Using bycatch data to inform ecosystem-based fisheries management:

A case study of a Scottish *Nephrops* trawl fishery in receipt of MSC accreditation

Muir Glendinning

BSc. (Hons)

Submitted in fulfilment of the requirements for the

Degree of Master of Science by Research

Institute of Biodiversity, Animal Health and Comparative Medicine

College of Medical, Veterinary and Life Sciences

University of Glasgow

March 2012

Abstract

Eco-labelling schemes that focus on sustainable fisheries have the potential to influence behavioural changes in fishing practices, which hopefully lead to the long term goal of productive, environmentally sound and sustainable fisheries. This thesis presents a case study of a *Nephrops* trawl fishery. Despite being a bottom trawl fishery, it has been certified as sustainable and well managed by the Marine Stewardship Council (MSC), a leading wild capture fisheries certification programme for sustainable seafood. In addition this thesis presents an overview of seafood eco-labelling schemes and discusses how bycatch data obtained through a partnership between science and industry can inform fisheries management.

The research on the fished ecosystem comprised an analysis of random sub-samples received from the fleet of certified trawlers. This involved evaluating a self-assessment scheme that was initially implemented to provide additional bycatch data across the whole fleet. Analysis showed that the scheme could produce robust results, conditional on the quantity and quality of the sub-samples collected by the fishermen being maintained at specified levels. Biological processing of the sub-samples also allowed the establishment of an extensive database, quantitatively detailing the amount of bycatch typically produced by a *Nephrops* trawl vessel in the region. Overall, the bycatch represented 37% of the whole catch by weight, with low catch rates of two sensitive species, Atlantic cod and Spurdog being recorded. The results from analyses of these sub-samples compare well with those from previous studies on this fishery in which the entire catch had been analysed. Similarity of the catch compositions found in the sub-samples also suggests a high degree of uniformity in the fishing process across this fleet. Two small studies on spurdog survivability and on fishing gear interactions with the sea pen *Funiculina quadrangularis* provided biological information relevant to satisfying the conditions of certification. This case study highlights how the MSC approach can be an effective tool for fisheries management and has the potential to generate more benefits than current non-participatory legislation.

Table of Contents

List of Tables

List of Figures

Author's Declaration

I declare that the work described in this thesis has been carried out by myself unless otherwise acknowledged or cited, under the supervision of Professor Douglas Neil. I further declare that this thesis has not, in whole or in part, been submitted for any other degree.

Muir Glendinning

March 2012

Acknowledgements

I would like to thank my supervisor Professor Douglas Neil for giving me the opportunity to complete this Masters degree and for the great support, advice and invaluable wisdom imparted through many interesting discussions! I have enjoyed every minute of working on this project and it has been a pleasure to have worked with you.

Thanks to Rosanna Milligan for her help and advice throughout the project and whose previous research on bycatch in the Stornoway fishery made my thesis possible.

I would also like to thank Dr David Bailey for his support and good humour and to Andrew Watts for his help on many occasions. Also thanks to my fellow colleagues in Room 321 for their generous supply of wit, tea and cake throughout the duration of my time in the office.

Thanks to Young's Seafood Ltd. for funding this project and especially Lorraine Pears at Young's in Stornoway who was instrumental in dealing with the skippers of the fishing vessels and arranging safe delivery of the samples. Special thank you to all the skippers and crewmembers of the Young's Stornoway fleet for their hospitality and for allowing me unrestricted access onboard their boats in order to sample their catches. Thanks also to those skippers that participated in the supply of random sub-samples. Thanks to Barry O'Neill at Marine Scotland for taking the time to answer all my questions regarding fishing gear technology.

Finally, thank you to my family particularly my parents and my wife Nicola, for enduring and listening to my endless fish chatter. I especially appreciate their support and patience during what has turned out to be a testing year for us all.

This thesis is dedicated to the memory of my best friend Brian Garscadden.

Preface

On 14th April 2009, The Marine Stewardship Council (MSC) awarded accreditation to ten trawling vessels targeting the Norway Lobster *Nephrops norvegicus* on the west coast of Scotland, based on their sustainable fishing standard. A requirement for continued certification was a set of conditions which had to be met over the course of the following four years by the client group Young's Seafood Ltd.

A partnership between Young's Seafood Ltd. and the University of Glasgow was established for the purpose of addressing several of these conditions. The University of Glasgow would undertake independent scientific research with the aim of improving a number of performance indicators relating to MSC Principle 2: Ecosystem Structure and Function. This included an in-depth evaluation of the catch composition and the monitoring of two sensitive fish species: Atlantic cod and Spurdog.

The outcome of the research would be a set of recommendations for the fishery, detailing measures which the client and the fishing vessels should adopt to minimise the catches of sensitive species, particularly cod and spurdog. Successful implementation of these measures would improve the scoring performance of the client fleet, leading to a healthier and more sustainable fishery.

The direction of the research was influenced to large extent by the MSC certification conditions set out by the certification body, and on some occasions was driven by additional objectives requested by the assessment team evaluating the fishery. This thesis is mostly based on the research completed during Year 3 of the certification, though it will also use and discuss baseline data generated during the first two years by the University of Glasgow research team (Milligan *et al.*, 2009; Milligan and Neil, 2010).

Detailed below are the original certification conditions set out by the certification body (Table 1) and the Year 3 objectives (Table 2) required to be delivered by the University of Glasgow and Young's Seafood Ltd.

Conditions for Certification

The certification report for the Stornoway *Nephrops* fishery outlined four conditions which had to be met over the four years following accreditation; two of these conditions were to be met by the University of Glasgow. These conditions are described in Table 1 and have been taken from the Certification Report by the MSC assessors, Moody Marine Ltd. (Andrews *et al.*, 2009).

Table 1 Conditions of the MSC certification to be undertaken by the University of Glasgow and Young's Seafood Ltd.

Condition 3
Cod Bycatch & Discards Interactions occur between *Nephrops* fisheries and cod populations. Cod is recognised as being in a depleted state and MSC certified fisheries are required to be prosecuted so as to promote rebuilding of depleted target and by-catch species. **Action required:** Measures should be identified and implemented to minimise catches of cod and future catches should be reported in relation to the proportion of cod in *Nephrops* catches, data from previous years and the relative status of the cod stock. Measures should remain in force until cod recovery has been achieved, and further measures adopted to prevent the *Nephrops* fishery from having adverse effects on the recovered stock. **Timescale**: Measures to minimise cod bycatches in the *Nephrops* directed fishery should be identified within 2 years of certification. Testing of measures should take place within 3 years of certification. Effective measures to reduce cod bycatch should be fully implemented within 4 years of certification. **Relevant Scoring Indicators**: 2.1.4.2, 2.3.1.3
Condition 4
Spurdog There is a small bycatch of spurdog in the *Nephrops* fishery. This species is listed on the IUCN Red List as an endangered species. **Action required** Measures should be identified and implemented to minimise bycatch of spurdog. Measures should remain in force until spurdog recovery has been achieved, and further measures adopted to prevent the *Nephrops* fishery from having adverse effects on the recovered stock. **Timescale**: Measures to minimise spurdog bycatches in the *Nephrops* directed fishery should be identified within 2 years of certification. Testing of measures should take place within 3 years of certification. Effective measures to reduce spurdog bycatch should be fully implemented within 4 years of certification. **Relevant Scoring Indicators**: 2.1.4.2, 2.3.1.3

Year 3 Objectives

The aims and milestone objectives for achieving the conditions of certification were outlined by the client fleet and University of Glasgow at the beginning of 2009. An action plan was developed with the aim of achieving specific objectives for each year of certification. The methods outlined below, which were initially developed on a single vessel during the first two years, would have a broader application across the whole working fleet during Year 3.

Table 2 Aims and milestone objectives for Year 3 of certification

Condition 3: Cod bycatch and discards

Jan 2011 – Dec 2011

- As new technical measures become available (through ongoing research at FRS), catches obtained with these on trial vessels will be tested against the existing data on cod bycatch.
- Periodic monitoring of cod bycatch to evaluate self-assessment data.
- Comparative analysis of new technical measures to minimize cod bycatch with previous data set.
- If a clear spatial / temporal trend is identified, alterations to fishing practice will be tested.

Milestones December 2011:

1. Evaluation of the effectiveness of new technical measures in reducing cod bycatch.
2. Evaluation of self-assessment scheme across the entire *Nephrops* fleet.

Condition 4: Spurdog bycatch and discards

Jan 2011 – Dec 2011

- As new technical measures become available (through ongoing research at FRS), catches obtained with these on trial vessels will be tested against the existing data on spurdog bycatch.
- Periodic monitoring of spurdog bycatch to evaluate self-assessment data.
- Comparative analysis of new technical measures to minimize spurdog bycatch with previous data set.
- If a clear spatial / temporal trend is identified, alterations to fishing practice will be tested.

Milestones December 2011:

1. Evaluation of the effectiveness of new technical measures in reducing spurdog bycatch.
2. Evaluation of self-assessment scheme across the entire *Nephrops* fleet.

Chapter 1 General Introduction

With increasing concern about the state of global fisheries (FAO, 2010) and their levels of exploitation over the last 100 years (Lotze *et al.*, 2006), fisheries management has evolved over recent decades to address issues such as overfishing and sustainability. Restoring sustainable fish stocks and maintaining the health of the ecosystem have involved the movement from the traditional management of single target stocks to a framework which has an emphasis on the whole ecosystem to which the target stock belongs (Bellido *et al.*, 2011). An ecosystem-based approach to management considers the entire ecosystem, for example non-target, endangered and protected species, habitats and trophic interactions. This holistic approach also considers ecological processes such as spawning and recruitment, while reducing levels of bycatch of non-target species or juvenile target species is also a prime objective (Pikitch *et al.*, 2004). In order to achieve these objectives, a suite of management measures has been developed to increase the likelihood that the whole ecosystem is maintained; this includes spatial management, legislation, selective fishing gears, reduced fishing capacity and the use of multispecies assessment and ecosystem models (Jennings *et al.*, 2001, Pikitch *et al.*, 2004, Worm *et al.*, 2009). Traditional approaches using single species tools (e.g. catch quotas, community co-management) are not discounted; rather they are combined with the ecosystem approach resulting in improved standards, reference points and control rules for rebuilding marine fisheries and ecosystems.

However, the problem with such ecosystem-based management strategies can be their demands for data and the number of processes and functions that have to be understood before they are implemented (Frid *et al.*, 2006, Beddington *et al.*, 2007). Furthermore, any attempt to implement a detailed ecosystem-based management strategy is a challenge, particularly due to differences in spatial scales. For example, many of the world's commercial fisheries operate over large areas of the sea and are regulated through large-scale spatial management, with regulations set on a scale of hundreds or thousands of kilometres. However, many marine species have discrete populations that operate within local biological and environmental conditions, and for these small-scale spatial management may be more appropriate, with regulations adapted to suit local conditions (Hilborn *et al.*, 2005). Ecosystem-based management has to address this mismatch of scales in order for the holistic ecosystem approach to work.

A recent key source for standard setting and governance of sustainable fisheries which takes an ecosystem-based approach has been the emergence of certification schemes such as that offered by The Marine Stewardship Council (MSC). The MSC is an alternative to "top-down" centralised regulation, incorporating the concept of consumer power and market forces to drive sustainability. The MSC certification scheme goes beyond normal codes of governance or voluntary self regulation by introducing specific standards for certification. Adhering to these standards represents "a well managed and sustainable fishery" and necessitates behavioural changes to fishing operations, and is supported by rigorous compliance protocols by an independent body (Gulbrandsen, 2009). It is primarily an ecosystem-based scheme that focuses not only on target species but also non-target bycatch species, and on limiting the impacts on the marine ecosystem in general (Thrane *et al.*, 2009). Fishermen have a large incentive to improve their environmental performance and create a sustainable fishery, because failure to comply with the sustainable standard would result in loss of certification. Schemes such as the MSC have the potential to influence the behaviour of the fishing industry and help reduce their ecological impact through the establishment of a high quality sustainable standard. In theory, accreditation and the reputation it brings would lead to other fisheries wishing to emulate the standard by seeking the MSC sustainable label (Ward, 2008).

Although the MSC is the standard bearer, they do not manage the assessment process for certifying which fisheries are granted accreditation. This task is undertaken by an independent third party certification body which assesses the fishery against the MSC standards, decides whether a fishery should be certified, and completes annual audits of fishing operations should a fishery attain accreditation. The certification body can impose conditions on the fishery if the assessment falls below a certain scoring threshold. These conditions are required to be addressed for certification to continue, and are incorporated into an action plan with specific objectives aimed at improving the fishery's environmental performance. How a fishery addresses these conditions are at the discretion of the client seeking the MSC standard, but usually the certification body recommends an appropriate course of action with progress evaluated during annual surveillance audits.

The evidence for changes in a fishery's ecological performance is often limited, and the challenge of proving if certification yields positive returns on issues such as increased biodiversity can be difficult to establish. Indeed, despite its intention to improve the health of marine ecosystems by rewarding well managed and environmentally responsible fisheries, the credibility of the Marine Stewardship Council standard has come into question (Jacquet *et al*., 2010, Kaiser and Edwards-Jones, 2006). Firstly, criticism arises from the subjective process of scoring a fishery against the MSC principles and criteria, upon which performance is measured against the set standard. Secondly, criticism is aimed at the MSC standard for not adequately protecting marine ecosystems, with doubt cast on certification bringing about any improvement on a fishery's environmental performance insofar as it helps to improve marine biodiversity (Ward, 2008).

On 14th April 2009, The Marine Stewardship Council awarded accreditation to a small group of trawling vessels targeting the Norway lobster *Nephrops norvegicus* on the west coast of Scotland, based on their sustainable fishing standard. A requirement for continued certification was a set of conditions which had to be met over the course of the following four years. The outcome of the fishery meeting these conditions would be an improved ecological performance of the fishery, specifically relating to bycatch of two sensitive species, cod and spurdog, caught whilst fishing for the target species *Nephrops*.

1.1 Bycatch issues in *Nephrops* trawl fisheries

The main cause for concern with the Stornoway *Nephrops* trawl fishery, and indeed all *Nephrops* trawl fisheries, relates to the bycatch that is caught when fishing for the target species. Today, bycatch and their discarding are two of the most significant issues relating to global fisheries and their management (Hall *et al.*, 2000). For centuries fishermen have been exploiting the resources of the oceans and inshore waters, and in the process have discarded unwanted parts of their catch back into the sea. As fishing effort has increased to meet the demands of a rising global population, this bycatch of marine mammals, seabirds, fish and invertebrates has also grown, in many cases to unsustainable levels (Leadley *et al.*, 2010). However, it was not until the second half of the 20^{th} century that concerns about this process really began to manifest, especially through the media and the work of conservationists, as reviewed by Jennings *et al.* (2001). Now fisheries are under intense pressure to change the way in which they target species in order to reduce incidental bycatch of non-target species and thus to fish in a more responsible and sustainable way.

It is important to define and understand the terms that are often used when considering bycatch and discards, as the terminology used in different countries or by different researchers often varies, providing the potential for confusion (Hall, 1999, Jennings *et al.*, 2001). The key concepts and definitions presented in Chapter 2 of Kelleher (2005) will be followed, here, and are outlined below:

"**Catch** is used to refer to the "gross catch" and includes all living biological material retained or captured by the fishing gear, including corals, jellyfish, tunicates, sponges and other non-commercial organisms, whether brought on board the vessel or not. Plant material is not considered part of the catch."

"**Target species** refers to catch of a species, a particular size or sex, or an assemblage of species that is primarily sought in a fishery, such as shrimp in a shrimp fishery"

"**Bycatch** is the total catch of non-target animals."

"**Discards** or discarded catch is that portion of the total organic material of animal origin in the catch, which is thrown away, or dumped at sea for whatever reason. It does not include plant materials and post harvest waste such as offal. The discards may be dead, or alive. Discards are *not* a subset of bycatch since the target species is often discarded."

"**Discard rate** is the proportion (percentage) of the total catch that is discarded."

In 2005 it was estimated that globally, fisheries produced on average 6.8 million tonnes of discards for a total recorded landing of 78.4 million tonnes annually, equating to a discard rate of 8% (Kelleher, 2005). Although not entirely comparable (due to different methodologies used when compiling the data), this recent estimation is lower by around 50% from the previous estimate reported by Alverson *et al*. (1994). This reduction is due to several major factors: the use of more selective gears, improved regulations and enforcement, effort reduction, utilising more of the bycatch for other commercial activities such as fishmeal and changes in target species to include those species previously discarded.

Analysing the data by area, together the Northeast Atlantic and the Northwest Pacific areas had almost 40% of the estimated global discards, largely as a result of high discards in many EU fisheries and some Japanese fisheries. For example, the dominance of demersal trawling for shrimp (*Crangon crangon*), *Nephrops* and flatfish in the western waters of EU Atlantic fisheries have generated substantial amounts of discards due to the fishing process used to catch these types of animals. The restriction on quotas has also resulted in high-grading (the retention onboard of only the larger, more desirable fish and the discarding of less valuable but still marketable catch) and other discarding behaviours in this area e.g. whiting discards represented 60% of the catch weight and more than 80% of the catch by number in 1999. One of the datasets used by Kelleher (2005) was that compiled by Garthe *et al*. (1996) who estimated that the North Sea region alone produced 262,000 t of roundfish, 293,000 t of flatfish, 15,000 t of elasmobranchs and 149,700 t of benthic invertebrates in 1994.

The major offenders (those producing the highest amounts of discards) are the shrimp trawl fisheries which account for 27.3% of the globally produced discards. In some instances the discard rate can be as high as 96% by weight. Coldwater shrimp and prawn fisheries also exhibit high discarding with rates, ranging from 20-94%. According to the discard database, *Nephrops* trawl fisheries produce a weighted discard rate of 43%, with fisheries in the North Atlantic typically discarding whiting, haddock, flatfish and undersized/damaged *Nephrops*. High discarding of juvenile whiting and haddock and bycatch of cod and spiny dogfish are of particular concern to EU fishery managers. However, various measures have been implemented recently that have decreased the discard rates in these particular fisheries, some of which are addressed in the review by Kelleher (2005).

Fishermen discard due to a number of factors, but the main reason relates to the creation of early fishing management in the 1950's. During that time single species management models were utilised for harvesting stocks and this resulted in gear technologists developing nets which enabled the target species to be caught at the optimal size. However, modern fishery management now considers selective fishing to include the concept of ecosystem-based management, avoiding non-target species or those without economic value. In the past it was economics and technology that dictated the way in which an ecosystem was exploited, rather than following the fundamentals of ecology and implementation of fishing techniques with minimal impact (Hall *et al.*, 2000). Also, fishermen have been motivated predominately by financial reward. Discarding of non-target species has therefore been based solely on economic considerations, whereby the commercial market dictates the low price of undesirable bycatch species, or in some cases regulations prohibit their landing. Finally, constraints on target species quotas can often result in high-grading being implemented on the vessel, whereby smaller individuals of the target species (though still above MLS) are discarded in favour of larger more valuable fish (Jennings *et al.*, 2001).

The widespread problems associated with bycatch and discards can be both numerous and complex and include: ecological issues relating to marine ecology; economic issues in terms of costs and benefits to the fisherman, administration and society in general; ethical issues; technology issues; and management issues relating to the design of strategies that fulfil the social, ecological and biological requirements but limit the amount of bycatch and discards (Kelleher, 2005). The issue of bycatch and discards is also related to wasting a fish resource i.e. it is almost universally accepted that returning large amounts of protein as dead fish back into the sea seems illogical given the state of global fisheries and the increasing demand for fish.

Perhaps the most critical issue is one of incidental mortality. All marine species caught during the fishing process and subsequently discarded into the sea have a high probability of dying. Long-lived species which have low productive rates, such as sea turtles, elasmobranchs and cetaceans, are particularly vulnerable and pose a serious conservation problem (Hall *et al.*, 2000). However, the level of discard mortality within different fisheries is variable and may change according to haul duration, species characteristics or catch composition (Catchpole *et al.*, 2005). Different physiological characteristics affect mortality, but in general fish discarded from fishing vessels have high mortality rates (Suuronen, 2005). For example, the presence of a gas swimbladder in many teleost fish can lead to mortality after capture due to the inflation, and probable bursting, of the swimbladder, since pressure decreases with decreasing depth when a fishing net is hauled up from the seabed to the fishing vessel. The on-deck exposure time and air temperature are also potential factors to consider when assessing discard mortality. Generally, shorter air exposure times and lower on-deck temperatures are associated with higher survival rates. Shelled molluscs and echinoderms may be the best adapted to survive capture and subsequent return to the sea, but in studies investigating the fate of discarded crustaceans mortality has been high or very high (Harris and Ulmestrand, 2004).

Those animals that escape the nets and the subsequent haul-back of the catch to the deck can still be subject to injury and mortality. A number of factors may cause stress or injury in escaping individuals and these stressors can be cumulative. Changes in environmental conditions such as water temperature, light conditions, currents, and atmospheric pressure may affect the fate of the animal. Other mechanisms include exhaustion through sustained swimming, crushing and injury by contact with the nets, predation, collisions with other animals and anoxic conditions in the codend. Escape does not guarantee survival and the collective effects of the stressors stated above may result in immediate or delayed mortality (Suuronen, 2005).

Consequently, discard mortality can have a detrimental effect on the marine ecosystem. Fishing mortality can reduce species diversity, and can change predator-prey interactions and the relative abundance of certain demersal species. It may also affect population dynamics in several species, favouring scavengers such as crabs and shrimps which consume discards, though the evidence for this remains relatively weak (Catchpole *et al.*, 2005). Nonetheless, heavy exploitation can ultimately lead to species becoming threatened, endangered or locally extinct. Unsustainable fishing (where bycatch and discards are a large part of the problem) have driven many species to significantly low levels, and the projected trends indicate that biodiversity in marine systems will probably decline in the coming decades (Leadley *et al.*, 2010).

1.2 Current fisheries management

Fisheries management, in an international context, is generally driven by legislation and guidelines provided by the Fishery and Agriculture Organisation of the United Nations (FAO). There is a myriad of management regulations and acts governing fishing in international seas, but the main examples include the United Nations Convention on the Law of the Sea (UNCLOS), the 1995 Code of Conduct for Responsible Fisheries and the more recently published FAO International Guidelines on Bycatch Management and Reduction of Discards (FAO, 2010).

