Master's Thesis

Expansion of *Lophius piscatorius* Distribution in Iceland:

Exploring the Ecological and Economic Viability for Establishing Sustainable Monkfish Fisheries in Northwestern Iceland

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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

Global climate change has had profound impacts on marine ecosystems by altering physical parameters such as: ocean temperature; salinity; and hydrographic features, which largely govern species richness and distribution of fish populations. In Iceland, climate change has induced northwest expansion of monkfish (*Lophius piscatorius*) distribution; enhancing unintended consequences which affect fisheries management under the ITQ system. This study examined the impacts of three broadly-defined regions (Northwest region, South region, and East region) collectively and individually by its constituent ports on annual monkfish landings from 1999-2012, proportion of exclusively caught versus by-caught monkfish from 1999-2012, and trends in fishing company ownership from 2002-2012. It analyzed weaknesses in monkfish management and the ITQ system while providing amendments that resolve contemporary issues marginalizing fishing-dependent communities. The study sought to provide evidence supporting the need to establish monkfish fisheries in the northwest region of Iceland. Since 1999, the South region has accounted for 47.2% (12,134 t) of monkfish landings in Iceland, while the Northwest region has accounted for 41.3% (10,607 t) of total monkfish landings. In the same time period, 42.9% of South region landings were identified as by-catch in the lumpfish season, while only 33.1% of Northwest region landings were caught as by-catch. Since 2008, the Northwest region has demonstrated greater contribution to annual monkfish landings than the South region with a 359% increase in average annual monkfish catch per port and 357.1% increase in regional contribution to annual average monkfish catch. This study indicates tremendous growth in both overall and port landings for the Northwest region; however, fishing company ownership has remained low and stagnant. Improvements to monkfish management include resolving information gaps; application of population dynamic modeling; and gear modifications. Recommendations for the amendment of the ITQ system are posited: cost recovery scheme; resource rental strategy; and quota recovery and re-distribution in support of the establishment of owned and operated monkfish fisheries in the Northwest region of Iceland.

This thesis is dedicated to my Dad, Mom, family & friends, who have supported and motivated me along the way.

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1 Introduction

1.1 The effects of climate change on marine environments

Global climate change is having a profound effect on the dynamics of marine ecosystems and species distribution (Pearson & Dawson, 2003). Common abiotic symptoms of marine ecosystems exacerbated by climate change include: the warming of seawater; acidification of seawater; variability in salinity; and changes in coastal current and sedimentation processes; (Gelpke et al, 2010; Anadon et al, 2007; Kennedy et al, 2002). Paralleling climate change induced impacts on the sea; marine environments, in which species richness of fish and invertebrate populations are largely dictated by temperature; salinity; depth; and hydrographic features, are greatly affected (Brander et al, 2003; Rose, 2005). Consequently, fish species have responded to warming ocean waters by modifying their distributional ranges according to site-specific ocean temperature conditions, largely latitudinal shifts in the distribution ranges of fish species in response to warming and cooling ocean water. Northward shifts in the distribution of commercial and non-commercial fish populations and the relative increase of warm water species interacting with cold water species in regions of overlapping distributional ranges is evident in the eastern part of the North Atlantic (Brander et al, 2003). Southward shifts in Atlantic fish species is related to specific local hydrographic features, while pelagic fish species in Australia are extending their distribution range farther south (Brander et al, 2003; Fisheries Research & Development Corporation, 2012). As climatic barriers to species invasion decrease, there is greater competition for food supply, resources, and habitat (Chen, 2008). Asymmetrical distributional patterns are evident with non-native species from lower latitudes spreading faster than resident species at higher latitudes moving poleward (Walther et al, 2002). The variability in the rate of shifting distributional ranges permits greater species richness for non-native species and alters community composition.

1.2 The effects of climate change on the Icelandic marine ecosystem

The change in fish species distribution in Icelandic waters corresponds with the gradual increase in sea temperature and salinity since the mid 1990s (ICES, 2007; Astthorsson et al, 2007). Monkfish in Iceland are one of few species to show the greatest distribution extension and increase in abundance in association with warming waters. Of late, monkfish have increased in abundance and extended their distribution into the entire west coast and northern shelf; whereas preceding 1985, monkfish were typically found in deeper waters off Iceland's southern coasts (Astthorsson et al. 2007).

Monkfish, or *Lophius piscatorius,* is distributed from the south-western Barents Sea to the Strait of Gibraltar (Fishbase, 2012). The distribution range extends into the Mediterranean and Black Sea, but predominately in regions north of latitude 55^{o}N (Hislop et al, 2001). Marine fisheries are affected, largely in terms of the effects of fish recruitment; distribution and growth; condition and survival of adults, by fluctuations in climate and oceanography (Tian et al, 2004). Iceland's unique hydrographic features have accelerated the alteration of the distributional range for monkfish. The current warming of ocean waters is augmenting the spatial distribution and abundance of monkfish in Iceland's waters (Solmundsson et al, 2007). While the stock size of monkfish has been increasing since 1998, the species distribution has extended along the continental shelf off Iceland's west coast (Solmundsson et al, 2007). It is believed that a part of the monkfish stock within Icelandic waters comes by way of larval drift or active migration of larger fish (Solmundsson et al, 2007). The pelagic larval stage of monkfish permits voluminous passive drift between Shetland and Iceland (Laurenson et al, 2008). However, according to the Icelandic groundfish survey (IceGFS), since 1998 local recruitment contributes more to the stock than possible migrations from other areas (Solmundsson et al, 2007). Improved recruitment of monkfish has led to a rapid increase in the stock biomass index (Solmundsson et al, 2007). Since 2003, monkfish have been found south and west of Iceland and throughout the north (Solmundsson et al, 2007). Until 1998, monkfish was entirely caught as by-catch in the fisheries for lobster and various groundfish species (Solmundsson et al, 2007). By 2000, commercial fishing directed at monkfish had begun, using footrope trawls and large-meshed gillnets (Hafrannsoknastofnun, 2007).

Monkfish has become a valuable commodity with markets in the United Kingdom, Spain, and France as some of the largest importers of the new luxury good. Therefore, this species has the potential for great economic benefits while supplementing Iceland's current fisheries operations.

1.3 Aims of this study

The purpose of this study is to evaluate the ecological and economic viability of developing new monkfish fisheries based in Iceland, namely the Westfjords and the northwestern region. The purpose is to identify the current trends and data (landings and ownership) in regional and port productivity, effectiveness of gear types, and the management plan in the fishery as evidence for the recent development in the Northwest region which exceeds national standards and warrants consideration for newly-established monkfish fisheries. It also determines if it is possible to actively enhance the economic value of this new resource for the Westfjords and marginalized fishing communities. The means and feasibility of changing the commercial fishery for monkfish in newly inhabited areas, from being primarily utilizing by-catch from other fisheries into a full-scale monkfish fishery, will be of primary focus. The study analyzes and provides amendments to contemporary legislation and current operations to mediate the development of new monkfish fisheries while maintaining the biodiversity and sustainability of monkfish populations. This study investigates changes to traditional monkfish management in Iceland that will permit a sustainable and equitable monkfish fishery in northwestern Iceland.

The research questions addressed in this study are: how have the dynamics in regional monkfish productivity changed over time in Iceland?; How has the proportion of regional monkfish landing been distributed between the exclusive monkfish season and by-catch season over time in Iceland?; How has ownership of fishing companies and regional affiliation been affected by changing regional productivity over time in Iceland?; and how statistically significant are differences for regional monkfish contribution over time in Iceland?

In order to determine the viability of the potential monkfish fisheries, many factors need to be addressed. This includes: identifying ecological changes in areas invaded; species diet; and population dynamics. The questions addressed in the study include:

- How has monkfish catch been increasing in the Westfjords?
- What changes to the ITQ system must be recognized to enable growth and development in the Westfjords?
- What future research will be imperative to support the establishment of Westfjords monkfish fisheries?

- How has the economic importance of monkfish been valued in different areas of Iceland over time?
- How can data collection methods be improved and implemented?
- How has monkfish fishery management been conducted differently internationally and what innovations can be integrated in the Icelandic fishery?
- Should monkfish be protected given they may deplete other commercial species stocks?
- What information gaps need to be addressed?

This study organizes Icelandic fishing ports into three distinct regions: Northwest region; South region; and East region while utilizing meta-analytic techniques to explore regional landing data; proportion of regional exclusively caught versus by-caught monkfish; and regional affiliation of fishing companies over time. Monkfish landing data is retrieved from Fiskistofa. Furthermore, it assesses the statistical significance of regional differences in productivity. This study utilizes experimental and case studies to compare the effectiveness of Iceland's current employment of gear types in the fisheries and its stock assessment capabilities. Finally, this study highlights problems in the Individual Transferable Quota (ITQ) system and amendments that rectify and enable the establishment of monkfish fisheries in the Westfjords.

The delimitations of the study include the lack of location data for monkfish catches that can reveal patterns for monkfish distribution and illicit stronger support to establish monkfish fisheries in the Westfjords. The lack of sex ratio data limits accurate stock assessments and biomass index estimation that are significant for modeling regional population dynamics and determining regional efficiency and effectiveness.

2 Theoretical Overview

2.1 Climate change

Marine ecosystems are vital components of the global ecosystem in terms of biodiversity and ecological productivity and provide many essential services for humans including: water for drinking and irrigation; and habitats for commercially important fisheries (Poff et al, 2002). Marine ecosystems are threatened by land-use change, environmental pollution, water diversion, and increasingly by the effects of global climate change (Poff et al, 2002). Impacts of anthropogenic-climate change include: diminishing ocean productivity, alterations to food web dynamics, reduced abundance of habitat-forming species, shifting species distribution, and higher incidence of disease (Hoegh-Guldberg & Bruno, 2010). Moreover, climate change affects the richness, behaviour and physiological responses of fish populations via changes to ocean temperature, low dissolved oxygen and salinity, low pH, changes to hydrographic features, and changes to oceanographic phenomena such as ocean currents (Roessig et al, 2004; Rose, 2005; Alderdice & Forrester, 1971). Sub-optimal environmental conditions can have many effects including decreased foraging, growth, and fecundity, altered metamorphosis; altered endocrine homeostasis and migratory behaviour (Roessig et al, 2004).

The mean global temperature has risen by 0.3-0.4^{O}C in the past 70 years, while the Intergovernmental Panel on Climate Change (IPCC) has predicted a 1-7^{O}C increase in mean global temperature within the next century (Ficke et al, 2007; Williams et al, 2007; Hansen et al, 2006). Higher latitudes are expected to experience a larger temperature change than tropical and subtropical latitudes, given that the degree of regional temperature change is associated with latitude (Ficke et al, 2007; Hansen et al, 2006). Consequently, fish populations enduring shifting thermal regimes as a result of warming ocean water, may be affected in terms of varying abundance, range expansions or contractions, and extinction (Ficke et al, 2007; Wrona et al, 2006). Coldwater temperatures have acted as a barrier to species adapted to warm-water and prevented the emergence of self-sustaining populations (Poff et al, 2002). According to Cheung et al (2009), climate change, by means of thermal shifting, may cause the local extinction of many species in the sub-polar regions, the tropics, and semi-enclosed seas. Changing thermal regimes can alter ecosystem dynamics and facilitate interactions between established non-native species and native species via competition for dominance/superiority, increased consumption of native prey species by non-native predators, or enhanced effects by non-native parasites on native species (Rahel & Olden, 2008; Wrona et al, 2006). According to Cheung et al (2009), thermal tolerance is lowest for species in high latitudes and greatest for marine species in mid-latitudes, given greater seasonal variability in low versus high latitudes. Species invasion is claimed to be strongest in the Arctic and Southern Ocean, resulting in a species turnover of over 60% of the present biodiversity (Cheung et al, 2009).

Temperature, salinity, and oxygen content in water layers are significant factors for determining the abundance and distribution of fish species (Ojaveer & Kalejs, 2005). Temperature is an important factor for marine species because of its influence on species' physiology, bioenergetics, behaviour, and biogeography; given that aquatic organisms are largely ectothermic (Rahel & Olden, 2008; O'Connor et al, 2007). Lower temperatures increase oxygen solubility in the high latitudes and decrease the oxygen requirements of polar ectothermic organisms (Roessig et al, 2004; Davis, 1975). Dissolved oxygen will likely decrease in local systems, given that dissolved oxygen levels are dependent on several factors including: ambient temperature, salinity, biological oxygen demand, local climate, atmospheric exchange, mixing of water masses (Roessig et al, 2004; Davis, 1975). With trends predicting higher temperatures and greater biological oxygen demand, hypoxic and anoxic conditions may predominate in confined systems (Ficke et al, 2007; Muusze et al, 1998). This makes native species further vulnerable to depleted resources and invasion by novel lower-latitude species. The implication that the rate of food consumption increases with a rise in temperature until equilibrium is reached is important because it can enhance the effect of non-native predators on native prey species in order to establish a sustainable population (Rahel & Olden, 2008). Invasion by non-native species, catalyzed by thermal shifting, can mediate the formation of alternative community composition and may have considerable effect on the native ecosystem (Williams et al, 2007; Wrona et al, 2006).

Initially, it was suggested that climate change-induced ocean warming and desalinization (e.g. via glacier melt, precipitation, and runoff) were driving forces for the ocean's overturning circulation (Toggweiler & Russell, 2008). According to this model, weakened overturning and greater stratification of polar oceans in both hemispheres is to be expected, however there is little evidence to prove this (Toggweiler & Russell, 2008). Accelerated eutrophication may be induced by stratification of the water column and reduce biodiversity by applying greater pressure on bottom-dwelling organisms (Chen, 2008). Furthermore, the stability of water columns in global oceans is strengthened by warming and desalinization (e.g. river runoff) of bottom water via heating of the surface layer (Strass & Nöthig, 1996; Coyle et al, 2008). This in turn has made replenishing oxygen in bottom waters difficult with the inability of oxygenated surface waters to sink (Chen, 2008). It is unclear what to expect from ocean overturning because warmer waters in conjunction with the hydrological cycle will weaken overturning, however stronger winds can negate this effect and maintain ocean overturning (Toggweiller & Russell, 2008). The difficulty with modeling the global overturning circulation is the restriction on resolution that requires long-term integration and many parameterizations for unresolved-scale phenomena (Hasumi, 2002).

The complexity of ecological interactions makes it difficult to ascertain a confident response on the community or ecosystem level from small-scale studies on individuals and populations (Walther et al, 2002). Furthermore, scenarios modeled from the manipulation of individual variables are often non-additive and do not confidently predict responses when incorporating multiple variables. Studies have not investigated the effect of compounding several impacts such as climate-change induced impacts, poorly understood anthropogenic impacts, pollution, overfishing, and coastal degradation when modeling species interactions and responses.

2.2 Oceanographic Features in Iceland

Iceland is located in the mid-Atlantic Ocean and is surrounded by the Irminger Sea to the west, the Iceland Sea to the north, the Norwegian Sea to the east, and the Iceland Basin to the south (Malmberg, 2004). Iceland lies south of the Arctic Circle where the Mid-Atlantic Ridge and Greenland-Scotland Ridge converge (Malmberg, 2004; Astthorsson et al, 2007). The shelf surrounding Iceland follows a 400-500 m depth contour and is the most narrow in the south coast, while being relatively broad (extending for 100-150 km from the coast) off the west, north, and east coasts (Astthorsson et al, 2007). Submarine ridges play a key role in manipulating oceanic circulation and water mass distributions, thereby affecting the biological productivity and distribution of marine species (Astthorsson et al, 2007). Similarly, topography affects biological productivity and community composition by determining the position of fronts separating water masses (Astthorsson et al, 2007).

The southern and western regions of Iceland differ from the north and eastern regions in terms of oceanographic features and faunal makeup (Astthorsson et al, 2007). The southern and western regions are constituted by warm and saline Atlantic water, while the north and eastern region are characterized by Atlantic, Arctic, and Polar water masses that are generally more affected by inter-annual variation (Astthorsson et al, 2007). The Atlantic water south of Iceland ranges from 6 to 11^{O} C governed by seasonal variability and salinity often ranges from 35.0- 35.2 ppt (Astthorsson et al, 2007; Malmberg, 2004). Polar water arriving from the Arctic Ocean is very cold with temperatures below 0^{O}C and relatively fresh water with salinity ranging from 34.5-34.9 ppt (Malmberg, 2004; Astthorsson et al, 2007). The mixture and cooling of differing ratios of Atlantic and Polar waters is largely attributed to the formation of the majority of water masses surrounding Iceland. The East Greenland Current transports Atlantic water from the Norwegian Atlantic Current and subducts beneath the lower density Polar water in addition to carrying sea ice from the Arctic (Astthorsson et al, 2007). The cold and low-salinity East Icelandic Current and the strong bottom currents passing through the Denmark Strait are essential components of the global thermohaline circulation (Astthorsson et al, 2007). Temperature and salinity are often variable depending on the location. The shelf area north of Iceland has been affected by above long-term mean temperatures and salinities in waters south and west of Iceland (Valdimarsson et al, 2012). Iceland's northern shelf shows the most variability because of the Polar Front that distinguishes the difference between Atlantic and Polar water masses (Astthorsson et al, 2007). The Atlantic water mass is typically warm and saline, however in the northern shelf of Iceland, temperature and salinity decreases in the direction of water flow through greater mixing of Polar water and freshwater runoff (Astthorsson et al, 2007). Since 1996, temperatures in the northern shelf of Iceland have increased, signifying the higher intensity of Atlantic water flow versus Polar water (Astthorsson et al, 2007). The south of Iceland faces more stable conditions with input flows largely from warm Atlantic water; however some inter-annual variations have affected temperature and salinity (Astthorsson et al, 2007). Since 1996, there has been a gradual increase in temperature and salinity in both the north and southern regions of Iceland, largely attributed to large-scale change in the North Atlantic Ocean (Astthorsson et al, 2007).

The influence of atmospheric conditions on ocean circulation has been demonstrated by numerous examples, such as the influence of Northerly winds in reducing the volume of Atlantic water passing through the Denmark Strait onto the northern shelf of Iceland (Astthorsson et al, 2007). It was further demonstrated by the relationship between local wind-stress and the volume of freshwater content in the Iceland Sea posing subsequent consequences such as effects on convection and biological productivity, namely temporal effects and the scale of primary production north of Iceland (Astthorsson et al, 2007). The seasonal and inter-annual variations induced by atmospheric pressures have been attributed to local manifestations rather than large-scale atmospheric patterns such as the North Atlantic Oscillation (Astthorsson et al, 2007).

Astthorsson et al (2012) and Valdimarsson et al (2012) illustrate the significance of understanding marine environments for fisheries in Iceland. Performing research, particularly on regions with little known with respect to marine environments and their impacts on monkfish is imperative. Greater understanding of marine environments in the northern region of Iceland can reveal the effects that a rapidly-changing physical environment, as a consequence of climate-induced changes, may have on marine species.

2.3 Impacts of Non-Native Species

The introduction of non-native species is a major threat to biodiversity, ecosystem properties, ecosystem processes, and community structure (Perrings et al, 2000; Levine et al, 2003; Lodge et al, 2006). It can have drastic impacts on local populations causing species loss, changes in distribution, and habitat degradation (Mainka & Howard, 2010). It is argued that climate is the primary constraint on species distribution and ecosystem function in addition to competitive exclusion, predation, species range shifts, extinction risks, biome shifts, altered disturbance regimes, and biogeochemical cycling (Williams et al, 2007; Mooney & Cleland, 2001). Furthermore, species endemic to specific climates risk population decline or extinction when those climates disappear or as temperature and moisture changes drive vegetation poleward (Williams et al, 2007). These impacts manifest in varying degrees depending on the adaptability of native species to changes in local environmental conditions (Thomas et al, 2004).

The spread of non-indigenous species constitutes a major global change that affects biodiversity on a global-scale (Kolar & Lodge, 1999). The potential responses of biological invasions to the drivers of global change (overfishing and collateral impacts; chemical pollution and eutrophication; habitat destruction and fragmentation; and global climate change) in the oceans faces a myriad of possibilities based on differing temporal and spatial scales (Carlton, 2000). Hellman et al (2008) identify three mechanisms that can lead to the establishment of new invasive species: species currently unable to persist in an area because of climatic constraints may be increasingly unable to survive and colonize; arriving species with a greater tolerance for climate may have a greater chance of overcoming biotic constraints on growth and establish persistent populations; and climate change-induced improvements in competitive ability or rate of spread can mediate the transformation of non-native species into invasive species.

The niche overlap theory suggests that maximum tolerable overlap should vary inversely with the intensity of competition (Pianka, 1974). The extent of tolerable niche overlap is more related to the number of competing species and intensity of diffuse competition than degree of environmental variability (Pianka, 1974). Carlton (2000) supports this notion by stating that the difficulty in determining the exact trajectories of biological invasions stems from the relation of broad-scale environmental changes to the rate and diversity of invasions. Carlton (2000) identifies four phenomena: changes to dispersal vector; changes in donor region; new donor regions becoming available; and changes in recipient region that creates heterogeneous processes which may directly alter the diversity, rate, and number of inoculations of potentially invasive species.

Parker et al (1999) state that the total impact of a non-native species on a community or ecosystem can be calculated by the product of its spatial extent (the size of the range occupied by the non-native species); average abundance within the range; and per capita (or per-unit biomass) effect. The size of the target native population or the scarcity of native resources, which is affected by climate change, influences the magnitude of impact non-native species project (Hellmann et al, 2008; Parker et al, 1999).

There is limited literature available that addresses how climate change alters range, abundance, and per capita effect (i.e. non-native species impact) (Hellmann et al, 2008). Furthermore, the breadth of information addressing species invasions does not extend specifically to examples in Iceland. The availability of literature pertaining to the effects of non-native species, specifically monkfish, on Icelandic fish populations, ecosystems, and marine environments is limited.

2.4 Monkfish (*Lophius piscatorius)*

The genus *Lophius* descended from a common ancestor of *Lophius*, a monotypic genus distributed to the western Pacific and Indian Ocean, by the closure of the Tethys Sea (Farina et al, 2008). Palaeo-oceanographic events in the Mediterranean Sea permitted the emergence of European species, *Lophius piscatorius* and *L. budegassa* (Farina et al, 2008).

In the Shetland Isles, there is a gradual shift towards mainly larger and older fish with increasing depths (Laurenson et al, 2001). Normally, age estimation is determined through examination of the first ray of the dorsal fin sections (*illicia),* followed by vertebrates, and otoliths while applying the von Bertalanffy growth model (Duarte et al, 1997). Variations in obtained age-approximations can be explained by the existence of geographical differences in growth rate or the selection of the structure used to determine lengths-at-age (Laurenson et al., 2005). Age-approximations made using illicia are generally lower than those using otoliths (Laurenson et al., 2005). Regardless of the structure used to approximate age, there has been difficulty in age approximation due to the location of the first annulus and the presence of false annuli (Farina et al, 2008). It has been determined that the first annulus that forms in illicia does not correspond to an annual ring and thereby affects the validity of past interpretations for growth rate estimates (Laurenson et al., 2005). Furthermore, mark-recapture experiments on *L. piscatorius* have determined faster growth rates than those inferred from illicia analysis (Laurenson et al, 2005). Studies on growth primarily using illicia and vertebrae to project a linear relationship between age and total length are not consistent with the von Bertalanffy growth model (Farina et al., 2008). The *L. piscatorius* shows faster growth rates than *L. budegassa* or more southern distributed species (Farina et al., 2008). For *L. piscatorius*, the accuracy in age determination is poor and needs to develop. Standardized growth analysis procedures and techniques need to be developed in order to attest the reliability and comparability of results from different studies. Furthermore, basic datasets are incomplete and need to address more intensively length composition, abundance index, and size distribution of large populations.

In the Shetland Isles, the sex ratio for sampled size-classes indicated that at 58 cm the sex ratio was approximately 1:1, while above this size the ratio of females increase with length (Laurenson et al, 2001). The general trend for mature monkfish capable of spawning within the population appears to be more abundant with increasing depth (Laurenson et al, 2001). However, higher ratios of reproductively active males were found at all depth ranges (Laurenson et al, 2001). Males typically mature at a smaller size. Laurenson et al (2001) demonstrates a strong linear relationship between average length and age of monkfish and depth around Shetland which supports existing data on this relationship by Duarte et al (1997). For *L.* piscatorius, length-at-age increased in a mainly linear pattern until ages 11-15

(Farina et al, 2008; Duarte et al, 2007; Landa et al, 2007). In addition, female monkfish mature at a larger size and older age than males (Farina et al, 2008; Laurenson et al, 2001). This phenomenon helps drive the sex ratio with an increased ratio of large female monkfish as the fish become larger. Females attain greater lengths and age than their male counterparts (Farina et al, 2008). The L_{oo} (asymptotic maximum) for females ranged from 110-160 cm and for males from 68-129 cm, while age estimates were 25 and 21 years, respectively (Farina et al, 2008). Laurenson et al (2001) attributed the small proportion of large, old, mature females in the monkfish population to exploitation from intense, targeted fishing pressure that has reduced the proportion of large and mature individuals in Scotland's monkfish population.

Species of the *Lophius* genus often populate in bathydemersal continental shelves and upper slopes down to depths greater than 1000 m, mainly on sand and gravel substrata (Farina et al, 2008). Within their life histories, eggs and larvae normally reside in the water column and progress to benthic habitats as juveniles and adults (Farina et al, 2008; Hislop et al, 2001). Despite the relatively well-documented life histories of *L. piscatorius*, little is known about the maturation, reproduction, spawning time or location, or the larval phase (Farina et al, 2008).

The genetic sequence of populations is little known causing difficulty in distinguishing independent species of the *Lophius* genus (Farina et al, 2008). The *L. piscatorius* shows limited genetic structure and low genetic variation (Farina et al, 2008). However, *L. piscatorius* was observed having high levels of microsatellite polymorphism from populations in the Cantabrian Sea (Blanco et al, 2006). In contrast, O'Sullivan et al (2006) reported an absence of spatial and temporal genetic differentiation in *L. piscatorius*. The lack of genetic variability between *Lophius* species may indicate unrestricted gene flow over large areas (Farina et al, 2008). Hislop et al (2001) suggest that the unrestricted gene flow is mediated by a broad dispersal capacity via an extensive larval pelagic phase, namely passive transport across substantial distances. In addition, large migrations are not wholly-restricted to mature monkfish. Laurenson et al (2005) documented displacements as far as 876 km, from the Shetland Isles to southeast Iceland, by an immature female. Hislop et al (2000) reported vertical displacements of immature and mature *L. piscatorius* in the Northeast Atlantic, from as deep as the seabed to the near surface. The displacement has been related to spawning or feeding patterns, however the cause is unknown. Three stocks have been defined for *L. piscatorius* because sufficient differences between populations from western and southern European waters have been identified; however, there is no significant genetic disparity to encourage stock separation for *Lophius* species in the North Atlantic (ICES, 2006; Duarte et al, 2004).

