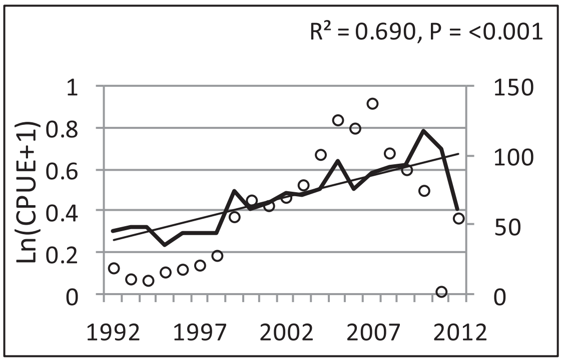
e) Average depth



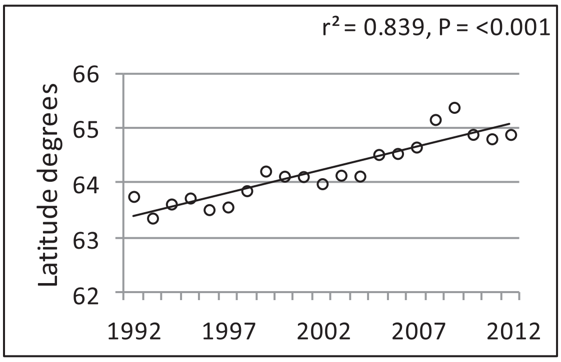
Appendix 6. (a) Linear model indicating the abundance trend for catfish between 1992 and 2012. Thick black line represents the ln(CPUE+1) trend, left y-axis, dots represent the number of stations the given species was caught in any year, right y-axis. X-axis represents the time. Results for linear model indicate a significant decrease in population abundance over the study period ($P = <0.001$, $r^2 = 0.654$). (b) No significant changes in latitudinal distribution were found. (c) The geographic centre of the catch east ($P = 0.046$, $r^2 = 0.139$). (d) Linear model indicates that mean bottom temperature increased ($P = 0.022$, $r^2 = 0.246$). (e) Mean depth preference did not change over the study period, as indicated by the linear model.

Appendix 7. Monkfish (*Lophius piscatorius*)