In Europe, governance is directed by The Common Fisheries Policy (CFP), a European Union (EU) policy allowing all member states access to the shared resource of EU fishing grounds. It was initially launched in 1970 by the six founding members of the European community, although it was not until 1983 that the CFP became properly established and total allowable catches, species quotas and mesh sizes were introduced (European Commission, 2009). The principal aim of the CFP is to "promote sustainable fisheries and aquaculture in a healthy environment which can support an economically viable industry providing employment and opportunities for coastal communities" (European Commission, 2009: p8). This is achieved by setting quotas for the amount of each species that member states can land, in addition to a comprehensive set of rules regarding technical restrictions. Fishing effort is also controlled by limiting the capacity of fleets and the amount of time vessels are at sea. Although the principles of the CFP were foremost aimed at conserving fish stocks, most states and the EU itself acknowledge that the CFP has failed in this respect. Since its inception, the CFP has failed to protect many of the important commercial stocks such as North Sea Cod, with several stocks showing signs of serious decline and possible collapse (ICES, 2009; Daw and Gray, 2005). In 2003 following reported low levels of cod in EU waters, a long term recovery plan was implemented to safeguard declining stocks which were outside safe biological limits and in imminent state of collapse. At the time of writing, the European Commission is in the process of reforming the CFP with proposals to ban discarding and ensure that stocks are exploited at sustainable levels, producing the maximum sustainable yield by 2015 (European Commission, 2011).

1.3 Fisheries management in Scotland

Scotland is one of the most significant fishing countries in the EU and is the major fishing nation in the UK. Its coastal waters and fisheries zone is approximately 470,000 km^2 and comprises some of the most productive fishing grounds in the world (Marine Scotland, 2009). Fisheries management in Scotland is primarily guided by the principles which underpin the CFP, and in the past decade it has adopted the “precautionary approach” to species stock management. This involves taking advice from the International Council for the Exploration of the Sea (ICES) through stock assessments, enabling a decision to be made on how much fishing effort can take place for each species in each region (Marine Scotland, 2010).

Discards are recognised by the Scottish government as a serious fishery management issue, and as well as supporting EU initiatives such as the cod recovery plan they have implemented their own unique and sometimes innovative measures. These include the use of more selective fishing nets to avoid catching unwanted animals in the first place; prohibiting the use of high-grading; and the introduction of CCTV and observer programmes which deter discarding (Marine Scotland, 2010).

In 2008, with the EU offering member states the opportunity to administer their own days at sea scheme, the Scottish Conservation Credit Scheme was launched as a result over growing concern about discards. The scheme aims to improve fisheries management by applying best practices in order to reduce mortalities of cod and other whitefish. Incentives for fishermen in the form of days at sea are offered in return for adopting conservation methods which aim to reduce cod mortality by 25%. This is achieved by reducing fishing effort and also by avoiding cod in the first place.

The imposition of real time closure is one mechanism which allows the fishing fleet to avoid cod stocks and usually such closures are triggered when the number of cod caught per hours of fishing reaches a predetermined threshold (in 2010 it was 40/hour). In addition, closures will last for 21 days, allowing the cod to fully disperse. Another conservation measure is the creation of "Amber areas". These are regions where cod abundance has been calculated as being likely to be high. The data used for these suppositions can be extrapolated from averaged vessel data sets (VMS and log books) operating within a certain area. Vessels that sign up to avoid these areas can secure additional days at sea, whilst those that do not register do not incur any penalty (WWF, 2009). Real time closures also include permanent or seasonal closed areas (e.g. Long hole fishing grounds in the North Sea which are important areas for spawning cod).

Overview of thesis

The main objectives of this thesis are:

Firstly, to present an overview of seafood eco-labelling schemes, specifically the one promoted by the Marine Stewardship Council, and how its fishery standard is becoming a popular tool in fisheries management (Chapters 1 and 2). In addition, background information will be presented on how the Stornoway MSC *Nephrops* fishery achieved MSC certification (Chapter 3).

Secondly, to use the Stornoway MSC *Nephrops* fishery as a case study to show how a biological study can inform fisheries management and help address certification conditions required for a sustainable fishery. This has been achieved by assessing the effectiveness of a self-assessment scheme for measuring bycatch across a fleet of *Nephrops* trawl fishing vessels (Chapter 4) and by measuring the bycatch composition of trawls made by the vessels in the fleet (Chapter 5).

Thirdly, to review the progress made by the Stornoway MSC *Nephrops* fishery up to the end of Year 3 of certification, and to consider how it may improve its performance in relation to reducing its impact on non-target bycatch species (Chapter 6). This will be based on the completed research and the published literature currently available.

Finally, to offer a consideration of the MSC fishery standard, and an evaluation of its effectiveness as a management tool for modern fishery management.

Chapter 2 Eco-certification

The concept of labelling products that goes beyond the voluntary self regulatory mode of governance, and meets certain criteria concerning standards, is not new; many examples exist in relation to agriculture and timber products (Kaiser and Edwards-Jones, 2006). However, in recent times concern for the sustainability of seafood and the impacts of fishing on the environment have emerged, prompting the creation of eco-labelling schemes that focus on sustainable fisheries and aquaculture. These range from labels that concentrate solely on one aspect of the fishing process, such as the “Dolphin friendly” label, to those labels that embrace several or all aspects of the process, beginning at sea and including all stages through to the consumer’s table (“Fish to Dish”) (Thrane *et al.*, 2009). These schemes have the potential to influence behavioural changes in fishing practices, with the intention in the long term of creating productive fisheries that are both environmentally sound and sustainable (Peterman, 2002).

Organisations that have emerged in recent times include Naturland, Krav, Fair-Fish, Friend of the Sea and the Marine Stewardship Council. Naturland and Krav are examples of eco-label schemes that focus on smaller niche markets which may involve artisanal fisheries or organic products produced locally. The Friend of the Sea eco-label is a non-profit non-government organisation and is the only international scheme which uses the same standardised procedures to certify products from both fisheries and aquaculture. Furthermore, it is the only scheme which certifies fishmeal, fish oil and fishfeed. Since its inception in 2006, it has assessed more than 10 million metric tonnes of wild catch and 500 thousand metric tonnes of farmed products (Friend Of The Sea, 2011).

Although these eco-label schemes have had varying degrees of success, they have not achieved the same level of recognition and support from both producers and retailers as that afforded to the one from the Marine Stewardship Council.

2.1 The Marine Stewardship Council

The Marine Stewardship Council (MSC) offers the leading wild capture fisheries certification programme for sustainable seafood. The council was originally founded by the conservation organisation World Wide Fund for Nature (WWF) and Unilever in 1996 but established itself as a fully independent organisation two years later in the interests of neutrality and credibility (Gulbrandsen, 2009). It is an example of an eco-label that focuses on protection of marine resources, predominately the target species. In addition, it has concerns for non-target bycatch species and also for limiting the impacts on the marine ecosystem in general (Thrane *et al.*, 2009). Through collaborations with fishers, retailers, processors and consumers, the MSC has a vision to have “the world’s oceans teeming with life, and seafood safeguarded for this and future generations” (Marine Stewardship Council, 2012). The basic values supporting the MSC philosophy are mirrored in other eco-labelling schemes, including those outside the marine fisheries realm. The main aims are to:

- use the eco-label and fishery certification programme to contribute to the health of the world’s oceans by recognising and rewarding sustainable fishing practices
- influence the choices people make when buying seafood
- work with MSC stakeholders and partners to transform the seafood market to a sustainable basis

In February 2007, the MSC published a strategic plan aimed at achieving specific milestones both in the short to medium term and in the long term (Marine Stewardship Council, 2007). In the short term the key objectives were to gain a stronghold in the large fish-consuming nations of the developed Western world, including Germany, UK, United States and France. This was to be achieved through gaining the support of the large supermarket chains and establishing MSC labelled products in the food service sector. The longer term objectives, which go beyond 2020, were: to establish a global presence in most of the major seafood producing and consuming markets around the world; have most key global species and fisheries certified; and have compelling evidence of a reversing decline to the global fish stocks.

At a basic level, the presence of the MSC label on a particular product indicates that certain principles or practices have been applied during the course of its production. This allows consumers, who are concerned about specific production issues, to make an informed choice at the point of sale, based on their own personal morals and beliefs (Kaiser and Edwards-Jones, 2006). The growing demand from consumers for sustainably-sourced seafood has forced retailers to examine their marketing strategies, and in the UK retailers such as Sainsbury's and Marks and Spencer are aiming to sell only MSC-certified products. The UK in now spending £178 million p.a. on sustainable seafood, a rise of 154% over a two year period between 2007-2009 (Co-Operative, 2010). In the United States, the global food services company Sodexo aims to have 100 percent of its contracted fresh and frozen seafood certified as sustainable by the Marine Stewardship Council (MSC) or Best Aquaculture Practices (BAP) by 2015. The Findus group (one of Europe's largest frozen food and seafood companies) has a similar aim of having all wild-caught seafood used in its products as MSC certified by 2012. Also, there is a commitment by the Danish fishing industry to having all its fisheries (50 fisheries incorporating 33 species) certified by the end of 2012. This growing movement towards sustainable seafood exerts pressure on the MSC to certify enough fisheries to satisfy this demand. In addition, there is pressure on fisheries to become certified, as without certification they run the risk of losing custom from this growing market.

Once certified, the benefits to fisheries of achieving an eco-label certification usually include a price premium in comparison to similar products without an eco-label. There is also the opportunity to improve the sustainability of the fishery, gain access to new markets and distinguish it from other competitive fisheries (Goyert *et al.*, 2010). However, the costs incurred in order to achieve certification may be prohibitive to some. For example, costs are usually cumulative during the implementation process, with additional expenditure required for annual license fees, audits, improvements and a percentage of sales going to the MSC. In addition, a fishery must also consider the likelihood of certification being attainable, the requirements for retaining it through subsequent inspections and audits, and whether the market will continue to provide price premiums to MSC labelled products under changing economic conditions (Goyert *et al.*, 2010).

2.2 Principles of MSC standard

The environmental standard which the MSC has created for a global sustainable fishing certification programme follows a specific set of principles and criteria. These principles were developed following an international consultation process with more than 300 individuals and organisations, and comply with the FAO published guidelines for eco-labelling of fish and fishery products from marine capture fisheries (FAO, 2005, Marine Stewardship Council, 2010). They allow an independent third party auditor to undertake an assessment of the fishery, in order to determine whether it may be considered sustainable and well managed (Thrane *et al.*, 2009).

There are three guiding principles which underpin the basic philosophical approach taken by the MSC when any fishery seeks certification. Although they predominately evaluate the ecological health and integrity of any fishery, they also acknowledge any social and economical factors which may impact on the potential sustainability of the fishery (Marine Stewardship Council, 2010).

Principle 1: Stock Exploitation
A fishery must be conducted in a manner that does not lead to over-fishing or depletion of the exploited populations and, for those populations that are depleted, the fishery must be conducted in a manner that demonstrably leads to their recovery.

Principle 1 ensures the resource is maintained at a high level over the longer term. It also allows depleted stocks to be considered for certification on the basis that measures are in place which will restore the long term capabilities of the fishery. Furthermore, fishing should not alter the age, genetic structure or sex composition in such a way that it harms reproductive capacity.

Principle 2: Ecosystem Structure and Function
Fishing operations should allow for the maintenance of the structure, productivity, function and diversity of the ecosystem (including habitat and associated dependent and ecologically related species) on which the fishery depends.

Principle 2 considers the management of the fishery using an ecosystem approach. Biodiversity should be maintained, with fishing having a minimal impact on mortality of endangered, threatened or protected species. Provision should be made using a precautionary approach for depleted species, whereby recovery is allowed to occur over a specified timescale to a level that is deemed acceptable.

Principle 3: Effective Management and Certification
The fishery is subject to an effective management system that respects local, national and international laws and standards and incorporates institutional and operational frameworks that require use of the resource to be responsible and sustainable.

Principle 3 focuses on operational and management criteria which allow for the implementation of principles 1 and 2. There are 17 criteria in total which cover a wide range of points relating to the success of a sustainable fishery. Management criteria state that the fishery should be conducted in a manner that follows local and international laws, and considers the legal and customary rights of those individuals dependent on fishing for food and livelihood. The management system should also include a research plan and requires that the biological status of the resource and the impact of fishing be periodically assessed. The fishery should be prepared to act upon any scientific uncertainty using a precautionary approach, with procedures in place to facilitate monitoring, control and compliance, ensuring that the exploited populations are not over-fished. Operational criteria highlight the use of fishing gear and best practices which minimise non-target bycatch.

2.3 The certification process

The certification process involves a number of phases with which the client has to engage before any product is allowed to carry the MSC logo. It is often a rigorous and time consuming process, with the client investing substantial amounts of money in order to proceed through each detailed stage. Initially the fishery has to undergo a formal pre-assessment by an independent third party certification body accredited by the MSC. The main aim of the pre-assessment is to provide the client with a confidential report on the suitability and the probability of the fishery achieving certification when it undertakes a full assessment. Once the client has evaluated the pre-assessment it has the option to withdraw its application (without a great financial loss) or proceed to full assessment (Marine Stewardship Council, 2010).

The full assessment phase is undertaken by the certification body which appoints an assessment team comprising individuals who have an expertise in the relevant fields of fishery management, for example stock assessment or environmental impacts. It should be noted that although the assessors should have the appropriate knowledge of the fishery applying for certification, they should be fully independent of it. The full assessment is a transparent public process that is supported by key assessment reports and documents, which are also uploaded to the MSC website. This provides stakeholders with an opportunity to contribute to the assessment process, allowing objections at any stage to be addressed by the assessment team (Gulbrandsen, 2009). An assessment tree is defined and constructed which includes a set of performance indicators and “scoring guideposts” that reflect the nature of the particular fishery under assessment. Part of the assessment involves site visits, data collection and stakeholder consultations, providing the information on which the fishery can be scored against the standard, using the performance indicators and criteria.

The scoring procedure is a qualitative process which involves the assessment team coming to an agreement on a score for each individual performance indicator. A score above 80 for all performance indicators enables the fishery to be certified without any conditions attached. A score of less than 80 but above 60 still enables the fishery to be certified, but it must meet certain conditions for specific performance indicators following certification. If any of the performance indicators achieve a score below 60 the fishery fails certification.

In July 2008, a new more transparent and explicit Fisheries Assessment Methodology (FAM) was introduced. One of the main aims of this updated methodology was to improve the robustness and credibility of fishery assessments by increasing the consistency of interpretation and application of the MSC standard.

Certification is valid for a maximum of five years, during which time the fishery is subject to annual audits of fishing operations by third party assessors. Before the five year certification period ends, the fishery must be fully re-assessed for it to preserve its uninterrupted certification. This usually takes place when it reaches its fourth anniversary. In conjunction with the fishing operations assessment a "chain of custody" assessment is also performed. This process scrutinizes the product supply chain and has the intention of tracking the product from its origin through the numerous stages of buying, processing to the point of sale. Traceability is a key component of the chain of custody and assures the consumer that the product originates from a fishery that meets the environmental standard for sustainability (Marine Stewardship Council, 2010).

2.4 Adoption trends

Since its inception over a decade ago, the MSC has grown to become the world's most established fisheries certifier (Jacquet *et al.*, 2010). In March 2000, two fisheries, the Thames-Blackwater herring fishery and the Western Australia rock lobster fishery, became the first to achieve certification. Since then the number of fisheries adopting the principles of MSC and becoming certified has increased substantially year on year (Figure 1). As of 23 January 2012 the cumulative total number of fisheries engaged in the MSC program was 274, with 133 fully certified, 141 fisheries in assessment (cumulative) and a further 40-50 in confidential pre-assessment (Marine Stewardship Council, 2012).

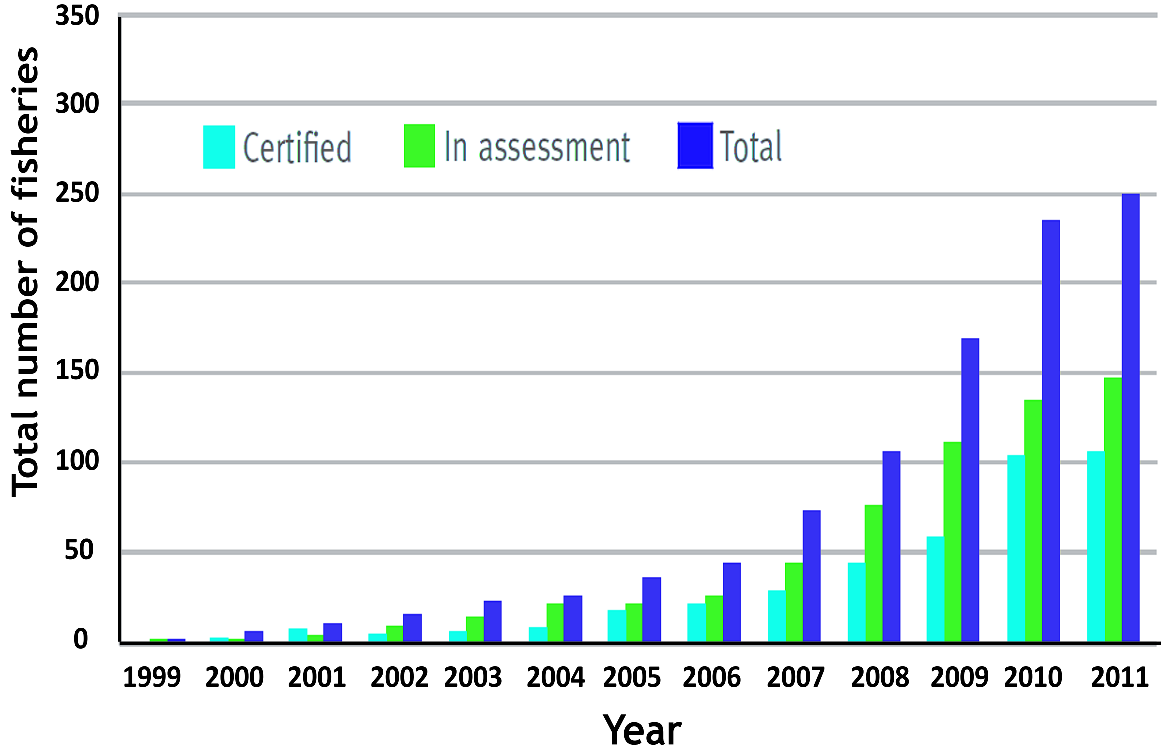


Figure 1. The cumulative total number of fisheries participating in the MSC programme since 1999. Source: MSC Annual Report 2010/2011.

This increase in MSC certified fisheries has resulted in the amount of seafood products which can be traced back to these certified fisheries rising to approximately 13,000. This equates to a certified catch of over 5 million metric tonnes, representing ~ 6% of the total annual global harvest of wild captured fish (Marine Stewardship Council, 2012).

Although the MSC publishes the progress details of fisheries at each stage of the certification whilst in full assessment, and therefore those that fail are known, the number of fisheries that enter pre-assessment but do not proceed to full assessment (whether that be the decision of the client or the assessors) are less clear. During the early years of MSC certification (up to 2004) it was reported that of those the fisheries that had undergone pre-assessment, less than half decided to proceed to a full assessment (Gulbrandsen, 2009). To date the pre-assessment phase still remains confidential between a prospective fishery and the MSC, with no public statistic published by the MSC regarding this aspect of certification. However, Cambridge *et al.* (2011) has recently detailed the number of fisheries entering pre-assessment, with the eventual outcomes also noted. Since 1997, 447 fisheries have undergone pre-assessment, with most of these completed in the last four years (Figure 2). Out of the 447, 35% were not recommended for full assessment, 48% had cautionary issues and only 17% were recommended without having any major issues. In total, 65% did not move on to full assessment. A large proportion of the pre-assessed fisheries were located in the North Atlantic, with shellfish fisheries the most likely to be recommended for full assessment compared to other types of fisheries. Furthermore, small scale fisheries were least likely to enter into full assessment, even if they had received a recommendation from the certifying body.

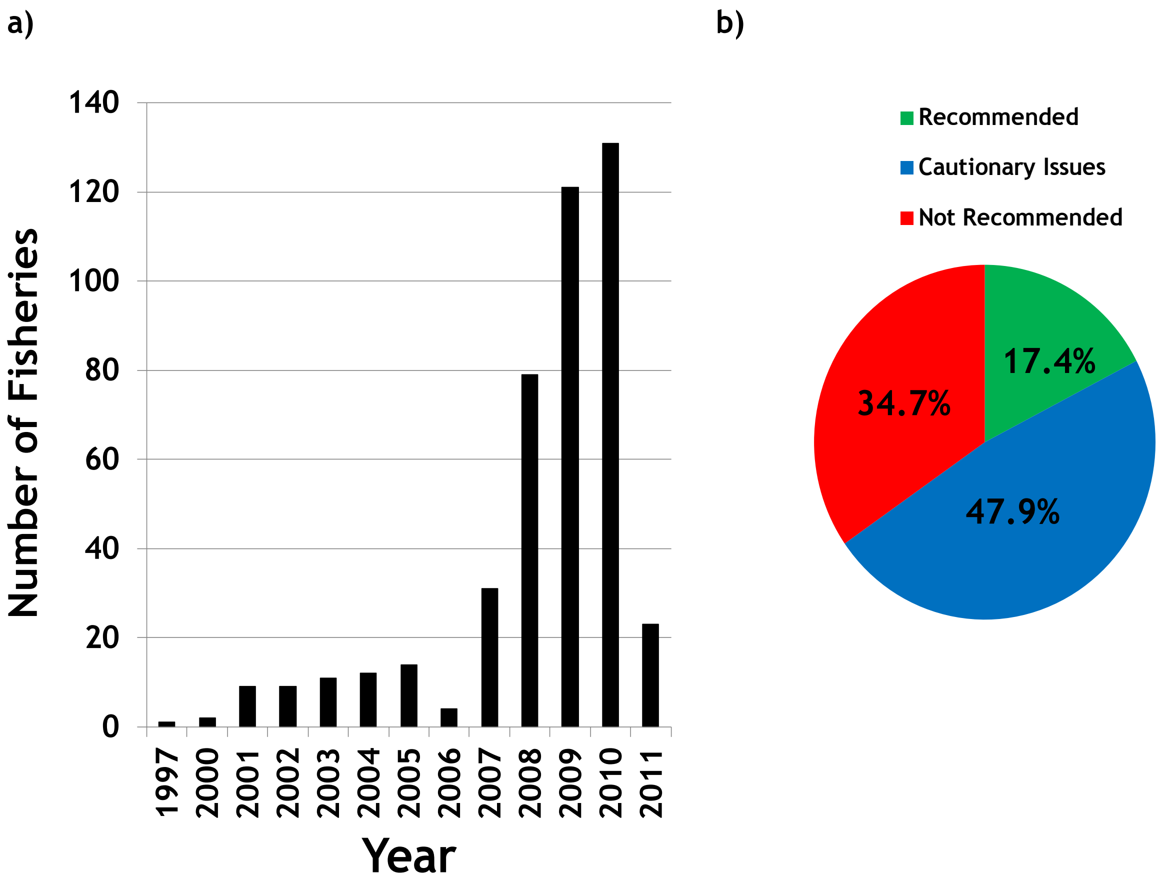


Figure 2. (a) The number of pre-assessments conducted by certification bodies each year (n = 447); (b) the outcome of these pre-assessments (n = 447). (Cambridge T *et al.*, 2011).