Monkfish are classified as opportunistic, non-selective feeders that are typically sit-and-wait predators (Farina et al, 2008). The main predation method is luring prey by raising and moving the illicium (Farina et al, 2008). The *L. piscatorius* exhibit a diet that is mainly size-dependent. The prey size selection has largely been attributed to the size and morphology of the mouth as much as visual or sensory factors (Gordoa & Macpherson, 1990). Small juvenile monkfish comprise a considerable proportion of their diet with the consumption of invertebrates; however, this disproportionate consumption of invertebrates decreases with age (Farina et al, 2008). A wide variety of pelagic and benthic fish prey constitutes the diet of larger juveniles and adults, with larger monkfish typically consuming larger prey (Farina et al, 2008). Moreover, diets are not dependent solely on developmental processes, but also predator size and geographic area (Laurenson & Priede, 2005; Crozier, 1985). Monkfish are ambush feeders and naturally there is a seasonal variation in diet in accordance with the spatio-temporal patterns in prey availability and abundance (Laurenson & Priede, 2005; Crozier, 1985). Norway pout (*Trisopterus esmarkii*) is the main prey species for *L. piscatorius* in northern European waters, while blue whiting (*Micromesistius poutassou*) remains a predominant prey species in southern European waters (Farina et al, 2008). The *L. piscatorius* has demonstrated a greater incidence of feeding activity in the autumn and winter (Farina et al, 2008).

The early development stage requires further research to address questions about the pelagic larval phase, mortality, and the survival of recently settled juveniles.

A significant amount of energy is allotted for reproduction evidenced by the gonad mass of a mature female in spawning state which forms up to 35-50% of total body mass (Armstrong et al, 1992; Yoneda et al, 2001; Walmsley et al, 2005). Long ribbons of gelatinous matrix, inside of which houses mature eggs in separate chambers, comprises the ovarian structure (Armstrong et al, 1992; Alfonso-Dias & Hislop, 1996). The long ribbons, which can be greater than 10 m long, may contain greater than a million eggs in a ripe female before spawning buoyant gelatinous egg masses (Armstrong et al, 1992; Yoneda et al, 2001). Despite fertilization being an external process, observations of the phenomenon in the Atlantic are poorly understood. It has been reported that *L. piscatorius* produces a single batch during the spawning season, which lasts from November to May (Farina et al, 2008).

However, even the timing of spawning period has been contested displaying an array of possible ranges: November-May (Alfonso-Dias & Hislop, 1996); January-June (Duarte et al, 2001); and May-June (Laurenson et al, 2001; Quincoces et al, 1998). It was demonstrated that while eggs and larvae are pelagic, the pelagic phase for *L. piscatorius* lasts for only four months after hatching (Hislop et al, 2001). Little is known about the early life stages.

Further research is required on maturation processes including: the function of the gelatinous veil, spawning behaviour, spawning areas, and fecundity. Much information pertaining to the physiological, genetic, ecological, and abundance of monkfish is incomplete or not understood and requires further research. The abundance of historical datasets with respect to populations or size and composition data is not readily available.

2.5 Monkfish in Iceland

The stock size of monkfish has been increasing since 1998 while extending its distributional range to northwestern and northern Iceland (Solmundsson et al., 2007). Icelandic waters above 400 m with temperatures exceeding 5^{O}C has doubled since 1989, facilitating thriving conditions for monkfish which are typically not found in bottom waters with temperatures below 5^{O}C (Solmundsson et al., 2007). The co-occurrence of expanding monkfish populations with rising sea temperature may have been beneficial to juvenile monkfish which are exhibiting greater recruitment and larger year classes since 1998 (Solmundsson et al., 2007). It remains unclear if portions of the Icelandic monkfish stock originate from far distances via passive larval drift or active migration by larger mature monkfish. However, it is understood that since 1998 local recruitment has contributed far greater to the growth of the population than the potential influence of migration (Solmundsson et al., 2007). Small changes in hydrographical conditions can greatly influence distribution and fish community composition as exemplified by the effect of warming waters on monkfish species richness and distribution in Iceland (Solmundsson et al., 2007).

The effect of environmental or climate change on Icelandic fish stocks is not unprecedented. The warm period of the mid 1920s and 1960s saw an increased incidence of cod, capelin, and herring spawning in the north of Iceland (Solmundsson et al., 2007). In addition to affecting spawning locations, environmental change affected the migration patterns and feeding areas of herring by extending it north of Iceland (Solmundsson et al., 2007).

From 1985-1997, monkfish was mainly caught off Iceland's southern coast in low amounts (Solmundsson et al., 2007). Since 2004, there has been an increased amount of monkfish catch in the northwest coast of Iceland and erratic catch amounts on Iceland's northern coast. This supports the trend of increased abundance of mid-latitude species corresponding with the decline of cold-water species in Icelandic waters (Bjornsson & Jonsson, 2004).

The stock biomass index for monkfish has been stable over recent years at approximately 2500 t, with a record high biomass index of 4000 t from 2002-2005 (Solmundsson et al., 2007). From 1985-1997, recruitment of monkfish was very low; however, 1998-2006 saw a higher abundance index as well as a greater proportion of 1 year and 2 year fish (Solmundsson et al., 2007). The progress in recruitment facilitated an increase in stock biomass index.

According to the Icelandic Groundfish Survey (IceGFS), the majority of monkfish catch occurs in waters between 6-9^{O}C, while a minority of the catch occurs in waters below 5^{O}C (Solmundsson et al., 2007). The implication of a net west- and northward drift of eggs and larvae along predominant ocean currents is supported by IceGFS reporting that 1 year monkfish typically have a more westerly and northerly distribution, than older fish (Solmundsson et al., 2007). This is important because it may catalyze the expansion of the monkfish nursery area with the normal westerly distribution of 1 year monkfish (Solmundsson et al., 2007). In addition to the expansion of the monkfish nursery, higher ocean temperatures and greater salinity have provided greater habitat availability in the north. Solmundsson et al (2007) estimates that 100% more habitats have been provided for monkfish in Iceland in comparison with that of 1985-1989.

Research has aimed to gain knowledge of life history, population structure, and effects of monkfish on ecosystems in recently colonized habitats along the west and northern coasts of Iceland (Nebel et al, 2011). Studies have been conducted on monkfish caught as by-catch in lumpfish vessels; effects of new predation pressures by monkfish in northwestern Iceland; and disproportionate sex ratio in monkfish landings (Nebel et al, 2011). The research revealed that lumpfish, *gadidae*, and cod experience significant predation from monkfish, despite their dynamic feeding strategies (Nebel et al, 2011). In addition, it revealed a higher proportion of female monkfish in landings (Nebel et al, 2011).

Although the recent rapid growth in monkfish abundance and distribution in Iceland has largely been attributed for the most part to the effects of climate-induced warming and more saline waters, it remains unclear if the monkfish population growth is the result of secondary effects such as habitat and prey availability (Solmundsson et al., 2007). However, the unavailability of monkfish stock biomass and landing information limits the ability to draw extensive conclusions connecting the two periods.

Historical and current information about Icelandic monkfish abundance and biomass is limited. There is little information about spawning behaviour or location of Icelandic populations of monkfish. There needs to be more research on the impact of monkfish on other commercial species and on the physical, marine environment of Iceland to estimate potential growth rate, and infer direct and indirect effects of monkfish. This will provide more insight into the carrying capacity of Iceland's bio-physical environment and aid future management recommendations.

2.6 Monkfish Management in Iceland

The Icelandic Ministry of Fisheries and Agriculture [MFA] was founded in 2007 and is responsible for fisheries management; research, conservation and utilization of fish stocks, living marine resources of the ocean and seabed, management of areas implicated in resource harvesting; control of conservation and utilization of fish stocks; research and control of production and import of fisheries products; mariculture of marine species; and supporting the research, development, and innovation in the fisheries sector (Ministry of Fisheries and Agriculture, 2012)

Established in 1965, the Marine Research Institute of Iceland (MRI) works under the patronage of the MFA to carry out its directives, namely: to conduct research on Iceland's living resources and marine environment; provide guidance to the government on catch levels and conservation measures; and to raise awareness and inform the government, fishery sector, and public about Iceland's seas and living resources (MRI, 2012a). The MRI provides recommendations for the Total Allowable Catch (TAC) of monkfish based on estimated stock status, but ultimately the Ministry of Fisheries outlines the TAC. Based on the stock survey and CPUE, the monkfish stock has been deemed large, but decreasing (MRI, 2012b). Since 2008, the size of monkfish cohorts has been small, thereby reducing the fishable biomass (MRI, 2012b). This trend will continue into the future if a reduction in catch effort is not imposed. The MRI advised a decrease in fishing pressure in the quota year 2012/2013 for total landings to be 1500 tonnes (MRI, 2012b). In addition to reducing monkfish TAC, the MRI is investigating methods to reduce juvenile by-catch in trawls.

The Directorate of Fisheries (Fiskistofa) is an Icelandic government institution within the jurisdiction of MFA that is responsible for implementing government policies on fisheries management and handling of seafood products; enforcing laws and regulations in fisheries management; monitoring of fishing activities and penalizing transgressions pertaining to illegal catches; and collecting, processing, and publishing fisheries data in collaboration with Statistics Iceland (Directorate of Fisheries, 2012).

In 1976, the extension of the fisheries jurisdiction to 200 miles reduced the impact of foreign fishing fleets on Icelandic fisheries and strengthened the need for management measures to increase Iceland's economic performance (Runolfsson & Arnason, 2003). In 1984, the introduction of the demersal vessel quota system preceded increasing management that resulted in a uniform Individual Transferable Quota (ITQ) system in nearly all fisheries by 1991 (Runolfsson & Arnason, 2003). *The Fisheries Management Act*, a comprehensive ITQ legislation, was enacted in 1990 (Runolfsson & Arnason, 2003). According to the ITQ system, all fisheries are subject to vessel catch quotas which represent shares in TAC (Runolfsson & Arnason, 2003). The quotas are permanent, perfectly divisible, and fairly freely transferable (Runolfsson & Arnason, 2003; Arnason, 2005). The quotas retain an annual fee that maintains enforcement costs (Runolfsson & Arnason, 2003; Arnason, 2005). Initially, quotas were allocated based on catch history of the vessel prior to the implementation of the ITQ system (Arnason, 2005).

In 2001, monkfish landings accounted for the third highest annual landing caught in Icelandic waters, totaling 3200 tonnes (MRI, 2012b). Catch per unit effort (CPUE) has increased steadily in most gear types since 2001 (MRI, 2012a). Landing information from 2011 revealed that 62% of landings were caught in gillnets, while 36% were caught in Danish seine and trawls (MRI, 2012b). This is in distinct contrast with figures ranging from 2001-2010 that indicated approximately half of total landing attributed to gillnet capture (MRI, 2012b). This trend indicates a decrease in CPUE using gillnets since 2000, when direct targeting of monkfish became common (MRI, 2012b). The recent significant decrease in the proportion of young fish in by-catch, via gears other than gillnets, indicates weaker recruitment for monkfish (MRI, 2012b). When monkfish displayed strong recruitment, by-catch of juvenile fish was abundant as exemplified by the Norway lobster harvesting (MRI, 2012b).

Historically, the south and southeast coast of Iceland were primary fishing grounds for monkfish; however in 2011, 72% of landings came from west of Reykjanes Peninsula, while the south coast boasted only 28% of annual monkfish landings (MRI, 2012b).

2.7 History of the ITQ system

In December, 1983, the Icelandic Parliament passed a Fisheries Management Act according to the Fisheries Assembly resolution to be an experiment detailed within the jurisdiction of the Ministry of Fisheries and to be reviewed following the recovery of the cod stock (Eythorsson, 2000; Runolfsson & Arnason, 1996). Initially, allocation of catch quota was determined by the catch history of each vessel for the prior three years; however, an 'effort quota' that was based on limited days at sea was an alternative option provided for vessel owners inactive in previous years used to determine allocation of quota share (Eythorsson, 2000; Runolfsson & Arnason, 1996). By 1991, the effort quota alternative was suspended due to exploitation of a virtually unrestricted fishing program (Haraldsson, 2008). Initially, the exchange and leasing of quota was freely permitted with the caveat that transfers between parties of different communities required the Ministry's approval in addition to consultation with affected municipalities and workers unions (Eythorsson, 2000). With the enactment of the 1990 Fisheries Management Act, the exchange and leasing of quota was largely free and did not require consultation with the Ministry of Fisheries, affected municipalities, or workers unions. This was an important event because it diminished the ability of municipalities, specifically in the Northwest region, to retain quota rights that might have been central drivers of the economies of small, fishing villages. Eythorsson (2000) describes the change in stakeholder representation during changes in the ITQ system from 1984-1991 from a smaller body of representatives consisting of fisheries administration and the harvesting sector in 1985 to the larger committees consisting of a diverse group of representatives. There was fervent opposition to such radical changes in the traditional framework for labour and employment (Runolfsson & Arnason, 1996). The diversity in stakeholders can largely be attributed to the realization that regulations determined by the Ministry of Fisheries for fisheries management were imminently permanent. The permanence of the allocation of fishing rights would have considerable impact for the economy and development of communities in addition to continued operations for owners in the fisheries sector. An important goal of the ITQ system was to reduce the catch capacity in the fisheries

(Haraldsson & Carey, 2011). Eythorsson (2000) demonstrated that while fishing fleet had greatly reduced since the commencement of the ITQ system, fleet capacity had been steadily increasing owed to the growth in the factory trawler fleet. This was to be expected given that freely transferable quota was equitable for poorly-managed or inefficient vessels that would be bought out by more efficient operations looking towards expansion. The flexibility of quota transfers and the resulting increased efficiency lead to a substantial concentration of quota shares in large, vertically-integrated companies (Haraldsson & Carey, 2011; Eythorsson, 2000).

The confusing nature of the individual transferable quota is fundamental in its exploitation of management loopholes and its regional concentration. In 1990, TAC-shares were permanently allocated as an extension of the primary quota share allocation in 1983, based on historical catch records (Haraldsson & Carey, 2011; Eythorsson, 2000). Under the Fisheries Management Act, fish resources would remain as national property because quota holders could not be granted private property rights of a common good. Despite the jurisprudential argot, permanent allocation of quota increased the vulnerability of coastal communities dependent on fisheries while providing de-facto privatization of a common good to vessel owners (Eythorsson, 2000). Paralleling the anticipated goal of more efficiency with the introduction of the ITQ system, quota was retained by fewer firms (Gissurarson, 2000). The increase in mergers and acquisitions; the collapse of smaller, less-profitable firms; the consolidation of firms in public corporations; and the advent of fisheries companies integrated in the Icelandic stock market are reasons for the marginalization of coastal fishery-dependent communities. Economic policies distanced itself from the traditional notion of fisheries management and fish processing being central to fishing communities while public corporations with little to no affiliation with any particular community retained and consolidated quota (Eythorsson, 2000). This demonstrates the shift in values and doctrine that permeates through Iceland. With an increase in the formation of large conglomerates that hold quota, there has been a reduction in the direct transfer of quota shares. The direct transfer of quota has become less desirable because of greater taxation on quota holding and greater restrictions applied to the leasing of quota (Eythorsson, 2000). The institution of a Share-price Office controlled landing prices and implicitly the compensation for crew that made quota leasing less profitable for fishing companies (Eythorsson, 2000). This alleviated some of the contract leasing problems between vessel owners and crew. Prior to implementing the Share-price Office, contract fishing was extensively used typically by large, vertically-integrated fishing companies retaining large quota holdings which leased out quota at a fixed price to smaller fishing companies that retained smaller quota holdings. Since the vessel retains a fixed amount and the crew earn a fixed percentage of the catch, the crew of contracted vessels stood to earn far less than the crew of a comparable operation using its own quota. This ploy became especially apparent in 1993 when contract fishing commanded nearly half the market price of cod as a fixed price while the remaining balance was payment for leasing quota (Eythorsson, 2000). The pseudo-monopoly of fishing company owners increased labour effort while decreasing wages. This development greatly affected the most desperate and vulnerable of society: populations of marginalized fisheries-driven communities, in particular the inhabitants of the Northwest region.

3 Materials and Methods

This study focuses on providing responses to the following research questions: how have the dynamics in regional monkfish productivity changed over time in Iceland?; how has the proportion of regional monkfish landing been distributed between the exclusive monkfish season and by-catch season over time in Iceland?; how has ownership of fishing companies and regional affiliation been affected by changing regional productivity over time in Iceland?; and how statistically significant are differences for regional monkfish contribution over time in Iceland?

This paper is founded largely on *Lophius piscatorius* landing information provided by the Icelandic Directorate of Fisheries (Fiskistofa) which has been conducted annually since 2001. The monkfish landing data has been collected for the entirety of Iceland, however this study mainly focuses on the productivity of the Northwestern region of Iceland, primarily the Westfjords in comparison to south and east fishing ports. A systematic review was performed with monkfish landing data provided through Fiskistofa's online real-time database to address the necessity and outline the feasibility for establishing monkfish fisheries in the Northwest region. This research employs meta—analytic statistical techniques to review and summarize available Icelandic regional monkfish landing data from 1999-2012. Fishing company owners and quota holder information, available through Fiskistofa's online database, was summarized and reviewed with respect to region to identify patterns in regional ownership from 1999-2012. The management of monkfish internationally, primarily the Maine monkfish management plan, was used as a basis to compare the Icelandic management of monkfish and how it fits in perspective, given the recent and rapid introduction of the monkfish species especially in the Northwestern coast. The Maine monkfish management plan was primarily used as a template because of its strengths in stock assessment protocols, model-based decision-making, and gear modification innovations. Moreover, it encounters similar problems in sustainable management of monkfish, impacts of by-catch in overlapping fisheries, and altered distribution of monkfish that serve as a comparative example for management inclusions and decision-making.

This study investigated experimental research that provided innovative solutions for gear modification programs that showed increased efficiency and promoted more sustainable monkfish management actions. Furthermore, this study analyzed Iceland's ITQ system and demonstrated weaknesses in its current capacity that limits opportunities for the Westfjords' monkfish fishery development and growth in marginalized fisheries-driven communities. This study provided suggestions and amendments to the ITQ system that would mediate and enable development in the Westfjords and other marginalized fishing communities.

3.1 Study area and sample ports

3.1.1 Northwest ports

The Northwest region is comprised of the ports: Arnarstapi, Rif, Olafsvik, Grundarfjörður, Stykkishólmur, Patreksfjörður, Tálknafjörður, Bíldudalur, Þingeyri, Flateyri, Suðureyri, Bolungarvík, Ísafjörður, Drangsnes, Hólmavík, Husavik, Skagaströnd, Siglufjörður, Ólafsfjörður, and Akureyri.

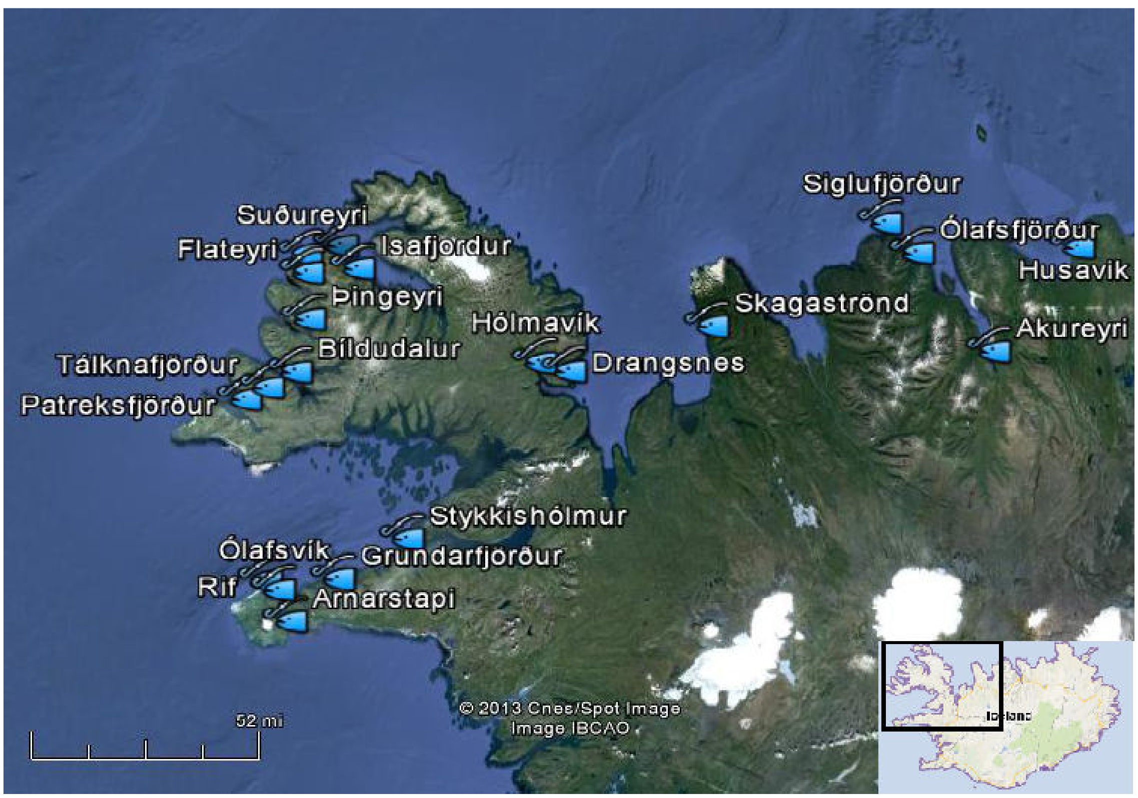

Figure 1- Northwestern Fishing Ports of Iceland. Source: Google Maps (2012)

The Northwest region is characterized by rocky cliffs and many fjords that open northwestward to the sea and form irregular coastlines (Einarsson, 1984; Malmstrom, 1958).

The northwest is characterized by considerable precipitation, relatively low temperatures, and comprised of Eocene basalts that range from black to gray in colour and are mainly found interbedded with narrow layers of weathered ash or lava (Thordarson, 2012; Ogilvie, 1995; Malmstrom, 1958). In addition, it possesses fine drainage textures and displays many features of valloy glaciations: cirquos, U-shaped valloys, and fjords (Malmstrom, 1958). The Northwest region is characterized by rocky or erosional coasts with habitation centers largely limited to small, depositional features such as spits (Malmstrom, 1958). The tidal range is relatively small with an average of 1m neap tides and 2-2.5 m spring tides (Jonsson, 2013; Malmstrom, 1958).

3.1.2 South ports

The Southern region is comprised of the ports: Vestmannaeyjar, Þorlákshöfn, Grindavik, Sandgerð, Keflavík, Hafnarfjörður, Reykjavík, and Akranes.

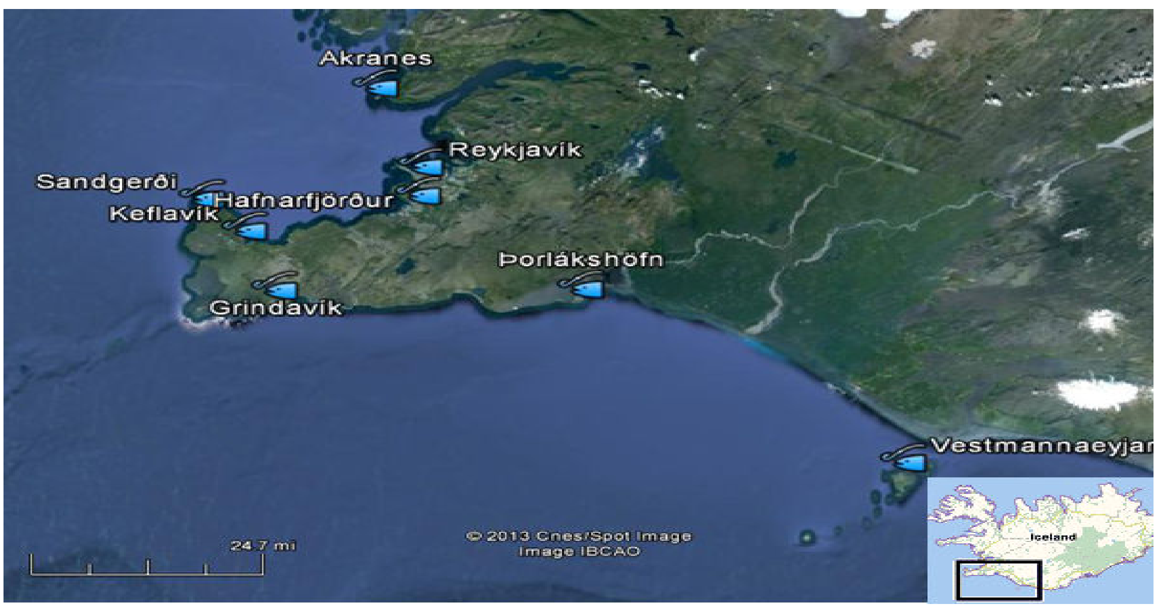

Figure 2- Southern Fishing Ports of Iceland. Source: Google Maps (2012)

The South region is largely characterized by smooth, sandy coasts with intermittent pinnacles of rock; and where lowlands are typically found in Iceland with elevations below 400 m with medium drainage textures (Einarsson, 1984; Malmstrom, 1958). This region is characterized by a Tuff formation composed of a mixture of sub-glacial and sub-aerial eruptives, along with glacial, glaciofluvial, fluvial, and eolian deposits (Sigvaldason, 1968; Malmstrom, 1958). The South region is characterized by a sandy or depositional coast with the largest tidal ranges of 2 m at neap tide and 4-5 m at spring tide (Etienne & Paris, 2010; Thordarson, 2012; Malmstrom, 1958). This region features four major solfatere fields that draw significant heat to the surface and is characterized by high precipitation and temperature (Malmstrom, 1958; Ogilvie, 1995).

3.1.3 East ports

The Eastern region is comprised of the ports: Seyðisfjörður, Neskaupstaður, Eskifjörður, Fáskrúðsfjörður, Stöðvarfjörður, Breiðdalsvík, Djúpivogur, and Hornafjörður.