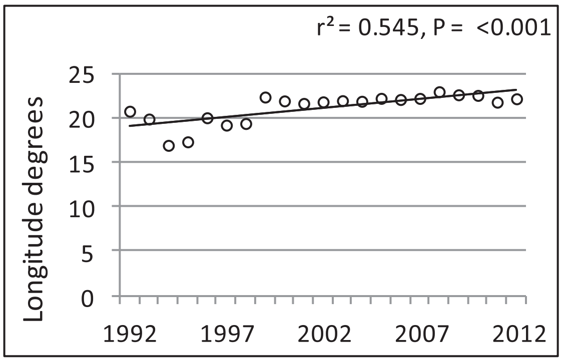
a) Average CPUE per station



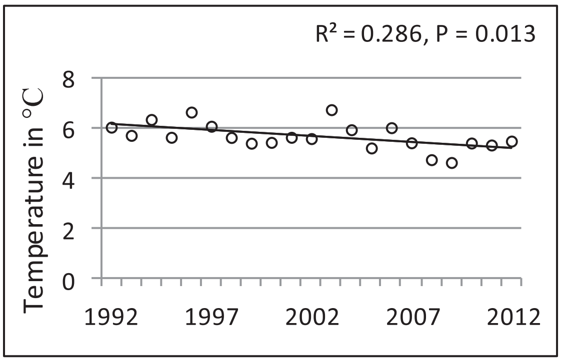
b) Average latitude



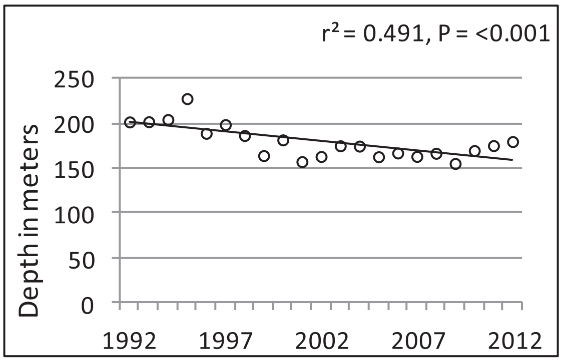
c) Average longitude



d) Average temperature



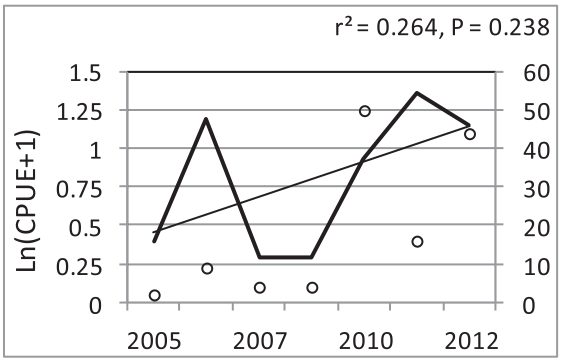
e) Average depth



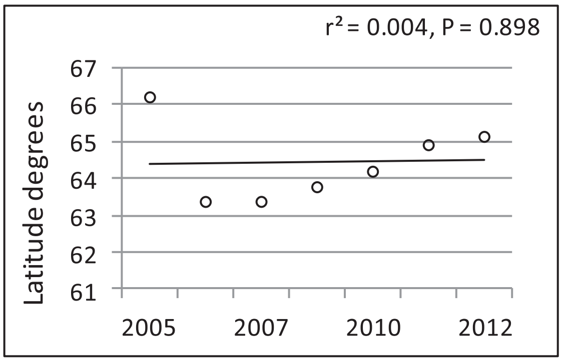
Appendix 7. (a) Linear model indicating the abundance trend for monkfish between 1992 and 2012. Thick black line represents the ln(CPUE+1) trend, left y-axis, dots represent the number of stations the given species was caught in any year, right y-axis. X-axis represents the time. Results for linear model indicate a significant increase in population abundance over the study period ($P = <0.001$, $r^2 = 0.690$). (b) The mean latitude of the species moved north ($P = <0.001$, $r^2 = 0.839$) and the mean longitude of the species shifted west (c) ($P = <0.001$, $r^2 = 0.545$). (d) Linear model indicates that mean bottom temperature increased ($P = 0.013$, $r^2 = 0.286$). (e) Mean depth preference decreased over the study period, as indicated by the linear model ($P = <0.001$, $r^2 = 0.491$).

Appendix 8. Mackerel (*Scomber scombrus*)

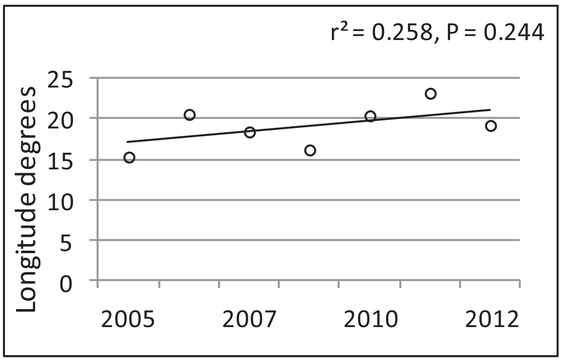
a) Average CPUE per station



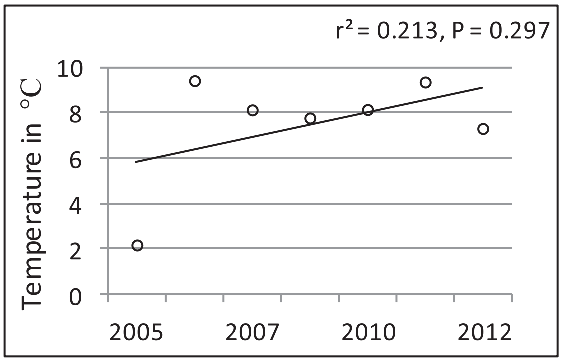
b) Average latitude



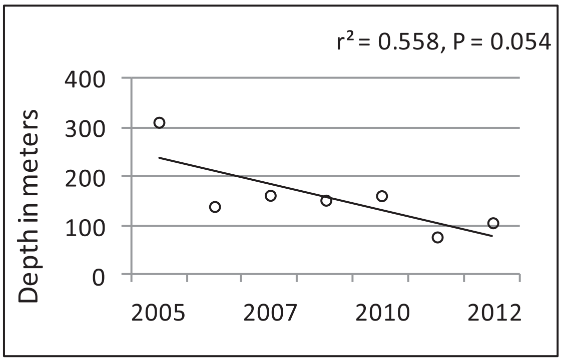
c) Average longitude



d) Average temperature



e) Average depth



Appendix 8. (a) Linear model indicating the abundance trend for mackerel between 2005 and 2012. Thick black line represents the ln(CPUE+1) trend, left y-axis, dots represent the number of stations the given species was caught in any year, right y-axis. X-axis represents the time. Results for linear model indicate that the population showed no significant changes over the study period. Mean latitude (b) and longitude (c) as well as average temperature (d) and average depth (e) of mackerel did not show significant changes over the study period as linear models indicate.

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