However, there is more clarity concerning success rates of those fisheries entering full assessment, and since 2000, when the first fisheries began to be MSC certified, only four have failed the full assessment. The first of these was the NESFC Lobster fishery located in the North of England which failed in August

2007. The fishery passed on two of the three principles but failed Principle 1: stock exploitation. Although it failed the full assessment it had the opportunity to proceed with research concerning the stock status within a three year period. Completion of this research would enable the fishery to re-engage with assessment further down the tree. The fishery has now re-entered full assessment with a completion date and outcome confirmed in March 2012 (Marine Stewardship Council, 2012).

The most recent fishery to complete the full assessment but not be certified was the north east Atlantic mackerel fishery operated by the Faroese Pelagic Organisation. The fishery was originally granted certification by the certification body Det Norske Veritas, but an objection lodged by the Scottish government agency Marine Scotland was upheld and the fishery failed on 28 January 2011. The details of the failure centred on the Faroese government's decision on a mackerel quota that was substantially greater than their previous share of the TAC recommended by ICES, thus potentially endangering the biomass of the stock needed to deliver a sustainable yield.

The remaining fisheries that failed full assessment were the St Helena pole and line and rod and line tuna fisheries and the Faroe Islands queen scallop fishery. The certifying body failed the St Helena fishery under Principle 1: Sustainability of the targeted stock, due to the lack of well defined harvest control rules and no evidence of fishermen reducing TAC should the stock need rebuilding (Carleton *et al.*, 2010). The Faroe Islands queen scallop fishery also failed Principle 1 and was not awarded certification.

2.5 Fisheries suspended

The Loch Torridon *Nephrops* creel fishery was one of the earliest fisheries to be assessed against the MSC principles and criteria for sustainable fishing. In 2000, prior to certification, creel fishermen in Loch Torridon were successful in gaining a closed area for all mobile fishing gear which had previously been open to trawlers through the 1984 Inshore Fishing (Scotland) Act. A management group was formed by the fishers and an application to certify 17 baited-creel vessels as a sustainably-managed resource was accepted by the MSC in January 2003. All vessels participating in the certified fishery had to comply with a voluntary code of practice established by the management group themselves. The principal components of the code were: the introduction of escape gaps/panels in all creels; the requirement to return all ovigerous ("berried") females to the sea; *Nephrops* having a carapace length that exceeds regulatory requirements; the introduction of a maximum number of fishing days; the requirement to utilise a maximum number of creels per boat; and only one gear haul per day (Bennett and Hough, 2008). In addition the fishery had to meet certain conditions relating to the implementation and the ongoing assessment of the fishery. The fishery was first re-assessed in 2008 and although it passed, the fishery attained a score of below 80 for a number of performance indicators. Therefore a number of conditions were applied by the certification body in order to improve the scoring to at least 80. The reason for the low scoring was related to the lack of effort control by the management group i.e. too many non-MSC boats were fishing the closed area but the management group had no authority to stop them. Although ICES considered the *Nephrops* stock in FU 11 and 12 to be exploited sustainably (at that particular time), creel fishing in the Loch Torridon closed area had substantially increased since certification was granted, possibly reaching saturation. Ultimately, the inability to control vessels that were not willing to participate in the voluntary code could have led to the localised stock depletions of *Nephrops* in the closed area (Bennett and Hough, 2008).

The Loch Torridon *Nephrops* creel fishery had its MSC certificate suspended in January 2011 and the certificate was withdrawn on 4th July 2011. The rationale for the suspension was based on the potential problems previously identified in 2009, which had not been suitably addressed by the client in the appropriate timeframe. It has thus become the first MSC certified fishery to have its certificate suspended since the council commenced its scheme back in 1996.

2.6 Criticism

In principle the MSC may offer fishermen an incentive to move towards better practice and better exploitation of global fish stocks, but it is not without its opponents who believe it is risking its credibility by certifying fisheries that do not protect healthy marine ecosystems and wild fish stocks (Jacquet *et al.*, 2010). Objections of this kind have increased over recent years and also include those from conservation groups including Greenpeace and certain branches of the WWF. Criticism has focused on the variability and sometimes loose interpretation of the MSC principles and criteria. Ward (2008) suggested that this flexible interpretation left the assessment model open to criticism as certifiers may be influenced by commercial pressures. There may also be a conflict of financial interest if for example, certifiers have a generous interpretation of the MSC standard and thus may expect to receive additional work from compulsory annual audits and re-assessments needed for continued certification (Jacquet *et al.*, 2010). This key issue in the assessment process which creates potential variation in assessment outcomes could, over time, undermine the consumer trust in seafood certification (Gulbrandsen, 2009). Kaiser and Edward-Jones (2006) also question whether schemes such as MSC can deliver significant benefits to fisheries, given that consumers are sceptical about such schemes and the fact that the policies fail to recognise and reward individual fishermen who fish sustainably but are constantly constrained by the bad practice of others.

2.7 MSC theory of change

Although the MSC aims to “contribute to the health of the world’s oceans by recognising and rewarding sustainable fishing practices”, there has been limited credible evidence that shows this contribution. However, the MSC has previously commissioned a study examining the environmental benefits arising from fisheries achieving MSC certification (Agnew, 2006). The “theory of change study” focused on the environmental or ecological impacts of certification to the MSC standard, and assessed the evidence that the certification programme provides positive benefits to the marine environment. Only fisheries for which one or more surveillance reports had been published were analysed. Environmental gains were categorised into the following five different categories:

- **No gain** - Satisfying a certification condition could have been expected to result in an environmental gain but such a gain did not ensue or where satisfying a condition only required the provision of information to the certification body.

- **Institutional** - changes to institutions and processes involved in fisheries management that could lead to environmental gains, including to the way that those institutions do business, the way they define the fisheries management systems, the data they require from the fishery and its regulations.
- **Research** - new research that should lead to environmental gains if implemented by management, for example research which may focus on any aspect of the target stock, environment or management system.
- **Operational - Action** - New activities that are expected to result in environmental gains such as fishing gear regulations, discard practice or mitigation measures.
- **Operational - Result** - Conclusive results from operational actions that have resulted in environmental gains such as reduced numbers of bycatch and discards or a recovery in benthic diversity in a closed or protected area.

The results of the study identified a total of 89 environmental gains over ten fisheries in the period 1999 to 2006. Sixteen of those were in the most desirable category "***operational – result***" and represent tangible improvements in minimising the impact of fisheries on the environment. Twenty seven were identified in the "***Research***" category with eight identified as no gain. Overall, certification resulted in all ten certified fisheries demonstrating some environmental gain. Generally the biggest environmental gains were in areas which carried conditions for certification, with some evidence indicating that research and action in one certified fishery may have positive effects on both certified and uncertified fisheries in different fishing regions of the world.

In 2010 the MSC commissioned a similar independent study examining the evidence for environmental impacts related to the MSC certification programme (Cambridge *et al.*, 2011). Analysis showed that MSC certification can yield environmental benefits, with 12% of scores relating to **Principle 2: Ecosystem**

Structure and Function improving during or post certification. Improvements were measured by tracking changes in FAM performance indicator scores, but only to those fisheries that had been participating in the programme for long enough to make analysis meaningful. The majority of improvements were associated with increasing certainty that fishing impacts are low, with research and new management measures credited as the main sources of these improvements.

However, both these studies are limited in their interpretation due to the lack of control fisheries used for comparison. Thus it was not possible to answer the question: how would a similar uncertified fishery fare over the same study period?

Chapter 3 Stornoway *Nephrops* fishery and MSC Certification

3.1 The target species: The Norway Lobster *Nephrops norvegicus*

The Norway Lobster *Nephrops norvegicus* (hereafter referred to by genus alone) is a marine decapod crustacean also known as Langoustine or Dublin Bay prawn, with the detached and processed tail of smaller individuals more commonly referred to as 'scampi'. They are widely distributed on the continental shelf of Europe from Morocco to Iceland, at depths ranging from 15 to 800 m, but their distribution within this range is dependent upon the presence of a fine cohesive mud substrate in which they can construct burrows (Chapman, 1980; Howard, 1982). *Nephrops* spend the majority of their time within or at the entrance of their burrow systems on the seabed, emerging only for a short time each day to feed or to mate. Emergence patterns are rhythmic and are related to light intensity at the seabed, with tidal and lunar cycles also thought to have an influence on *Nephrops* activity (Howard, 1982). Juveniles remain mostly in their burrows until sexually mature, and ovigerous ("berried") females rarely leave their burrows during the incubation period (Chapman, 1980). Thus, the most sensitive parts of the *Nephrops* life cycle are protected from fishing, which is by trawling or using baited creels as a method of capture, and the stock can potentially be exploited in a sustainable manner.

3.2 Study site: the Minch

The Stornoway *Nephrops* fishery is located in the Minch, a North Atlantic sea channel situated in the north west of Scotland between the islands of the Northern Inner Hebrides and the outer Hebridean islands of Lewis and Harris. The region is one of complex coastlines containing both deep and shallow fjordic sea lochs, some of which contain Sites of Special Scientific Interest and Marine Nature Reserves. It is one of the most productive marine areas in the UK, containing a mixture of Clyde and Irish Sea water, warmer currents from the

Atlantic and some freshwater runoff. These warm Atlantic waters together with a substratum dominated by mud and sand sediments provide a productive ecosystem, with a high abundance of crustaceans and echinoderms (Pinn *et al.*, 1998). Environmental conditions found in the Minch are also favourable for an array of sensitive species which may be of conservation importance to some environmental bodies. The list of Priority Marine Features (PMFs) in Scottish territorial waters includes numerous species that are specific to certain discrete habitats found in the Minch (Scottish Natural Heritage, 2010). These include the tall sea pen *Funiculina quadrangularis*, the burrowing heart urchin *Brissopsis lyrifera* and the fireworks anemone *Pachycerianthus multiplicatus*. The OSPAR List of Threatened and/or Declining Species also features the spurdog *Squalus acanthias* and species of skate, ray and cod, all of which reside or migrate through the Minch during all or part of their life cycle.

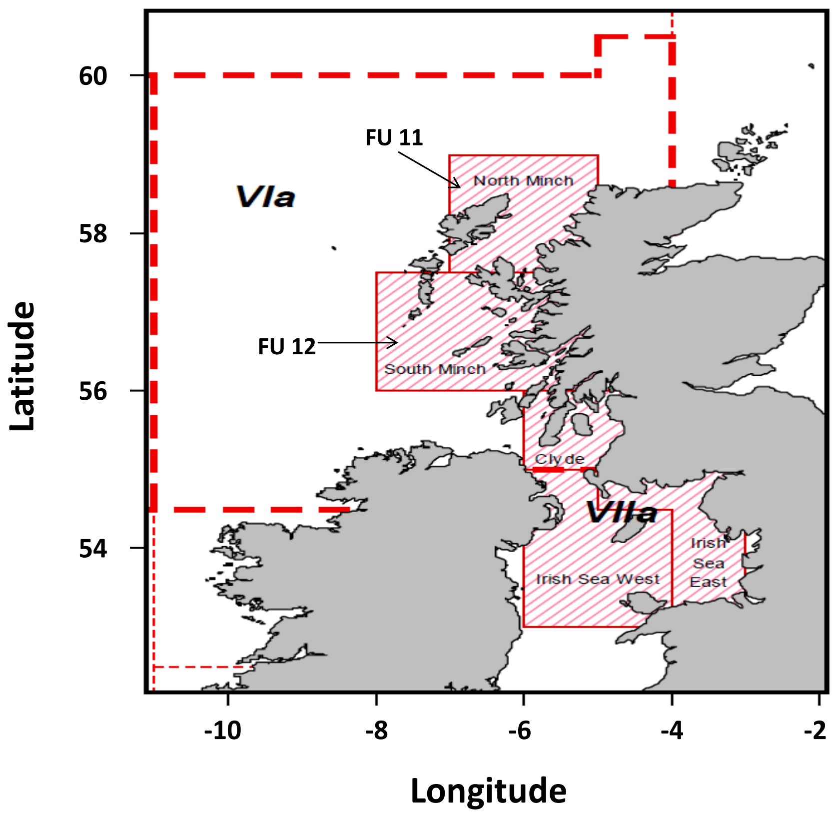


Figure 3. Map showing Functional Units within ICES division VIa in the west coast of Scotland (ICES, 2011).

The fishery is located in ICES sub-area VIa (Figure 3) and the certification boundaries fall into two regions of stock assessment called functional units (FUs). The two regions, the North Minch (FU 11) and the South Minch (FU 12) are based on discrete patches of mud which the *Nephrops* inhabit, and upon which ICES gives advice on stocks and catch effort.

3.3 History of the Stornoway *Nephrops* fishery

The west of Scotland *Nephrops* fisheries are single species fisheries which target solely *Nephrops,* though they are permitted to land a small amount of bycatch species as part of their fishing quota. The fishery operating in the Minch and landing catches to Stornoway has existed for over 40 years. At its peak there were over 100 vessels operating in the Minch (personal communication from John Nicholson, former Operations Manager at Young's Seafood Ltd.) but currently there are only around 20 small single rig inshore trawlers, with 9 of these landing their catch exclusively to Young's Seafood Ltd.

The Minch has historically been under considerable pressure from a mixture of static and mobile fishing activities including dredging, trawling and creeling, whilst in recent times the marine aquaculture industry has continued to expand along the coasts of Lewis, Harris and the mainland. A number of areas within the Minch have received statuary restrictions on the type of fishing permitted within a closed area. These may be annual or seasonal closures prohibiting all fishing, or specific restrictions on trawling or creeling. For example Broad Bay, a sea area lying enclosed between mainland Lewis and the Eye Peninsular, has been closed to all mobile fishing gear since 1984. Previously it had hosted a scallop dredging fishery but was served a prohibition order by the Scottish government in order to protect juvenile fish stocks.

Many commercial whitefish stocks in the west of Scotland, including those found in the Minch, are believed to be at extremely low levels (Keltz and Bailey, 2010), and the impact of commercial fishing practice where species belonging to depleted stocks are captured as bycatch are still of concern to fishery management. However, the state of the demersal fish communities in the Minch over the last decade suggests that the situation may be stabilising, with improvements or beneficial changes in all aspects of fish community composition, structure and function. These include metrics assessing abundance, biomass and productivity, size composition, and species richness (Greenstreet *et al.*, 2010).

3.4 The *Nephrops* trawl fishery

Commercial trawling for *Nephrops* in the Minch is predominantly by trawling, with a small proportion (15-17%) landed by creel fishermen (Keltz and Bailey, 2010). The fleet of trawlers operating in this region are mainly small inshore vessels, with the occasional large freezer-type vessel also fishing in the region. The vessels landing for Young's Seafood Ltd. were built during the 1960's and 1970's, have a length between 15 and 19 m and a maximum power output of no more than 355 KW. Vessels trawl by towing their fishing gear over the seabed using the otter trawl technique. This technique uses a special rigging system enabling the net to form a funnel shape with extended wings which guide animals into the mouth of the net along the extension and into the codend (Figure 4). The fishing gear is connected to the vessel via extended wire warps attached to large metal trawl doors that sit on the seabed. The doors provide the net with horizontal spread (door-door: 40-50 m for a single-rig vessel, 100-120 m for a twin-rig vessel) and are connected to the fishing net by sweeps and bridle ropes, which also help to herd the catch into the mouth of the net. Plastic floats attached to the upper edge provide vertical height, extending the net upward from the seabed (~1m). The groundgear provides good contact with the seabed, allowing the fisherman to effectively target demersal species. The net can be weighted down using several types of groundgear ranging from large rockhopper disc ropes (used on uneven rocky grounds) to light grassropes weighted with small lead rings (used on clean, smooth grounds). The geometry of the fishing gear can be tailored to suit the skipper's fishing preferences such as depth, catch and vessel speed. Some vessels use twin or multi-rig fishing gear which enables two nets to be fished simultaneously side by side and provides a greater area of seabed that can be swept (Galbraith *et al.*, 2004).The length of time for which the fishing gear is towed is variable, as it depends on the seasonality and availability of the target species, but normally tows range from 2-6 hours.

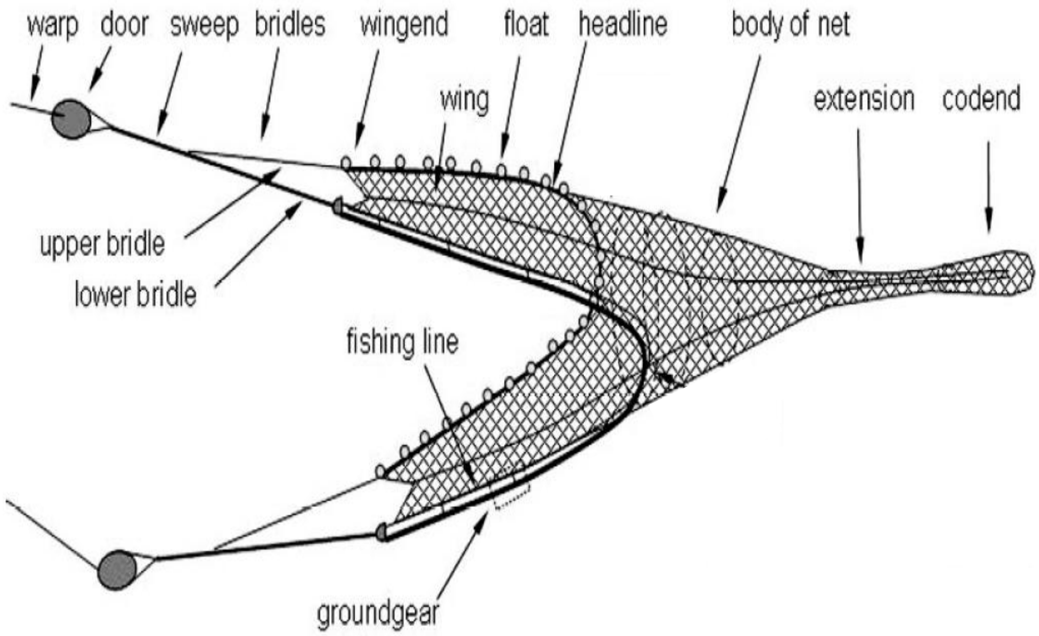


Figure 4. Single rig otter trawl typically used by vessels targeting *Nephrops* (He *et al.*, 2007).

Regulations applicable to vessels targeting *Nephrops* on the west coast of Scotland are an 80 mm minimum size standard codend mesh with a 120 mm square mesh panel (SMP) inserted 12-15 m from the codline. The SMP was introduced as a conservation measure aimed at reducing the numbers of fish bycatch by providing a potential escape route prior to animals entering the codend (Catchpole and Revill, 2008). Despite these conservation measures, selectivity of the fishing gear remains relatively poor and large quantities of bycatch and discards are still produced. These include demersal fish, invertebrate species and unmarketable, undersized *Nephrops*.

3.5 MSC certification

The Stornoway *Nephrops* trawl fishery and the client Young's Seafood Ltd. entered the full MSC fishery certification assessment in August 2007. Moody Marine Ltd. was the certification body selected to evaluate the fishery for compliance with the MSC international Standard for well-managed and sustainable fisheries. The fishery was assessed under an assessment tree that included a total of 77 performance indicators and scoring guideposts developed by the certification body. These were based on the old MSC FAM as the new MSC FAM was not introduced until 2010. To achieve certification, the fishery would have to score an overall weighted average score of 80 for each Principle, (with 100 being the theoretical ideal level of performance).

Table 3 The overall average weighted scores in relation to each Principle assessed (Andrews *et al.*, 2009).

MSC Principle	Fishery Performance
Principle 1: Sustainability of Exploited Stock	Overall : 82 PASS
Principle 2: Maintenance of Ecosystem	Overall : 81 PASS
Principle 3: Effective Management System	Overall : 90 PASS

The fishery passed by scoring more than 80 for each Principle (Table 3) and not scoring less than 60 for any of the performance indicators (PIs), and therefore achieved certification. However, a total of eight performance indicators within Principles 1, 2 and 3 were awarded a score less than 80 but above 60. Three of these PI's were from Principle 1; they were related to stock assessments of the target species, and included having appropriate biological reference points for fishing mortality and also management at the scale of the functional unit (i.e. FU 11 and 12). Two were from Principle 3 and were related to having practical management procedures should target stock levels and harvest ratios become a concern.

The three remaining conditions were in Principle 2: Maintenance of the Ecosystem, and are the main focus of this study. Below are the details of these PIs taken from the final assessment report.

Indicator and Guidepost 2.1.4.2 "*Does the removal of non-target species have unacceptable impacts on populations or ecosystem structure and function?*"

The assessment team scored the fishery 75 due to the uncertainty concerning the fleet's impacts on the ecosystem and populations of sensitive non-target species. These include the rare tall sea pen *Funiculina quadrangularis* and two fish species Atlantic cod *Gadus morhua and* spurdog *Squalus acanthias,* both of which are subject to conservation measures by the European Commission in order to recover their low stocks. To improve the score of 75 to 80 or above, the client and fishery are required to continue to reduce the impacts of the fleet on the ecosystem and the sensitive non-target species.