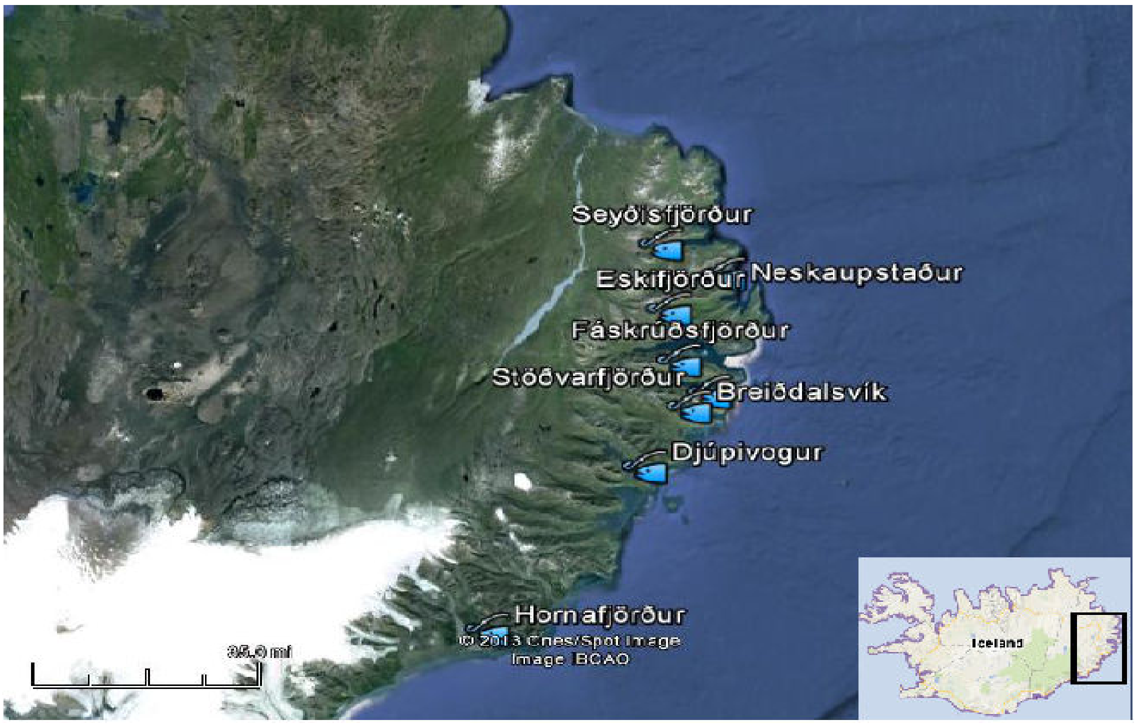

Figure 3- Eastern Fishing Ports of Iceland. Source: Google Maps (2012)

The East region is characterized by three large indentations in the north and numerous, narrow fjords in the south; away from Hornafjordur, there are no further indentations of the coast (Malmstrom, 1958). This region is characterized by Eocene basalts and intrusive rocks (granite, gabbro, and rhyolite) forming dykes and sills while producing a fine drainage texture (Thordarson, 2012; Malmstrom, 1958). The East region is characterized by rocky, erosional coasts that provide habitats in spits (Einarsson, 1984; Malmstrom, 1958). The tidal range is relatively small with an average of 1m neap tides and 2-2.5 m spring tides (Jonsson, 2013; Malmstrom, 1958).

3.2 Sampling technique standard

The monkfish landing data provided by Fiskistofa endures a rigorous collection process which ensures its quality and accuracy. The monkfish landing data utilized in this study was a primary source available through the Directorate of Fisheries interactive queries retrieval system. Specifically, the Catch by ports; Catches by month; and Catch Individual species features of the interactive queries retrieval system were utilized to organize monkfish catch by port and subsequently region, monthly monkfish catch, and to determine monkfish landings for specific intervals, namely between the exclusive monkfish season and lumpfish (monkfish by-catch) season. Information regarding the top 50 fishing companies was retrieved from the assigned quota feature of the Fiskistofa interactive queries retrieval system, but specifically in the annual summaries of fishing year from 2002-2012. Monkfish landing data is published in Annual Reports which focus on job reports and activities of the industry. Annual reports address many issues including: TAC for monkfish over time, performance share units between ships, overall performance and quotas between vessels across time, statistics of annual monkfish catch, and the export of unprocessed monkfish.

The Directorate of Fisheries maintains compliance on land and at sea by employing inspectors that ensure that laws and regulations are upheld (Fiskistofa, 2012). This administrative role is partitioned into supervision on land and supervision at sea (Fiskistofa, 2012). The at-sea inspectors monitor fishing methods and catches to mediate the sustainable use of fish stocks (Fiskistofa, 2012). The inspector's role includes: preventing the fishing of juvenile species; prevent the discard of catches and survey catch methods; ensure the appropriate application of fishing gear; determining the species and size composition of species; and the weighing and recording of catches (Fiskistofa, 2012). The on-land inspectors monitor catch landings and make certain of accurate weighing and recording of landing data (Fiskistofa, 2012). The Department of quota allocations, under the guidance of the Directorate of Fisheries, is responsible for monitoring the compliance to rules of weighing and recording catches for catches landed by Icelandic fleets in Iceland (Ministry of Fisheries and Agriculture [MFA], 2012). All catch is weighed on certified scales by licensed operators, while port authorities are ultimately responsible for accurate weighing and recording of catches (MFA, 2012). All landing ports in Iceland are connected to the Directorate of Fisheries database. All catches are landed and weighed by authorized weighmasters prior to being forwarded to the Directorate of Fisheries via the catch registration system (Fiskistofa, 2012). This dynamic system ensures real-time updates on catch information and quota status

(Fiskistofa, 2012). The Directorate of Fisheries' inspectors are privy to log book information which details fishing practices including: location, date, gear and catch quantity (MFA, 2012).

3.3 Description of data analysis

Annual monkfish landing data was divided into two periods for analysis. Landing data from March to July (lumpfish fishing season) was categorized as a largely monkfish by-catch period. Landing data from August to December was identified as comprising the exclusive monkfish fishing season. The temporal-based groups were analyzed to identify the impact of each period to annual monkfish landings. In addition, regional contribution within the two broadly-defined time periods and more specifically individual port contribution to annual monkfish landings was analyzed. Annual monkfish landing data was analyzed from 1999-2012.

For the purpose of this study, Iceland's ports have been organized into three distinct groups: the Northwest region, Southern region, and the Eastern region. These regions were analyzed both by its individual components (ports designated to a region) and as a collective (sum of the ports designated to a region) to determine the relative impact of select variables: total annual monkfish landings by port and subsequently as a collective by region (from 1999-2012); monkfish landings during the exclusive monkfish season per port and collectively by region (from 1999-2012); and monkfish by-catch during the lumpfish fishing season per port and collectively by region (from 1999-2012).

Information pertaining to the 50 largest fishing companies in Iceland was used to identify the regional affiliation of the largest companies and was utilized to determine the extent of regional impact and influence of Iceland's largest fishing companies. The data was used to determine relative regional contribution to annual monkfish landings and infer the proportion of quota holdings attributed to each region (Northwest, South, and East). Fishing company data was analyzed from 2001-2012.

Iceland's 50 largest fishing companies were organized by regional affiliation and used to determine their contribution to annual monkfish landings in total and relative terms (from 2001-2012). The annual contribution to monkfish landings by Iceland's 50 largest fishing companies were used as a collection of the three region's totals to determine their annual relative contribution to monkfish landings (from 2002-2012). The average monthly monkfish landings were used to determine the productivity of the exclusive monkfish fishing season versus the lumpfish season (monkfish caught as by-catch).

The average annual monkfish catch by port was analyzed from 1999-2012 to give an indication of historical port productivity and provide a baseline. Average annual monkfish catch by port was also analyzed against two other time periods with defining characteristics: 1999-2007 (historically strong south region productivity) and 2008-2012 (increasingly productive northwest region). The average annual monkfish catch by region (northwest, south, and east) was analyzed from 1999-2012 to give an indication of historical productivity and provide a baseline for further analysis. Average annual monkfish catch by region was also analyzed against two other time periods with defining characteristics: 1999-2007 and 2008-2012.

ANOVA testing was conducted on the top 8 ports of each region, with respect to annual monkfish landings, to determine if there were any statistically significant differences in average annual monkfish landings by region.

Paired sample t-tests were performed to compare the Northwest and South region's average annual monkfish landings in their top 8 ports and were conducted in two time periods: 1999-2007 and 2008-2012. It was conducted to not only determine if differences in mean landings were statistically significant but if the trend persisted post 2008, when developments in monkfish landings in the Northwest region were accelerating.

These factors were evaluated to posit evidence which supports the establishment of monkfish fisheries in the Westfjords based on the recent improvement in Northwest region productivity in addition to displaying factors that equaled or exceeded levels in the South region.

3.4 Limitations

The main limitation of this secondary research is the availability of quality monkfish-related data. This includes a lack of sex ratio and age data, gear-use data (to estimate CPUE), and location of monkfish landings. The uncertainty in the completeness of information affects the reliability of statistical differences between the three regions. Furthermore, a more extensive database of monkfish fishing locations would provide a better basis to determine the importance of the Northwest region's holistic contribution to national monkfish landings. Many gaps in information need to be addressed to effectively determine the impacts of fishing in different areas. For example, the lack of sex ratio and age data availability prevents determining the actual impacts of different ports with comparable landings on recruitment, stock biomass, and environmental impacts. The lack of catch location data is a major impediment to justify the case for the establishment of monkfish fisheries in the Northwest region. Availability of this information can directly implicate heavy-dependence of fisheries on Northwest sites for monkfish catches.

Furthermore, this study focuses on the productivity and regional impact of the 50 largest fishing companies of Iceland to annual TAC, but does not extend the evaluation to all fishing companies for annual fishing seasons.

4 Results

4.1 Assessment of total landings

4.1.1 South ports landings assessment

From 1999-2012, Southern fishing ports accounted for 12,134 t of total cumulative monkfish landings or approximately 47.2% of all monkfish landings in Iceland within that time frame (Table 1). Of the total Southern port monkfish landings from 1999-2012, 5,201 t or approximately 42.9% were landed as by-catch during the lumpfish fishing season (Table 1). Thus, only 6,933 t or 57.1% of total monkfish catch in Southern ports from 1999-2012 was landed during the exclusive monkfish fishing season. Þorlákshöfn port contributed the most to total monkfish landings from 1999-2012 with 4,056 t or approximately 33.4% of total south landings. However from 1999-2012, the Þorlákshöfn port reported an annual average landing of 164.8 t during the lumpfish season against an annual average landing of 124.7 t during the exclusive monkfish fishing season (Table 1). The second largest contributor was the Sandgerði port contributing 3,314 t or 27.3% to total Southern port monkfish landings from 1999-2012. In contrast to Þorlákshöfn, the Sandgerði port reported an annual average landing of 105.6 t during the lumpfish season against an annual average landing of 131.1 t during the exclusive monkfish fishing season. The Southern ports displayed an average of 55.2 t in landings per port from 1999-2012 (Table 1).

4.1.2 Northwest ports landings assessment

Northwestern fishing ports were the second largest contributors by region to total monkfish landings and accounted for 10,607 t of total cumulative monkfish landings or approximately 41.3% of total monkfish landings in Iceland from 1999-2012 (Table 2). Of the total Northwestern port monkfish landings from 1999-2012, 3,515 t or approximately 33.1% were landed as by-catch during the lumpfish season (Table 2). Therefore, approximately 7,092 t or 66.9% of total monkfish catch in Northwestern ports was landed during the exclusive monkfish fishing season. Rif port contributed greatest to total Northwestern monkfish landings from 1999-2012 with 4,034 t or approximately 38.0% of total Northwestern monkfish landings. Furthermore, Rif port reported an annual average landing of 94.9 t during the lumpfish season against an annual average landing of 193.2 t during the exclusive monkfish fishing season (Table 2). The second largest contributor was the Olafsvik port contributing 2,860 t or 27.0% to total Northwestern monkfish landings from 1999-2012. Moreover, Olafsvik port reported an annual average landing of 74.4 t during the lumpfish season against an annual average landing of 129.9 t during the exclusive monkfish fishing season (Table 2).

4.1.3 East ports landings assessment

Eastern fishing ports were the smallest contributors by region to total monkfish landings and accounted for 2,959 t of total cumulative monkfish landings or approximately 11.5% of total monkfish landings in Iceland from 1999-2012 (Table 3). Of the total Eastern port monkfish landings from 1999-2012, 1,582 t or approximately 53.5% were landed as by-catch during the lumpfish season (Table 3). Therefore, approximately 1,377 t or 46.5% of total monkfish catch in Eastern ports were landed during the exclusive monkfish fishing season. Hornafjörður port produced an extremely disproportionate contribution for monkfish catch in the region with 2,848 t or approximately 96.2% of total monkfish landings from 1999-2012. Furthermore, the Hornafjörður port reported an annual average landing of 109.2 t during the lumpfish season against an annual average of 94.2 t during the exclusive monkfish fishing season (Table 3).

4.2 Production of exclusive monkfish fishing season versus lumpfish season

From 1999-2012, monkfish landed during the lumpfish season has totaled 11,496 t, while monkfish landed in the exclusive monkfish fishing season has totaled 17,867 t (Table 4). Therefore, 39.2% of monkfish was caught as by-catch, while only 60.8% was caught during its exclusive fishing season. On average, 884.3 t of monkfish was landed annually during the lumpfish season as by-catch, while 1329.7 t was landed during the exclusive monkfish fishing season from 1999-2012 (Table 4).

From 1999-2007, there were 7,084 t of monkfish caught as by-catch during the lumpfish season versus 9,113 t of monkfish caught during the exclusive monkfish season (Table 5). From 1999-2007, approximately 43.7% of monkfish was caught as by-catch. Since 2008, 4,412 t of monkfish was caught as by-catch during the lumpfish season versus 8,173t of monkfish caught during the exclusive monkfish season (Table 5). Since 2008, approximately 35.1% of monkfish was caught as by-catch.

There have been discrepancies in regional efficiency with respect to by-catch and exclusively caught monkfish. From 1999-2012, the Southern region caught 5,201t of monkfish as by-catch and 7,171t exclusively; therefore, approximately 42.0% of Southern monkfish landings was by-catch (Table 1). From 1999-2012, the Northwest region caught 3,515t of monkfish as by-catch and 7,092t exclusively; therefore, approximately 33.1% of Northwest monkfish landings was by-catch (Table 2). From 1999-2012, the East region caught 1,582t of monkfish as by-catch and 1,377t exclusively; therefore, approximately 53.5% of East monkfish landings was by-catch.

4.3 Northwest ports with greatest potential to establish monkfish fisheries

Since 2008, Arnarstapi has landed 1,196 t in total and annually averaged 296 t in monkfish landing (Table 2). Since 2008, Rif has landed 2,935 t in total and annually averaged 587 t in monkfish landings (Table 2). Since 2008, Olafsvik has landed 2,235 t in total and annually averaged 447 t in monkfish landings (Table 2). Since 2008, Grundarfjordur has landed 477 t and annually averaged 95.4 t of monkfish landings (Table 2). Since 2008, Bolungarvik has landed 404 t and annually averaged 80.8 t of monkfish landings (Table 2). In 2011, Flateyri had 66 t in monkfish landings of which 60 t was caught during the exclusive monkfish fishing season. Since 2009, Sudureyri has landed 56 t and annually averaged 14 t (Table 2)

The total monkfish landings of 2010 and 2011 respectively have been some of the highest to date at 3,598 t and 3,377 t, respectively (Table 5). Since 2008, the contribution of Northwestern port monkfish landings has exceeded monkfish landings in the Southern ports and Eastern ports. Furthermore, the proportion of monkfish caught as by-catch since 2008 in the Northwest region has remained at historically low levels. Since 2008, the Northwest region has caught 2,652t of monkfish as by-catch and 4,958 exclusively; therefore, approximately 34.8% of monkfish landings were by-catch (Table 2).

Table 1- Southern Ports Monkfish Landings in Iceland from 1999-2012. *Grey indicates lumpfish season (monkfish by-catch); White indicates exclusive monkfish fishing season

Port/Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total	Average
Vestmannaeyjar	24	30	27	34	29	28	21	38	49	11	12	25	69	61	458	32.7
	27	103	49	19	12	111	267	207	141	17	112	174	202	149	1590	113.6
Þorlákshöfn	89	242	229	111	149	159	265	222	172	171	187	131	93	87	2307	164.8
	103	327	188	29	47	94	112	74	135	98	181	162	125	71	1746	124.7
Grindavík	15	22	32	45	59	117	85	43	84	31	22	17	15	16	603	43.1
	5	14	11	17	41	98	106	76	153	11	62	61	66	25	746	53.3
Sandgerð	12	19	51	50	198	188	104	85	164	157	227	76	69	78	1478	105.6
	18	25	38	115	359	215	32	138	127	196	200	146	146	81	1836	131.1
Keflavík	1	2	18	4	11	10	8	13	2	1	3	44	7	4	128	9.1
	4	23	37	32	37	85	34	48	35	35	77	65	61	14	587	41.9
Hafnarfjörður	1	1	2	1	17	1	3	1	3	1	1	5	2	4	43	3.1
	1	3	6	13	25	1	0	1	2	9	6	5	5	3	80	5.7
Reykjavík	1	3	2	5	9	5	5	9	10	8	3	20	14	5	99	7.1
	2	12	14	25	23	20	9	18	17	23	44	79	47	15	348	24.9
Akranes	0	1	1	1	3	4	9	2	2	0	8	8	25	21	85	6.1
	0	1	2	6	3	6	5	3	3	89	83	16	11	10	238	17.0
Total	**303**	**827**	**705**	**501**	**1019**	**1136**	**1060**	**975**	**1096**	**769**	**1145**	**1018**	**946**	**634**	**12134**	**55.2**

Table 2- Northwest Ports Monkfish Landings in Iceland from 1999-2012. *Grey indicates lumpfish season (monkfish by-catch); White indicates exclusive monkfish fishing season

Port/Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total	Average
	0	0	0	1	2	3	101	87	88	70	73	10	69	56	560	40
Arnarstapi	0	0	0	1	2	86	342	79	180	231	225	158	240	64	1608	114.9
	1	2	13	12	34	49	31	80	78	236	323	126	120	224	1329	94.9
Rif	0	4	9	9	20	74	172	253	258	340	445	310	429	382	2705	193.2
	1	6	22	7	11	45	21	40	25	91	253	106	224	190	1042	74.4
Ólafsvík	2	17	15	13	21	90	132	84	73	165	309	301	269	327	1818	129.9
	1	1	4	4	7	13	9	13	20	12	30	32	39	17	202	14.4
Grundarfjörður	0	0	1	1	4	3	59	68	19	10	21	115	120	81	502	35.9
	0	0	1	0	1	5	1	2	2	0	3	12	8	4	39	2.8
Stykkishólmur	0	0	0	1	3	0	0	1	0	1	2	16	9	0	33	2.4
	0	0	0	0	0	0	0	1	2	1	5	2	5	2	18	1.3
Patreksfjörður	0	0	0	0	0	0	2	3	5	4	4	5	15	16	54	3.9
	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0.1
Tálknafjörður	0	0	0	0	0	0	0	1	1	1	2	3	2	0	10	0.7
	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.1
Bíldudalur	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0.1
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Þingeyri	0	0	0	0	0	0	0	0	0	0	1	2	0	3	6	0.4
	0	0	1	0	0	0	0	1	0	0	0	0	6	7	15	1.1
Flateyri	0	0	0	0	1	1	0	2	0	0	0	1	60	11	76	5.4
	0	0	0	0	0	0	0	0	1	2	3	6	3	6	21	1.5
Suðureyri	0	0	0	0	0	0	1	3	2	2	7	11	13	7	46	3.3
	0	0	0	0	0	0	0	1	1	6	20	40	38	99	205	14.6
Bolungarvík	0	0	0	0	0	1	2	3	5	8	20	34	56	83	212	15.1
	0	0	0	0	0	1	0	0	2	8	17	13	8	3	52	3.7
Ísafjörður	0	0	0	0	0	1	0	1	3	2	3	6	3	1	20	1.4
	0	0	0	0	0	0	0	0	0	0	0	3	3	2	8	0.6
Drangsnes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	0	0	0	0	0	0	0	0	0	0	0	3	0	2	5	0.4
Hólmavík	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Husavik	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.1
	0	0	0	0	0	3	2	0	0	1	0	0	1	2	9	0.6
Skagaströnd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	0	0	0	0	0	0	0	0	0	0	1	2	0	1	4	0.3
Siglufjörður	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Ólafsfjörður	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	1	0	0	0	0	2	0	0	0	1	0	0	0	0	4	0.3
Akureyri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Total	6	30	66	49	106	377	875	723	765	1192	1769	1318	1741	1590	10607	18.9

Table 3- East Ports Monkfish Landings in Iceland from 1999-2012. *Grey indicates lumpfish season (monkfish by-catch); White indicates exclusive monkfish fishing season

Port/Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total	Average
Seyðisfjörður	0	1	0	1	1	2	1	1	1	0	3	1	2	1	15	1.07
	1	1	0	1	0	1	1	1	1	0	1	1	1	0	10	0.71
Neskaupstaður	1	0	1	1	0	0	1	1	1	1	2	1	1	0	11	0.79
	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2	0.14
Eskifjörður	1	1	0	0	0	3	0	1	1	0	1	0	0	0	8	0.57
	0	0	0	0	0	1	0	0	0	0	0	0	1	0	2	0.14
Fáskrúðsfjörður	1	0	0	1	0	2	1	2	1	2	2	2	1	1	16	1.14
	0	0	0	1	1	0	1	1	0	1	3	1	1	0	10	0.71
Stöðvarfjörður	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.07
	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0.14
Breiðdalsvík	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0.00
Djúpivogur	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2	0.14
	0	0	0	0	0	0	0	2	8	6	4	7	2	3	32	2.29
Hornafjörður	125	56	72	82	143	112	128	120	99	144	124	121	91	112	1529	109.21
	64	91	56	54	32	47	117	76	155	75	109	205	124	114	1319	94.21
Total	**194**	**150**	**130**	**141**	**177**	**168**	**251**	**205**	**267**	**229**	**251**	**340**	**225**	**231**	**2959**	**13.21**

Table 4- Icelandic Monthly Monkfish Landing in tonnes. *Yellow highlight represents lumpfish fishing season. *Grey indicates lumpfish season (monkfish by-catch); White indicates exclusive monkfish fishing season

Month/Year	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13
August	72	141	20	89	100	184	240	307	273	336	378	548	352	0
September	70	149	117	87	116	184	403	326	525	534	652	501	437	328
October	91	156	99	89	182	269	547	438	453	474	630	491	474	253
November	117	264	112	99	244	404	381	292	273	232	470	467	411	0
December	64	226	87	109	165	170	127	162	90	122	242	217	205	0
January	90	145	77	83	118	123	110	119	55	110	149	126	54	0
February	48	104	74	52	83	118	119	101	121	138	123	67	63	0
March	83	145	66	104	110	93	115	95	109	145	97	97	45	0
April	62	19	66	86	117	126	114	146	143	133	133	80	102	0
May	132	116	144	184	250	322	263	242	206	263	227	189	191	0
June	136	160	83	166	248	248	228	213	340	571	301	280	268	0
July	114	114	58	214	170	178	184	232	340	378	196	314	402	0
Total	**1079**	**1739**	**1003**	**1362**	**1903**	**2419**	**2831**	**2673**	**2928**	**3436**	**3598**	**3377**	**3004**	**581**

Table 5- Icelandic Landings in Lumpfish Season vs. Exclusive Monkfish Season from 1999-2012. *Grey indicates lumpfish season (monkfish by-catch); White indicates exclusive monkfish fishing season

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total	Average
Spring (Lumpfish Season)	527	554	417	754	895	967	904	928	1138	1490	954	960	1008	0	11496	884.3077
Fall (Exclusive Monkfish Season)	414	936	435	473	807	1211	1698	1525	1614	1698	2372	2224	1879	581	17867	1329.692

4.4 Production of regional ports after 2008

4.4.1 Northwest ports production after 2008

The production of Northwestern ports has seen tremendous growth (Figure 11 & 12). Since 2008, the average annual monkfish catch per port for Northwestern ports has risen by 359% from 8.3 t in 1999-2007 to 38.1 t in 2008-2012. In contrast, the average annual monkfish catch per port for Southern ports has had marginal increases of 11.1% from 53.1 t in 1997-2007 to 59.0 t in 2008-2012. The Eastern ports showed strong growth in average annual monkfish catch per port with a 35.6% increase from 11.8 t in 1999-2007 to 16.0 t in 2008-2012.

Northwestern ports as a collective have experienced steady growth since 1999 (Figure 10). The annual average monkfish catch for Northwestern ports has risen by 357.1% from 333.0 t in 1999-2007 to 1,522.0 t in 2008-2012. The annual average monkfish catch for Southern ports have experienced a marginal increase of 6.6% from 846.9 t in 1999-2007 to 902.4 t in 2008-2012. The annual average monkfish catch for Eastern ports have also shown strong growth and risen by 36.5% from 187.0 t in 1999-2007 to 255.2 t in 2008-2012.

Since 2008, the Northwest region has exceeded the South region in annual monkfish landings (Figure 4). The introduction of additional monkfish quota in 2010 permitted the Northwest region to extend its dominance by putting distance between it and the South region by 2011. In addition, the ratio of monkfish landed in the exclusive monkfish fishing season versus those landed as by-catch in the lumpfish season has increased following the 2008 fishing season (Figure 5). While it appears landing of monkfish as by-catch is decreasing, average monthly landings since 1999 describe March through July (lumpfish season) as a significant contributor to annual monkfish landings (Figure 6). Total annual monkfish landings have displayed a decreasing trend since 2008, however they remain as record highs of annual monkfish landings since 1999 (Figure 7). Since 2008, annual monkfish landings have exceeded 3,000 tonnes with 3,436 t, 3,598t, 3,377 t, and 3,004 t from 2008-2011 respectively (Figure 7).

4.5 Contribution of the 50 largest fishing companies

The contribution of the 50 largest fishing companies in Iceland to total monkfish landings has remained relatively stable from 2001-2012 (Table 6). There has been considerable variation in the 50 largest fishing companies of Iceland since 2003 (refer to Appendix- Table

11). The comprehensive list of annual largest fishing companies since 2003 is presented in Table 11 of the appendix. Since 2003, the top 50 largest fishing companies in Iceland have contributed on average 65.12% of total annual monkfish landings. In 2009 and 2010, they accounted for 70.67% and 74.92% of total annual monkfish landings, respectively (Table 7).

4.5.1 Assessment of northwest fishing companies

Since 2001, the 50 largest fishing companies of the Northwest region have contributed on average 2.39% to total annual monkfish landings and approximately 48.5 t annually. However since 2008, the top 50 largest fishing companies represented in the Northwest region have averaged 66.4 t of monkfish landing annually in contrast to the 35.7 t annual landing average from 2001-2007. In addition, they have represented on average 2.99% of annual landings since 2008 in contrast to the 1.96% of average annual landings from 2001-2007. The Northwest region has experienced growth since 2008, albeit relatively small, through a 52.6% increase in percentage of annual landings and 85.9% increase in the average annual landings from the 2001-2007 periods.

4.5.2 Assessment of southern fishing companies

Since 2001, the 50 largest fishing companies representing the Southern region have averaged 749.7 t of monkfish landings annually and 38.09% of total monkfish landings annually. Since 2008, the top 50 largest fishing companies in the Southern region have averaged 969.4 t or 43.72% of total annual monkish landings. From 2001-2007, the largest companies of the South averaged 597.08 t or 34.08% of total annual monkfish landings. The strong growth in the South since 2008 is supported by the 28.3% increase in the percentage of annual landings

and 62.4% increase in average annual landings from the 2001-2007 period.

4.5.3 Assessment of eastern fishing companies

Since 2001, the 50 largest fishing companies representing the Eastern region have averaged 284.0 t of annual monkfish landings and 14.87% of the total monkfish landings annually. Since 2008, the top 50 largest fishing companies in the Eastern region have averaged 328.1 t or 14.92% of total annual monkfish landings. From 2001-2007, the largest companies of the East averaged 252.6 t or 14.84% of total annual monkfish landings. The East region has displayed marginal growth since 2008 with a 29.9% increase in average annual landings and 0.54% increase in the percentage of average total landings from the 2001-2007 periods.

Table 6- Relative contribution of Iceland's 50 largest fishing companies for annual monkfish landings. The total annual landings in kilograms and percent of total annual landings by region

Year	Total Landings	Top 50 Largest Total Landing	Percentage of Total
2002	1,350,000	614,831	45.54%
2003	1,800,000	1,010,997	56.20%
2004	1,800,000	1,000,930	55.60%
2005	2,250,000	1,320,813	58.70%
2006	2,699,790	1,629,244	60.35%
2007	2,250,003	1,537,406	68.33%
2008	2,700,001	1,908,057	70.67%
2009	2,250,004	1,685,788	74.92%
2010	2,250,000	1,553,864	69.06%
2011	2,223,307	1,521,427	68.43%
2012	1,576,635	1,086,941	68.94%

Table 7- Relative contribution of Iceland's top 50 largest fishing companies towards annual monkfish catch

Region	Northwest		South		East	
Year	*Total*	*Percent*	*Total*	*Percent*	*Total*	*Percent*
2001	6,742	2.78%	103,472	42.64%	48,079	19.81%
2002	13,826	1.02%	301,388	22.33%	167,475	12.41%
2003	18,853	1.05%	565,303	31.41%	240,953	13.39%
2004	19,423	1.08%	540,314	30.02%	263,104	14.62%
2005	53,053	2.36%	707,141	31.43%	338,004	15.02%
2006	92,628	3.43%	874,358	32.39%	397,775	14.73%
2007	45,584	2.03%	1,087,574	48.34%	312,560	13.89%
2008	73,866	2.74%	1,204,913	44.63%	397,778	14.73%
2009	130,913	5.82%	1,024,161	45.52%	337,068	14.98%
2010	42,836	1.90%	951,391	42.28%	337,068	14.98%
2011	47,139	2.12%	955,460	42.97%	332,622	14.96%
2012	37,059	2.35%	680,992	43.19%	235,949	14.97%

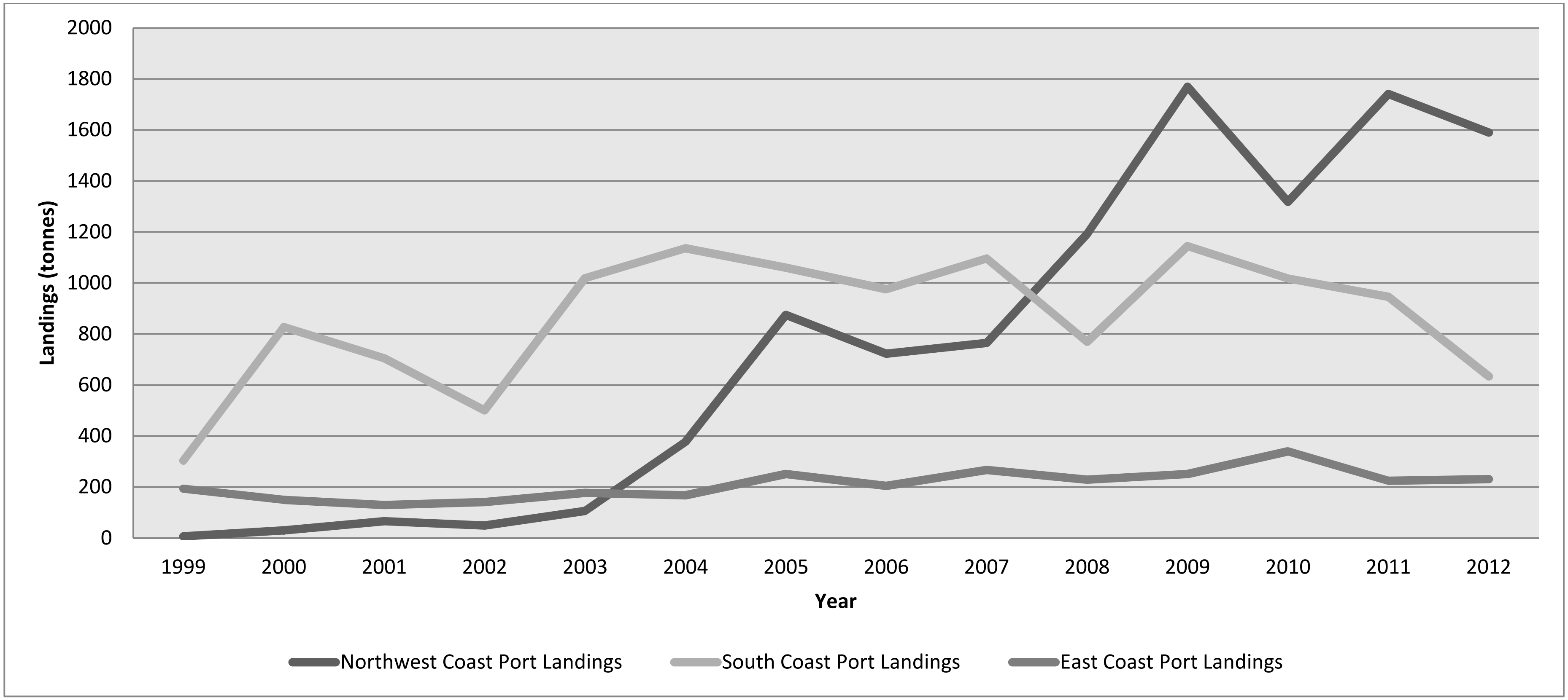

Figure 4- Iceland Annual Monkfish Catch Contribution by Coastal Region from 2000-2012

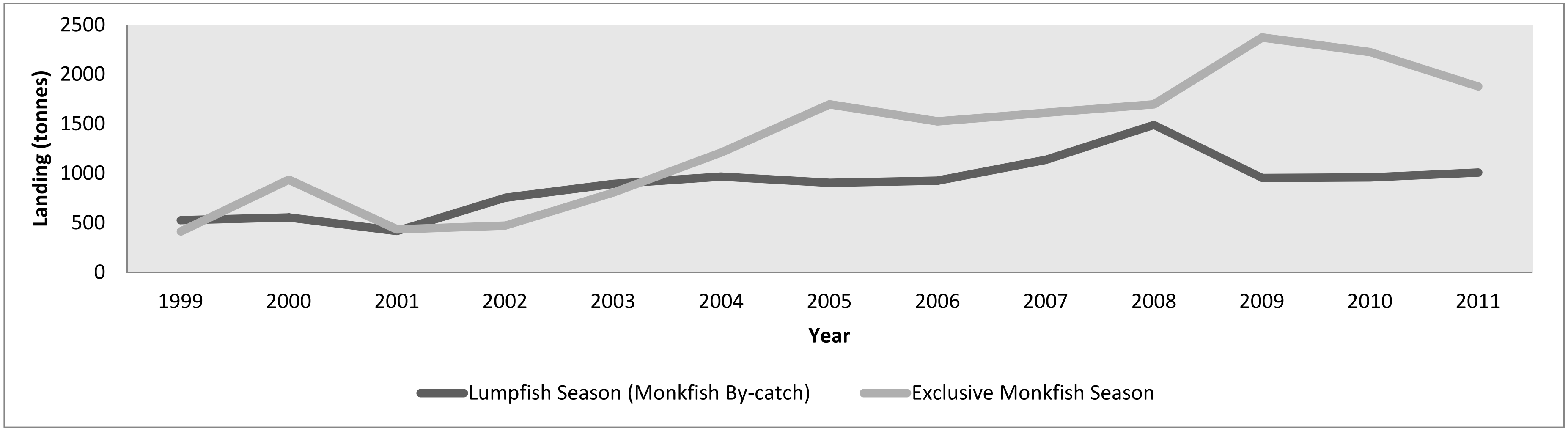

Figure 5- Icelandic Annual Total Spring Landings (Lumpfish Season) vs. Fall Landings (Exclusive Monkfish Season) from 1999-2012

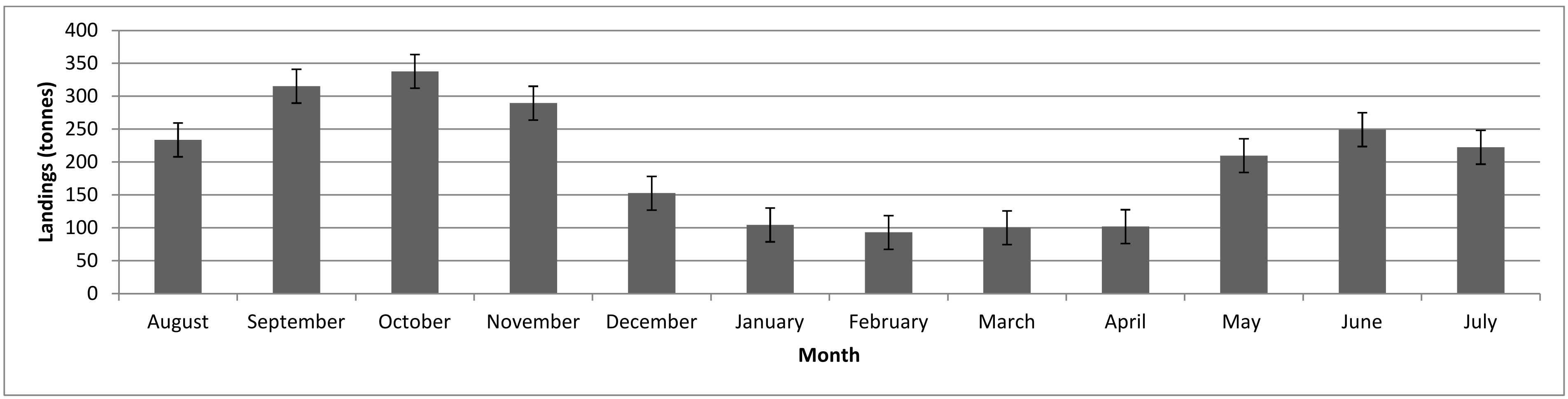

Figure 6- Icelandic Average Monthly Monkfish Landings from 1999-2012. *August-December (Exclusive Monkfish Season); March-July (Lumpfish Season)

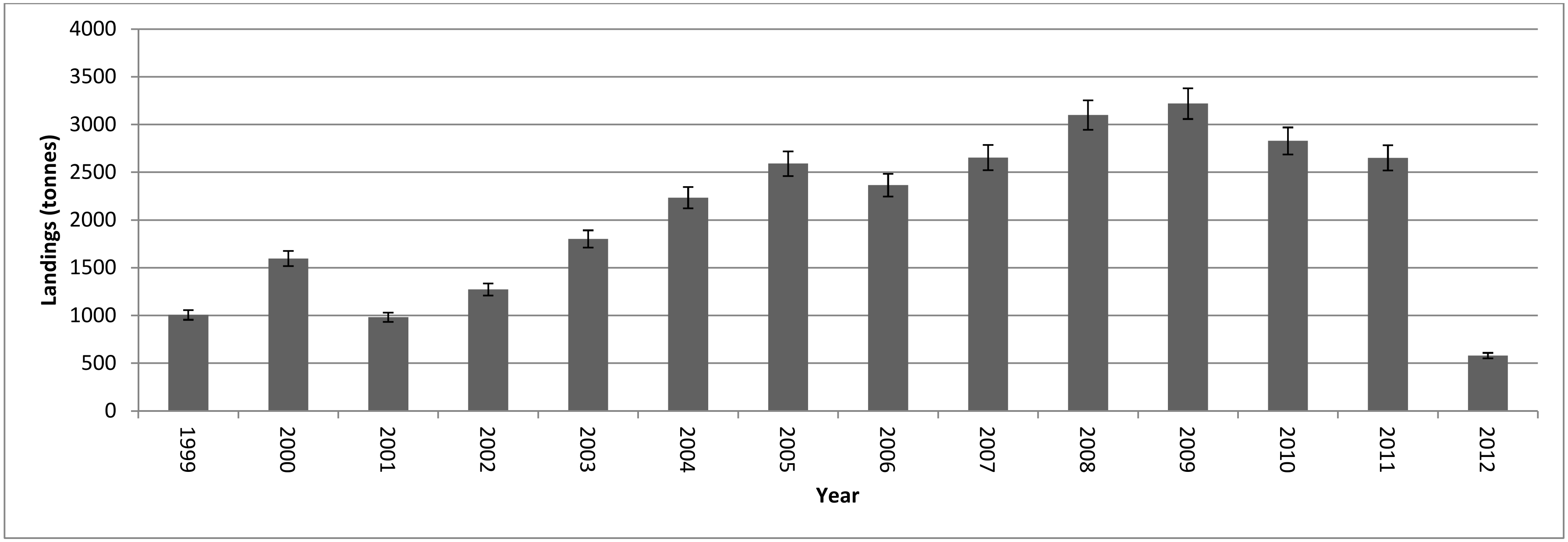

Figure 7- Icelandic Total Annual Monkfish Landings from 1999-2012

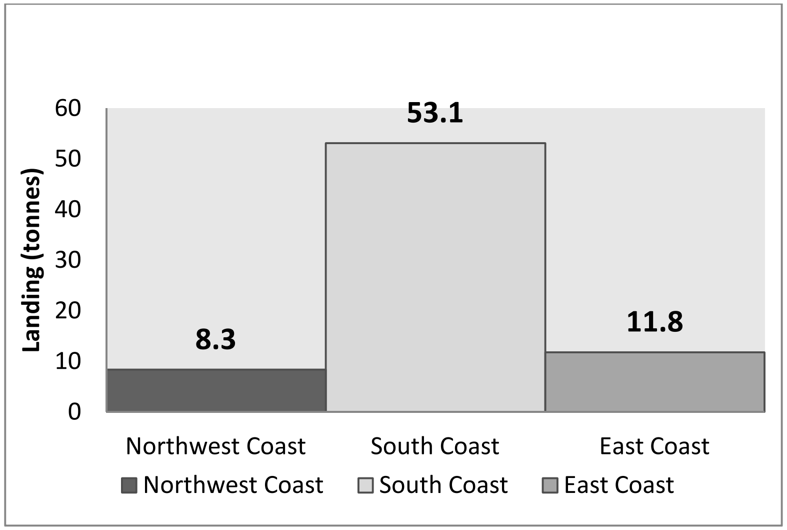

Figure 8- Icelandic Average Annual Monkfish Catch by Port from 1999-2007

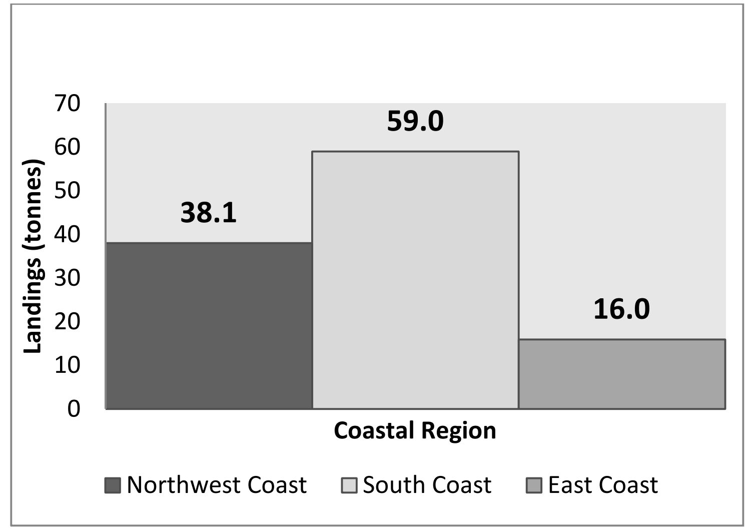

Figure 9- Icelandic Average Annual Monkfish Catch by Port from 2008-2012

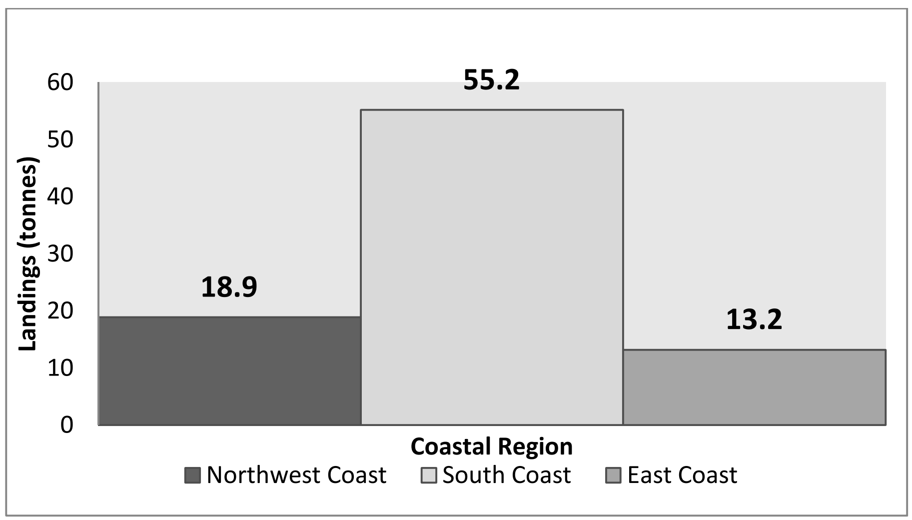

Figure 10- Icelandic Average Annual Monkfish Catch by Port from 1999-2012

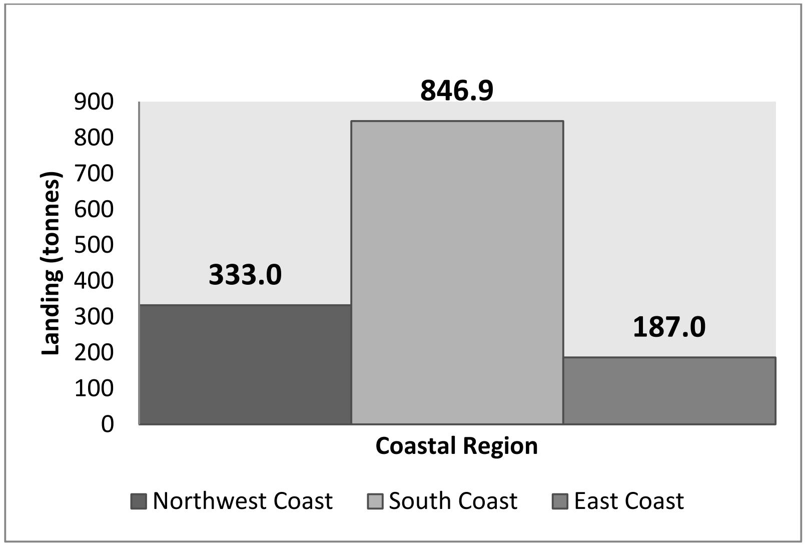

Figure 11- Icelandic Average Annual Monkfish Catch by Region from 1999-2007

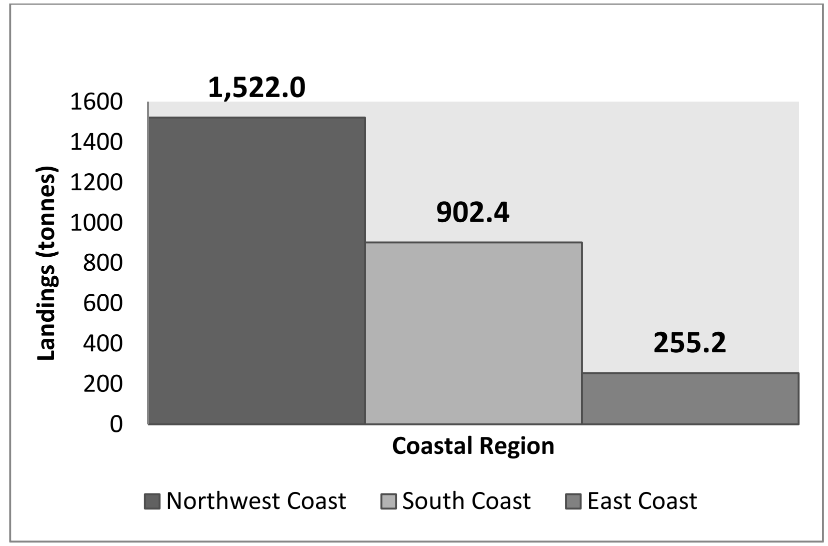

Figure 12- Icelandic Average Annual Monkfish Catch by Region from 2008-2012

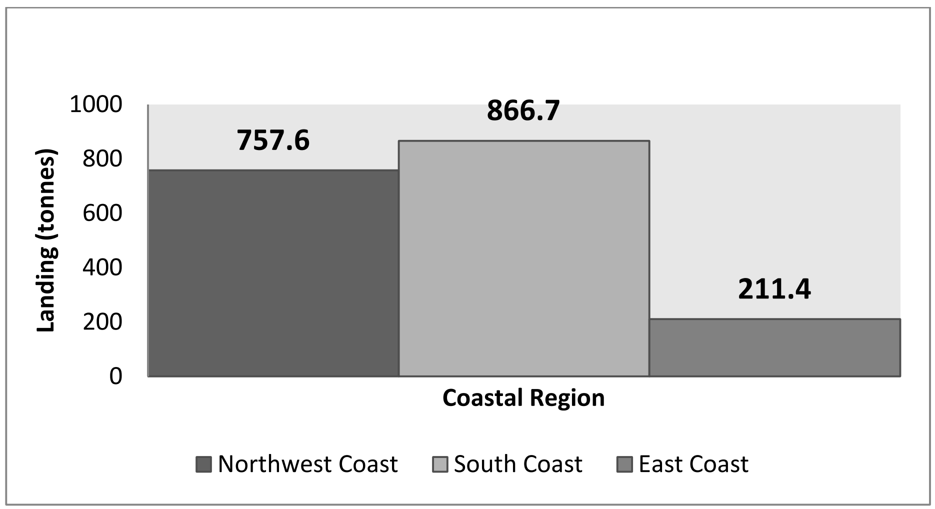

Figure 13- Icelandic Average Annual Monkfish Catch by Region from 1999-2012

4.6 Statistical analysis of regional monkfish landings

A single factor ANOVA analysis was performed on the top 8 ports of the three regions: Northwest region, South region, and East region to determine if there were any statistically significant differences between the average annual landing data from 1999-2012. This allowed us to determine whether the performances in annual regional monkfish landings by port were comparable or different.

The null hypothesis assumes that there is no statistically significant difference between regional monkfish landing production by port. The alternative hypothesis suggests that there is a statistically significant difference in regional monkfish landing production by port.

Table 8-ANOVA analysis of regional monkfish landing productivity in Iceland

Anova: Single Factor α= 0.01

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
South	8	883.7143	110.4643	11020.92
NW	8	744.1	93.0125	11862.27
East	8	211.3571	26.41964	5116.165

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	31473.8	2	15736.9	1.686135	0.209361	5.780416
Within Groups	195995.5	21	9333.12			
Total	227469.3	23				

According to the summary (Table 8), average monkfish landing per port is greatest in the South region (110.5 t), followed by the Northwest region (93.0 t) and East region (26.4 t). However, the p-value of 0.209361 is greater than the significance level (0.01) and the F test statistic (1.686135) is less than F critical value (5.780416).

Therefore, there were no statistically significant differences between group means as determined by one-way ANOVA ($F(2,21)= 1.686135$, $p= 0.209361$). Therefore, we fail to reject the null hypothesis at a 99% confidence level in that there is no statistically significant difference between regional monkfish landing production by port as seen from 1999-2012.

Table 9-Descriptive statistics for regional top 8 ports for annual monkfish landings in Iceland

	South	*Northwest*	*East*
Mean	110.4642857	93.0125	26.41964286
Standard Error	37.1162385	38.50693554	25.28874592
Median	73.71428571	40.05	1.357142857
Mode	#N/A	5.1	#N/A
Standard Deviation	104.9805757	108.914061	71.5273749
Sample Variance	11020.92128	11862.27268	5116.165361
Kurtosis	-0.668966028	-0.486590327	7.996666452
Skewness	0.885992568	0.988273276	2.827641804
Range	280.7142857	283	203.4285714
Minimum	8.785714286	5.1	0
Maximum	289.5	288.1	203.4285714
Sum	883.7142857	744.1	211.3571429
Count	8	8	8
Largest(1)	289.5	288.1	203.4285714
Smallest(1)	8.785714286	5.1	0
Confidence Level(99.0%)	129.8876567	134.7543778	88.49754395

The Northwest region (M= 93.0, SD= 108.9), South region (M=110.5, SD=104.9), and East region (M=26.4, SD=71.5) had no statistically significant differences.

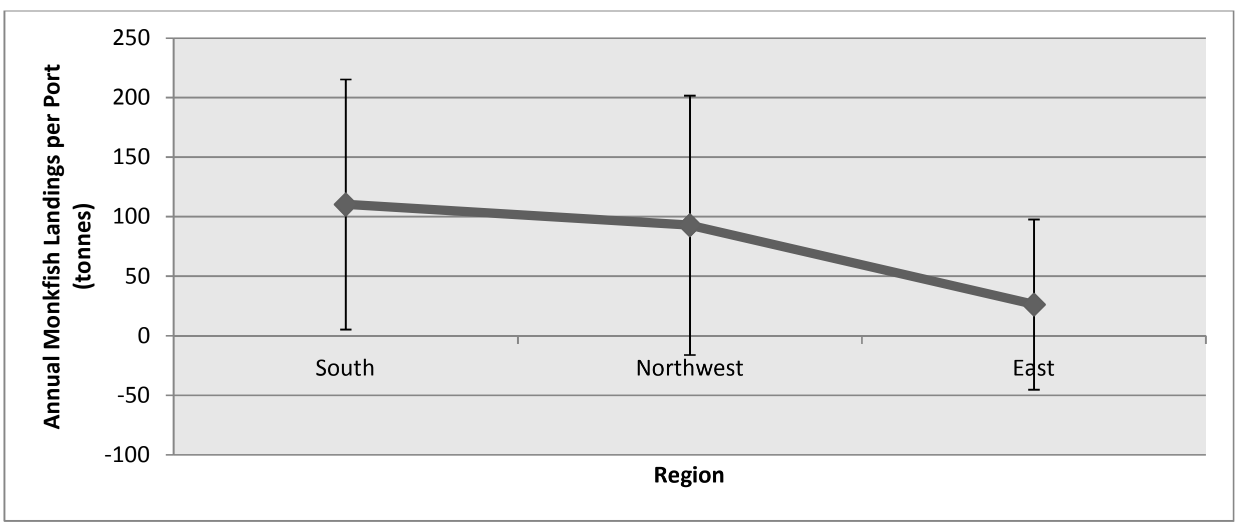

Figure 14- Regional differences in monkfish landing production in Iceland. There is no statistically significant difference between means in the regions

A paired t-test was conducted on the South and Northwest region's average annual monkfish landings in their top 8 ports and compared between two time periods: 1999-2007 and 2008-2012. It was conducted to determine whether the mean landings in the South and Northwest regions were statistically different from each other. The null hypothesis was that the average means are the same.