Indicator and Guidepost 2.2.1.3 *"Do interactions (with protected, endangered or threatened species*) *pose an unacceptable risk to such species?"*

Concerns remain about the potential effects the fleet has on spurdog populations, therefore the assessors could only award a score of 75.

Indicator and Guidepost 2.3.1.3 "Do management measures allow for recovery of affected populations?" (Relating to exploited non-target species whose populations are depleted)

Once the benefits of new (more selective) fishing gear and monitoring equipment have been demonstrated, a higher score will be appropriate. In the meantime a score of 65 was deemed appropriate.

Although the fishery was awarded certification, a number of conditions were set as a result of the low scoring performance indicators. For continued certification Young's Seafood Ltd. would be required to address these conditions within the four year time frame agreed with the certification body. The progress of the fishery against these conditions would be evaluated through annual surveys by an assessment team. Failure to adequately address these certification conditions could result in suspension or withdrawal of the fishery certificate.

Following accreditation, Young's Seafood Ltd. agreed to a new programme of research to improve their understanding of the impacts of the fishery on non-target species, and to address the conditions arising from the MSC assessment.

Chapter 4 The effectiveness of a self-assessment scheme for measuring bycatch in a *Nephrops* fishery

4.1 Introduction

Due to their heterogeneous spatial distribution and high temporal variability (Bellido *et al.*, 2011), accurate estimates of bycatch and discards occurring within a fishery can only be obtained from sampling programmes (Rochet *et al.*, 2002). Generally, data can be collected by scientific observers only a few times per year, and then on only a few vessels, due to the high costs of hiring vessels and the limited available trained manpower. Thus, spatial and temporal trends cannot be properly identified, and considerable time and money would have to be invested in order to monitor the long term catch composition across the fleet.

As part of a programme of research commissioned by Young's Seafood Ltd. to improve their understanding of the impacts of the Stornoway *Nephrops* fishery on non-target species, and to address the conditions arising from the MSC assessment, during Years 1 and 2 of the MSC certification, sampling by a research team from the University of Glasgow enabled the catch composition to be measured using one fishing vessel from the fleet over the course of 18 months (Milligan and Neil, 2010). Survey trawls were completed using a single rig *Nephrops* vessel on commercial fishing grounds typically used by the Stornoway fleet.

One of the main objectives of the present study, representing Year 3 of this certification, was to measure the catch composition across the whole fleet of the Stornoway *Nephrops* fishery, therefore allowing vessels of different age, power, net configurations and general fishing behaviour to be considered. However, delivering a programme involving regular scientific sampling of all the vessels in the fleet would be too costly, both financially and in terms of qualified personnel. As a result, a self-assessment sampling programme was designed and introduced to enable scientists to analyse information on the distribution and abundance of bycatch species from the whole Stornoway MSC certified fleet.

Self-assessment schemes are popular (Catchpole and Gray, 2010) due to the lower cost of collecting a greater number of samples, compared to observer-only schemes (Uhlmann *et al.*, 2011). Furthermore, they can provide information on the fishery over the long-term, with crews free to work as normal with no extra people on board. Depending on the methods used, such a system need not significantly disrupt normal working practice.

This self-assessment scheme would also have the objective of giving the fleet more responsibility for generating their own bycatch data and a better understanding of what they were catching. Participation from each vessel and successful operation of the scheme would eventually result in the fleet becoming more self-sufficient in monitoring their bycatch, with less reliance on an outside organisation for this task. However, periodic scientific sampling and analysis would still be required to ensure the scheme was not abused and was accurate and effective.

4.2 Methodology

4.2.1 Obtaining samples

Random sub-samples from commercial catches were provided in two forms:

1. Sub-samples provided solely by the fishermen, and
2. Sub-samples provided by the fishermen when a scientific observer was present.

Together they would provide the necessary data for identifying catch composition trends across the fleet, both spatially and temporally.

4.2.2 Self-assessment methodology

The proposed self-assessment scheme was originally based on the methods developed and used during the scientific surveys in Years 1 and 2, and required crews to sort one or two trawls per calendar month into five groups: *Nephrops*, Invertebrates, Roundfish, Flatfish and Sharks, Rays & Skate. However, it was generally felt that sorting an entire catch required too much time, and the methodology was therefore adjusted and a simpler protocol was introduced. In this revised scheme skippers were asked to provide a random sub-sample of the whole catch at regular intervals (once a month) throughout the year (Figure 5). This sub-sample was then frozen and transported to the University of Glasgow for more detailed analysis of the species composition, weights and numbers. Certification conditions specifically required cod and spurdog abundance in the catches to be reported; therefore skippers were asked to record additional data on these two species. Initially these data, along with details on the target catch (*Nephrops*) and the vessels fishing activity (e.g. time trawling, hauling the gear, travelling) were to be recorded on an electronic monitoring system developed by the company holding the certification and installed on each vessel. However, technical problems with the monitoring system throughout the sampling programme resulted in no data being received from this source. Therefore, paper logbooks were regularly distributed to all vessels for the purpose of recording cod and spurdog abundance, along with information concerning that particular catch such as date, time of haul, depth, GPS coordinates and type of fishing gear used.

Figure 5. Vessels are supplied with polystyrene fish boxes (left) into which they put a random sub-sample of the catch (right).

4.2.3 Scientific observer methodology

Observer samples were collected throughout the year by skippers in the presence of a scientific observer. The observer trips were carried out on board vessels of different age, power and gear type. These included both single and twin rig vessels using “clean” and also “intermediate disc” ground gear on various commercial fishing grounds in the North Minch. The GPS tracks for the tows made between November 2010 and December 2011 are shown in Figure 6 and summary data for each trawl are displayed in Table 4.

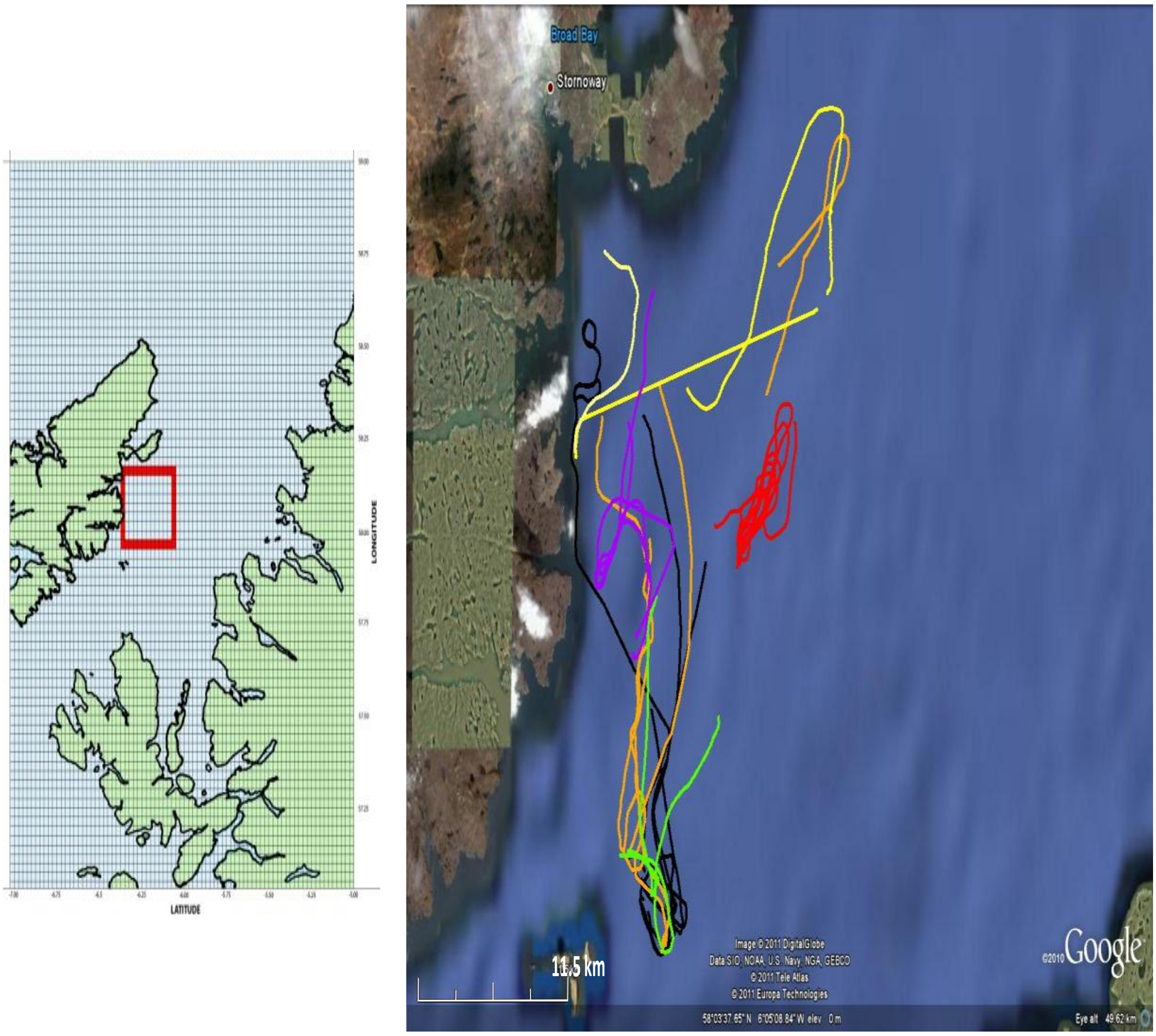


Figure 6. Maps of the study area: (a) The limits of the sampling area are highlighted by the red box and (b) Individual GPS tracks of each tow are shown and colour-coded by month: Bright Green: November 2010; Orange: January 2011; Yellow: April 2011; Red: June 2011; Purple: July 2011; Black: October 2011; Maps generated using Garmin MapSource Ver. 6.15.11 and Google Earth.

The number of trawls varied with fishing season, but two or three daily trips were completed every 7-8 weeks depending on fishing and climatic conditions. Physical data were also recorded to aid the subsequent analysis of the catches, including:

- Trawl date and time and duration (minutes),
- Decimal GPS location (shot and haul points),
- Mean trawl depth (metres; average of start and end depths),
- Gear type - Single or twin rig (clean, disc or hopper),

To ensure that the processed data would be scientifically meaningful, care was taken not to bias the sampling regime. Each day, one haul was randomly selected and a random sub-sample of the whole catch was obtained. This was achieved using a shovel to fill a large fish box of bulk from the hopper before any processing by the crew commenced (Figure 7). All hauls were also observed for total cod and spurdog abundance, and these individuals were recovered, landed and boxed. All samples were stored on ice on the vessels and then frozen at -20°C at the premises of Young's Seafood Ltd. in Stornoway before being transported on ice to the University of Glasgow by haulier approximately one week after capture. The samples were re-frozen at -20°C on arrival at the university and stored until they were required.

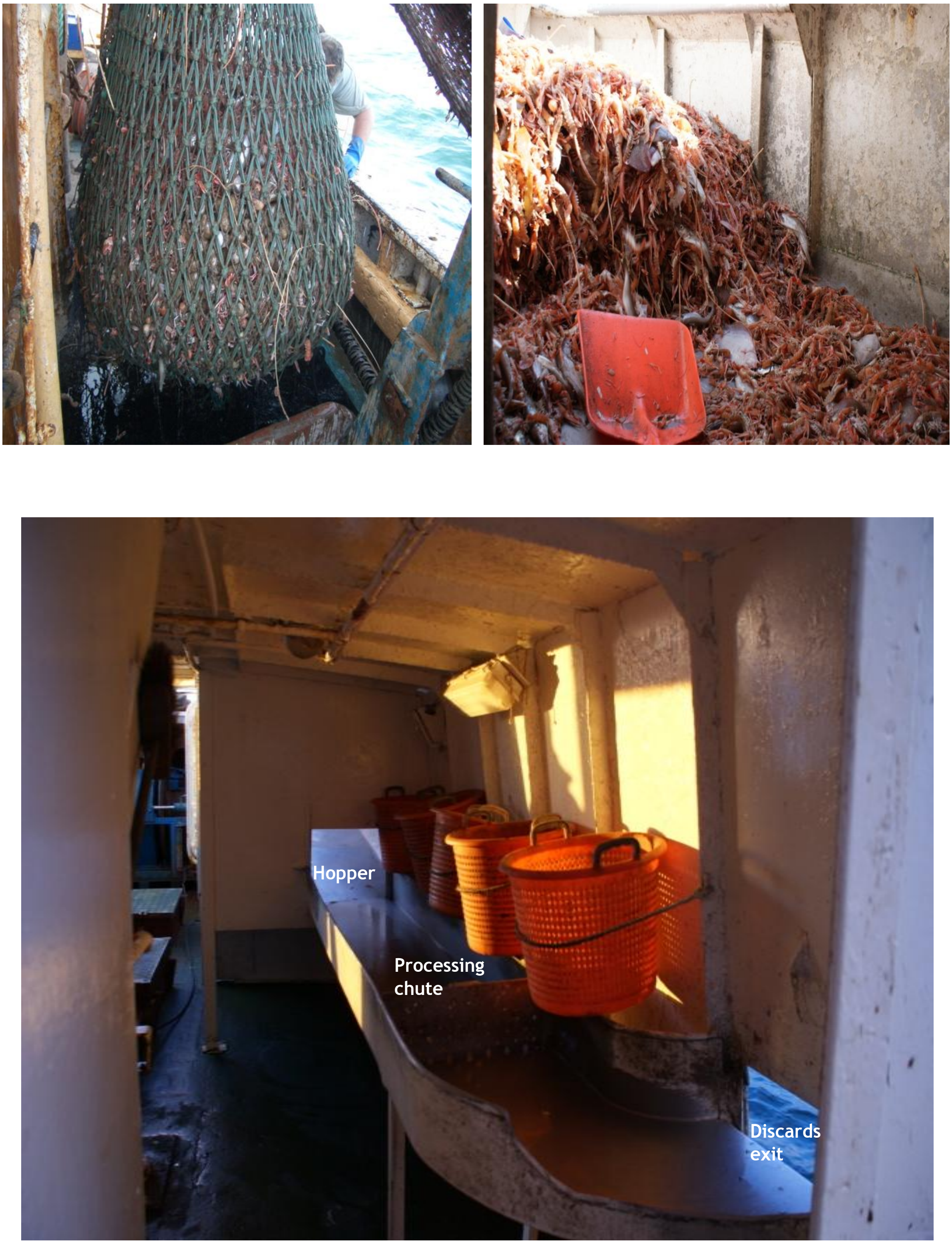


Figure 7. Top left: The codend of the net containing the catch is lowered into the hopper. Top right: The catch is held in the hopper before being shovelled into the processing chute. Bottom: The processing chute is used to sort *Nephrops* into size classes whilst unwanted animals are discarded back into the sea.

Table 4. Summary data for each observer trawl

Trawl ID	Vessel	Date	Time Shot	Duration (mins)	Average Depth (metres)	Gear Type	GPS Shot	GPS Haul
Trawl 13 A	Vessel A	23/11/2010	810	260	95	SR-Disc	58°02’N 6°15’W	57°56’N 6°17’W
Trawl 13 B	Vessel A	23/11/2010	1240	290	100	SR-Disc	57°56’N 6°17’W	57°59’N 6°09’W
Trawl 15 A	Vessel A	26/01/2011	830	285	128	SR-Disc	58°03’N 6°15’W	57°55’N 6°17’W
Trawl 15 B	Vessel A	26/01/2011	1330	255	129	SR-Disc	57°54’N 6°14’W	58°03’N 6°15’W
Trawl 16 A	Vessel C	27/01/2011	805	300	104	SR-Disc	58°06’N 6°14’W	57°56’N 6°17’W
Trawl 16 B	Vessel C	27/01/2011	1320	265	140	SR-Disc	57°56’N 6°17’W	58°05’N 6°19’W
Trawl 17	Vessel B	28/01/2011	805	350	123	SR-Clean	58°09’N 6°05’W	58°06’N 6°06’W
Trawl 22 A	Vessel G	06/04/2011	715	345	125	TR-Clean	58°06’N 6°12’W	58°08’N 6°01’W
Trawl 22 B	Vessel G	06/04/2011	1340	525	99	TR-Clean	58°08’N 6°02’W	58°04’N 6°21’W
Trawl 22 C	Vessel G	06/04/2011	1835	160	75	TR-Clean	58°05’N 6°21’W	58°09’N 6°18’W
Trawl 25 A	Vessel A	08/06/2011	515	345	92	SR-Disc	58°03’N 6°10’W	58°02’N 6°08’W
Trawl 25 B	Vessel A	08/06/2011	1130	260	88	SR-Disc	58°02’N 6°08’W	58°02’N 6°08’W
Trawl 25 C	Vessel A	08/06/2011	1615	235	93	SR-Disc	58°02’N 6°08’W	58°04’N 6°06’W
Trawl 25 D	Vessel A	08/06/2011	2030	115	83	SR-Disc	58°04’N 6°05’W	58°05’N 6°04’W
Trawl 28 A	Vessel C	26/07/2011	710	285	115	SR-Disc	58°05’N 6°17’W	58°00’N 6°16’W
Trawl 28 B	Vessel C	26/07/2011	1145	300	117	SR-Disc	58°01’N 6°16’W	58°02’N 6°15’W
Trawl 28 C	Vessel C	26/07/2011	1710	285	113	SR-Disc	58°02’N 6°15’W	58°08’N 6°14’W
Trawl 29 A	Vessel C	11/10/2011	0825	265	105	SR-Disc	58°05'N 6°15'W	57°55'N 6°15'W
Trawl 29 B	Vessel C	11/10/2011	1310	240	111	SR-Disc	57°55'N 6°15'W	57°55'N 6°15'W
Trawl 29 C	Vessel C	11/10/2011	1725	165	103	SR-Disc	57°55'N 6°15'W	57°59'N 6°15'W
Trawl 30 A	Vessel A	12/10/2011	0720	270	104	SR-Clean	58°02'N 6°10'W	57°55'N 6°15'W
Trawl 30 B	Vessel A	12/10/2011	1225	285	102	SR-Clean	57°55'N 6°15'W	57°58'N 6°14'W
Trawl 30 C	Vessel A	12/10/2011	1745	255	55	SR-Clean	57°58'N 6°13'W	58°07'N 6°20'W

4.2.4 Processing samples and species identification

Samples were allowed to defrost at room temperature for at least 24 hours before processing. Once fully defrosted, animals were identified and sorted into five groups: *Nephrops*, Invertebrates, Roundfish, Flatfish and Elasmobranchs (Figure 8). Numbers and weights of each individual group of species were recorded whilst the carapace length (CL: measurement taken from the base of the orbit to the mid posterior edge using Wiha dial calipers) and sex of *Nephrops* were also noted. Biometric measurements for key fish species including cod, spurdog, whiting, haddock, hake and pouts were also completed. This involved measuring the animal's total body length (rounded down to the nearest 5 mm), total weight, viscera weight, gonad weight, sex and maturity. Weights were measured using Ohaus electronic scales.

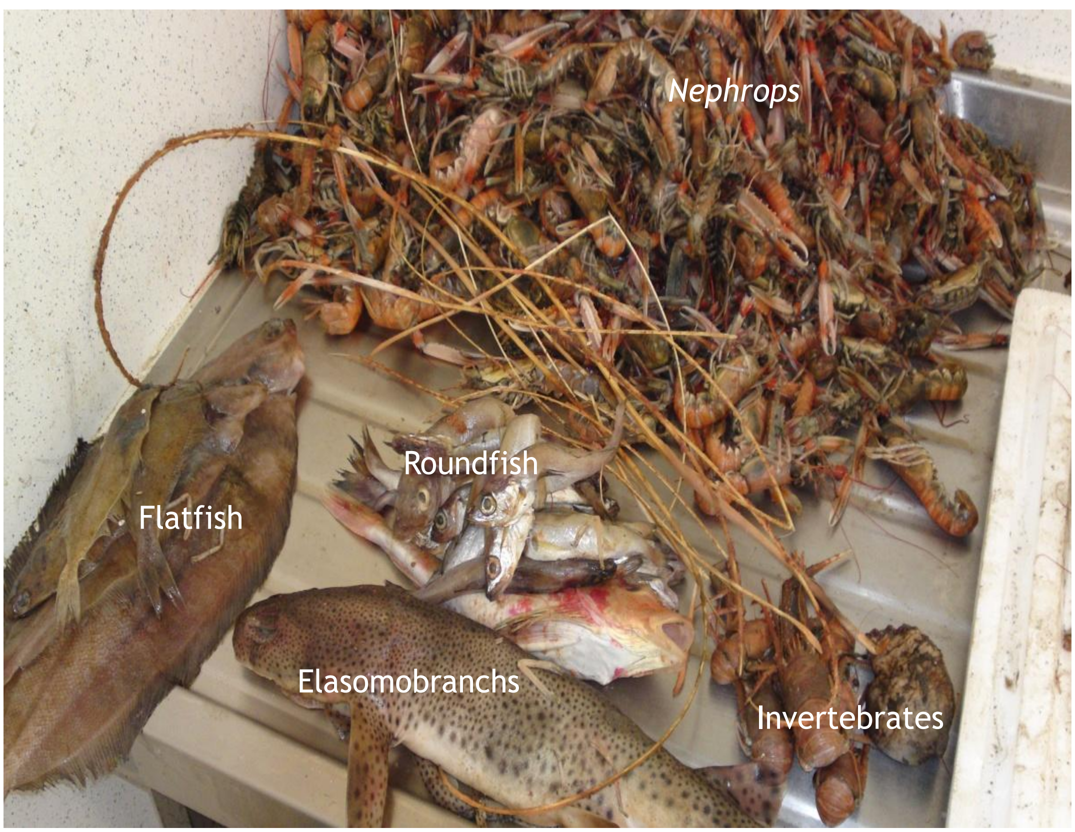


Figure 8. A sub-sample is sorted into five different animal groups after defrosting from polystyrene fish box.

4.2.5 Validating the self-assessment methodology

Self-sampling programmes may be prone to systematic sampling errors that may bias the data received from the fishermen (Hoare *et al.*, 2011). The quality of the data is important if any inferences are to be made which may lead to management measures being introduced aimed at reducing bycatch rates within the fishery. However, bias may occur if the fishermen are to record data which they believe may be detrimental to fishery in the short term, for example, recording high catch rates of sensitive species. Sub-samples that are not truly random would also be a source of bias if, firstly, the fishermen are not prepared to allow larger, more valuable animals in their catch to be included in the sub-sample, and secondly, that they select animals which they perceive to be a true reflection of a typical catch.