Table 10-Paired t-test for South and Northwest regions between 1999-2007 and 2008-2012 in Iceland

t-Test: Paired Two Sample for Means **α=0.05**

	1999-2007		2008-2012	
	South	***NW***	***South***	***NW***
Mean	106.2639	41.30139	118.025	186.4
Variance	11848.64	2627.972	10571.08	48551.66
Observations	8	8	8	8
Pearson Correlation	0.773394		0.498177	
Hypothesized Mean Difference	0		0	
df	7		7	
t Stat	2.403275		-1.01157	
P(T<=t) one-tail	0.023619		0.172712	
t Critical one-tail	1.894579		1.894579	
P(T<=t) two-tail	0.047238		0.345425	
t Critical two-tail	2.364624		2.364624	

According to the paired t-test analysis (Table 10), from 1999-2007, the p-value (0.023) was less than the significance level (0.05). Therefore, we reject the null hypothesis with a 95% confidence level and conclude that average means of monkfish landings were different from 1999-2007.

According to the paired t-test analysis, from 2008-2012, the p value (0.173) was greater than the significance level (0.05). Therefore, we fail to reject the null hypothesis with a 95% confidence level and conclude that the average means of monkfish landings were not statistically different and are concluded as the same.

5 Discussion

The monkfish landing data was very telling of the current status of monkfish in Iceland. Data outlining the productivity of Iceland's largest fishing companies with respect to monkfish landings illustrated the disparity in regional ownership of quota rights. Trends found in data reinforced the efficiency and scale of operation in the Westfjords. Trends in data substantiate the need for the establishment of owned and operated monkfish fisheries in the Northwest and illustrate fundamental problems in the ITQ system that have persisted and continues to influence contemporary management. Moreover, it revealed knowledge gaps and inadequate technical innovation pertinent for effective management of the fishery. The initial allocation of quota rights and certain regulations of the ITQ system have shown to be influential factors that strongly shaped the regional development of monkfish fisheries in Iceland and limit the ability to develop monkfish fisheries in the Westfjords presently.

The ITQ system was analyzed and its weaknesses identified in order to isolate factors that hinder development in marginalized fishing communities. Suggestions for amendments have been provided to enhance the current ITQ system and mediate subsequent monkfish fisheries development primarily in the Northwest region, but can be used in general to support development in marginalized fishing villages.

5.1 Monkfish contribution by the northwest region

The impact and contribution of Iceland's northwest coast for the national monkfish industry has steadily increased since 1999. In 2011, only 28% of monkfish landings came from the southern region of Iceland, in stark contrast to the 72% of landings from west of the Reykjanes Peninsula (MRI, 2012b). This has become a point of contention regarding the governance and issuance of quota for monkfish in Iceland. Initially, quota was assigned based on historical catch records. This led to the majority of monkfish quota owners based in southern Iceland. However, the predicament for the Icelandic monkfish industry lies in the unprecedented nature of climate-driven poleward distribution of monkfish. Monkfish was primarily found and caught off the southern coast of Iceland. Given the increases in ocean temperature, the regional distribution of monkfish has expanded as far as northwestern

Iceland. Today, the majority of monkfish is captured in northwestern Iceland, exceeding that of South and East monkfish landings. Despite the greater catch in northwestern Iceland, the majority of owners remain based in Iceland's South region. This is important because of the economic and social impacts it has on small northern towns that can be supported or rely on small-scale fishing ventures. Ownership of monkfish quota can help to sustain smaller, rural towns that can greatly benefit from additional sources of revenue. Furthermore, local ownership will mitigate illegally-caught monkfish and promote sustainable development of the monkfish resource because of the change in relationship dynamics (i.e. landlord vs. tenant). There will be more incentive as an 'owner' versus a 'tenant' or on-looker to institute long-term management strategies, surveillance, and monitoring that maintain the integrity and quality of the monkfish resource for the future. In addition, the positive externalities of effectively managing a monkfish fishery can manifest itself in other sources of revenue, such as increasing property value and attracting populations to smaller, coastal towns.

5.1.1 Fishing company ownership

Since 2001, ownership of monkfish quota amongst the 50 largest owners has disproportionately represented the Northwest region in favour of the South region. A comprehensive list of the largest Icelandic fishing companies since 2003 is presented in Table 11 of the appendix. Of the 50 largest owners of quota, Northwest ownership of quota has only accounted for approximately 2.39% or 484.49 tonnes of monkfish landings since 2001 (Table 6). In contrast, of the 50 largest owners of quota, Southern-based ownership of quota accounted for 38.09% or approximately 7497.06 tonnes of monkfish catch since 2001 (Table 6). Since 2003, the top 50 largest owners have contributed approximately 65.12% to the total annual catch limit for monkfish (Table 7). Notably in 2009, the top 50 largest owners of quota accounted for 74.92% of total allowable catch for monkfish (Table 7). 2011 observed 72% of landings from west of the Reykjanes Peninsula, moreover it exemplified the disparity in the regional ownership of monkfish quota. In 2011, the top 50 largest owners of monkfish quota accounted for approximately 68.43% or 1,521.4 tonnes of the total allowable catch (Table 7). Owners of quota share based in the Northwest region accounted for a mere 2.12% or approximately 47.1 tonnes of catch, while owners of quota based in the South region accounted for a significantly higher 42.97% or approximately 955.5 tonnes of monkfish total allowable catch (Table 6). While the Northwest region has shown tremendous growth since 2008, there still remains much disparity in the ownership of quota and where monkfish is being landed. Even though the annual average monkfish catch for Northwestern ports has risen 357.1% from 333.0 t prior 2007 to 1, 522 t since 2008, they have only achieved marginal improvements in fish company ownership (Figure 11 & Figure 12). While an 85.39% increase in average annual landings with respect to fishing company ownership since 2008 appears to be positive, this is only a relative improvement. In absolute terms, this has only been an improvement to 2.99% since 2008 from 1.96% prior to 2007 in fishing company ownership (Table 6). The current trends show strong growth for the future of the Northwest region monkfish landings; however it displays very slow progress with respect to fishing company ownership or increased access to quota rights.

5.1.2 Impact of supplementary quota allocation

In March 2010, Althingi, the Icelandic parliament, enacted legislation to increase the monkfish quota up to 2000 tonnes within the two following fishing seasons under the direction of the Minister of Fisheries (Iceland Review, 2010). Provisions included the sale and allocation of additional quota to fishing companies at a specified fee. Approximately, in-excess of 200 boats were assigned additional quota. The majority of allocation totaled greater than 2.9 t per boat and was sold for a fee of approximately 120kr per kilogram (Morgunbladid, 2010). The bill suggests that the revenues generated from the quota fees will be distributed by the Treasury; 40% allocated to a research fund focused on increasing the value of fish and 60% allocated to a regional development plan (Morgunbladid, 2010b). The legislation faced much backlash and opposition from the Confederation of Icelandic Employers (SA) that vehemently protested its inception because of its impact on the continuity of the Stability Pact (Iceland Review, 2010). The SA argued that the enactment of legislation that changes monkfish quota would affect the relations between the SA and the government, specifically during periods of wage contract negotiations (Iceland Review, 2010).

The Stability Pact was signed on June 26, 2009. It is a government plan that aims to spur economic recovery which includes outlining the manner in which employers and employees (both in the private and public sector) operate in cohort with the state and municipalities (Prime Minister's Office, 2009). A significant outcome of the agreement was the removal of labour market uncertainties via the conclusion of collective bargaining agreements in both the private and public sectors in order to lessen the burden on the lowest income groups (Prime Minister's Office, 2009).

5.1.3 Primary candidates to establish monkfish fisheries

The implementation of legislation changing monkfish quota allocation profoundly affected the permanence of the Stability Pact and the growth of the Westfjords via the majority of additional monkfish quota distributed to the Westfjords. The Northwest region has shown steady growth in monkfish landings from 1999. ANOVA analysis revealed no statistically significant differences in average monkfish landings in the top 8 ports of each region from 1999-2012. This is important because of the implication that South region historical catch records have not significantly exceeded the productivity of the Northwest region as long as documentation of monkfish landing information in Iceland has been collected. It provides more justification for the establishment of monkfish fisheries in the Northwest region in terms of comparable productivity. Furthermore, paired t-test analyses revealed the growth of monkfish landings in the Northwest region and further substantiated the need to establish monkfish fisheries in the Northwest region. The 1999-2007 periods displayed a statistically significant difference in average means supporting the dominance of the South region. The 2008-2012 periods revealed a reversal in trends in that the difference in average means between the South and Northwest region were not statistically significant. This is important because it reveals the improvements, development, and greater capacity for monkfish landings in the Northwest region since 2007. This is a strong impetus for establishing monkfish fisheries in the Northwest region.

Since 2008, five fishing ports in the Northwest region have displayed tremendous growth: Arnarstapi, Rif, Olafsvik, Grundarfjordur, and Bolungarvik. These sites would be primary candidates to establish a monkfish fishery. Rif and Olafsvik in particular have shown high productivity, annually averaging 587 t and 447 t, respectively (Table 2). Since 2008, this has accounted for approximately 17.96% and 13.68% of total annual landings. Within the Westfjords: Bolungarvik, Sudureyri, and Flateyri were primary candidates to establish monkfish fisheries. Bolungarvik has shown strong productivity since 2008 annually averaging 80.8 t and landing 182 t thus far in the current 2012/2013 fishing campaign (Table 2). Suðureyri has shown modest gains, averaging 14 t of monkfish annually since 2008; however it has been displaying a growing trend with strong 2010 and 2011 fishing campaigns. Because the majority of its monkfish is landed during the exclusive monkfish fishing season, it is yet to be seen how much growth Suðureyri will incur in the current fishing campaign. Flateyri experienced a strong 2011 season with annual monkfish landings of 66 t (Table 2). This was significantly higher than previous fishing campaigns. Similar to

Suðureyri; Flateyri caught the majority of its monkfish, 60 t of its total 66 t, during the exclusive monkfish fishing season. It is yet to be seen whether they can improve on the result during the current fishing campaign. If Flateyri does show a strong haul again, it will re-enforce its candidacy as a potential site in the Westfjords to establish a monkfish fishery. These ports represent monkfish fisheries in their infancy with great potential to grow. They should be granted the support to develop the fishery based on current levels of operations and their steady progress since 2008. Furthermore, each port will have significant impacts on their small communities given the opportunity to develop their fisheries. Additionally, these ports largely adhere to management stipulations and ecological restrictions by landing the majority of monkfish during the exclusive fishing period.

The 2010 and 2011 fishing campaigns showed interesting trends in the Westfjords. Following the re-issuing of quota rights in 2010, the majority of which was allocated to Westfjord ports, there was a surge in monkfish landings for several ports during the 2010 and 2011 fishing campaigns. Bolungarvik, Suðureyri, and Flateyri showed noticeable increases in monkfish landings for both the 2010 and 2011 fishing campaign. The effect of additional quota manifested visibly in several ports with traditionally low monkfish landings. Isafjordur produced historical highs of 16 t and 11 t in 2010 and 2011, respectively (Table 2). However in 2012, Isafjordur was unable to sustain its growth with a poor haul of only 4 t. Similarly, Stykisholmur displayed historically high levels of monkfish catch during this period with 28 t and 17 t, respectively; however in 2012, it produced a mere 4 t (Table 2). Patreksfjordur produced 7 t and 20 t in 2010 and 2011, respectively (Table 2). Interestingly, Patreksfjordur has sustained its growth in 2012 with 18 t of landed monkfish (Table 2). It is interesting to note the immediate positive impact of additional quota for several Northwest ports, particularly Isafjordur, Stykisholmur, and Patreksfjordur in the Westfjords and its equally abrupt and negative impact following the non-issuance of additional quota in subsequent years. It is difficult to ascertain an accurate estimate of monkfish landings in Westfjord ports during the 2010 and 2011 fishing campaigns because of the high incidence of unreported and illegally caught monkfish. Information about unreported and illegally caught monkfish would provide a more comprehensive idea about the volume of monkfish availability in the Westfjords. This is important because Westfjord ports that are poorly reflected in reported data may actually be landing significant amounts of monkfish without concern for sustainable development and integrated management. Moreover, it limits the complete and accurate reflection of the actual or potential productivity of the region as a basis for fisheries development and expansion.

5.2 By-catch in the lumpfish season

The *Lophius piscatorius* or monkfish has been exclusively fished for in Iceland approximately between August and December annually since 1999. The lumpfish fishing season typically runs from March to the end of July annually and targets sexually mature female lumpfish. Since 2011, the lumpfish fishing season has been shortened to 50 consecutive days (Hafro Lumpfish, 2012). In concert with the reduction in fishing days, fewer female lumpfish harvesting permits have been issued (Hafro Lumpfish, 2012). Female lumpfish mature sexually between the ages 5-6 and reach a length of approximately 34-40 cm (Johannesson, 2006). The *L. piscatorius* females typically reach 83 cm in length at first maturity, while males reach 57 cm in length (Ofstad & Laurenson, 2007). Ofstad & Laurenson (2007) suggest that the *L .piscatorius* spawning season proceeds from late winter to early spring, based on observations of ripe females and Gonadosomatic index (GSI) values. This spawning period for *L. piscatorius* coincides with the exclusive lumpfish fishing season in Iceland and will affect monkfish recruitment with excessive by-catch of monkfish, specifically juvenile and undersized fish.

Monkfish by-catch has been relatively high in the exclusive lumpfish fishing season in Iceland since 1999 (Table 5). The monkfish by-catch has comprised a significant proportion of the annually-allocated quota share for *L. piscatorius*. In the years 1999, 2001, 2002, and 2003, monkfish by-catch nearly equaled or exceeded the landings of monkfish in the exclusive monkfish fishing season 527t to 414t, 417t to 435t, 754t to 473t, and 895t to 807t, respectively (Table 5). From the period 1999-2012, monkfish by-catch has accounted for approximately 39.94% of the total quota allocation (Table 5). Furthermore, from 1999-2012, the average annual ratio of monkfish landed as by-catch versus caught exclusively is approximately 4:5. Since 2009, the ratio of by-catch to exclusively caught monkfish dropped to a historically low ratio of approximately 2:5 and has since risen and leveled off at an approximately 1:2 ratio in 2012 (Table 5).

Despite recent improvements in the reduction of by-catch, the levels of monkfish by-catch in the lumpfish fishing season remains relatively high and needs to be improved. Given that approximately 40% of monkfish quota share since 1999 has been caught as by-catch, there needs to be greater improvement in management to sustainably develop the monkfish resource. Several methods need to be employed to better comprehend the issue and subsequently implement innovative solutions that reduce the ecological implications of excessive fishing in a period sensitive to population turnover. The lack of integrated and comprehensive data about the fisheries is a major impediment to effective management. Resolving information gaps is a vital first step in addressing issues such as excess monkfish by-catch during the lumpfish fishing season.

5.3 Resolving information gaps

5.3.1 Addressing lack of physiology and spawning information

There are tremendous gaps in information regarding monkfish that lessen the degree of comprehension about the species. There is limited knowledge and poor understanding of the biology and life history of *L. piscatorius* in Iceland. Further research needs to be conducted to assess physiological aspects that can provide a better understanding of function as well as quantifiable, categorical information such as sex ratio. Many aspects of the monkfish need to be identified in order to better manage the resource.

Limited information is available about Iceland's monkfish stock. The limited information on physiological process hinders the ability to effectively manage the resource. Research needs to explore the stages of maturation, reproduction, spawning time, spawning behaviour, and spawning areas. Very little is known about the nature of passive larval drift versus active migration. Furthermore, knowledge about the location and time of spawning events would be crucial to effectively manage monkfish by providing better estimates of recruitment and determining when and what areas to close off to fishing to ensure a successful spawning event. In addition to when spawning events occur, the ability to understand how the spawning process occurs is also crucial to managing the monkfish resource. Determining how spawning occurs can identify vulnerable stages in the process and employ a more holistic management plan that limits interaction during exposed periods in an effort to enhance recruitment. The mechanisms of the spawning period need to be better understood in order to maintain the optimal environment for successful reproductive cycles and the production and retention of a larger stock biomass. Physiological factors are important to implement selective-catch programs. Berkeley et al (2004) indicates the compounding effect of fishing in terms of not only reducing biomass through the act of fishing itself, but catalyzing local exhaustion by affecting age and size structure of fish populations. Berkeley et al (2004) posits the idea that recruitment may arise from different factions of the spawning population annually and that stocks of fish may actually be comprised of many reproductively isolated units. This is evidenced through more resilient and faster growing offspring produced by older, larger female rockfish than those produced by younger fish (Berkeley et al, 2004; Sogard et al, 2004; Palumbi, 2004). A similar study applied to Iceland's monkfish populations can provide insight into the impact and contribution of specific factions of the spawning population for recruitment efforts. Resolving this uncertainty is important for determining the appropriate gear type restrictions and selectivity of age-class for fishing operations and guiding management actions. Addressing the limited knowledge about monkfish physiological parameters can provide greater insight into spawning efficiency, recruitment, and offer greater foundation for subsequent management decisions that are most effective for sustainable growth.

5.3.2 Addressing lack of landing location and gear type information

The difficulty in attaining landing location data and gear type used further exemplifies gaps in information and inaccessible records that hinder integrated management of the monkfish resource. Landing location data is important because it can outline predominantly monkfish-populated areas. This provides greater insight for management decisions such as instituting area closures. Moreover, seasonal location data can be used to infer temporal-spatial patterns for monkfish population habitation. Temporal-spatial data can serve as a baseline for future research in monkfish location, habitat requirements, and mobility. Currently, obtaining monkfish landing location information is extremely difficult because of poor recording and the inaccessible nature of the data. Fiskistofa has been unhelpful releasing sensitive location-based information. There needs to be greater accessibility and collection of location-based information. Gear type information is more readily available than location data; however it too needs to be more refined and presentable. It was difficult determining CPUE for vessels when gear types were not identified. A distinct problem was the discrepancy in gear types used across vessels that made CPUE values difficult to compare from one vessel to the next which used different gear types. This is especially important because it can reveal the efficiency of regional production. Despite the greater amount of landings in the Northwest region since 2008, it is poorly understood whether this is a result of more efficient catch effort or more intensive fishing operations. Understanding fishing effort is crucial to determining 'real' production in the Northwest region. CPUE or efficiency of catch effort should be utilized to gauge regional production efficiency with respect to monkfish landings. Furthermore, it should be included as criteria evaluated for development fund allocation and establishing monkfish fisheries in regions, specifically the Northwest region.

A comprehensive stock assessment must be conducted on Iceland's monkfish stock. It is important to determine abundance and biomass indices in an attempt to gauge population estimates and quantify the impact of fishing on the total population. Greater information about abundance and biomass can provide more bases for the implementation of detailed and effective guidelines for monkfish management plans. In addition to greater population and abundance estimates, the composition and ages of monkfish stocks needs to be investigated to determine the ratio of male to female monkfish and the distribution of age in the population. Information about the monkfish stock sex ratio will greatly impact the ability to infer the stock's potential for recruitment and growth. Information about the proportion of population within each stage class helps model and extrapolate population scenarios and infer recruitment capabilities.

5.3.3 Implementing modeling strategies

The use of age-structured modeling has been integrated in other fisheries, such as the South Pacific Albacore and yellowfin tuna, to understand population dynamics of fisheries and influence the design of management programs (Fournier et al., 1998; Hampton & Fournier, 2001). An extensively-conducted age-structured model to uncover population dynamics can forecast the number of individuals in successive stage classes annually. Studies based on GPS (Geographic Positioning System) tracking of monkfish can reveal the locations of monkfish habitats, show patterns of monkfish movement, and reveal potential spawning regions. With the aid of GPS technology, performing a longitudinal study or cross-sectional study is feasible. A longitudinal study follows a newborn cohort from birth through their entire life in order to estimate age or stage survival and offspring reproduction (Kaplan, 1998). While it provides insights into individual demographics, this option is less favourable because of the lack of certainty regarding spawning periods and reproductive cycles of monkfish which make it difficult adhering to the parameters of a longitudinal study. A cross-sectional study collects data from a wide-range of individuals across a diverse age-range including their birth histories in order to estimate reproductive data and age or stage-specific survival (Perrin et al, 2009). This method permits extensive collection of morphological and biological data that explicitly confirms age estimations and reproductive and physical maturity (Perrin et al, 2009). This is more feasible in Iceland given the unavailability of information regarding monkfish reproduction, spawning period, and spawning location. The ability to annually forecast the abundance of individuals in different stage classes is a rather large and extensive project. It requires reliable information about the number of offspring produced by a female in a given age or stage class. It also requires the probability of an individual surviving from one age or stage class to the successive class. The contributions of each age class can be determined over a specific time period; thus, the total population over a specific time period can be determined by the sum of contributions across all age classes. This model can be used to execute sensitivity analysis. By isolating individual variables, the model can predict the effects of manipulating a variable on the long-term population size. Sensitivity analysis is an important tool for determining where to direct resources with respect to management efforts.

Furthermore, age-structured modeling can produce survivorship curves to estimate the population size, composition, and resiliency. Survivorship curves can be used as feedbacks to determine the effect of management decisions on monkfish. The effects of the experimental imposition of new and diverse selection pressures on monkfish via changes to management can be gauged by its effect on the survivorship curve. This feedback tool is important for the future because it provides accountability and insights into the direct effects of management. This is an important tool that can be used to efficiently manage monkfish in Iceland.

Understanding the population dynamics of the monkfish resource can reveal factors that control or affect the size of monkfish populations. Administering age-structured modeling of the populations and sensitivity analysis are crucial steps for the development of monkfish stock assessment policies and the subsequent managerial decisions used to effectively promote sustainable development of the monkfish resource. The foremost limitation of modeling population dynamics rests in the reliability of input information. The goal of administering an age-structured model is to provide a dependable estimate of the degree of change in population sizes resulting from the volatility of a specific variable rather than producing a perfect forecast of long-term population size. The variability in specific parameters, ranging from the actions of management decisions to environmental pressures, can influence a degree of change in population sizes. Therefore, age-structured modeling is a tool that should be utilized for risk analysis or strategic environmental assessments. It should be used in concert with the precautionary principle to advise management decisions, rather than for sheer forecasting purposes for absolute benchmarks guiding industry goals. The nature of the spatially-sensitive age-structure information limits its effectiveness when used in other regions hosting monkfish populations, but may serve as an indication of ranges and expectations. Therefore, the collection of information regarding the age structures of monkish is an important requirement for Iceland because of the place-based nature of the information and differences in life cycles in different habitats.

5.3.4 Modified landing assessment procedures

In addition to an age-structured modeling regime, there should be more frequent and thorough assessments of monkfish landings. The current landing procedures are fairly extensive and rigorous, with both sea and land supervision. Aspects of the current inspection procedure focus on ensuring the appropriate application of fishing gear; determining the species and size composition of species; and the weighing of landings (Fiskistofa, 2012b). In addition to these categories, there should be more focus on determining sex ratios and size compositions of monkfish (length can infer age), even on a short-term basis, to establish a substantial database of baseline information. The necessity for baseline data is important in order to enhance the efficacy of age-structured modeling and understand monkfish population dynamics. A cross-sectional study, focusing on age-structured modeling largely relies on individuals at different ages in a population and their birth history. Thorough examination of monkfish landings can identify the proportions of different age-classes and sizes found in landings and contribute to age-class mortality rate data. Sex ratio data is important for population dynamic studies. It can provide insight into how the sex composition of landings may differ from the lumpfish season versus exclusive monkfish season. The ratio of female monkfish in landings from the exclusive monkfish fishing season has been noticeably lower than females in by-catch of monkfish in the lumpfish fishing season (Nebel et al, 2011). In July 2011, a comparative study of sex ratio in monkfish nets and lumpfish nets in Breidafjordur, Iceland revealed that females accounted for approximately 59% of monkfish caught in monkfish nets and approximately 70% of monkfish caught in lumpfish nets (Nebel et al, 2011). In addition to a majority of females being landed, nearly all females caught in the study years 2010 and 2011 were in pubertal stage 1 (Nebel et al, 2011). This persisting trend underlies the significance of sex ratio monitoring. Sex ratio data in landings can be used to gauge the need for sex selective fishing. The disparity in the ratio of female monkfish in seasonal landings can be used to implement sex selective fishing programs in order to stabilize monkfish population growth. Age-class and sex ratio data recorded in landings can be used in culmination with age-structured population dynamics modeling to advise decisions in an integrated and holistic management system that aims to promote sustainable development.

Selective fishing in the monkfish industry is an important tool that may need to be invoked more frequently in the future. Preliminary findings in Iceland point to niche shifts, primarily female monkfish selecting habitats with higher feeding values (Nebel et al, 2011). These preliminary findings in Iceland have been substantiated by similar findings in the Maine monkfish fishery. Studies in Maine showed differences in monkfish feeding as a function of habitat and size and their interaction (Sherwood & Grabowski, 2007). Sherwood & Grabowski (2007) identified an important behavioural shift at approximately 80 cm that involved a change in habitat association (sand/mud to rocky/ledge), a change in diet (higher trophic position and larger prey), and a change in condition factor. This is an important development considering the greater proportion of females in larger size classes for monkfish. Sex selective fishing programs in Iceland may require integrating size-dependent habitat association factors in order to reduce fishing pressure on female monkfish. Furthermore, this may require the avoidance of complex or rocky/ledge environments in order to reduce the levels of female monkfish landings in the exclusive season and lumpfish season.

A comprehensive, highly intensive assessment of age structures and birth histories are necessary for accurate estimations of population size and dynamics, and making well-informed management decisions. Comprehensive ecological knowledge is needed to reconcile environmental problems associated with managing differing expectations of human values and biological capacity. Monitoring is crucial following the implementation of a highly-intensive assessment period for monkfish age-structure. Management decisions based on modeling, while founded on data, is as reliable as the data used: hypothetical, and does not illustrate a causative effect. Therefore, it is imperative that a modeling regime be accompanied with an on-going monitoring program that remains present to ensure the reliability of models and data.