To assess whether the data obtained from the skippers using the self-assessment system were reliable, samples were cross-checked against scientific observer samples which were obtained around the same date and within the same fishing area. This post hoc method compared the size distribution of the carapace lengths of the target species, *Nephrops* in each sample. A mean carapace length distribution obtained from a fishermen's sample that was significantly smaller than the observer's sample suggested a sampling bias. Furthermore, a high prevalence of the smallest size class (discards) of *Nephrops* or missing values in the largest most valuable size class measured in the sample also suggested sampling bias, and the sample was therefore rejected. In addition, a sample was rejected if the total biomass was below 5 kg. Post hoc analysis revealed that samples below this weight threshold are more likely to be influenced by the presence of a few large individuals and therefore can be less representative of the whole catch.

4.2.6 Data Analysis

The data were analysed using Minitab version 16 software. As samples were from a non-normal distribution after transformation, a non-parametric Kruskal-Wallis analysis was used to compare carapace length of *Nephrops* in each sub-sample. P values lower than 0.05 were considered statistically significant.

4.3 Results

4.3.1 The composition of sub-samples from fishermen and observer

A total of 20 random sub-samples were received from all vessels in the Stornoway fleet between July 2010 and October 2011 (Table 5). The screening process resulted in 8 of these being acceptable (**A** sub-samples: Mean 7.11 kg, Range kg 6.7– 11.78 kg) and 12 of these being rejected (**B** sub-samples: Mean 3.33 kg, Range 1.37 kg – 6.06 kg) either due to the fact that the total weight of the sub-sample was below the notional minimum deemed necessary to be truly representative of a typical catch, or as a result of cross-checking the size profile of *Nephrops* with a set of 8 scientific sub-samples (**S**). An example of this cross-checking process is shown in Figure 9, which presents a graphical summary of the size class distribution of *Nephrops* in two fishermen's sub-samples (**A** and **B**) and the scientific sub-sample (**S**) obtained around the same time from the same fishing location using the same gear configuration. These size classes are those typically used by fishermen who grade *Nephrops* whilst processing at sea in preparation for landing them to the harbour-side market (Figure 10). The fishermen's sub-sample **B** includes a large percentage of discards compared to the other two sub-samples, whilst there are also no large prawns present in sub-sample **B**. Combined with a statistical test, a judgement can be reached whether to accept or reject the sub-sample. In this instance a Kruskal-Wallis test was used. Analysis showed a significant difference between the median carapace lengths of *Nephrops* of the fishermen's sub-sample **B** and the other two sub-samples $H(2) = 33.56$, $p = 0.000$. This suggests that the methodology used in taking the sub-sample may have been incorrect (e.g. by it happening after the processing has started, or because the large, more valuable *Nephrops* had been extracted from the sub-sample).

The mean proportions of each major group (by wet weight) in the sub-samples received from fishermen or taken by the observer are shown in Figure 11. Overall, analysis of catch composition shows that the two methods of collection produce results that are reasonably similar in terms of catch composition. However, Figure 15 highlights how the composition of a small sub-sample (**B**) may deviate from a normal catch composition. In this instance a sub-sample weighing 2.47 kg was received and the inclusion of a few larger heavy fish species (red gurnard) appeared to bias the results towards a composition high in roundfish. Red Gurnard are normally relatively rare in the catch, typically representing only 1.4% of roundfish in the whole catch in comparison to other fish species (Milligan and Neil 2010). This particular sub-sample suggested that red gurnard represented 50% of the roundfish biomass in the catch, but the likelihood of them occurring in such a high biomass in the whole catch is actually very low.

Table 5. Random sub-samples received from each vessel between July 2010 and October 2011.

	Vessel A	Vessel B	Vessel C	Vessel D	Vessel E	Vessel F	Vessel G	Vessel H	Vessel I	Vessel J
Jul-10	-	-	-	-	-	-	-	-	-	Yes
Aug-10	Yes	Yes	-	-	-	-	-	-	-	
Sep-10	Yes	Yes	Yes	Yes	-	-	-	-	-	-
Oct-10	Yes	Yes	-	-	Yes	-	-	-	-	-
Nov-10	-	Yes	-	-	-	-	-	-	-	-
Dec-10	-	-	-	-	Yes	-	-	-	-	-
Jan-11	-	-	-	-	-	Yes	-	-	-	-
Feb-11	-	-	-	-	-	-	-	-	-	-
Mar-11	Yes	-	Yes	Yes	-		-	-	-	-
Apr-11	-	-	-	-	-	-	-	-	-	-
May-11	-	Yes	-	Yes	-	-	-	-	-	-
Jun-11	-	-	-	-	-	-	-	-	-	-
Jul-11	Yes	-	Yes	-	-	-	-	-	-	-
Oct-11	-	-	-	-	-	-	-	-	-	-

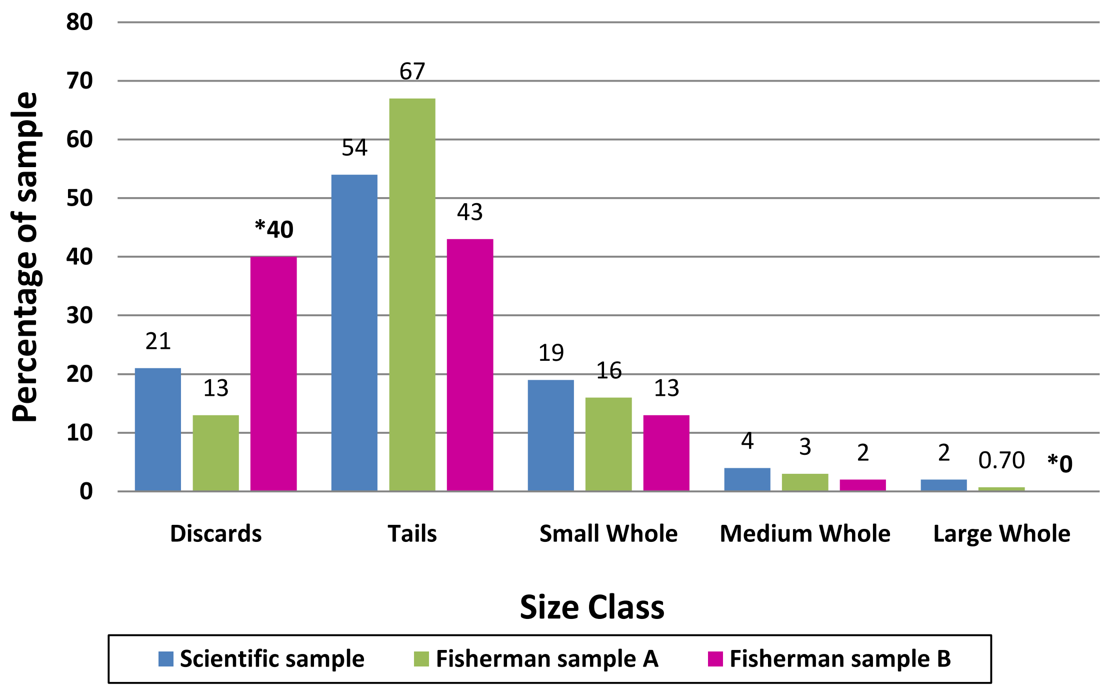
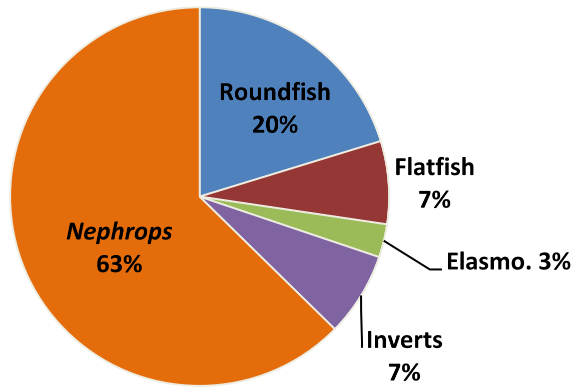


Figure 9. *Nephrops* obtained from individual random sub-samples either from a scientific observer (**S**) or from fishermen (**A** and **B**). Note the large proportion of discards and the absence of large whole *Nephrops* in the fishermen's **B** sample. The data which underlie this chart are included in Appendix B.

Figure 10. Crew members process the catch and grade *Nephrops* into typical commercial size classes prior to icing and landing to harbour-side market.

a) Fishermen only
Sub-samples (**A**)



b) Observer only
Sub-samples (**S**)

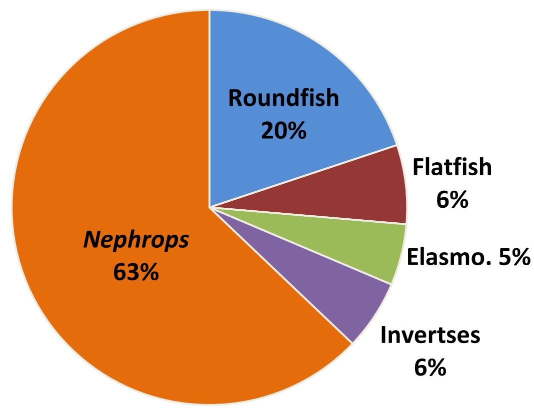


Figure 11. Mean catch composition of random sub-samples by wet weight grouped by: a) acceptable sub-samples supplied by fishermen (**A**) (n=8); b) sub-samples obtained by the scientific observer (**S**) (n=8).

Acceptable sub-sample (**A**) Total weight of sample = 11.8 kg

Rejected sub-sample (**B**). Total weight of sample = 2.47 kg

Figure 12. Catch composition by wet weight of selected individual random sub-samples supplied by fishermen, representative of the acceptable (**A**) and rejected (**B**) categories.

4.3.2 Feedback from fishermen

Informal discussions were held with the fishermen to establish their views on the self-assessment methods for measuring their own bycatch. The general consensus was that most skippers interviewed did not have a problem participating in the amended scheme of supplying random sub-samples. Though in periods of poor fishing when there are fewer *Nephrops* on the grounds then they are less likely to give away a proportion of their catch as a sample. Financial constraints placed on the vessels over the past twelve months had resulted in fewer crew members being onboard for processing the catch, and therefore making it even less feasible that sorting the bycatch into groups was possible. Skippers were reluctant to record numbers of individual species (cod and spurdog) as they feared that more management measures would be placed upon the fishery, for example closed areas, should they voluntarily disclose such information. In general, skippers were unaware of the importance of long-term monitoring of their bycatch, with many feeling it was no benefit to the fishery.

4.4 Discussion

The random sub-samples analysed in this study have been shown to correspond well to the catch composition of the whole catch reported on the same fishery in previous years (Milligan and Neil, 2010). For example, the catch composition ratio for target species and bycatch analysed during Years 1 and 2 produced a mean ratio of 61% target species (*Nephrops*) to 39% non-target species (bycatch). The ratio of target species to non-target species obtained from the validated sub-samples (i.e. categories **A** + **S**) during Year 3 produced a similar result, with a ratio of 63% : 37%. Furthermore, analysing *all* the fishermen sub-samples without validating them for reliability (i.e. categories **A** + **B**), produces a *Nephrops* to bycatch ratio of 61% : 39%. However, there appears to be some variability within some of the bycatch groups in the rejected sub-samples (category **B**) and so these sub-samples are useful only for the broad analysis, i.e. target species : bycatch ratio. For a descriptive analysis providing greater detail of the bycatch composition, then larger sub-samples are required. Whilst it was expected that some of the rarer species would be absent from the sub-samples, and data on these could be collected through periodic monitoring by fishermen and/or an onboard observer, the continual supply of very small sub-samples (<5 kg) resulted in analyses that had limited value. Nevertheless, the results demonstrate how a validation process whereby cumulative evidence is gathered (such as a sub-sample weight threshold, and the size profile of *Nephrops* in the catch) when assessing sub-samples, can preserve data quality.

The self sampling protocol introduced into this particular fleet is one that has had success in other fishing areas, due to its simple concept and ease of application onboard commercial vessels (Lordan *et al.*, 2011). The quality of sub-samples received from fishermen was variable and although the final analysis of the bycatch composition is encouraging, there is a caveat that if the sub-samples are very small (< 5 kg), the data are of limited value. Small sub-samples are less likely to be representative of the whole catch and the presence of a few large animals can skew the results and consequentially the results can be misleading.

Some vessels failed to participate in the programme and skippers may still have to be convinced of the benefits of such self-sampling programmes. The receipt of small or no sub-samples may be a result of economic conditions currently faced within the industry, for example increasing fuel and vessel running costs. An extra monetary incentive for the vessels that provide sub-samples of an adequate size and quality may be required if participation is to be maintained, This is an important point noted by other studies (Hilborn *et al.*, 2005, Grafton *et al.*, 2006) especially those faced with similar data collection obstacles, including 'participation fatigue'(Hoare *et al.*, 2011). Nonetheless, these are encouraging results which indicate that the self-assessment scheme has the potential to be successful if the fleet wishes to continue with the long- term monitoring of the fishery.

Chapter 5 Catch composition using self-assessment and observer data.

5.1 Introduction

5.1.1 Overall catch composition

The problem of discarded bycatch in *Nephrops* fisheries has been well documented (Briggs, 1985, Stratoudakis *et al.*, 2001, Catchpole *et al.*, 2005, Bell *et al.*, 2008) but many of those studies focus on commercially important roundfish species such as cod, whiting and haddock. Few studies have quantified the non-commercial fish species and invertebrates occurring in the catch. Furthermore, most studies have obtained information from the large fishing grounds in the North Sea, with very little data on west of Scotland grounds, particularly the Minch. Management measures incorporating statutory gear-based measures such as increased mesh sizes and selectivity devices have also changed in recent years, with trends in catch composition possibly changing as a result.

As the MSC takes an ecosystem-based approach to assessing each fishery, the requirement is therefore to quantify the overall catch composition from the trawlers operating in the Minch. Such a study would consider factors specific to this region e.g. economical, environmental, biological and fishermen's behaviour, whilst also taking into account new gear regulations.

The aim of the present study was to measure the catch composition across all the MSC certified trawlers, using the data gathered from the self assessment scheme and the observer trips. Analyses would consider spatial and temporal trends and differences between sub-samples at the community level.

5.1.2 Key Species - Cod and spurdog

Cod is a commercially important fish species in Scotland but stocks are in a very poor condition, and although subject to the EU cod recovery plan the evidence for recovery remains limited (Keltz and Bailey, 2010). The inshore waters around the north of Lewis and the North Minch are spawning grounds for cod, and these areas fall within FU 11 and the boundary of certification. Thus, there may be some interaction between the certified fleet which is permitted to fish within these grounds and cod populations that also use these areas. As the amount of cod in the sea depends on the number of juvenile cod surviving each year into the adult population, the removal of reproductively immature cod by the fishery has implications for recruitment to adult stocks (Longhurst, 1998). *Nephrops* fisheries have historically caught large numbers of undersized immature fish, including cod, which are subsequently discarded dead (Catchpole *et al.*, 2006). Minimising the amount of cod retained by *Nephrops* trawls would help to reduce the total amount of fishing effort on cod and allow stocks to rebuild (Catchpole and Revill, 2008).

The spurdog is classified in the IUCN Red List of threatened species as vulnerable globally, and critically endangered in the Northeast Atlantic (Fordham *et al.*, 2010). Stocks around European waters may have decreased by at least 95% from their original stock biomass (Hammond and Ellis, 2004) and could be in danger of collapse due to targeted fisheries unsustainably removing them in the past (ICES, 2008). Although the majority of large-scale target fisheries have now closed, the behaviour of spurdog in aggregating in schools makes this valuable species highly vulnerable to localised, seasonal fisheries. Capture and retention of by-catch from mixed and demersal fisheries has also been unrestricted until recently. Today, fishing vessels in Scotland are not permitted to land spurdog due to the implementation of a zero TAC in European Union waters (Council of the European Union, 2009).

The aim of the present study was to assimilate the long term monitoring and analysis data of cod and spurdog in the fishery recorded over Years 1-3, and discuss how this biological analysis is important for promoting a sustainable fishery. A small pilot study was also completed to investigate the short-term post-capture mortality of spurdog which are caught as bycatch during trawling for the target species *Nephrops*, but must be returned to the sea.

5.1.3 Key Species – The tall sea pen *Funiculina quadrangularis*

Funiculina quadrangularis is a large whip-like sea pen that has a restricted UK distribution, mostly confined to the north west coast of Scotland. Although not protected by any statutory conservation measures, it is classified as a nationally rare species and is now a UK Biodiversity Action Plan priority species. Unlike other UK sea pens, *Funiciulina* is unable to withdraw into the sediment, and combined with its brittle structure is thus susceptible to physical disturbance, particularly by fishing gear from demersal trawlers. Consequently, *Funiculina* has the potential to be used as an ecological indicator species, where its presence or absence in certain demersal fishing areas may indicate the state of a benthic community (e.g. an impoverished or unspoiled state) (Greathead *et al*., 2007).

Although the previous study by Milligan and Neil (2010) in the Minch quantified the presence of *Funiculina* within the codend of the net, there is the possibility that these results may have under-represented the abundance of *Funiculina* in the bycatch. Often, *Funiculina* become lodged and trapped in sections of the fishing gear other than the codend (Figure 13), so that the impact of the trawling is not being fully recorded. The aim of the observational study undertaken here was therefore to note the presence/absence of *Funiculina* occurring on the trawl gear outwith the codend of the net.

Figure 13. *Funiculina* entangled around floats attached to the bridles (left) and individuals protruding from the codend extension (right).

5.2 Methodology

5.2.1 Overall catch composition: Collection of samples

The analyses were performed on validated sub-samples only; the details of how they were collected and validated are described in Chapter 4.

5.2.2 Key Species - Cod and Spurdog

Cod and spurdog were obtained both from sub-samples provided by fishermen, and from observer trips. All hauls carried out on observer trips were also inspected for total cod and spurdog abundance, and these individuals were recovered, landed, boxed and delivered to the University of Glasgow, as described in Chapter 4 Section 4.2. Before analysis, the samples were allowed to defrost at room temperature for at least 24 hours. The sex, total length (rounded down to the nearest 5 mm) and total weight of each individual fish were recorded, in addition to the weight of the viscera and the gonad mass.

5.2.3 Spurdog survivability pilot study

All spurdog were caught during commercial fishing operations in the North Minch, Scotland. The vessels were either single or twin-rig *Nephrops* trawlers using a clean or small disc *Nephrops* net with a with a diamond mesh cod end of 80 mm and a 120 mm square mesh panel positioned 12 m from the codend. Trawl duration commenced during daylight hours and was measured from the time the winches began lowering out the trawl gear to the time they restarted. The gear was recovered back from the sea floor and lowered into the processing hopper where it remained until the crew were ready to begin sorting the catch. The spurdogs were removed from the catch and visually inspected for signs of life, with close attention being paid to the presence of respiratory functioning of the gills and spiracles. Those that showed any sign of life were carefully placed in a container of fresh seawater, where they were allowed to recover. Animals were inspected for recovery every 15 minutes until up to a maximum time of three hours when they were then classified as being dead or alive. The seawater was replenished every 30 minutes. Dead spurdog were frozen and transported to Glasgow University where they were allowed to defrost at room temperature and biometric measurements were recorded (length, weight and condition). Any individual spurdog which survived were returned to the sea after analysis.

5.2.4 Key Species – The tall sea pen *Funiculina quadrangularis*

Observations were carried out in daylight hours between April 2011 and October 2011 in the North Minch region on the west coast of Scotland. The vessels were either single or twin-rig *Nephrops* trawlers using a clean or small disc *Nephrops* net with a diamond mesh codend of 80 mm and a 120 mm square mesh panel positioned 12 m from the codend. Trawl duration varied between 4.75 and 5.45 hours and was measured from the time the winches began lowering out the trawl gear to the time they restarted to recover it. The trawl gear was inspected prior to each trawl, to ensure that no *Funiculina* were present before lowering the net into the sea. Observations were related to a four-point scale: Absent (0), Present (=1), Present (2-4), Present (≥5). Observations were compromised to some extent by the dangers associated with the crew handling the gear and the rough sea conditions.

5.2.5 Data Analysis

5.2.5.1 Overall catch composition

Analyses of the abundance and biomass of bycatch species or groups were carried out using PRIMER 6 software (Clarke and Gorley, 2006). In order to ensure that trends were accurately identified and analysed, the numbers of each species and the weights of the major groups in each haul's sub-sample were standardised prior to analysis, to give numbers and weights per sub-sample. Multivariate analyses were then carried out on both transformed and untransformed data. The untransformed data were examined to determine the gross relationships between catches, for which the analyses would give most weighting to the dominant species (including *Nephrops*, which is the most commercially significant species). More subtle relationships arising as a result of the rarer species were examined by fourth root transformation of the data, counteracting the effect of the highly abundant or high biomass species groups, and giving more notice to the rarer species in the catch. Where comparisons between samples were examined, the abundance and biomass data were converted to a similarity matrix using the Bray-Curtis similarity index.

Multi-Dimensional Scaling (MDS) and cluster analysis were used to determine the relationships between the bycatch 'communities' from each haul, and ANOSIM (**AN**alysis **O**f **SIM**ilarity) analyses were used to determine the significance of factors in explaining the differences in these communities. In general, MDS analyses were restarted at least 100 times and 99 permutations were used for ANOSIM tests. In each case, significance was taken as $p < 0.05$. Temporal effects were tested at the season level i.e. Spring, Summer, Autumn and Winter as there were insufficient samples to test time over monthly periods.

Mean and standard deviation of male and female *Nephrops* and berried females were calculated to show the seasonal cycle of emergence patterns between sexes.

5.2.5.2 Key Species - Cod and spurdog

Temporal trends were analysed in relation to the abundance and biomass of total cod and spurdog caught over the 3 year study period. Mean and standard deviation of total cod abundance and biomass were calculated. A one way ANOVA was used to compare $\log_{10}$ transformed total cod length between survey years with p values lower than 0.05 considered statistically significant. A post hoc Tukey test was used to confirm where differences existed within significant relationships. The health of fish were also calculated and compared between sampling month using the following condition indices:

Fulton's Condition Index (CI):

$$CI = \frac{\textbf{Weight (g)}}{\textbf{Length (cm)}^3} \times 100$$

Fulton's condition Index can be used to compare the growth condition of an animal reflecting the degree of nourishment and well being of an animal, e.g. a high condition factor close to 1 would normally indicate a good environmental quality and high food availability.

Somatic Condition Factor (SCF): $$\mathbf{SCF} = \frac{\textbf{Carcass weight (g)}}{\textbf{Length cm}^3} \times 100$$

Removing the viscera enables the carcass weight and the somatic condition factor to be calculated. Like Fulton's condition index, SMF is an indirect measure of the health of a fish, but the SCF may be a more accurate measure of the long term condition of an animal as it does not account for recently ingested prey items.

Gonadal-somatic Index (GSI): $$\mathbf{GSI} = \frac{\textbf{Gonad weight (g)}}{\textbf{Total weight (g)}} \times 100$$

Gonadal-Somatic Index (GSI) is the ratio of gonad weight to body weight used to estimate reproductive condition.

Hepatosomatic index (HSI): $$\mathbf{HSI} = \frac{\textbf{Liver weight (g)}}{\textbf{Total weight (g)}} \times 100$$

The Hepatosomatic Index (HSI) is the ratio of liver weight to body weight. As the liver is an important store of energy reserves, it provides an indication of the energy status of an animal.

5.3 Results

5.3.1 Overall catch composition

5.3.1.1 Species composition and broad trends

A total of 16 valid random sub-samples were used in the final analysis with the target species *Nephrops* being the most dominant species in the catches both by abundance (approx. 81% of sample on average) and by wet weight (approx. 63% of sample on average). The bycatch was typically dominated by small juvenile fish, particularly whiting, haddock and pouts and also small crustaceans. Table 6 shows the five most abundant bycatch species by number, while the dominant species by wet weight are shown in Table 7. In each case, the values have been averaged across all sub-samples. A species list of all recorded animals is given in Appendix A.

Table 6. The five most dominant bycatch species (by number as a percentage) occurring in random sub-samples.

Species	Percentage of random sub-sample by number
Norway pout (*Trisopterus esmarkii*)	3.15%
Whiting (*Merlangius merlangus*)	2.51%
Squat lobster (*Munida rugosa*)	1.72%
Pink shrimp (*Pandalus borealis*)	1.69%
Haddock (*Melanogrammus aeglefinnus*)	1.12%

Table 7. The five most dominant bycatch species (by wet weight as a percentage) occurring in random sub-samples.

Species / Group	Percentage of random sub-sample by weight (kg)
Whiting (*Merlangius merlangus*)	12.23%
Haddock (*Melanogrammus aeglefinnus*)	5.57%
Sharks & Rays	3.42%
Hake (*Merluccius merluccius*)	2.9%
Crustacea	2.7%

The mean proportion of each component of the sub-sample by wet weight is shown in Figure 14, and the mean proportion of each component by month in Figure 15. Overall, *Nephrops* comprised the largest component of the catches (mean = 63%), with non-target bycatch organisms accounting for the remaining 37%.

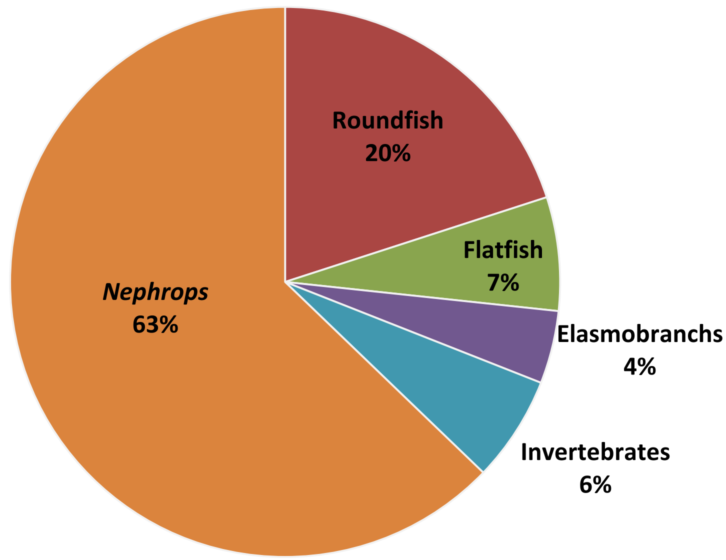


Figure 14. Mean overall catch composition by wet weight from observer and validated random sub-samples from June 2010 to October 2011.

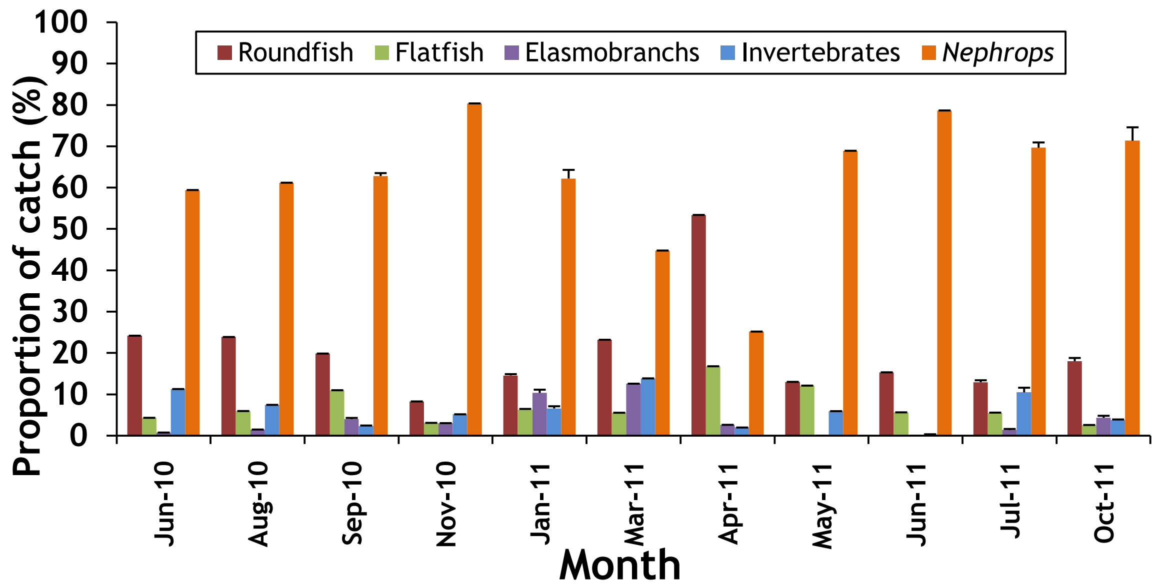


Figure 15. Mean proportion of each component group, in different months. Data from observer and validated random sub-samples (n = 16). Error bars represent 1 standard deviation.

The sex ratio of *Nephrops* was also measured over the study period. Figure 16 shows the seasonal variation, with males dominating the catch in the winter months, and with an increase in females in the summer months, since after incubation of the eggs they emerge from their burrows for longer periods each day, and are thus more available for capture. The number of berried females caught was generally low, averaging just under 4% of the total sub-sample over the year, though there was a high number recorded in September 2010 (~ 27% of total *Nephrops*), reflecting the autumn period of egg release.

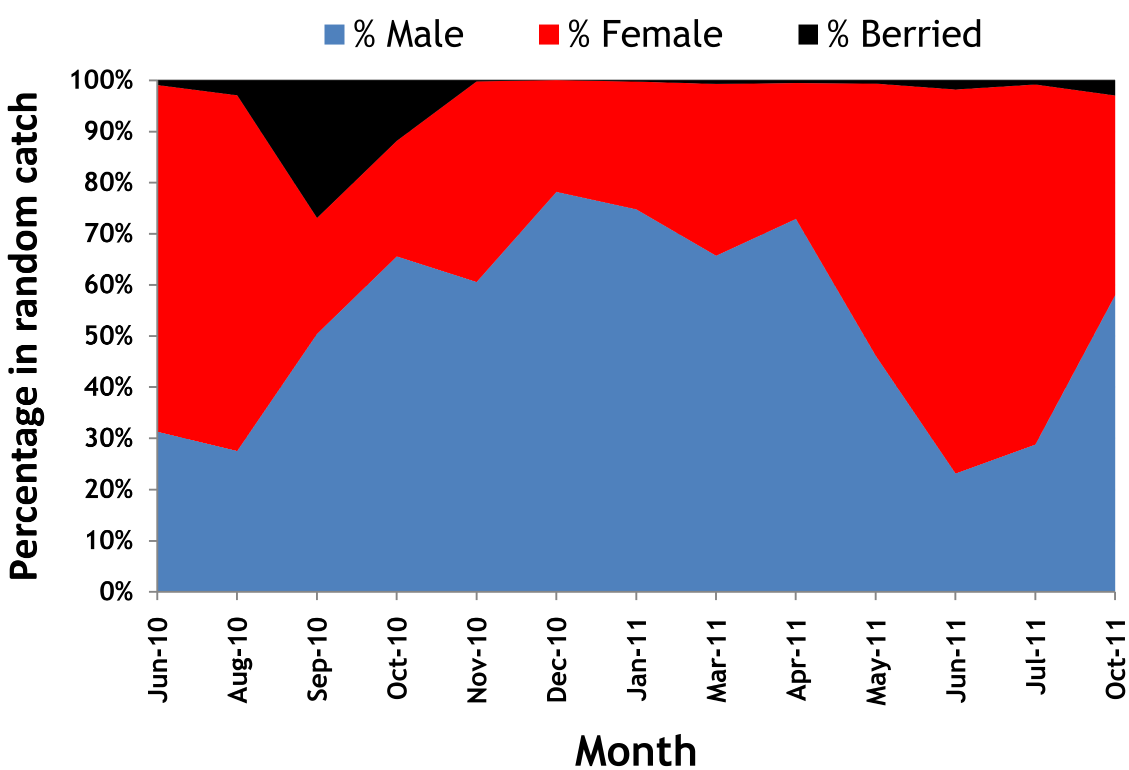


Figure 16. Sex ratio of *Nephrops* obtained from random sub-samples. Males dominate in the winter months (reaching 70-75% of the total), while females dominate in the summer months (reaching 75-80% of the total). Ovigerous "berried" females comprise a relatively low percentage throughout, but peak at ~ 27% of the total (i.e. 54% of the females) in September 2010. The data which underlie this chart are in Appendix C.

5.3.1.2 Relationships between catches: Species abundance

To visualise the relationships between the species abundance of catches, non-parametric 2D Multi-Dimensional Scaling (MDS) ordination was carried out, with the season of capture indicated in each case (Figure 17). These data generally show clustering by most of the vessels on the untransformed data with a few outliers, thus indicating a degree of uniformity within the catch composition at a broad scale (Figure 17 A). At a finer scale, trends in the transformed data are less apparent (Figure 17 B) with only slight clustering by season, although the stress (simplistically, a measure of the error) of the 2D plot is relatively high (0.21).

The ANOSIM test, carried out to determine whether sampling season or vessel had a significant influence on the similarity between catches (ANOSIM is testing the hypothesis that there are no differences between random sub-samples in the species catch composition), showed a significant effect of season on transformed data only (ANOSIM: global R = 0.392, $p = 0.04$).

In summary, the abundance data suggests there may be an effect of season but only at the finer scale.

Bubble plots were produced for individual species, thus allowing the effect each species has on the relationships between sub-samples to be displayed (Figure 18). Bubbles are superimposed onto each point on the 2D MDS plot, with the size of each bubble being proportional to the abundance in that sub-sample. Not every species was plotted using this method, only those species of concern including *Funiculina*, elasmobranchs and important roundfish species such as cod, haddock and whiting.

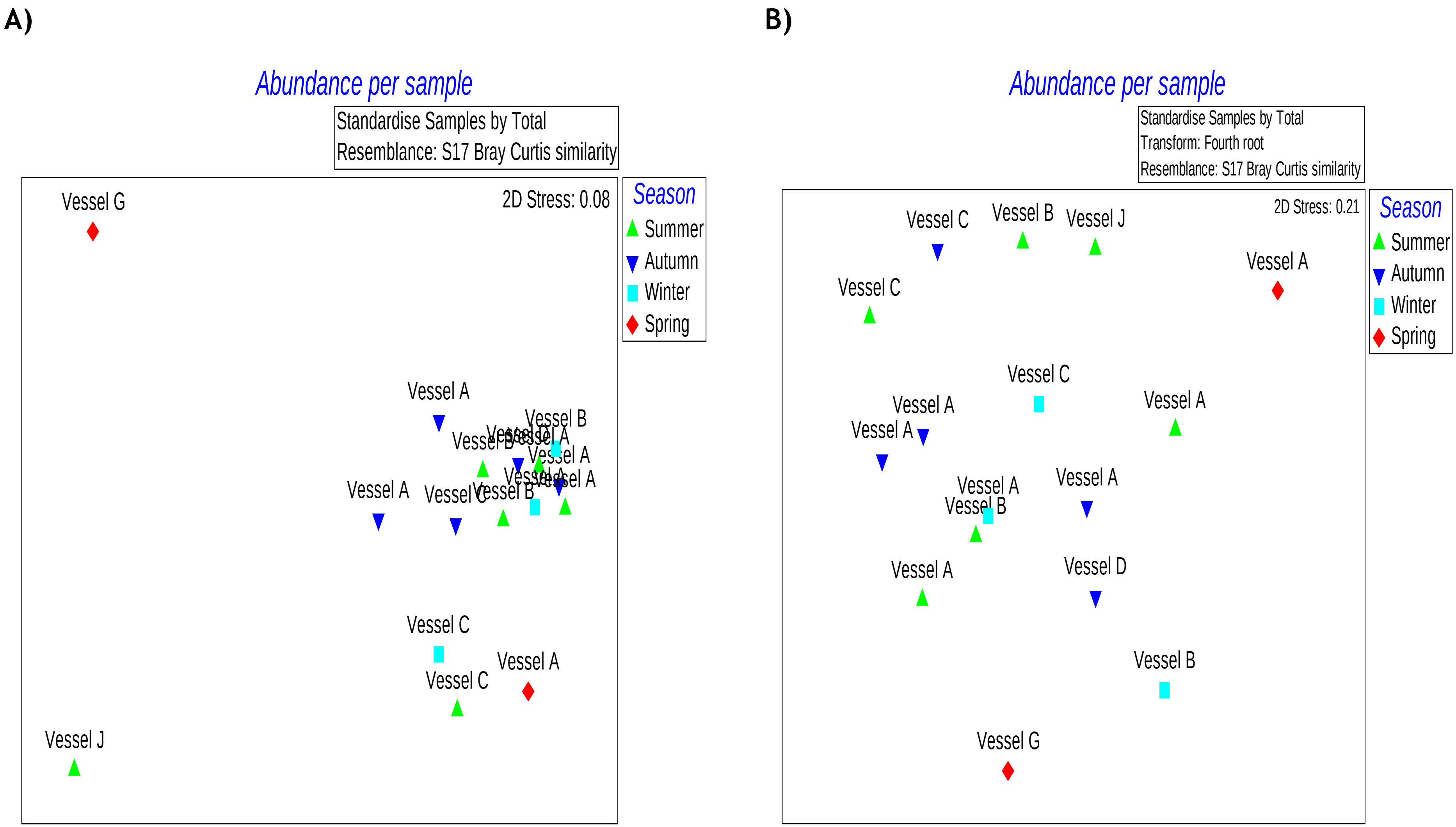


Figure 17. 2D MDS plot showing the relationships between the catches for each vessel and month for A) non-transformed data and B) fourth root transformed data. (ANOSIM for untransformed data: season and vessels $p > 0.05$; ANOSIM for transformed data: Season $p = 0.038$, and vessels $p > 0.05$). The season is indicated for each catch.

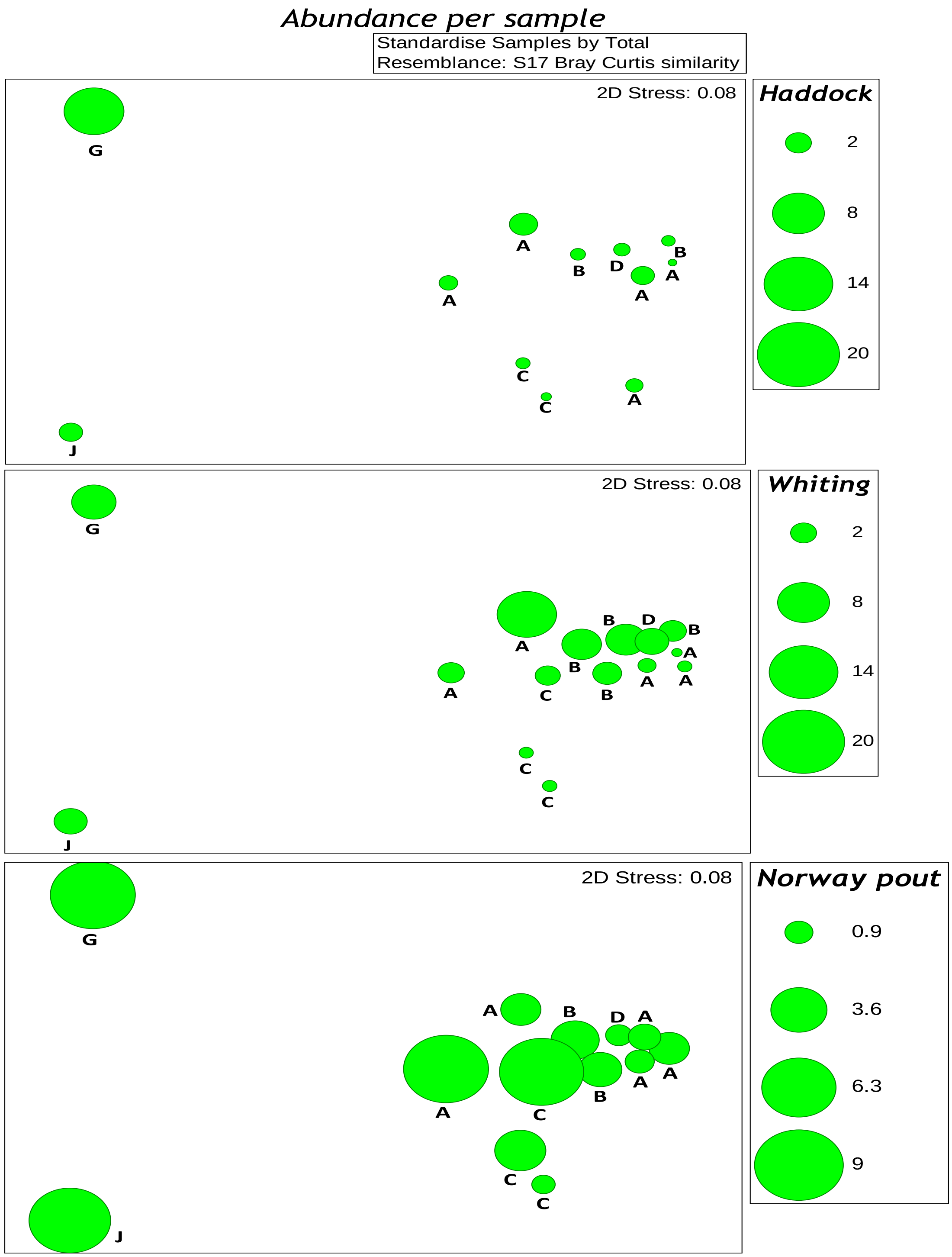


Figure 18. Bubble plot of number of haddock, whiting and Norway pout over a 2D MDS ordination of untransformed abundance data (from Figure 17). In this instance vessels are represented by a letter.

5.3.1.3 Relationships between catches: Biomass

To visualise the relationships between the species biomass of catches, non-parametric 2D Multi-Dimensional Scaling (MDS) ordination was carried out, with the season of capture indicated in each case (Figure 19). Analysis at the broad scale of the non-transformed data shows a high degree of uniformity in the catch composition of the sub-samples with only one outlier (Figure 19 A). ANOSIM confirms this with season and vessels having no significance ($p > 0.05$). The spread of the transformed data in Figure 19 B suggests there may be some differences in the catch composition at the finer scale with both season and vessel significant for explaining similarities between the catches (ANOSIM: Season: $R = 0.645$ $p = 0.013$; Vessel: $R = 0.434$ $p = 0.03$). However, the stress of the 2D transformed data is relatively high (0.18). Testing for similarities between catches using gear type as a factor was not possible due the lack of repeat sub-samples for twin-rig gear.

In summary, the biomass data suggests season and vessel may have an effect on the variation on catch composition of sub-samples but only at the finer scale when rare species and more subtle relationships are considered.