5.3.5 Genetic analysis of monkfish populations

Of primary importance regarding the high proportion of monkfish landings derived from the Northwest as opposed to the South would be genetic analysis of monkfish populations in the broadly defined regions of Iceland. There has been little done using the genetic sequence of monkfish to distinguish independent species of the *Lophius* genus. Genetic analysis of monkfish from the South and Northwest can be compared to determine their degree of similarity in order to deem them a single homogenous stock or multiple stocks. Genetic sequencing maybe able to isolate distinct polymorphisms that identify distinct and individual stocks. Carrying out a genetic analysis program is a fundamental tool for establishing locally-owned monkfish fisheries in the Northwest on the basis of identifying individual and unique stocks of monkfish in the South and Northwest. Categorization of monkfish populations that distinguishes regional stocks can be the impetus to re-assess currently accepted fishing practices and validity of distributing allocated quota shares based on historical catch records. If stocks of monkfish in the Northwest are deemed a unique and independent stock from that of the South, it may induce negotiations and concessions to current fishing practices and standards. The findings would at least provide sufficient evidence authorizing the re-evaluation of the process used to allocate initial quota shares and advertise the marginalizing effects of the ITQ system on small, fishing communities. It would bring to light the inadequacy of the distribution method of perpetual rights for quota shares and invoke discussion and draw attention to the current state of administration over Iceland's fisheries with fewer players based mostly in the Southwest.

This possible development may provide more opportunities for locally-owned initiatives in the Northwest to establish a monkfish fishery. This could be a rallying point to lobby for greater share allocation of monkfish TAC to Northwest-based owners and help develop efficient, locally-owned fisheries that serve multi-prong functions such as: promoting beneficial externalities (sustainable development, efficient management), stimulating local economies in small coastal fisheries-dependent communities, and reducing the migration of people to the Southwest. Whether or not genetic analysis deems Northwest monkfish stocks an independent population, undertaking such a process would draw attention to the disparity in distribution and owners of fishing rights holders and catalyze lobbying efforts.

5.4 Effect of non-native species on local environments

When monkfish endeavour farther north and inhabit new areas, they alter the functionality of an existing ecosystem. The effect of multiple drivers of climate-change is difficult to isolate and ascertain given its intricacy and often non-cumulative progression. Climate change has forged reservoirs that serve as hotspots for the introduction of species, notably seen with the introduction of monkfish in Northwest Iceland (Rahel & Olden, 2008). Moreover, climate change has expedited the development of competitive and predatory effects of introduced species on native species while increasing the spread of disease (Rahel & Olden, 2008). Introduced species resulting from human-induced global climate change affect native biological diversity, modify the structure of communities, and affect the functioning of ecosystems (Vitousek et al, 1997; Wrona et al, 2006).

Furthermore, monkfish have varying degrees of impact on predator-prey relations with respect to fishing areas and monkfish nets versus lumpfish nets fishing operations. Diet comparisons of monkfish revealed a variety of different prey species based on region. Diet comparisons between monkfish nets and lumpfish nets in Breidafjordur revealed that monkfish caught in lumpfish nets constituted a large portion of *Cyclopterus lumpus, Cyclopterus lumpus male, Pholis gunnellus, Myoxocephalus scorpius, Gadus morhua, Ammodytidae, radjidae,* and *Merlangius merlangus* (Nebel et al, 2011). Monkfish caught in monkfish nets were fished in a special area of Breidafjordur frequented during monkfish-specific fishing expeditions impacted to a much smaller extent: *Pleuronectes platessa, Hippoglossoides platessoides, Mallotus villosus, Melannogrammus aeglefinus, Anarhichas lupus, Merlangius merlangus,* Radjidae, and *Gadus morhua* (Nebel et al, 2011). In addition, comparison of main diet items in monkfish from Breidafjordur, Isafjarardjup, and Strandir revealed even differences in regional impact. Monkfish in Breidafjordur largely consumed *Gadus morhua, Myoxocephalus scorpius, Cyclopterus lumpus*, and *Pholis gunnellus*; in Isafjardardjup: *Hippoglossoides platessoides, Anarhichas lupus, Pleuronectes platessa*, and *Gadus morhua*; and in Strandir: *Gadus morhua, Limanda limanda, Hippoglossoides platessoides*, and *Anarhichas lupus* (Nebel et al, 2011).

The effects of global climate change are extensive regarding the introduction of species. The expansion of the monkfish range into Northwest Iceland endangers coastal communities in the region through a breadth of impacts. Despite the knowledge of the impacts of introductory species on newly colonized areas, there have been no complete assessments identifying vulnerabilities or changes to coastal ecosystems of recently monkfish colonized areas. This illustrates the state of marginalized fisheries-dependent communities. In addition to not having quota for monkfish to drive local economies, they are further penalized by the poor or complete lack of assessments on the possible negative impacts of monkfish colonization. This includes the economic, ecological, and environmental impacts on indigenous commercial species and natural resources.

Estimating the extent of damage influenced by the introduction of monkfish to new ecosystems will be difficult, but there needs to be greater studies, assessments, and monitoring on the impact of the poleward distribution of monkfish. They can affect ecosystems in terms of altering the local food chain, modify existent predator-prey relations, and affect the physical environment (Zavaleta et al, 2001). Further research is required to determine the direct and indirect impacts of the introduction of monkfish in Northwestern Icelandic environments in terms of ecological, environmental, and economic impacts. Furthermore, assessments are necessary to promote sustainable development and reduce the risk of illegal practices. Marginalized communities with fewer options are more likely to illegally utilize monkfish resources because of its value. The arrival of monkfish may have detrimental effects on other species that generate revenue and force small fisheries-dependent communities into short-term, unsustainable practices with respect to illegal monkfish landings. Therefore, it is imperative to conduct assessments on the effect of monkfish colonization in Northwest communities and respond appropriately with management actions that mitigate impacts on native species and secondary impacts of illegal and unsustainable harvesting by marginalized fishing communities.

5.5 Gear modification

Improving the availability of information addressing the composition of monkfish by-catch and the utility of specific mesh sizes are important factors that can reduce the extent of by-catch and impact of fishing on ecosystems. An important method to combat the high levels of by-catch capture may lie in the modification of fishing gear. Gear modification can improve the efficiency of capturing targeted commercial species, control size at capture thereby enhancing yield per recruit, and reduce discards and impacts on non-target species (Guijarro & Massuti, 2006; Armstrong et al, 1990; MacLennan, 1992).

Currently bottom trawls are employed, more specifically specialized small mesh trawls, to catch Icelandic northern shrimp and nephrops lobsters (Icelandic Fisheries, 2013). The reduction in by-catch of monkfish has been aided by the introduction of sorting grids which became a mandatory implement in 1996 (Icelandic Fisheries, 2013). However, vast amounts of by-catch of monkfish have been recorded as a result of the non-use of sorting grids by lobster trawlers (Icelandic Fisheries, 2013). Sorting grids are not a compulsory measure. The mandatory use of sorting grid in the lobster industry must be enforced to reduce by-catch of monkfish. The use of sorting grids will limit the detrimental effects of the sub-legal by-catch of monkfish which affects monkfish recruitment and spawning population.

Gillnets in Iceland experience wide-range use coinciding with the migration of cod to spawning grounds in the late winter (Icelandic Fisheries, 2013b). Given the extensive use of gillnets beginning in January, plateauing in March, and concluding in May; large quantities of monkfish by-catch can be attributed as casualties of the cod fishing season (Icelandic Fisheries, 2013b). The gillnets used for cod range from 5.5" to 8"in mesh size (Icelandic Fisheries, 2013b). In addition to the abundance of cod gillnets during the late-winter season, a variety of customized gillnets targeting other species are employed. This includes gillnets specialized for haddock (5.5-6 inch mesh size), flatfish (6.5-7.87 inch mesh size), and Atlantic halibut (18 inch mesh size) (Icelandic Fisheries, 2013b). Importantly, lumpfish gillnets (7-10.5 inch mesh size) are in large-scale use during the period of March to July, prior to the exclusive monkfish fishing season. According to Salerno et al. (2010), the highest levels of by-catch of monkfish were found in the 10" gillnet mesh size. Notably, Salerno (2010) described the trend of increased length of monkfish proportionate to increasing mesh size. Therefore, the lumpfish mesh sizes unfavourably target a greater proportion of sub-legal or smaller monkfish. The practice is both inefficient in terms of CPUE and detrimental to the overall biomass of monkfish populations and health of the stock. The extensive use of lumpfish-specialized gillnets on the larger end of the spectrum (10.5 inch mesh size) negatively affects monkfish recruitment and spawning population by selectively catching monkfish in earlier age classes.

5.5.1 Application of experimental gillnet sizes

The Gulf of Maine Research Institute investigated the effects of size selectivity and by-catch in a monkfish gillnet fishery. The study employed an otter trawl and tie-down gillnets of 10", 12", and 14" mesh size aimed specifically for monkfish. The study found that the mean monkfish lengths increased with an increase in gillnet mesh size; while the length of trawl caught monkfish was considerably smaller than gillnet caught fish (Salerno et al, 2010). In addition, gillnet caught monkfish are significantly larger, with respect to length, than trawl caught monkfish. Moreover, a notable difference in the length to girth ratio was present in trawl versus gillnet caught fish (Salerno et al, 2010). The study concluded that 12" mesh gillnets captured the greatest catch of monkfish by weight; 14" gillnets produced the smallest catch of monkfish by weight and number; and female monkfish were predominant in the catch from 12" and 14" gillnets (Salerno et al, 2010). Of considerable note, the lowest levels of by-catch were found in 12" gillnets, while the greatest levels of by-catch were discovered in 10" gillnets (Salerno et al, 2010).

The amount of female monkfish landed in the lumpfish season is noticeably greater than female monkfish caught during the exclusive monkfish season. The targeting of larger fish in the lumpfish fishery is mainly female selective. To stabilize fishing effort on the selective fishing of sexes, it may be necessary to target smaller fish in the lumpfish season to reduce pressure on female monkfish. Changes to gillnet mesh-sizes need to be implemented in Iceland to enhance the quality of monkfish catch, stabilize monkfish populations, and to reduce the impact on non-target commercial and non-commercial species during the lumpfish season. The 10" mesh size shows lower levels of females in landings however demonstrates the greatest levels of by-catch. An initial experimental inclusion of the 10" mesh is advised to determine the impact on female monkfish landings before a large-scale implementation of the gear modification. Innovative strategies with merit are imperative to successfully conduct an effective by-catch reduction campaign. The utilization of experimentally successful gillnets mesh sizes can contribute to the re-growth of Iceland's monkfish stocks.

5.5.2 Experimental application of codends

A codend refers to the closed end of a trawl net which affects size selectivity of catch mainly through mesh size, mesh shape, and type of constituent material, and net construction (Reeves et al, 1992; Galbraith et al, 1994).

Eayrs (2008) investigated measures to reduce the ecological impact of demersal trawling via the use of experimental codends to identify selectivity. The study, conducted in August of 2008, coincides with the beginning of the exclusive monkfish fishing season. The diamond-mesh codends fared poorly against both the 6.5" square-mesh codend and 7" square-mesh codend in terms of the capture of legal-sized commercial species such as the monkfish. All legal-sized monkfish were captured by square-mesh codends, while maintaining the lowest proportions of dominant by-catch species (Eayrs, 2008). The selectivity of square-mesh codends reduced by-catch without limiting the efficiency of the commercial catch (Eayrs, 2008). Furthermore, the selectivity of square-mesh codends permitted the escape of a significant amount of non-commercial catch and sub-legal species (Eayrs, 2008). In normal conditions, approximately 40% of fish and other animals are expected to pass through codends and avoid capture, while the 7" square-mesh allowed approximately 60% of fish and other animals to pass through and avoid capture (Eayrs, 2008). All three experimental codends decreased the capture rate of sub-legal commercially valuable fish (Eayrs, 2008). Moreover, the 7” square-mesh codend was most effective in reducing the capture of sub-legal commercial species, having retention rates of 7% and 3% for sub-legal American plaice and sub-legal Grey sole (Eayrs, 2008).

The selectivity of codends on demersal trawls has the ability to influence the life history and population dynamics of monkfish and other commercial species, specifically affecting recruitment. Eayrs (2008) concluded that the diamond-mesh codends prevented sub-legal monkfish from escaping; however, the square-mesh codends mediated a greater amount of escape, the open structure of the square-mesh affording easier passage for sub-legal monkfish. Interestingly, all three experimental codends prevented any escape by legal-sized monkfish (Eayrs, 2008). Eayrs (2008) posits that the chaffing net behind codends limits the escape of sub-legal commercial species and both commercial and non-commercial species of fish and animals. While the chaffing net improves the targeting of legal-sized commercial fish, the effect can be replicated by use of square-mesh codends instead (Eayrs, 2008).

The implementation of Eayrs’ findings can improve the efficiency of the lumpfish fishing season. The use of square-mesh codends has been proven to reduce the capture of sub-legal monkfish. This advancement could prove instrumental in making the lumpfish fishery more efficient in terms of capturing its target species more efficiently (higher CPUE) and reducing its impact on other non-commercial and commercial species, namely monkfish. Experimental usage of square-mesh gillnets needs to be investigated to determine the appropriate size for optimal commercial lumpfish capture and to limit non-target species retention.

5.6 The confusing legal status of quota rights

The primary problem of establishing a monkfish fishery in the Northwest stems from the short-sighted initial allocation and perplexing legal status of quota rights. The questionable inception of policies governing the ITQ system and unpredictability of quota rights case verdicts undermine the authority of the system.

5.6.1 Negative impacts of ITQ system on small, fishing communities

Small fishing communities have greater insecurities and are more liable to unemployment and collapse since the institution of the ITQ system. Communities with few alternative employment options are heavily reliant on quota share holdings to generate revenue. Eythorsson (2000) states that small communities with fewer than 500 inhabitants have on average lost a greater proportion of their share of quota than larger communities due to owners relocating or selling their quota. This is troubling for small communities where a lack of quota holdings has a compounding effect on their economic disadvantage. Additionally, small fishing communities are being marginalized by technological advancements that deem them obsolete. The advent of large factory trawlers, which has increased in quantity since the institution of the ITQ system, has onboard processing operations that limit the requirement for land-based processing plants (Haraldsson & Carey, 2011). Fisheries-dependent communities with little or no quota have few alternatives because of a lack of diverse and multifarious economy. The inclusion of small boats within the ITQ system and measures undertaken to reduce the practice of contract fishing has severely limited the ability of fisheries-driven communities to survive. Prior to the inclusion of small boats in the ITQ system, there may still have been the option of employing an effort quota strategy. In fact, the effort strategy greatly benefitted small vessel owners and small fisheries-driven communities since they did not reduce fishing effort and were not affected by conservation efforts, of which the brunt was borne by the ITQ fleet (Haraldsson, 2008). Eythorsson (2000) states that the demoralizing effect on populations of fisheries dependent communities is very strong when losing the right to fish. Many remote villages are traditionally organized as single-enterprise communities in tandem with the geographical and economical distribution of Icelandic fisheries (Eythorsson, 2000). Because of the lack of economic diversity, quota owners in small fisheries-dependent or single-enterprise communities can greatly influence the rest of the community by relocating or selling their share. Quota shares are equitable because of their transferability. The economic hardships of communities that lose quota share are further stressed by emigration because communities cannot financially support their entire population and often have few alternatives necessary to retain its population. This positive feedback mechanism is further exacerbated when infrastructure such as houses that residents of a community own, have invested in, and built become greatly depreciated in value or cannot be sold. The culmination of losses in employment, mass emigration, and highly depreciated property value collapse small fisheries-dependent communities. Furthermore, the poor state of small fisheries-dependent communities detracts immigration with little to draw populations resulting in the antithesis of central policies' efforts to reduce migration to Iceland's southwest. The liberalization of regulations in the fisheries sector mediated economic uncertainty for many small fisheries-dependent communities. The shift from a stringently-managed and regulated industry with units of production situated in communities to a free market system with global aspirations and diverse production bases in terms of mobile and aggregate production created an economically successful ITQ system which compensated for the severe social externalities experienced by marginalized fisheries-driven communities.

5.6.2 Paradoxical nature of quota rights

The difficulty in defining the legal status of quota stems from the contradictory nature of the device utilized as both private property for operational circumstance and public property by law. In actuality, the semi-privatized good has restrictions similar to those of privatized goods with the exception that it is national property. The main points of contention that drew criticism were the roles of taxation, depreciation, and the utilization of quota shares as collateral for loans (Eythorsson, 2000). By 1993, the Icelandic Supreme Court motioned the taxation of quota share as private capital while instituting a 20% annual depreciation rate (Eythorsson, 2000). By 1998, it was declared that quota was no longer an object that would depreciate (Eythorsson, 2000). The object of using national property as collateral for private loans was subject to mutual agreements devised by banks and vessel owners in order to resolve. The agreements provided security in that quota shares and vessels remained unified unless decided by both parties involved (Eythorsson, 2000).

The foremost problem to establishing a monkfish fishery in Northwestern Iceland remains in the initial allocation of quota. A Supreme Court decision brings to light the unconstitutional nature of the decision that resonates today. In December of 1998, an Icelandic fisherman was denied catch quota and a fishing licence based on lack of experience in the historical catch record period that initial quota allocation was founded on (Eythorsson, 2000). The Supreme Court found the denial unconstitutional based on Iceland's equal employment rights and deemed that the introduction of the ITQ system dispensed the publicly owned Icelandic fish resource (Eythorsson, 2000). The Supreme Court further asserted that the act of relinquishing perpetual rights to a certain assemblage of fishing vessel owners at a specific point in time did not substantiate the compulsion to protect resources or secure the collective interest of the public (Eythorsson, 2000). Therefore, the unconstitutional nature of quota share allocation was publicly vindicated; however, the ITQ system faced little reprimand because the

Supreme Court deemed it constitutional with the exception of the nature of its inception and delegation. In 1999, the vessel Vatneyri BA won a case in Low Court regarding the possession of catch exceeding their appropriated quota shares; however in April 2000, the Supreme Court contradicted itself by overturning the decision on the grounds that since quota shares were not legally defined as private property, perpetually allocated quota was not unconstitutional (Eythorsson, 2000). The back-and-forth contradictory outcomes demonstrate a lack of clarity in ITQ-legislation. It illustrates the shaky foundation the system is based upon. The lack of certainty regarding the legal status of quota shares needs to be addressed in order to develop a solid foundation which supports a newly-reformed ITQ system that includes marginalized communities such as those in the Northwest region. Thus, the unanticipated consequences of entrusting perpetual rights to a relatively arbitrary group of people, (vessels owners active within the confines of 1980-83 historical catch records), greatly affects the ability of thriving locally-owned and operated monkfish fisheries to be established in Northwestern Iceland today. A significant problem is the irreversible momentum carried by the institution of the ITQ system and its initial allocation of quota shares. If quota shares were initially distributed on a temporary basis, the legality issues accompanying perpetual rights may have been avoided. The application of a temporary allocation of quota would have proved an effective experiment to troubleshoot flaws in the system and gauge its efficacy. Instead, the lack of adequate preparatory measures manifests as downstream repercussions which permeate and affect, most often small, fisheries-driven communities today. The current allocation of perpetual quota rights has become far too central and ingrained in the socio-economic and structural landscape of Iceland to altogether remove. The process of re-initiating a system to distribute quota rights is unlikely because of the resulting economic impacts of compensating current quota owners who have invested in the resource. The economic ramifications would predominate despite in principle, the ability of the government to reclaim allocated quota rights without compensation (Haraldsson & Carey, 2011; Eythorsson, 2000). This is a tremendous impediment to the establishment of monkfish fisheries in the Northwest. Ironically, the power, leverage, and lobbying capacity of companies with large quota holdings can be attributed to equity gained through capital from an unfairly distributed initial resource allocation. The growth of companies with large quota holdings enabled greater purchasing power and organic growth to make companies competitive and more efficient. Vessel owners represent the faction of stakeholders with the greatest to lose followed by crew unions and other stakeholder groups. Since vessel owners command the strongest position and the greatest incentive to actively engage in ITQ management decisions, the re-allocation of quota holdings is not likely to take place. Furthermore, the confusion about the legal status of quota rights has been shown to re-enforce the contemporary position favouring fishing companies. Addressing the legal status of quota shares is imperative to developing a strong foundation for the ITQ system, in particular to base the establishment of monkfish fisheries in the Northwest.

The ITQ system is characterized by regulations that seek to maximize economic efficiency. However, certain regulations hamper economic efficiency and any prospect of development, especially small-scale operations, that may predominate in the Northwest region. These legislations can be debilitating for start-up ventures and marginalize monkfish fisheries in the Northwest region. The extensive restrictions on potential holders of ITQs limit the ability of the quota market to allocate quotas in the most economically efficient manner (Runolfsson & Arnason, 1996). This greatly affects the development of monkfish fisheries in the Northwest region with restrictions such as: only vessels with valid fishing licences can hold quotas or a vessel's fishing capacity must equal or exceed total quota holdings (Runolfsson & Arnason, 1996). These restrictions reduce the ability of prospective candidates' entrance into the industry by implementing strict regulations which deter the ability to create and introduce new, small-scale monkfish fishing company operations.

Within this context, other strategies need to be in place to mediate the reclamation of quota holdings in fisheries-dependent communities of the Northwest region. Presently, special catch quota allocation for small scale operations in rural fishing communities is issued almost as a concession for re-entry after 'selling out'(Haraldsson & Carey, 2011). This special allocation poses many restrictions including specific times of the day fishing is permitted, restrictions on gear use (hand lines), and limits on catches per trip (Haraldsson & Carey, 2011). While this program provides opportunities for marginalized fisheries-dependent communities albeit in a much less effective and profitable form than the ITQ system, it is designed to prevent organic growth by limiting productivity and efficiency. At this moment, only refurbishments or minor amendments to the ITQ system can realistically be drawn while maintaining the stability of the system in order to establish monkfish fisheries in the Northwest region.

5.7 Amendments to the ITQ system

The basic tenets of the ITQ system regarding the free transfer of quota holdings is central to driving competition and efficiency and is accepted by the public as a fundamental characteristic that should remain central to any subsequent fisheries management regime

(Eythorsson, 2000). The point of contention lies in the distribution of profitable rights through the conversion of fishing rights into capital. Several strategies can be employed to mitigate the impacts of the contestable distribution method while generating revenues and stimulating local and national economies.

5.7.1 Cost recovery program

Establishing the collection of consumer fees for regulatory action and services in the form of a cost recovery scheme is a potential concept that will generate revenues and stimulate economies (Haraldsson & Carey, 2011; Eythorsson, 2000). The collection of user fees can be utilized for management and fisheries-related purposes such as funds for research endeavours, proficient and regularly scheduled stock assessments, monitoring and compliance, and development funds that would engage and utilize fisheries-dependent communities. Presently, the Ministry imposes an upper limit of 0.4% of the estimated catch value for catch quotas to compensate for monitoring and enforcing regulations (Runolfsson & Arnason, 1996). This system will more likely benefit from the support of vessel and quota holders. Unlike typical taxation, it provides incentive for quota holders through collection and administering of funds that support, develop, and safe-guard 'their' fishing resources. The cost recovery program stands to protect and grow their investments with the negation of externalities and procurement of essential services. This alleviates the responsibility of the government and places more of the burden on quota holders. From an industry perspective, greater responsibility on services and regulatory activities may prove beneficial. This could provide quota holders with greater sovereignty over management in terms of influencing regulations and standards through implicit (lobbying and changes to funding policies) or explicit means ('buying' decisions). The negative aspect of such program would be the increased likelihood of conceding authority or allowing quota holders greater jurisdiction over management issues. This may allow for greater integration of quota holders into research and management bodies which can dictate objectives more aligned with profit-seeking than ecologically-sound strategies.

5.7.2 Resource rentals program

A second option for the distribution of wealth to small fisheries-driven communities is the administration of resource rentals (Haraldsson & Carey, 2011; Eythorsson, 2000). The resource rental method would retrieve a resource rent generated by the quota holders and fishing industry and distribute it in small fisheries-dependent communities in order to stimulate local economies. The resource rents can be used for establishing novel fishers operations (monkfish fisheries), sustainable resource management, entrepreneurial/business grants, infrastructure investments, developing human capital, job creation, and community population stabilization. The main problem with this method is the strong opposition for its institution by the fishing industry. To the fishing industry, resource rents are synonymous with taxation and only serve to limit the competitiveness, both locally and globally, of quota holders. It is argued that resource rents have little impact on their target region's economic development and reduce the efficiency of fisheries companies (Runolfsson & Arnason, 1996). The fishing industry opposes the idea because of its few direct benefits. The main problem with implementing a resource rental regime would likely be the changing of attitude by quota holders with respect to processes that increase the value of ITQs, such as the application of conservation efforts. Sufficiently high resource rentals that reduce the value of ITQs will likely remove incentives for fishermen such as lobbying for lower TACs and monitoring of other fishermen. This will lead to a short-term increase in catches and a long-term decrease in resource rents (Haraldsson & Carey, 2011). This is an important development because Arnason (2011) describes a scenario whereby the reduction of TAC, from current levels that satisfy sustainable catch thresholds, and were reduced even lower to a rent-maximizing threshold. Arnason (2011) argues that TAC should be set at a rent-maximizing level and thus lower than that prescribed by the Marine Research Institute (MRI) coinciding with an increase in fisheries resource rent tax which capitalizes through the capture of increased rent. This may be the least attractive and feasible option to stimulate economic development in Northwestern Iceland or for the establishment of a monkfish fishery.

5.7.3 Perpetual recovery and distribution of quota rights

The two former options provide means of funding and generating revenue which can be utilized to develop the economies of marginalized Northwestern fisheries-dependent communities. Revenue generation or funding can implicitly contribute to the goal of establishing monkfish fisheries in the Northwest through developing infrastructure, purchasing necessary tools and equipment, and developing human capacity. However, these methods do not directly permit the establishment of monkfish fisheries, but provide capital to proceed in developments. Additionally, the transparency of funding, creation of institutions to determine need, and monitoring of funding usage may dilute the efficacy and impact of the programs.

The final option provides the elusive component of quota holdings to establish a monkfish fishery in the Northwest. The nature of perpetual rights allocation permits an indefinite possession of quota shares. Since Iceland's fishing resource is a public resource and national property, a new strategy can be employed that addresses the controversial primary allocation of quota shares. Instead of a resource rental, the Icelandic government can annually retrieve a limited proportion of quota shares without compensation (Haraldsson & Carey, 2011; Eythorsson, 2000). The annually-recovered quota share is collected by the government on behalf of the public. This allows the public greater access and possession of its property. Furthermore, the recovered shares can be a source of revenue for the public or stimulate the economy. The public will have the ability to auction shares for a temporary, specified period or distribute quotas based on specified parameters to small fishing communities (Eythorsson, 2000). This method can provide opportunities to marginalized fisheries-driven communities with fisheries-specific infrastructure and prior technical experience to establish monkfish fisheries. It has the ability to stabilize local populations and even attract population because of work opportunities.

This regime illustrates multiple beneficial outcomes for an efficient fishing industry. Firstly, it renews the ability of marginalized communities to access fishing resources thereby improving economic efficiency for the ITQ system. This develops local economies, retains and even draws populations, reduces emigration to the southwest, and mobilizes and empowers demoralized fisheries-driven communities. It can promote job creation and stabilize populations in coastal communities by providing reparations through funding or in the form of entrepreneurialism (i.e. operation of fishing companies via newly-allocated quota). Furthermore, these changes to management preserve the fundamental doctrines and constitution of the ITQ system while resolving the issues of initial allocation of perpetual rights. In addition, the changes elucidate the confusing legal status of quota shares by providing a more representative medium that addresses the ambiguous nature of the private and public duality of quota rights. The main drawback of this option is the strong opposition it will face by fishermen who would have to re-pay for access to a resource that they perceive they already 'own'. In addition, Iceland's reputation for protecting property rights will face much scrutiny if the current regime were to be abrogated (Haraldsson & Carey, 2011). However, this is the best option to concurrently establish a monkfish fishery in the Northwest region, reduce immigration to the southwest, and provide a 'back-bone' to the ambiguous definition of quota rights.

6 Conclusion

In conclusion, the increased productivity and landings of monkfish in Northwest Iceland has demonstrated the need to establish owned and operated fishing companies based in the Northwest region. Since 2008, the Northwest region has independently contributed to a greater proportion of the monkfish TAC than the South region and East region of Iceland. Furthermore, the increased total landings were not accompanied by an increased percentage of ownership by Northwest-based fishing companies. The lack of quota rights ownership in the Northwest region destabilizes local economies of fisheries-dependent communities and needs to resolve the discrepancy between labour and ownership. This exceptional case illustrates the difficulty of impacts of human-induced global climate change on contemporary fisheries management. The financial value associated with monkfish and its recent expansion into Iceland’s Northwest region makes it more susceptible to illegal and unsustainable fishing practices by marginalized fishing communities. This study illustrates major impediments for effective management such as: information gaps and the accessibility of sensitive information such as location and age composition of monkfish catch. Further research on monkfish reproduction and spawning, age-class information, sex ratio, and biomass indices are imperative to fill information gaps, requisites for model-based population dynamics estimates, and evoke management plans that promote integrative and sustainable development. Employing model-based population dynamics is an innovative strategy that may provide more accurate estimates of monkfish populations and permit more effective management. It can have greater influence over fisheries policies such as: area closures, days-at-sea restrictions, and effort restrictions. While model-based decisions are innovative and will improve the quality of management, an emphasis on increased monitoring of monkfish fisheries needs to accompany such innovations and be strictly enforced. Regular monitoring will provide up-to-date information on the status of the monkfish fishery. Improvements to gear modification that can reduce the levels of monkfish by-catch during the lumpfish fishing season need to be tested integrated in Iceland’s fisheries. In addition, gear modification for the exclusive monkfish fishing season is vital in terms of selecting for legal-sized monkfish and reducing the by-catch of monkfish in the lumpfish season and other species in the exclusive monkfish season. Finally, expansion of the monkfish range highlights the inadequacies of the ITQ system to resolve the conflict and the unclear legal status of fishing rights. This case illustrates the failure in the inception of the ITQ system and legislation to foresee and resolve this complex problem and describes its key role in marginalizing small, fisheries-dependent communities. Cost recovery, resource rentals, and recovery of quota rights are several ideas posited to limit the extent of the ITQ system's negative externalities and provide opportunity to establish locally owned/operated monkfish fisheries in the Northwest region of Iceland.

7 Future research considerations

Subsequent research investigating the establishment of monkfish fisheries in the northwest region of Iceland will benefit with the inclusion of several variables omitted from this study. This study sought to display, quantitatively, the discrepancy in regional productivity with respect to monkfish landings and the proportion of fishing company ownership as an impetus for structural reforms in the ITQ system and implicitly Iceland's monkfish industry. The inclusion of monkfish catch location information in subsequent studies could be used to further support the proposed regime change assuming it supports the observed trend of greater northwest region resource utility with poor turnover for compensation or quota allocation. Information about the location of monkfish catches can be telling of the geographical extent of fished monkfish populations. The regional implications of monkfish location data and whereabouts have its place in supporting the establishment of monkfish fisheries in Iceland's northwest region.

Additionally, the inclusion of gear type information for vessels that have landed monkfish can be used to infer the efficiency of fishing operations. This study excluded gear type data because of its poor availability and the diversity of gear types currently employed. Future studies can use gear type data to determine region-specific CPUE as a basis to support establishing owned and operated monkfish fisheries in the Northwest region. It can employ meta-analysis techniques such as a systematic review to create data synthesis for the amalgamation and analysis of the impacts and efficiency of the diversity of gear types used in vessels fishing for monkfish. This information is significant for guiding sustainable management actions. Moreover, it can explicate regional operations that support the establishment of monkfish fisheries in the northwest region of Iceland.

References

Alderdice, D.F., Forrester, C.R. (1971) *Effects of Salinity, Temperature and Dissolved Oxygen on Early Development of the Pacific Cod (Gadus macrocephalus).* Journal of the Fisheries Research Board of Canada, 28(6): 883-902

Alfonso-Dias, I., Hislop, J.R.G. (1996) *The reproduction of anglerfish Lophius piscatorius Linnaeus from the north-west coast of Scotland.* Journal of Fish Biology, 49: 18-39

Armstrong, D.W., Ferro, R.S.T., MacLennan, D.N., Reeves S.A. (1990) *Gear selectivity and conservation of fish.* Journal of Fish Biology, 37A: 261-262

Armstrong, M.P., Musick, J.A., Colcovoresses, J.A.(1992) *Age, growth, and reproduction of the goosefish Lophius americanus (Pisces Lophiiformes).* Fishery Bulletin US, 90: 217-230

Arnason, R. (2005) *Property rights in fisheries: Iceland's experience with ITQs*. Reviews in Fish Biology and Fisheries, 15: 243-264

Arnason, R. (2011) *Rent and Rent Loss in the Icelandic Cod Fishery.* Wiley Encyclopedia of Operations Research and Management Science

Astthorsson, O.S., Valdimarsson, H., Gudmundsdottir, A., Oskarsson, G.J. (2012) *Climate-related variations in the occurrence and distribution of mackerel (Scomber scombrus) in Icelandic waters*. ICES Journal of Marine Science, 69(7): 1289-1297

Astthorsson, O.S., Gislason, A., Jonsson, S. (2007) *Climate variability and the Icelandic marine ecosystem*. Deep-Sea Research II, 54: 2456-2477

Berkeley, S.A., Hixon, M.A., Larson, R.J., Love, M.S. (2004) *Fisheries Sustainability via Protection of Age Structure and Spatial Distribution of Fish Populations*. Fisheries, 29(8): 23-32

Bjornsson, H., Jonsson, E. (2004) *Estimation of hidden mortality of Icelandic haddock caused by the fisheries.* ICES CM/FF:24. 24 pp.

Blanco, G., Borrell, Y.J., Cagigas, E., Vazquez, E., Prado, S. (2006) *A new set of highly polymorphic microsatellites for the white and black anglerfish (Lophiidae).* Molecular Ecology Notes, 6: 767-769

Brander, K., Blom, G., Borges, M.F., Erzini, K., Henderson, G., MacKenzie, B.R., Mendes, H., Ribeiro, J., Santos, A.M.P., Toresen, R. (2003) *Changes in fish distribution in the eastern North Atlantic: Are we seeing a coherent response to changing temperature?* ICES Marine Sciences Symposia, 219: 261-270

Carlton, J.T. (2000) *Global Change and Biological Invasions in the Oceans.* In, *Invasive Species in a Changing World (pp.31-54)*. Washington, D.C.: Island Press

Chen, C.A. (2008) *Effects of Climate Change on Marine Ecosystems*. In Fisheries for Global Welfare and Environment, 5th World Fisheries Congress. P307-316. Retrieved from: http://www.terrapub.co.jp/onlineproceedings/fs/wfc2008/pdf/wfcbk_307.pdf

Cheung, W.W.L, Lam, V.W.Y., Sarmiento, J.L., Kearney, K., Watson, R., Pauly, D. (2009) *Projecting global marine biodiversity impacts under climate change scenarios.* Fish and Fisheries, 10: 235-251

Coyle, K.O., Pinchuk, A.I., Eisner, L.B., Napp, J.M. (2008) *Zooplankton species composition, abundance and biomass on the eastern Bering Sea shelf during summer: The potential role of water-column stability and nutrients in structuring the zooplankton community*. Deep Sea Research Part II: Topical Studies in Oceanography, 55(16-17): 1775-1791

Crozier, W.W. (1985) *Observations on the food and feeding of the angler-fish, Lophius piscatorius L. in the northern Irish Sea.* Journal of Fish Biology, 27:655-665

Davis, J.C. (1975) *Minimal Dissolved Oxygen Requirements of Aquatic Life with Emphasis on Canadian Species: a Review*. Journal of the Fisheries Research Board of Canada, 32(12): 2295-2332

Directorate of Fisheries [Fiskistofa] (2012) Directorate of Fisheries Home. Retrieved from: http://en.fiskistofa.is/

Directorate of Fisheries [Fiskistofa (2012b)]. The Icelandic Directorate of Fisheries-Responsibilities and main tasks. Accessed: October 24, 2012. Retrieved from: http://www.fiskistofa.is/media/utgefid_efni/DOF.pdfhttp://www.fiskistofa.is/media/utgefid_efni/DOF.pdf

Duarte, R., Azevedo, M., Landa, J., Pereda, P. (2001) *Reproduction of anglerfish (Lophius budegassa Spinol and Lophius piscatorius Linnaeus) from the Atlantic Iberian coast.* Fisheries Research, 51: 349-361

Duarte, R., Azevedo, M., Pereda, P. (1997) *Study of the growth of southern black and white monkfish stocks*. ICES Journal of Marine Science, 54: 866-874

Duarte, R., Bruno, I., Quincoces, I. Farina, A.C., Landa, J. (2004) *Morphometric and meristic study of white and black anglerfish (Lophius piscatorius and L. budegassa) from the south-west of Ireland to the south-western Mediterranean.* ICES Document CM 2004/EE: 22. 19pp

Duarte, R., Landa, J., Azevedo, M., Sampedro P., Farina, A.C., Costas, G. (2007) *Age-length keys and catch-at-age of black anglerfish (Lophius budegessa) in Atlantic Iberian waters from 1996 to 2006.* ICES Document CM 2007/K: 31 Poster

Eayrs, S. (2008) *Evaluation of the selectivity of four codends in the New England Ground fish fishery*. Gulf of Maine Research institute. 36p.

Einarsson, M.A. (1984) *Climate of Iceland.* In: van Loon, H. ed., *Climates of the Oceans*. Amsterdam, NL: Elsevier, 673-697

Etienne, S., Paris, R. (2010) *Boulder accumulations related to storms on the south coast of the Reykjanes Peninsula (Iceland)*. Geomorphology, 114(1-2): 55-70

European Policies Research Centre (2001) *Policies and Strategies for Regional Development: A Paradigm Shift?:* Regional and Industrial Policy Research Paper Number 46. Glasgow, UK: Bachtler, J., Yuill, D.

Eythorsson, E. (2000) *A decade of ITQ-management in Icelandic fisheries: consolidation without consensus*. Marine Policy, 24: 483-492

Farina, A.C., Azevedo, M., Landa, J., Duarte, R., Sampedro, P., Costas, G., Torres, M.A., Canas, L. (2008) *Lophius in the world: a synthesis on the common features and life strategies*. ICES Journal of Marine Science, 65: 1272-1280

Ficke, A.D., Myrick, C.A., Hansen, L.J. (2007) *Potential impacts of global climate change on freshwater fisheries.* Rev Fish Biol Fisheries, 17: 581-613

FishBase (2012, July 3). *Lophius piscatorius* Linnaeus, 1758. Retrieved from: http://www.fishbase.org/summary/Lophius-piscatorius.html

Fisheries Research & Development Corporation (2012) *Climate Shift to Push Recreational Species South*. Retrieved from: http://www.frdc.com.au/image-story/Pages/climate_shift_to_push_recreational_species_south.aspx

Fournier, D.A., Hampton, J., Siber, J.R. (1998) *MULTIFAN-CL: a length-based, age-structured model for fisheries stock assessment, with application to South Pacific albacore, Thunnus alalunga.* Canadian Journal of Fisheries and Aquatic Sciences, 55(9): 2105-2116

Galbraith, R.D., Fryer, D.J., Maitland, K.M.S. (1994) *Demersal pair trawl cod-end selectivity models.* Fisheries Research, 20: 13-27

Gelpke, N., Visbeck, M. (2010). Climate change impacts on marine ecosystems. In *World Ocean Review 2010:Living with the oceans*. Mare, Hamburg. P100-117

Gissurarson, H.H (2002) *Overfishing: The Icelandic Solution*. The Institute of Economic Affairs. West Sussex, Great Britain: Hartington Fine Arts Limited.

Guijarro, B., Massuti, E. (2006) *Selectivity of diamond- and square-mesh codends in the deepwater crustacean trawl fishery off the Balearic Islands (western Mediterranean)*. ICES Journal of Marine Science, 63(1): 52-67

Hafrannsoknastofnun (2007). State of marine stocks in Icelandic waters 2006/2007. Prospects for the quota year 2007/2008. Hafrannsóknastofnunin, fjolrit 129. 180 pages.

Hafro. (2012) *Lumpfish- Cyclopterus lumpus*. Retrieved from: http://www.hafro.is/Astand/2012/eng/20-lumpfish-12.PDF

Hampton, J., Fourner, D.A. (2001) *A spatially disaggregated, length-based, age-structured population model of yellowfin tuna (Thunnus albacores) in the western and central Pacific Ocean.* Marine and Freshwater Research, 52: 937-963

Hansen, J., Sato, M., Ruedy, R., Lo, K., Lea, D.W., Medina-Elizade, M. (2006) *Global temperature change*. Proceedings of the National Academy of Sciences of the United States of America, 103(39): 14288-14293

Haraldsson, G. (2008) *Impact of the Icelandic ITQ system on outsiders.* Aquatic Living Resources, 21: 239-245

Haraldsson, G., Carey, D. (2011) *Ensuring a Sustainable and Efficient Fishery in Iceland*. OECD Economics Department Working Papers No. 891. OECD Publishing.

Hasumi, H. (2002) *Modeling the Global Thermohaline Circulation*. Journal of Oceanography, 58: 25-33

Hellmann, J.J., Byers, J.E., Bierwagen, B.G., Dukes, J.S. (2008) *Five Potential Consequences of Climate Change for Invasive Species*. Conservation Biology, 22(3): 534-543

Hislop, J. R. G., Gallego, A., Heath, M. R., Kennedy, F. M., Reeves, S. A., and Wright, P. J. (2001). A synthesis of the early life history of the anglerfish, *Lophius piscatorius* (Linnaeus 1758) in northern British waters. – ICES Journal of Marine Science, 58: 70–86.

Hislop, J.R.G., Holst, J.C., Skagen, D. (2000) *Near-surface captures of post-juvenile anglerfish in the North-east Atlantic- an unsolved mystery*. Journal of Fish Biology, 57: 1083-1087

Hoegh-Guldberg, O., Bruno, J.F. (2010) *The Impact of Climate Change on the World's Marine Ecosystems.* Science, 328(5985): 1523-1528

Icelandic Fisheries. (2013) *Small Mesh Trawl*. Information centre of the Icelandic Ministry of Fisheries and Agriculture. Retrieved from: http://www.fisheries.is/fisheries/fishing-gear/small-mesh-trawl/

Icelandic Fisheries. (2013b) *Gillnets*. Information centre of the Icelandic Ministry of Fisheries and Agriculture. Retrieved from: http://www.fisheries.is/fisheries/fishing-gear/gillnets/

Icelandic Ministry of Fisheries and Agriculture [MFA]. Icelandic Fisheries- Enforcement. Accessed: October 24, 2012. Retrieved from: http://www.fisheries.is/management/fisheries-management/enforcement/

Iceland Review. (March 23, 2010) *Monkfish Legislation Upsets Icelandic Stability Pact*. Retrieved from: http://www.icelandreview.com/icelandreview/daily_news/Monkfish_Legislation_Upsets_Icelandic_Stability_Pact_0_359846.news.aspx

ICES. (2006) *Report of the ICES Advisory Committee on Fishery Management, Advisory Committee on the Marine Environment and Advisory Committee on Ecosystems, 2006.* ICES Advice, 1-10. Book 5, 271 99., and Book 7, 113 pp.

ICES (2007) *Report of the Working Group for Regional Ecosystem Description (WGRED)*. ICES, Copenhagen, p19

Johannesson, J. (December 30, 2006) *Lumpfish Caviar- from Vessel to Consumer*. FAO Fisheries Technical Paper. No. 485. 60p.

Jonsson, S. (2013) *Waves and Tides.* Retrieved from: http://www.fisheries.is/ecosystem/oceanography/waves-and-tides/

Kaplan, I.M. (1998) *Regulation and compliance in the New England Conch Fishery: A case for co-management.* Marine Policy, 22(4-5): 327-335

Kennedy, V.S, Twilley, R.R, Kleypas, J.A, Cowan Jr, J.H, Hare, S.R. (2002) *Coastal and marine ecosystems & Global climate change: Potential Effects on U.S. Resources*. Arlington, VA: Pew Center on Global Climate Change

Kolar, C.S., Lodge, D.M. (2000) *Freshwater Nonindigenous Species: Interactions with Other Global Changes.* In, *Invasive Species in a Changing World (pp. 3-30).* Washington, D.C.: Island Press

Landa, J., Duarte, R., Sampedro, P., Azevedo, M., Farina, A.C., Costas, G. (2007) *Age-length keys and catch-at-age of white anglerfish (Lophius piscatorius) in Atlantic Iberian waters from 1996 to 2006.* ICES Document CM 2007/K: 25 Poster

Laurenson, C. H., Dobby, H., McLay, H. A., and Leslie, B. (2008). *Biological features of the Lophius piscatorius catch in Scottish waters*. – ICES Journal of Marine Science, 65: 1281–1290.

Laurenson, C.H., Johnson, A., Priede, I.G. (2005) *Movements and growth of monkfish Lophius piscatorius tagged at the Shetland Islands, northeastern Atlantic*. Fisheries Research, 71: 185-195

Laurenson, C.H., Priede, I.G. (2005) *The diet and trophic ecology of anglerfish Lophius piscatorius at the Shetland Islands, UK.* Journal of the Marine Biological Association of the UK, 85: 419-424

Laurenson, C.H, Priede, I.G., Bullough, L.W., Napier, I.R. (2001). Where are the mature anglerfish? - The population biology of *Lophius piscatorius* in Northern European waters. ICES Annual Science Conference C.M.2001/J:27. 15 pp.

Levine, J.M., Vila, M., D'Antonioa, C.M., Dukes, J.S., Grigulis, K., Lavotel, S. (2003) *Mechanisms underlying the impacts of exotic plant invasions.* Proceedings of the Royal Society of London Series B- Biological Sciences, 270: 775-781

Lodge, D.M., et al. (2006) *Biological invasions: recommendations for U.S. policy and management.* Ecological Applications, 16: 2035-2054

MacLennan, D.N., editor (1992) *Fishing gear selectivity*. In: Fisheries Research, 13: 201-352

Mainka, S.A., Howard, G.W. (2010) *Climate change and invasive species: double jeopardy*. Integrative Zoology, 5(2): 102-111

Malmberg, S.A. (2004) *The Iceland Basin- Topography and Oceanographic Features*. Marine Research Institute. Retrieved from: http://www.hafro.is/Bokasafn/Timarit/fjolr-109.pdf

Malmström, V.H. (1958) *A Regional Geography of Iceland.* Washington, D.C.: National Academies

Marine Research Institute of Iceland [MRI] (2012a) Marine Research Institute General. Retrived from: http://www.hafro.is/undir_eng.php?ID=1&REF=1

Marine Research Institute of Iceland [MRI] (2012b, August 17). State of stocks 2011/2012- Prospects 2012-2013. Retrieved from: http://www.hafro.is/Astand/2012/eng/19-anglerfish-12.PDF

Ministry of Fisheries and Agriculture [MFA] (2012) The Ministry's role and function. Retrieved from: http://eng.sjavarutvegsraduneyti.is/ministry/role-and-function/

Mooney, H.A., Cleland, E.E. (2001) *The evolutionary impact of invasive species*. Proceedings from the National Academy of Sciences of the United States of America, 98(10): 5446-5451

Morgunbladid. (February 2, 2010b) *Discussions on fisheries management in Parliament*. Retrieved from: http://www.mbl.is/frettir/innlent/2010/02/02/raett_um_stjorn_fiskveida/

Morgunbladid. (April 30, 2010) *Over 200 boats for monkfish quotas*. Retrieved from: http://www.mbl.is/frettir/innlent/2010/04/30/um_200_batar_fa_skotuselskvota/

Muusze,B., Marcon, J., Van den Thillart, G., Almeida-Val, V. (1998) *Hypoxia tolerance of Amazon fish: Respirometry and energy metabolism of the cichlid Astronotus Ocellatus.* Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 120(1): 151-156

Nebel, S., Olafsson, H.G., Jonsson, B. (2011) *Lífshættir, stofnsamsetning og vistfræðileg áhrif skötusels (Lophius piscatorius) á nýjum útbreiðslusvæðum.* Unpublished Manuscript. BioPol ehf

Ofstad, L.H., Laurenson, C. (2007) *Biology of anglerfish Lophius piscatorius in Faroese waters*. International Council for the Exploration of the Sea. Theme Session on Monkfish Across the World: Common Problems and Common Solutions. 2007/K:07. 16p.

Ogilvie, A.E.J. (1995) *Documentary evidence for changes in the climate of Iceland, A.D. 1500 to 1800*. In R.S. Bradley and P.D. Jones (Ed.) Climate Since Ad 1500 (pp. 92-142). London and New York: Routledge

Ojaveer, E., Kalejs, M. (2005) *The impact of climate change on the adaptation of marine fish in the Baltic Sea.* ICES Journal of Marine Science, 62(7): 1492-1500

O'Connor, M.I., Bruno, J.F., Gaines, S.D., Halpern, B.S., Lester, S.E., Kinlan, B.P., Weiss, J.M. (2007) *Temperature control of larval dispersal and the implications for marine ecology, evolution, and conservation*. Proceedings of the National Academy of Sciences of the United States of America, 104(4): 1266-1271

O'Sullivan, M., Wright, P.J., Verspoor, E., Knox, D., Piertney, S. (2006) *Absence of spatial and temporal genetic differentiation at microsatellite loci in north east Atlantic anglerfish (Lophius piscatorius)*. Journal of Fish Biology, 69:261

Palumbi, S.R. (2004) *Fisheries science: Why mothers matter*. Nature, 430: 621-622

Pearson, R.G., Dawson, T.P. (2003). *Predicting the impacts of climate change on the distribution of species: are bioclimate envelope models useful?* Global Ecology & Biogeography, 12: 361-371

Perrin, W.F., Wursig, B., Thewissen, J.G.M. (2009) *Encyclopedia of Marine Mammals (2nd edition)*. Academic Press, p. 216

Perrings, C., Williamson, M.H., Dalmazzone, S. (2000) *The Economics of Biological Invasions.* Edward Elgar, Cheltenham, United Kingdom

Pianka, E.R. (1974) *Niche Overlap and Diffuse Competition*. Proceedings of the National Academy of Sciences of the United States of America, 71(5): 2141-2145

Poff, N.L., Brinson, M.M., Day Jr., J.W. (2002) *Aquatic ecosystems & Global climate change: Potential Impacts on Inland Freshwater and Coastal Wetland Ecosystems in the United States.* 56ps

Prime Minister's Office. (June 26, 2009) *Stability Pact signed*. Retrieved from: http://eng.forsaetisraduneyti.is/news-and-articles/nr/3793)

Quincoces, I., Santurtun, M., Lucio, P. (1998) *Biological aspects of white anglerfish (Lophius piscatorius) in the Bay of Biscay (ICES Division VIIIa,b,d), in 1996-1997.* ICES Document CM 1998/O: 48. 29 pp.

Rahel, F.J., Olden, J.D. (2008) *Assessing the Effects of Climate Change on Aquatic Invasive Species*. Conservation Biology, 22(3): 521-533

Reeves, S.A., Armstrong, D.W., Fryer, R.J., Coull, K.A. (1992) *The effects of mesh size, cod-end extension length and cod-end diameter on the selectivity of Scottish trawl and seines.* ICES Journal of Marine Sciences, 49:279-288

Roessig, J.M., Woodley, C.M., Cech Jr., J.J., Hansen, L.J. (2004) *Effects of global climate change on marine and estuarine fishes and fisheries.* Reviews in Fish Biology and Fisheries, 14: 251-275

Rose, G.A. (2005) *On distributional responses of North Atlantic fish to climate change.* ICES Journal of Marine Science, 62: 1360-1374

Runolfsson, B., Arnason, R. (2003). Evolution and Performance of the Icelandic ITQ System. Retrieved from: http://billhutten.s3.amazonaws.com/fw/docs/264.pdf

Runolfsson, B., Arnason, R. (1996) *Evolution and Performance of the Icelandic ITQ System.* ITQs in Iceland: A Descriptive Account

Salerno, D.J., Eayrs, S., Pol, M., Lee, S., Baukus, A. (2010) *Analysis of Size Selectivity and Bycatch in the Gillnet Fishery for Monkfish.* Gulf of Maine Research Institute. 34p.

Sherwood, G.D., Grabowski, J.H. (2007) *Diet and habitat shifts in New England (USA) monkfish (Lophius americanus): insights from stable isotopes and implications for fisheries assessments*. ICES Document CM 2007/K: 10

Sigvaldason, G.E. (1968) *Structure and products of subaquatic volcanoes in Iceland*. Contributions to Mineralogy and Petrology, 18(1): 1-16

Sogard, S.M., Berkeley, S.A., Fisher, R. (2008) *Maternal effects in rockfishes Sebastes spp.: a comparison among species*. Marine Ecology Progress Series, 360: 227-236

Solmundsson, J., Jonsson, E.,Bjornsson, H. (2007) *Recent changes in the distribution and abundance of monkfish (Lophius piscatorius) in Icelandic waters.* ICES CM 2007/K:02, 16

Strass, V.H., Nöthig, E.M. (1996) *Seasonal shifts in ice edge phytoplankton blooms in the Barents Sea related to the water column stability.* Polar Biology, 16(6): 409-422

Thomas, C.D., Cameron, A., Green, R.E., Bakkenes, M., Beaumont, L.J., Collingham, Y.C., Erasmus, B.F.N., Ferrerira de Siqueira, M., Grainger, A., Hannah, L., Hughes, L., Huntley, B., van Jaarsveld, A.S., Midgley, G.F., Miles, L., Ortega-Huera, M.A. Peterson, A.T., Philips, O.L., Williams, S.E.. (2004) *Extinction risk from climate change.* Nature, 427: 145-148

Thordarson, T. (2012) Proceedings from Chapman Conference 2012: *Outline of Geology of Iceland*. Selfoss, Iceland: AGU

Tian, Y., Ueno, Y., Suda, M. & Akamine, T (2004). Decadal variability in the abundance of Pacific saury and itsresponse to climatic/oceanic regime shifts in the northwestern subtropical Pacific during the last half century. Journal of Marine Systems 52: 235-257.