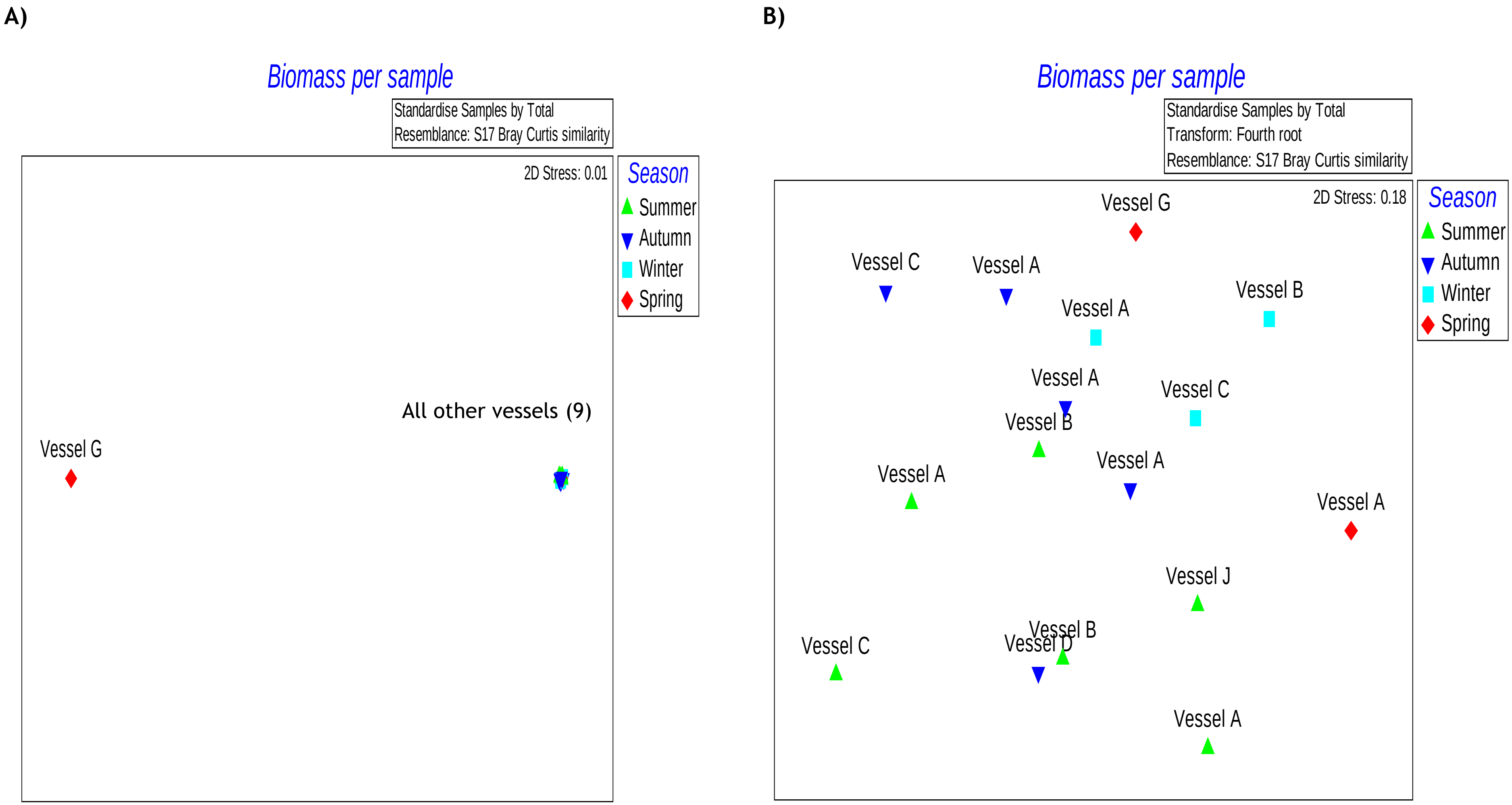


Figure 19. 2D MDS plot showing the relationships between the catches for each vessel for A) non-transformed data and B) fourth root transformed data. (ANOSIM for untransformed data: season and vessels $p > 0.05$, ANOSIM for transformed data: season $p = 0.01$, vessel $p = 0.03$). The season is indicated for each catch.

5.3.2 Key Species

5.3.2.1 Cod

Although paper logbooks were provided to the fishermen for the additional self sampling data on cod, no data were in fact received from them. However, all cod were recorded on the scientific observer trips, enabling data on the catch rates by number and weight to be extended from the first two years (Figure 20). A total of 55 cod were collected and analysed from 23 trawls between December 2010 and October 2011. Catches of cod were low throughout the study period and were rarely recorded in any of the random sub-samples. The average length of these cod was 41.4 cm (MLS = 35 cm) with undersized individuals comprising 24% of the total. The length-frequency distribution of captured cod shows a larger proportion of cod are above the MLS in Year 3 compared to Years 1 and 2 (Figure 21) with one-way ANOVA (F (2,171) = 13.10, $p < 0.001$) determining a statistically significant difference between the groups. A Tukey post-hoc test revealed that Year 3 (mean length = 41.42cm) was statistically significantly higher than Year 1 (mean length = 34.46, $p = 0.0007$) and Year 2 (mean length = 31.30, $p < 0.001$). There were no statistically significant differences between Year 1 and Year 2 ($p = 0.32$).

The mean Gonadal-somatic index (GSI) values were found to vary significantly with month (one way ANOVA F (5,37) = 512, $p = 0.001$) with values peaking at 1.83 in April (Figure 22). The condition index (CI) and somatic-condition index (SCF) were relatively stable throughout Year 3 (Figure 22), dropping slightly between April and June, though this was not significant (ANOVA: $p > 0.05$ for both CI and SCF).

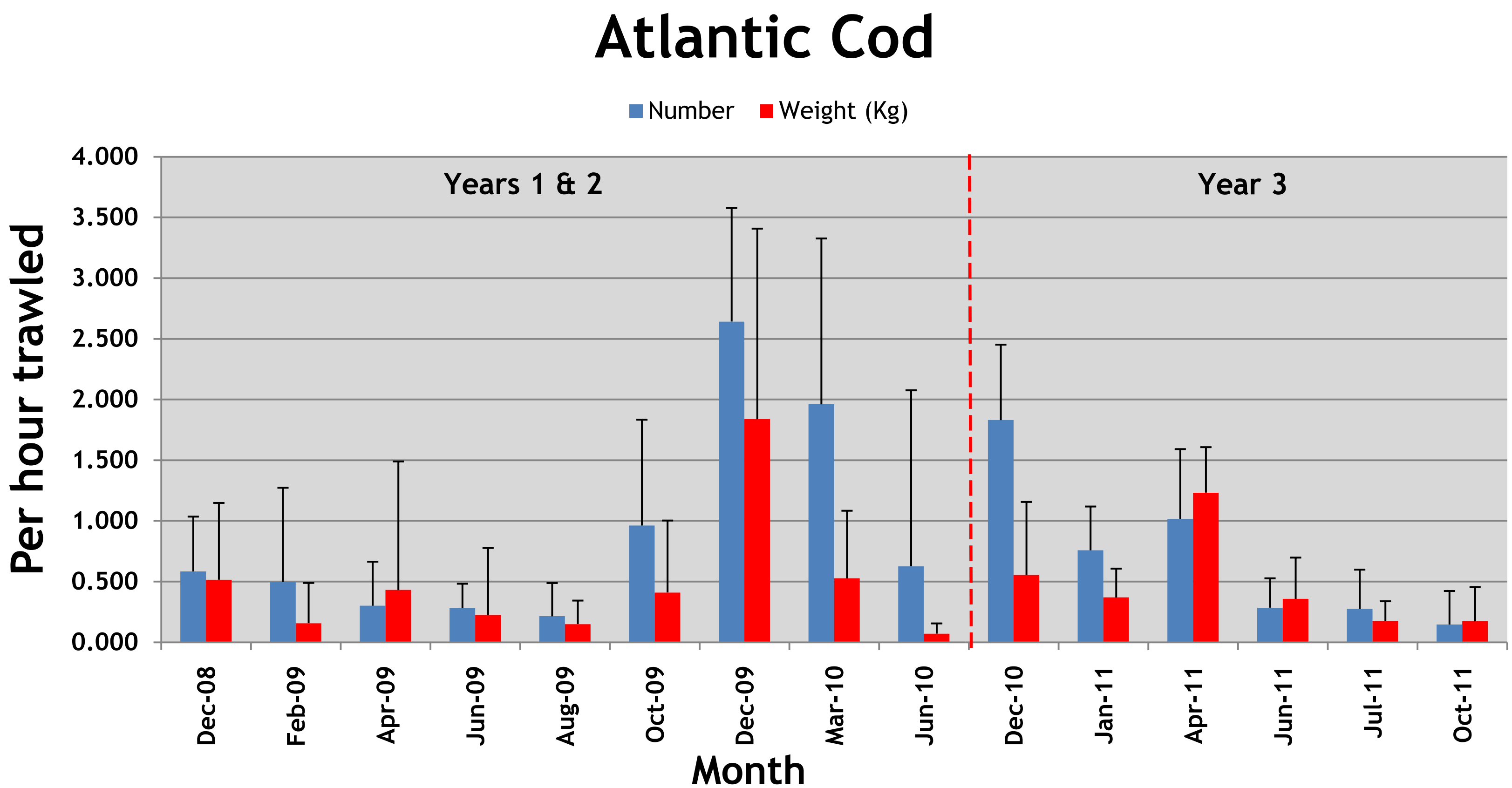


Figure 20. Mean number and weight of Atlantic cod captured during the first three years of the study. The red dotted line indicates the cross-over from sampling one vessel during Years 1 and 2 to sampling other vessels in the fleet during Year 3. Error bars represent one standard deviation. Data for Years 1 and 2 from Milligan and Neil (2010).

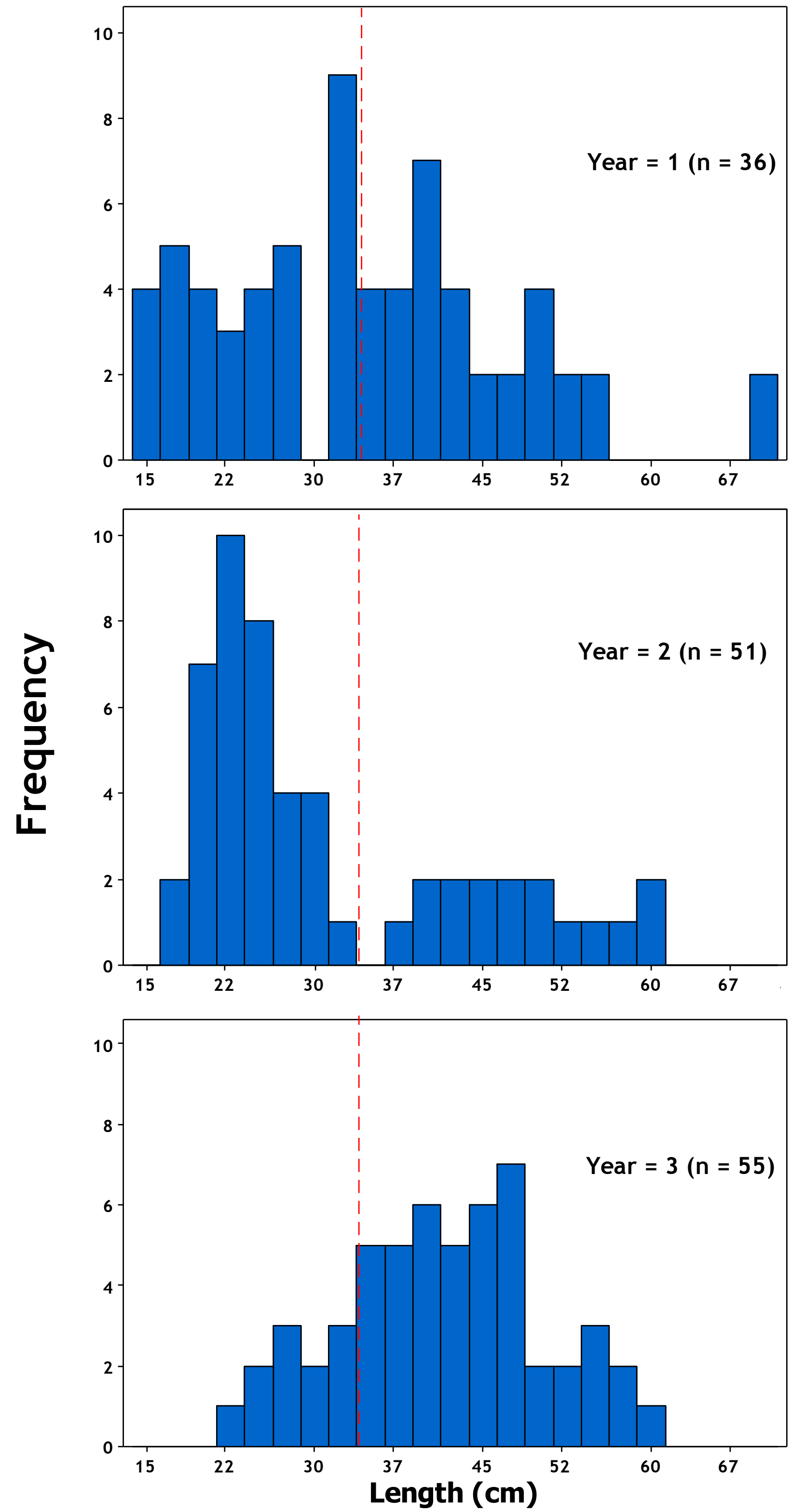


Figure 21. Length-frequency distribution of all Atlantic cod captured during the certification period, Year 1: Dec 2008 – Oct 2009, Year 2: Dec 2009 – Aug 2010, Year 3: Dec 2010 - Oct 2011. The red dotted line indicates minimum landing size (35 cm). Data for Years 1 and 2 from Milligan and Neil (2010).

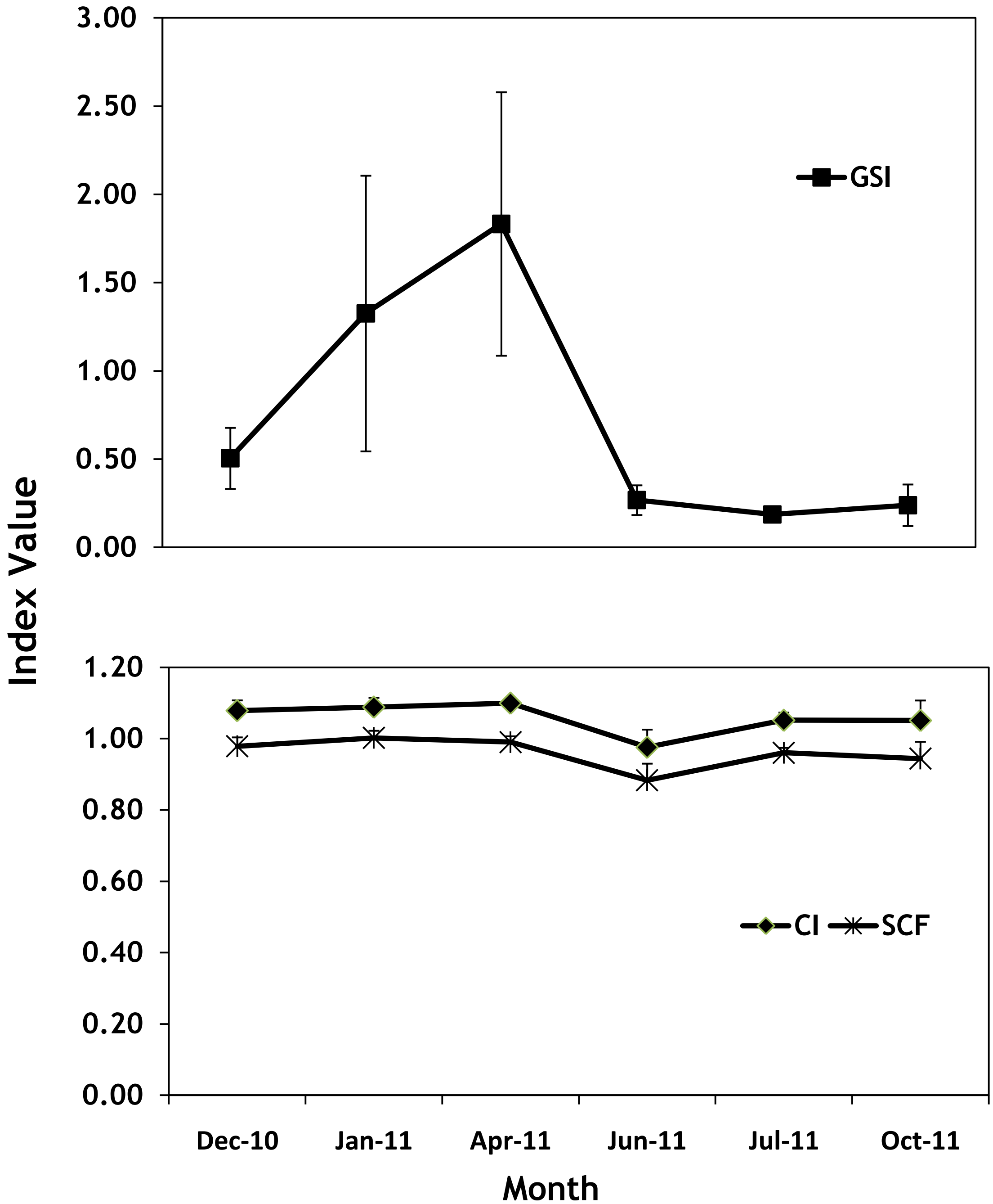


Figure 22. Mean Gonadal-somatic index (GSI), Condition Index (CI) and Somatic Condition Factor (SCF) of Atlantic cod. Error bars represent one standard deviation.

5.3.2.2 Spurdog

A total of 157 spurdog were recovered from all the trawls made between December 2008 and October 2011. The lengths and weights of the seven animals captured in December 2008 and October 2011 were recorded on board the fishing vessel, but all the other specimens were brought back to the University of Glasgow for more detailed examination. The numbers of spurdog captured during each survey trip are given in Table 8, and the length distributions for Years 1-3 are shown in Figure 23.

Figure 24 shows the relationship between the Hepatosomatic index and spurdog total length for Year 3 only, with the highest values being recorded in adult females specimens. One way ANOVA showed that female HSI values were significantly higher than male HSI values (F (1,54) = 10.1, p = 0.002).

Table 8. Numbers and mean lengths of spurdog captured between December 2008 and October 2011. Data for Years 1 and 2 from Milligan Neil (2010).

Month	Sex	Number captured	Mean length (cm) (± 1 SD)
Dec 2008	M	6	63.0 (± 18.5)
	F	0	
Feb 2009	M	0	
	F	0	
Apr 2009	M	0	
	F	0	
Jun 2009	M	27	26.2 (± 2.4)
	F	29	25.2 (± 3.1)
Aug 2009	M	5	30.5 (± 4.0)
	F	4	29.8 (± 5.1)
Oct 2009	M	5	72.3 (± 3.1)
	F	0	
Dec 2009	M	23	75.8 (± 3.5)
	F	1	95.0
Jun 2010	M	0	
	F	0	
Dec 2010	M	1	74
	F	1	78
Jan 2011	M	0	
	F	0	
Apr 2011	M	24	31.8 (± 4.39)
	F	23	30.4 (± 4.07)
Jun 2011	M	0	
	F	1	70
Jul 2011	M	0	
	F	0	
Oct 2011	M	5	37.3 (± 9.27)
	F	2	31 (± 0.71)

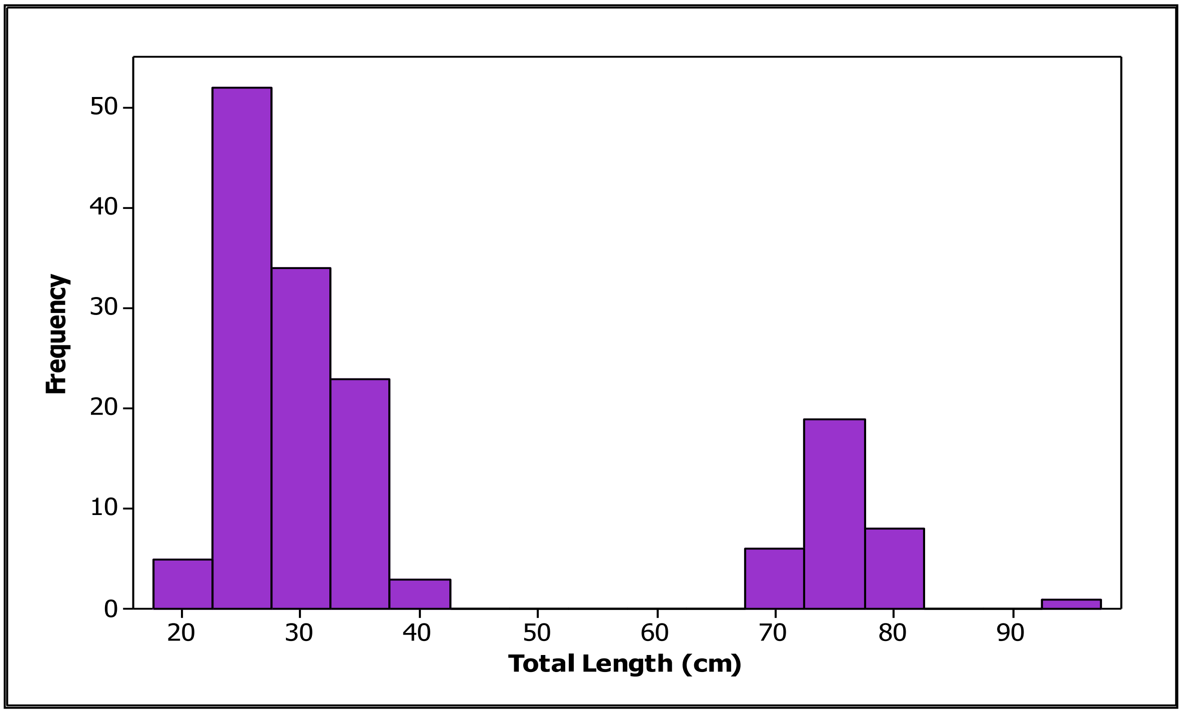


Figure 23. Length-frequency distribution of spurdog captured between December 2008 and October 2011 (n = 157).

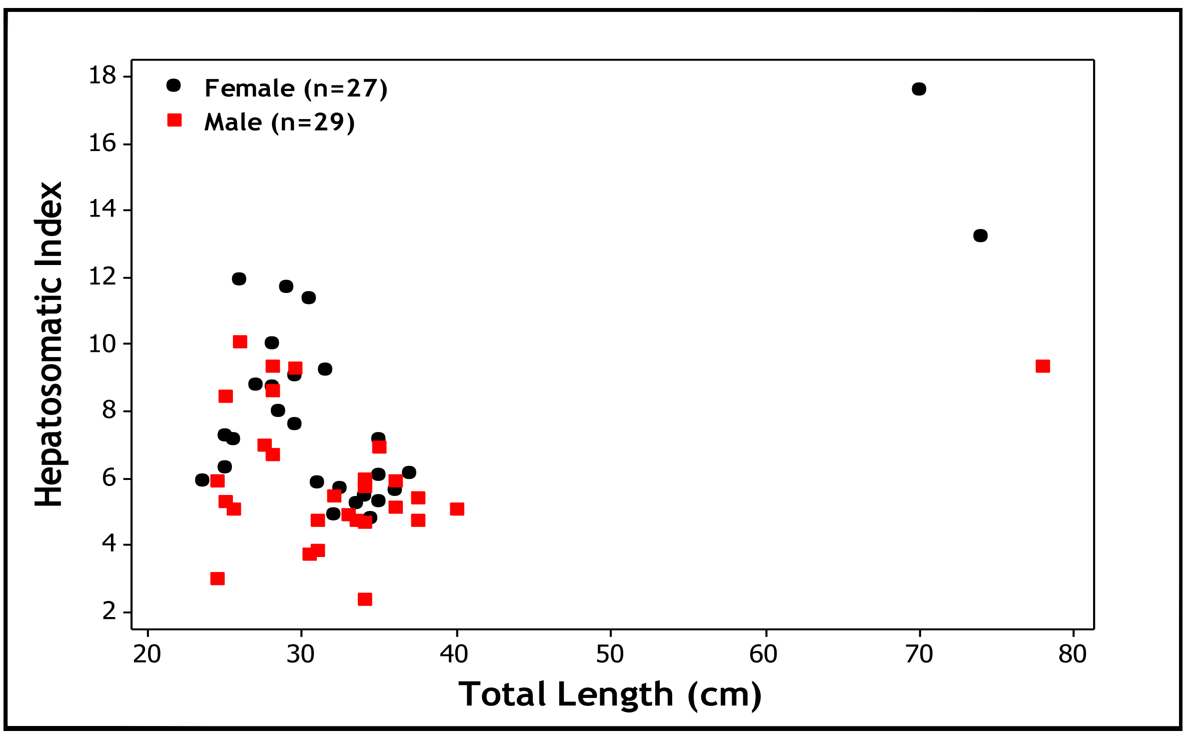


Figure 24. Relationship for spurdog hepatosomatic index (HSI) versus total length (TL, cm) for Year 3 only.