Toggweiler, J.R., Russell, J. (2008) *Ocean circulation in a warming climate.* Nature, 45: 286-288

Valdimarsson, H., Astthorsson, O.S., Palsson, J. (2012) *Hydrographic variability in Icelandic waters during recent decades and related changes in distribution of some fish species*. ICES Journal of Marine Science, 69: 816-825

Vitousek, P.M., D'Antonio, C.M., Loope, L.L., Rejamanek, M., Westbrooks, R. (1997) *Introduced Species: A Significant Component of Human-Caused Global Change*. New Zealand Journal of Ecology. 21(1): 1-16

Walmsley, S.A., Leslie, R.W., Sauer, W.H.H. (2005) *The biology and distribution of the monkfish Lophius vomerinus off South Africa.* African Journal of Marine Science, 27: 157-168

Walther, G.R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T.J.C., Fromentin, J., Hoegh-Guldberg, O., Bairlein, F. (2002) *Ecological responses to recent climate change*. Nature 416: 388-395

Williams, J.W., Jackson, S.T., Kutzbach, J.E. (2007) *Projected distributions of novel and disappearing climates by2100 AD.* Proceedings of the National Academy of Sciences of the United States of America, 104(14): 5738-5742

Wrona, F.J., Prowse, T.D., Reist, J.D., Hobbie, J.E., Levesque, L.M.J., Vincent, W.F. (2006) *Climate Change Effects on Aquatic Biota, Ecosystem Structure and Function.* Ambio, 35(7): 359-369

Yoneda, M., Tokimura, M., Fujita, H., Takeshita, N., Takeshita, K., Matsuyama, M., Matsuura, S. (2001) *Reproductive cycle, fecundity, and seasonal distribution of the anglerfish Lophius litulon in the East China and Yellow Seas.* Fishery Bulletin US, 99:356-370

Zavaleta, E.S., Hobbs, R.J., Mooney, H.A. (2001) *Viewing invasive species removal in a whole-ecosystem context*. TRENDS in Ecology & Evolution, 16(8): 454-459

Appendix

List of Top 50 Fishing Companies in Iceland with regional affiliation and landing in tonnes for years 2002-2013

Table 11- List of Top 50 Fishing Companies in Iceland with regional affiliation and annual landing in tones for years 2002-2013

2001/2002			2002/2003		
Fishing Company	**Location**	**Landing**	**Fishing Company**	**Location**	**Landing**
Grandi hf	East	472	Grandi hf	East	55,586
Síldarvinnslan hf	East	1,006	Síldarvinnslan hf	East	1,241
Skinney-Þinganes hf	East	41,943	Skinney-Þinganes hf	East	80,454
Hraðfrystihús Eskifjarðar hf	East	1,058	Hraðfrystihús Eskifjarðar hf	East	1,316
Kaupfélag Fáskrúðsfirðinga	East	1,006	Loðnuvinnslan hf	East	1,272
Gullberg ehf	East	2,594	Tangi hf	East	681
Útgerðarfélag Akureyringa hf	North	806	Gullberg ehf	East	3,200
Þormóður rammi - Sæberg hf	North	82,650	Melavík ehf	East	175
Fiskiðjan Skagfirðingur hf.	North	871	Eskey ehf	East	23,550
Samherji hf	NW	61	Útgerðarfélag Akureyringa hf	North	1,029
Hraðfrystihúsið - Gunnvör hf	NW	3	Þormóður rammi - Sæberg hf	North	124,742
BGB - Snæfell hf	NW	1,361	Fiskiðjan Skagfirðingur hf.	North	1,074
Skagstrendingur hf	NW	124	Frosti ehf	North	
Guðmundur Runólfsson hf	NW	3,845	Hóp ehf	North	5,297
Soffanías Cecilsson hf	NW	649	Samherji hf	NW	1,392
K G fiskverkun ehf	NW	699	Hraðfrystihúsið - Gunnvör hf	NW	4
Þorbjörn Fiskanes hf	South	9,220	Skagstrendingur hf	NW	153
Haraldur Böðvarsson hf	South	3,232	Guðmundur Runólfsson hf	NW	4,846
Vísir hf	South	351	Soffanías Cecilsson hf	NW	799
Útgerðarfélagið Tjaldur ehf	South		Hraðfrystihús Hellissands hf	NW	5,177

Ögurvík hf	South	
Nesfiskur hf	South	10,242
Gjögur ehf,Grenivík	South	2,156
Vinnslustöðin hf	Westman	26,077
Ísfélag Vestmannaeyja hf	Westman	18,694
Bergur-Huginn ehf	Westman	31,417
Ós ehf	Westman	2,083
Stálskip ehf		
Hjalteyrin, útgerðarfélag ehf		
Tangi hf		

Oddi hf	NW	47
K G fiskverkun ehf	NW	862
Sigurður Ágústsson ehf	NW	265
Þórsnes ehf	NW	281
Þorbjörn Fiskanes hf	South	21,829
Haraldur Böðvarsson hf	South	17
Vísir hf	South	16,105
Útgerðarfélagið Tjaldur ehf	South	7
Ögurvík hf	South	7
Nesfiskur hf	South	28,084
Gjögur ehf,Grenivík	South	2,658
Ingimundur hf	South	670
Sólbakki ehf	South	2,641
Auðbjörg ehf	South	33,942
Hafnarnes hf	South	35,357
Saltver ehf	South	190
Fiskkaup hf	South	48
Vinnslustöðin hf	Westman	32,166
Ísfélag Vestmannaeyja hf	Westman	72,256
Bergur-Huginn ehf	Westman	38,753
Ós ehf	Westman	5,166
Bárustígur ehf	Westman	1,916
Stígandi ehf	Westman	4,591
Dala-Rafn ehf	Westman	4,985
Hjalteyrin, útgerðarfélag		
Stálskip ehf		
Hraðfrystistöð Þórshafnar hf		
Garðar Guðmundsson hf		
Ljósavík hf		
Faxamjöl hf		

Table 11- (Continued)

2003/2004			2004/2005		
Fishing Company	**Location**	**Skötuselur**	**Fishing Company**	**Location**	**Landing**
Grandi hf	East	91,451	HB Grandi hf	East	91,064
Skinney-Þinganes hf	East	138,840	Skinney-Þinganes hf	East	146,811
Síldarvinnslan hf	East	1,662	Síldarvinnslan hf	East	1,655
Hraðfrystihús Eskifjarðar hf	East	1,762	Eskja hf	East	8,822
Loðnuvinnslan hf	East	1,662	Loðnuvinnslan hf	East	1,655
Tangi hf	East	912	Gullberg ehf	East	11,832
Gullberg ehf	East	4,305	Tangi hf	East	908
Melavík ehf	East	235	Garðey ehf	East	357
Garðey ehf	East	124	Þormóður rammi - Sæberg hf	North	175,186
Útgerðarfélag Akureyringa hf	North	1,376	Fiskiðjan Skagfirðingur hf.	North	1,433
Þormóður rammi - Sæberg hf	North	175,974	Frosti ehf	North	
Fiskiðjan Skagfirðingur hf.	North	1,440	Samherji hf	NW	1,857
Frosti ehf	North		Hraðfrystihúsið - Gunnvör hf	NW	6
Hóp ehf	North	7,098	Skagstrendingur hf	NW	204
Samherji hf	NW	1,865	Guðmundur Runólfsson hf	NW	6,465
Hraðfrystihúsið - Gunnvör hf	NW	6	Soffanías Cecilsson hf	NW	1,681
Skagstrendingur hf	NW	205	Hraðfrystihús Hellissands hf	NW	6,945
Guðmundur Runólfsson hf	NW	6,494	K G fiskverkun ehf	NW	2,202
Soffanías Cecilsson hf	NW	1,072	Oddi hf	NW	63
Hraðfrystihús Hellissands hf	NW	6,936	Brim hf	South	
K G fiskverkun ehf	NW	2,212	Þorbjörn Fiskanes hf	South	35,224
Oddi hf	NW	63	Vísir hf	South	31,405
Þorbjörn Fiskanes hf	South	29,452	Útgerðarfélagið Tjaldur ehf	South	1,381
Haraldur Böðvarsson hf	South	23	Ögurvík hf	South	10
Vísir hf	South	31,545	Nesfiskur ehf	South	75,800
Útgerðarfélagið Tjaldur ehf	South	10	Gjögur ehf	South	3,547

Ögurvík hf	South	10	Stakkavík ehf	South	222
Nesfiskur hf	South	42,639	Rekavík ehf	South	
Gjögur ehf	South	3,563	Auðbjörg ehf	South	45,281
Auðbjörg ehf	South	45,485	Fiskkaup hf	South	1,721
Ingimundur hf	South	898	Staðarvík ehf	South	1,195
Hafnarnes hf	South	47,381	Ingimundur hf	South	894
Fiskkaup hf	South	64	Hafnarnes hf	South	47,169
Saltver ehf	South	255	Sólbakki ehf	South	40,930
Sólbakki ehf	South	88,114	Hásteinn ehf	South	17,262
Vinnslustöðin hf	Westman	47,746	Vinnslustöðin hf	Westman	50,849
Ísfélag Vestmannaeyja hf	Westman	101,106	Ísfélag Vestmannaeyja hf	Westman	60,833
Bergur-Huginn ehf	Westman	51,930	Bergur-Huginn ehf	Westman	51,698
Ós ehf	Westman	25,501	Ós ehf	Westman	25,535
Bárustígur ehf	Westman	2,703	Bárustígur ehf	Westman	2,691
Stígandi ehf	Westman	6,153	Stígandi ehf	Westman	6,125
Dala-Rafn ehf	Westman	6,681	Dala-Rafn ehf	Westman	6,651
Frár ehf	Westman	14,391	Frár ehf	Westman	14,326
Matthías Óskarsson	Westman	19,653	Matthías Óskarsson	Westman	19,565
Stálskip ehf			Stálskip ehf		
Festi ehf			Hraðfrystistöð Þórshafnar hf		
Langanes hf			Langanes hf		
Hraðfrystistöð Þórshafnar hf			Steinunn hf		977
Garðar Guðmundsson hf			Útgerðarfélagið Frigg ehf		493
Jakob Valgeir ehf			Garðar Guðmundsson hf		

Table 11- (Continued)

2005/2006			2006/2007		
Fishing Company	**Location**	**Landing**	**Fishing Company**	**Location**	**Landing**
HB Grandi hf	East	113,833	HB Grandi hf	East	124,635
Skinney-Þinganes hf	East	183,558	Skinney-Þinganes hf	East	220,277
Síldarvinnslan hf	East	2,069	Síldarvinnslan hf	East	2,483
Eskja hf	East	11,030	Eskja hf	East	13,236
Loðnuvinnslan hf	East	2,069	Loðnuvinnslan hf	East	2,483
Gullberg ehf	East	5,358	Gullberg ehf	East	7,899
Fjarðarey ehf	East	1,118	Fjarðarey ehf	East	4,029
Geir ehf	East	18,943	Geir ehf	East	22,733
Salar Islandica ehf	East	26	Þormóður rammi - Sæberg hf	North	262,859
Þormóður rammi - Sæberg hf	North	219,042	Frosti ehf	North	158
Frosti ehf	North		Samherji hf	NW	2,787
Samherji hf	NW	2,322	FISK-Seafood hf	NW	2,456
FISK-Seafood hf	NW	2,047	Hraðfrystihúsið - Gunnvör hf	NW	9
Soffanías Cecilsson hf	NW	9,759	Soffanías Cecilsson hf	NW	16,512
Guðmundur Runólfsson hf	NW	8,083	Guðmundur Runólfsson hf	NW	9,700
Hraðfrystihús Hellissands hf	NW	8,856	Hraðfrystihús Hellissands hf	NW	22,110
Jakob Valgeir ehf	NW	19,061	Oddi hf	NW	1,447
Oddi hf	NW	172	K G fiskverkun ehf	NW	3,303
K G fiskverkun ehf	NW	2,753	Jakob Valgeir ehf	NW	
Þorbjörn Fiskanes hf	South	44,042	Útgerðarfélagið Ósk ehf	NW	32,045
Vísir hf	South	2,202	Þórsnes ehf	NW	562
Brim hf	South		Útnes ehf	NW	1,697
Ögurvík hf	South	12	Brim hf	South	2,812
Nesfiskur ehf	South	94,773	Þorbjörn Fiskanes hf	South	52,851
Stálskip ehf	South		Vísir hf	South	2,643
Gjögur ehf	South	32,015	Nesfiskur ehf	South	115,062

Stakkavík ehf	South	277	Ögurvík hf	South	14
Auðbjörg ehf	South	56,616	Stálskip ehf	South	
Staðarvík ehf	South	39,004	Gjögur ehf	South	38,420
Fiskkaup hf	South	2,152	Stakkavík ehf	South	
Hafnarnes hf	South	58,977	Fiskvinnslan Kambur ehf	South	3,022
Sólbakki ehf	South	51,176	Útgerðarfélagið Einhamar ehf	South	
Rekavík ehf	South		Fiskkaup hf	South	2,582
Hásteinn ehf	South	21,583	Auðbjörg ehf	South	67,942
Kló ehf	South	9,435	Hafnarnes hf	South	70,774
Vinnslustöðin hf	Westman	92,333	Saltver ehf	South	46,806
Ísfélag Vestmannaeyja hf	Westman	76,060	Sólbakki ehf	South	61,413
Bergur-Huginn ehf	Westman	64,694	Hásteinn ehf	South	25,901
Ós ehf	Westman	32,197	Vinnslustöðin hf	Westman	114,843
Bárustígur ehf	Westman	3,365	Ísfélag Vestmannaeyja hf	Westman	77,133
Dala-Rafn ehf	Westman	8,316	Bergur-Huginn ehf	Westman	77,636
Frár ehf	Westman	17,912	Ós ehf	Westman	38,638
Útgerðarfélagið Tjaldur ehf		2,344	Dala-Rafn ehf	Westman	9,979
Hraðfrystihúsið - Gunnvör hf		7	Bergur ehf	Westman	15,004
Hraðfrystistöð Þórshafnar hf			Matthías Óskarsson	Westman	29,388
Íshaf hf			Frár ehf	Westman	21,495
Arnar ehf útgerðarfélag			Steinunn hf		1,466
Steinunn hf		1,222	Rekavík ehf		
Norðureyri ehf			Guðbjartur ehf		
Útgerðarfélagið Einhamar ehf			Hraðfrystistöð Þórshafnar hf		

Table 11- (Continued)

2007/2008			2008/2009		
Fishing Company	**Location**	**Landing**	**Fishing Company**	**Location**	**Landing**
HB Grandi hf	East	103,870	HB Grandi hf	East	124,644
Skinney-Þinganes hf	East	183,579	Skinney-Þinganes hf	East	210,637
Eskja hf	East	11,032	Síldarvinnslan hf	East	2,483
Loðnuvinnslan hf	East	2,069	Eskja hf	East	13,237
Síldarvinnslan hf	East	2,069	Loðnuvinnslan hf	East	2,483
Gullberg ehf	East	6,583	Gullberg ehf	East	7,899
Fjarðarey ehf	East	3,358	Fjarðarey ehf	East	36,395
Rammi hf	North	91,556	Nóna ehf	East	
Frosti ehf	North	132	Rammi hf	North	229,876
Samherji hf	NW	2,322	Frosti ehf	North	158
FISK-Seafood hf	NW	2,047	G.P.G. fiskverkun ehf	North East	
Hraðfrystihúsið - Gunnvör hf	NW	1,143	Samherji hf	NW	2,787
Guðmundur Runólfsson hf	NW	8,085	FISK-Seafood hf	NW	2,456
Soffanías Cecilsson hf	NW	6,102	Hraðfrystihúsið - Gunnvör hf	NW	9,435
Hraðfrystihús Hellissands hf	NW	18,427	K G fiskverkun ehf	NW	3,304
Oddi hf	NW	1,228	Guðmundur Runólfsson hf	NW	9,701
Jakob Valgeir ehf	NW		Soffanías Cecilsson hf	NW	7,322
K G fiskverkun ehf	NW	2,753	Hraðfrystihús Hellissands hf	NW	36,513
Útgerðarfélagið Ósk ehf	NW	3,477	Oddi hf	NW	1,474
Brim hf	South	2,035	Guðbjartur ehf	NW	
Þorbjörn hf	South	47,354	Jakob Valgeir ehf	NW	
Vísir hf	South	2,203	Þórsnes ehf	NW	874
Nesfiskur ehf	South	121,356	Sæfell hf	NW	
Gjögur ehf	South	32,018	Brim hf	South	2,442
Ögurvík hf	South	12	Þorbjörn hf	South	57,782
Stálskip ehf	South		Vísir hf	South	2,643

Stakkavík ehf	South		Nesfiskur ehf	South	145,627
Fiskkaup hf	South	19,550	Ögurvík hf	South	14
Árberg ehf	South	100,008	Gjögur ehf	South	38,422
Smári Einarsson ehf	South	29,333	Stálskip ehf	South	
Auðbjörg ehf	South	72,549	Fiskkaup hf	South	23,460
Útgerðarfélagið Einhamar ehf	South		Stakkavík ehf	South	
Saltver ehf	South	39,008	Festi ehf	South	
Festi Útgerð ehf.	South		Miðtún ehf	South	35,200
Hafnarnes VER hf	South	58,983	Auðbjörg ehf	South	87,058
Hásteinn ehf	South	21,586	Hafnarnes VER hf	South	89,659
Sólbakki ehf	South	51,181	Útgerðarfélagið Einhamar ehf	South	
Vinnslustöðin hf	Westman	154,462	Saltver ehf	South	46,809
Ísfélag Vestmannaeyja hf	Westman	64,283	Hásteinn ehf	South	25,903
Bergur-Huginn ehf	Westman	68,139	Sólbakki ehf	South	61,418
Ós ehf	Westman	73,871	Vinnslustöðin hf	Westman	185,355
Stígandi ehf	Westman	7,659	Ísfélag Vestmannaeyja hf	Westman	165,784
Bergur ehf	Westman	40,007	Bergur-Huginn ehf	Westman	81,766
Dala-Rafn ehf	Westman	8,317	Stígandi ehf	Westman	9,191
Ufsaberg ehf	Westman	22,920	Bergur ehf	Westman	48,008
Matthías Óskarsson	Westman	32,826	Dala-Rafn ehf	Westman	9,980
Frár ehf	Westman	17,914	Ufsaberg ehf	Westman	27,504
Hraðfrystistöð Þórshafnar hf			Matthías Óskarsson	Westman	39,391
Guðbjartur ehf			Frár ehf	Westman	21,497
Langanes hf			Steinunn hf		1,466

Table 11- (Continued)

2009/2010			2010/2011		
Fishing Company	**Location**	**Landing**	**Fishing Company**	**Location**	**Landing**
HB Grandi hf	East	103,870	HB Grandi hf	East	103,870
Skinney-Þinganes hf	East	211,446	Skinney-Þinganes hf	East	183,579
Síldarvinnslan hf	East	2,069	Síldarvinnslan hf	East	2,069
Eskja hf	East	11,031	Eskja hf	East	11,031
Loðnuvinnslan hf	East	2,069	Loðnuvinnslan hf	East	2,069
Gullberg ehf	East	6,583	Gullberg ehf	East	6,583
Nóna ehf	East		Fjarðarey ehf	East	27,867
Rammi hf	North	191,564	Nóna ehf	East	
Frosti ehf	North	132	Rammi hf	North	188,563
G.P.G. fiskverkun ehf	North East	728	Frosti ehf	North	132
Samherji hf	NW	2,323	A300 ehf	North East	
FISK-Seafood hf	NW	2,047	Samherji hf	NW	2,323
Hraðfrystihúsið - Gunnvör hf	NW	1,143	FISK-Seafood hf	NW	2,047
Jakob Valgeir ehf	NW		Hraðfrystihúsið - Gunnvör hf	NW	1,143
K G fiskverkun ehf	NW	2,753	Jakob Valgeir ehf	NW	
Guðmundur Runólfsson hf	NW	8,085	K G fiskverkun ehf	NW	2,753
Hjalteyrin útgerðarfélag	NW		Guðmundur Runólfsson hf	NW	8,085
SC hf	NW	6,102	Soffanías Cecilsson hf	NW	6,102
Hraðfrystihús Hellissands hf	NW	18,427	Hraðfrystihús Hellissands hf	NW	18,427
Oddi hf	NW	1,228	Oddi hf	NW	1,228
Sæfell hf	NW		Þórsnes ehf	NW	728
Kristinn J. Friðþjófsson ehf	NW	2,118	Sæfell hf	NW	
Skarðsvík hf	NW	86,687	Norðureyri ehf	NW	
Brim hf	South	2,035	Brim hf	South	2,035
Þorbjörn hf	South	47,354	Þorbjörn hf	South	47,354
Vísir hf	South	2,203	Vísir hf	South	2,203

Nesfiskur ehf	South	124,833	Nesfiskur ehf	South	124,832
Ögurvík hf	South	12	Ögurvík hf	South	12
Stálskip ehf	South		Stálskip ehf	South	
Stakkavík ehf	South	998	Stakkavík ehf	South	998
Gjögur ehf	South	32,018	Fiskkaup hf	South	19,550
Fiskkaup hf	South	19,550	Gjögur ehf	South	32,018
Festi ehf	South		Ingimundur hf	South	29,333
Ingimundur hf	South	29,333	Auðbjörg ehf	South	72,548
Auðbjörg ehf	South	72,549	Einhamar Seafood ehf	South	
Hafnarnes VER hf	South	74,716	Hafnarnes VER hf	South	74,716
Einhamar Seafood ehf	South		Saltver ehf	South	19,841
Saltver ehf	South	19,841	Völusteinn ehf	South	
Hásteinn ehf	South	21,586	Vinnslustöðin hf	Westman	190,016
Sólbakki ehf	South	51,181	Bergur-Huginn ehf	Westman	68,139
Vinnslustöðin hf	Westman	212,936	Ísfélag Vestmannaeyja hf	Westman	64,282
Ísfélag Vestmannaeyja hf	Westman	138,153	Ós ehf	Westman	73,871
Bergur-Huginn ehf	Westman	68,140	Ufsaberg ehf	Westman	22,920
Bergur ehf	Westman	40,007	Bergur ehf	Westman	40,007
Stígandi ehf	Westman	7,659	Stígandi ehf	Westman	7,659
Matthías Óskarsson	Westman	32,826	Matthías Óskarsson	Westman	32,826
Dala-Rafn ehf	Westman	8,317	Dala-Rafn ehf	Westman	8,317
Frár ehf	Westman	17,914	Frár ehf	Westman	17,914
Steinunn hf		1,222	B og E ehf		32,652
Álfsfell ehf			Steinunn hf		1,222

Table 11- (Continued)

2011/2012			2012/2013		
Fishing Company	**Location**	**Landing**	**Fishing Company**	**Location**	**Landing**
HB Grandi hf	East	102,499	HB Grandi hf	East	72,709
Síldarvinnslan hf	East	2,043	Síldarvinnslan hf	East	1,449
Eskja hf	East	10,885	Eskja hf	East	7,722
Loðnuvinnslan hf	East	2,042	Loðnuvinnslan hf	East	1,449
Gullberg ehf	East	6,496	Gullberg ehf	East	4,608
Fjarðarey ehf	East	27,500	Nóna ehf	East	
Nóna ehf	East		Skinney-Þinganes hf	East	148,012
Skinney-Þinganes hf	East	181,157	Rammi hf	North	131,994
Rammi hf	North	186,076	Frosti útgerð ehf.	North	92
Frosti ehf	North	130	GPG fiskverkun ehf	North	
A300 ehf	North East		Samherji hf	NW	1,626
Samherji hf	NW	3,063	FISK-Seafood ehf.	NW	2,322
FISK-Seafood hf	NW	2,020	Hraðfrystihúsið - Gunnvör hf	NW	5,106
Hraðfrystihúsið - Gunnvör hf	NW	567	Útgerðarfélag Akureyringa ehf	NW	
Útgerðarfélag Akureyringa ehf	NW	2,009	Jakob Valgeir ehf	NW	397
Jakob Valgeir ehf	NW	560	K G fiskverkun ehf	NW	1,927
K G fiskverkun ehf	NW	2,717	Guðmundur Runólfsson hf	NW	5,659
Guðmundur Runólfsson hf	NW	7,977	Oddi hf	NW	860
Hraðfrystihús Hellissands hf	NW	18,184	Hraðfrystihús Hellissands hf	NW	12,899
Oddi hf	NW	1,212	Soffanías Cecilsson hf	NW	4,271
Soffanías Cecilsson hf	NW	6,021	Þórsnes ehf	NW	510
Þórsnes ehf	NW	719	Kristinn J. Friðþjófsson ehf	NW	1,482
Kristinn J. Friðþjófsson ehf	NW	2,090	Sæfell hf	NW	
Sæfell hf	NW		Þorbjörn hf	South	33,147
Þorbjörn hf	South	46,728	Vísir hf	South	1,542
Vísir hf	South	2,203	Brim hf	South	1,425

Brim hf	South		Nesfiskur ehf	South	87,383
Nesfiskur ehf	South	123,185	Ögurvík hf	South	8
Ögurvík hf	South	12	Gjögur hf	South	22,415
Gjögur ehf	South	31,596	Stálskip ehf	South	
Stálskip ehf	South		Stakkavík ehf	South	698
Stakkavík ehf	South	984	Fiskkaup hf	South	13,685
Fiskkaup hf	South	19,292	Auðbjörg ehf	South	50,784
Einhamar Seafood ehf	South		Miðtún ehf	South	20,533
Ingimundur hf	South	28,946	Sigurbjörg ehf	South	
Auðbjörg ehf	South	71,591	Saltver ehf	South	13,889
Hafnarnes VER hf	South	73,730	Hafnarnes VER hf	South	52,301
Saltver ehf	South	19,579	Stormur seafood ehf	South	23,588
Stormur Seafood ehf	South	33,252	Einhamar Seafood ehf	South	
Völusteinn ehf	South		Salting ehf	South	
Vinnslustöðin hf	Westman Islands	171,647	Vinnslustöðin hf	Westman	137,805
Ísfélag Vestmannaeyja hf	Westman Islands	63,434	Ísfélag Vestmannaeyja hf	Westman	44,998
Bergur-Huginn ehf	Westman Islands	67,241	Bergur-Huginn ehf	Westman	47,698
Ós ehf	Westman Islands	73,871	Ós ehf	Westman	54,386
Ufsaberg-útgerð ehf	Westman Islands	22,618	Bergur ehf	Westman	28,005
Bergur ehf	Westman Islands	39,479	Stígandi ehf	Westman	5,362
Stígandi ehf	Westman Islands	7,558	Dala-Rafn ehf	Westman	5,822
Matthías Óskarsson	Westman Islands	32,393	Matthías Óskarsson	Westman	22,978
Dala-Rafn ehf	Westman Islands	8,207	Frár ehf	Westman	12,540
Frár ehf	Westman Islands	17,914	Steinunn hf		855