5.3.2.3 Spurdog survivability pilot study

A total of 55 spurdog were obtained from four separate hauls out of a total of 13 trawls performed between April and October 2011. The depth of the trawling ranged from 49 m to 142 m, and the average trawl duration was 4.91 hours. Recovery of the gear ranged from 15 to 20 minutes and processing of the catch took up to 3 hours 45 minutes. The spurdog were a mixture of male and females but were primarily juveniles (96%). Of the 55 spurdog obtained, only two individuals showed signs of recovery after 3 hours, resulting in a 96.4% mean mortality rate. Due to fishing operations the maximum time for analysis was restricted to three hours. Summary data for each trawl in which spurdog were caught and subsequently assessed for their survival are provided in Table 9.

Table 9. Summary details describing number of spurdog caught in *Nephrops* trawls and the subsequent mortality rate after 3 hours of observation. SR = Single-rig vessel, TR = twin-rig vessel.

Vessel	Date	Gear	Trawl time (hrs)	Gear recovery (hrs)	Process (hrs)	Sex	Number Captured	Mean Length (cm) (±1 SD)	Number of fish alive after recovery from catch	Number of fish alive after observation period	Number of mortalities after 3 hrs	Mortality rate (%)
G	Apr 2011	TR-Clean	4.75	0.33	1.50	M	24	31.8(±4.39)	4	1	46	97.9
						F	23	30.4(±4.07)				
A	Jun 2011	SR-Disc	5.75	0.25	3.45	F	1	70	0	0	1	100
C	Oct 2011	SR-Disc	4.41	0.25	2.50	M	4	28.1(±4.13)	0	0	6	100
						F	2	31 (±0.71)				
A	Oct 2011	SR-Clean	4.75	0.33	2.50	M	1	73.8	1	1	0	0
Total			Mean = 4.92	Mean = 0.29	Mean = 2.49		55		5	2	53	Mean = 96.4

5.3.3 Key Species – The tall sea pen *Funiculina quadrangularis*

Figure 25 shows the occurrence of *Funiculina* in different sections of the fishing gear recorded during recovery of the net. Nets from five different trips were observed and results were expressed as a percentage of observations, using the four-point scale of occurrence. The highest occurrence was found in the top and bottom panels with approximately 70% of observations for that particular section showing five or more *Funiculina* present (point 5) on each haul. Lower numbers of *Funiculina* were recorded in the warps, doors and sweep sections of the gear. On one occasion *Funiculina* were recovered and counted from the codend of one of the nets (n = 410) in addition to observing their presence on other sections of the gear (n ~ 30). This resulted in a combined value of ~ 92 *Funiculina* per hour of trawling time and whilst this value was above the mean reported by Milligan and Neil, (2010) (21 per hour of trawling), it is certainly not the highest recorded over the study period. These values also allow for a very broad estimation of an additional 5-10% to be added to the codend abundance to give the total trawling impact, as an approximation.

Additional observations of *Funiculina* recovered from the gear showed that many individuals appeared intact from the top of the axis (where many of the polyps are concentrated) to the terminal peduncle (which is used to attach to the substrate). It is unclear if there was any internal damage to the axial rod or the polyps. However, there were also individuals that had been damaged by the fishing process, with axial rods that were split or completely broken.

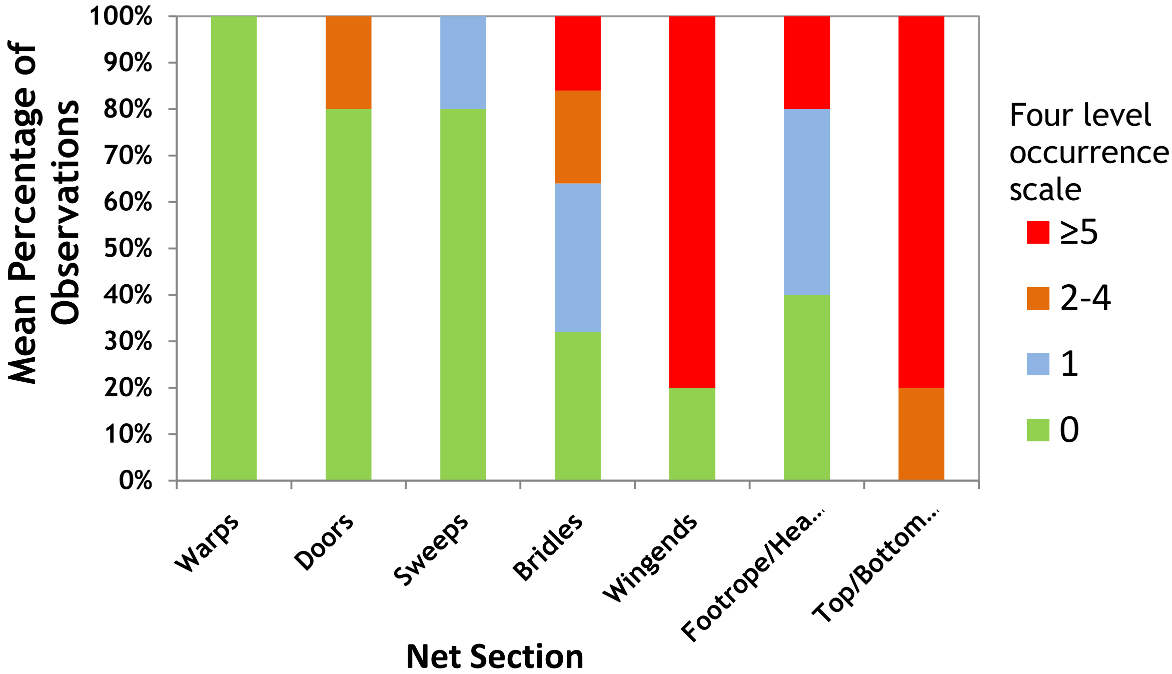


Figure 25. Mean percentage of *Funiculina* observations recorded in specific sections of the net using four-point scale.

5.4 Discussion

5.4.1 Overall catch composition

The results obtained from the analysis of the random sub-samples show a temporal variation in both abundance and biomass catch composition. This is a similar trend found in a previous study analysing the whole catch in the same fishery but only onboard a single vessel (Milligan and Neil, 2010). Although the data suggests season is a significant factor in the catch composition, the irregular supply of sub-samples throughout the year means no further detailed analysis concerning the temporal trend can be extracted from this set of data at this time.

However, what this present study has established is the high degree of uniformity within the sub-samples provided by different vessels, particularly at the broader scale. Vessel effects were only significant at the finer scales of analysis and only on the biomass data, suggesting there are only subtle differences in the catch compositions of the sub-samples across the fleet. Furthermore, evaluation of the mean overall catch composition of sub-samples

(Figure 14) produces a similar result with the previous study (Milligan and Neil, 2010) with almost the exact target species to bycatch ratio determined in both studies. Given these findings, it is possible to assume the vessels of the Stornoway fleet are fishing in broadly the same manner, with no one boat catching a larger amount of any one species compared to any other boat. This is an important point to note as this assumption can be incorporated into future studies on the certified fleet, for example a technical measure where other vessels within the certified fleet can be used as a control to compare with a test vessel.

One caveat to note is the outlying result produced by one twin-rig vessel (Vessel G). The sub-sample obtained was reliable and subsequent bubble plot analysis highlighted a larger proportion of haddock in the catch composition compared to other sub-samples (Figure 18). Although there was only one sub-sample received from this vessel and there may be other factors contributing to this result, it may indicate an underlying trend that has previously been noted in a scientific technical report. The 2005 report of the ICES Working Group on the Assessment of Northern Shelf Demersal Stocks noted that in the Irish Sea the use of twin-rigs increased the proportion of roundfish bycatch in *Nephrops* fisheries, compared with single rig otter trawls (ICES WGNSDS Report, 2006). Therefore, it may be useful to investigate this further by increasing the sampling frequency of twin-rig vessels during Year 4. No significance could be measured for gear effects on catch composition (due to lack of replicate sub-samples).

Analysis of the target species *Nephrops* shows that the Minch population undergoes similar seasonal cycles to those documented in the Clyde Sea area (Milligan *et al.*, 2009). Long term monitoring of the *Nephrops* population may help future management decisions, for example consideration might be given to exploiting the target stock at less vulnerable times of the year such as when berried females are caught in lower numbers.

Previous studies on *Nephrops* fisheries in the Celtic sea, Irish Sea and the North Sea have produced similar catch composition results where whiting, haddock and pouts have been recorded as the dominant bycatch species (Briggs, 1985; Stratoudakis *et al.*, 2001; Catchpole *et al.*, 2005; Rochet *et al.*, 2002; Bell, 2008). However, the study by Bergmann *et al.* (2002) is the only one that has described in detail the total catch composition including the invertebrates. That study in the Clyde Sea area had many similar invertebrate species to those recorded in the Minch, but at lower densities. There will always be ecological variation between different fishing grounds, but the subtle differences in community structure between these two studies highlights the importance of managing a fishery based on data from the whole ecosystem. For example, one notable absentee from the Clyde region that was present in the Minch region was the tall sea pen *Funiculina quandrangularis*. *F. quadrangularis* is a sensitive species that has a restricted and patchy distribution in UK waters, therefore its presence in the Minch raises many conservation issues. Its relatively high occurrence in the catches of the Stornoway fleet was also highlighted by the certification body in their Year 2 surveillance report, which commented on its high occurrence. The completion of additional detailed information on this species would help address their noted interest (see Section 5.4.3 below).

5.4.2 Key Species: Cod and spurdog

Cod and spurdog numbers have been consistently low throughout the study period, which makes spatial and temporal trends difficult to identify. Furthermore, the lack of information volunteered by the fishermen detailing numbers of cod and spurdog captured at periodic intervals has meant that no additional information on this population has been obtained as planned. Despite this, catch rates obtained from observer trips over the 12 months monitored show a low incidence of cod per haul. GSI showed a marked temporal variation with high values between January and April, indicating the seasonal spawning time of cod in this area and compares well with published west coast of Scotland data (Keltz and Bailey, 2010). There is also the suggestion of a larger age class of cod being caught in Year 3, indicating that the current sampling regime is robust enough to track growth changes in fish over time.

Although there may be insufficient bycatch by the *Nephrops* trawler fleet to have a large impact on mature west of Scotland cod, and that only a small increase in observed biomass trajectories will occur if the fleet moves to a clean catch of *Nephrops* (Bailey *et al.*, 2011), rebuilding and conserving cod stocks in Scottish coastal waters remains a priority for fisheries management in Scotland. The guiding principles of MSC certification state that “where exploited non-target species whose populations are depleted, management measures should allow for recovery of these affected populations". Therefore, the recording of these data is important in this context. If any management measures are introduced, such as more selective fishing gears, then these baseline data will allow comparisons to be made with data gathered with the new fishing gear.

The results for spurdog follow similar trends to those obtained in the previous years, when the majority of spurdog caught were immature schooling juveniles. The most valuable individuals in terms of recruitment and stock recovery are mature females (Pawson *et al.*, 2009), but since 2008 only 3 mature females have been recovered from all trips. Low catch rates made it difficult for any consistent trends in the data to be identified, but HSI analysis was comparable to other studies showing liver dimorphism between sexes (Capape and Reynaud, 2011). The liver plays an important role in the lifecycle of spurdog and continual monitoring of this condition index will contribute to measuring the population's long term recovery.

This survivability pilot study highlights the vulnerability of spurdog to demersal trawling. Spurdog are especially vulnerable to intense over-fishing compared to most teleosts, due to their k-selected life history strategy (i.e. slow growth and maturation) and the fact that they have a long gestation period (up to 22 months), produce very few young, typically have long life spans, and generally occupy a high position in trophic food webs (Stevens *et al.*, 2000).

Previous short-term survivability studies (Rulifson, 2007, Mandelman and Farrington, 2007) have demonstrated the resilience of spurdog when subjected to stress and physical damage encountered during the trawling process. In these studies mortality rates ranged from 0 – 50% with Rulifson (2007) suggesting that many spurdog are able to tolerate and survive the stress and injury associated with the trawling process. Results from the present preliminary study suggest that spurdog caught as bycatch in the Stornoway *Nephrops* fishery have very high mortality rates. Milligan and Neil (2010) previously noted the moribund state of spurdog captured during 2008/2009 in the same fishery, with none appearing to cope well with the trawling process. The present study supports these previous observations, but it should be stressed that these new observations are only preliminary and not conclusive. Therefore any inference should be made cautiously. Furthermore, comparisons with this present study and the studies of Rulifson (2007) and also Mandelman and Farrington (2007) should also be made with caution, due to differences in experimental design. Nevertheless, this present study indicates the trend of high spurdog mortality in the Stornoway *Nephrops* fishery. Tow duration, codend weight and species composition are likely reasons for the high rates of mortality. Tow duration in the Stornoway *Nephrops* fleet averages around four hours and in this particular study it was close to five hours. The survivability studies of Rulifson's (2007) and Mandelman and Farrington (2007) were based on tow times of no more than 90 minutes (compared to 345 minutes in this present study). Thus, tow time is perhaps the biggest factor which may influence the short term survivability of spurdog in this fishery. Longer tows will have a greater weight of both target and bycatch animals in the codend leading to increased stress encounters and potential injury. Furthermore, in some cases the potential time for any individual animal to be subjected to stress within the catch can amount to as much as 9.45 hours if the trawl time, recovery of the gear, and catch processing times are all considered.

5.4.3 Key Species – The tall sea pen *Funiculina quadrangularis*

This study has demonstrated that *Funiculina* are susceptible to capture on various sections of the fishing gear other than the codend, and have a particular vulnerability to being trapped in the wings and the top and bottom panels of the extension. Therefore the occurrence of *Funiculina* in the Stornoway *Nephrops* fishing gear appears to be under-represented, if only the bycatch from the codend is analysed. However this is a relatively minor under-estimate (5-10%) although it does not take into account those individuals dislodged but not retained by the fishing gear whilst the nets continue to fish on the seabed. Greathead *et al.* (2007) notes that *Funiculina* distribution will be greatly influenced by the level of physical disturbance caused by demersal trawling, as it is unable to withdraw into the sediment. However, it has been shown that *Funiculina* can withstand some level of disturbance where they are able to bend away if objects physically smother or are dragged across them, and can even re-anchor themselves back into the substrate after displacement (Kinnear *et al.*, 1996), There is the possibility that some *Funiculina* individuals caught in the gear of the Stornoway fleet and returned to the sea may be able to survive the trawling process. However, further work has to be completed before this is definitive. Future research may include considering the overall spread of the different types of gear used by the fishermen, and how they may impact on the total amount of *Funiculina* caught.

Despite its limitations, this short study nevertheless provides a better indication of the total trawling impact on this species.

Chapter 6 General Discussion

The main aim of this thesis was to demonstrate how bycatch data on a fished ecosystem obtained through a partnership between scientific research and industry can contribute to a sustainable fisheries management programme. This discussion examines this aim through the Stornoway MSC *Nephrops* fishery case study and also considers the effectiveness of the MSC approach to fisheries management.

6.1 The Stornoway MSC *Nephrops* fishery

Since 2009, detailed analysis of the target species and of the non-target bycatch has allowed an improved understanding of the fished ecosystem in the Stornoway *Nephrops* fishery. This has been possible through scientific survey work and a fishermen self-sampling programme which together have addressed many of the original certification conditions up to the end of Year 3. The main outcome has been the establishment of an extensive database, quantitatively detailing the amount of bycatch and discards typically produced by a *Nephrops* trawl vessel operating in the Minch region in the north west of Scotland. This was essential in order to precisely evaluate the fleet's total impact on the whole ecosystem. In addition, the accumulated data could be used as a measure of how successful any future management measure would be in relation to Principle 2: Ecosystem structure and Function. Specifically, this would allow the indicator and guidepost 2.3.1.3 highlighted in the original assessment, to be fully reassessed, demonstrating any benefits of any new more selective fishing gear and whether they were allowing for the recovery of exploited non-target species.

Evaluating the fisheries performance in relation to conditions 3 and 4, progress was on track up to the end of Year 2. During Year 3 some, but not all, of the objectives were addressed. The results from Chapter 4 show how the introduction of a self-assessment scheme can be used by fishermen to generate their own catch data. Although this scheme has only been partially successful, analysis showed that the scheme could produce robust results, conditional on the quantity and quality of the sub-samples collected by the fishermen being maintained. It would only take some small operational adjustments to the scheme in order for it to function more effectively. Chapter 5 highlighted how the two sensitive species, cod and spurdog, at which the conditions were primarily aimed, could still able to be monitored, but only through the observer trips. Many of the fishermen failed to participate in the self assessment scheme, resulting in less data being collected than was expected. Although the fishermen receive a monetary reward for participating in the MSC programme, the amount they receive may not be enough to act as an incentive for the additional work they are expected to complete. Consequently, the client may have to consider increasing this monetary incentive, especially in light of the following key objective that has yet to be addressed.

"Evaluation of the effectiveness of new technical measures in reducing cod and spurdog bycatch" was a key objective in the conditions that was not completed by the end of Year 3. This is perhaps the most important objective as it is a significant forward step for the fishery to take for achieving the required improvement in the performance indicators. The fishery would be demonstrating its commitment to operating in a manner that maintains the structure productivity, function and diversity of the ecosystem. Whilst the research has so far focused on quantifying the catch composition and introducing a method for generating robust baseline data, a move to testing more selective fishing gear on the sensitive species is the next logical step. Implementation of more selective fishing gear would not only have a positive effect on the ecosystem but it would also set the fishery apart from similar fisheries targeting the same species i.e. it would be fishing in a more responsible and sustainable manner compared to other *Nephrops* trawl fisheries.

With the spurdog survivability study indicating that mortality is high when this species is caught in the trawl gear in the Minch, and moreover with cod also not surviving the trawling process, the challenge for the Stornoway *Nephrops* fishery is to find a technical solution that prevents an individual fish from entering the fishing gear in the first place, or provides an opportunity for it to escape whilst in the net. Both of these approaches are common conservation measures used by net designers and take into account the behavioural reactions of the target species and the associated bycatch when they are confronted with fishing gear. One such design that uses this approach is the Swedish selection grid.

Selection grids function by introducing a metal structure into the net extension so larger animals are diverted up towards an opening in the top of the net whilst smaller animals are allowed through a row of metal vertical bars and are guided towards the codend (Catchpole and Revill, 2008). Despite their potential, uptake of this technical measure by *Nephrops* trawlers fishing in Scotland has been poor, due in large part to their concern about safety when handling the metal structure in rough sea conditions. Recent developments have utilised a lightweight flexible polymer composite material which improves the handling and manoeuvrability of the grid, especially during the recovery of the nets.

A flexible Swedish grid would potentially eliminate the larger cod and larger mature female spurdog from the codend in the Stornoway fleet, in addition to other larger fish species normally found in the bycatch. However, an impediment to its implementation is the percentage loss (up to 20% of CL size 50 mm) of large marketable *Nephrops* (Drewery *et al.*, 2011). In addition to the flexible grid, the use of a square mesh panel (SMP) with an increased mesh size greater than the standard 120 mm SMP currently in use in single species *Nephrops* fisheries would be beneficial. Square mesh panels with mesh sizes of 135 mm and 200 mm have been shown to reduce catches of gadoid fish, including cod, haddock and whiting (Thorsteinsson, 1991, Ingólfsson, 2011).

Considering the fishing gear technology currently available, an extended trial of the implementation of the flexible grid and a larger SMP is the best option for the Stornoway fishery for improving the Principle 3 performance indicator. An effective approach would be to deploy the technical measure on one vessel and compare the catch compositions with those of the rest of the fleet. This comparison is possible due to the high degree of uniformity in the catch compositions across the certified fleet established in Chapter 5. Therefore, exploiting this uniformity of performance would enable the rest of the fleet to be used as a control, but only if adequate sub-samples with the required nominal weight were received. However, failure to complete this objective within the allocated 3 year timescale means the fishery is currently behind schedule for fulfilling the certification conditions.

Up to this point the fishery has been successful in "research gain" only. An extensive database has been established and much more is known and understood about the nature of the fished ecosystem that otherwise would not be known had there been no certification. However, the fishery has now reached a pivotal point in the certification timeline where action has to be taken on fishing operations that allow recovery of depleted non-target species. Only then can it be deemed to be fully addressing the certification conditions and on track for meeting the criteria of a sustainable and well managed fishery.

Similar scientific sampling programmes have been introduced into other MSC fisheries as a result of certification conditions, leading to improved performance indicators. For example, the Alaska salmon fishery was required to provide evidence and a summary of the major non-salmon fish species, birds and marine mammals taken as bycatch in the salmon net fishery. Information was largely anecdotal and so the client developed a formal sampling programme which documented the bycatch, resulting in the requested condition being addressed and continued certification. The Stornoway MSC fishery has produced evidence similar to what was required in the Alaskan salmon fishery. Although scientific literature on catch composition on *Nephrops* fisheries was previously available, it was not specific to the certified fished area in the Minch, and was also not recent. Thus, the research shown in this thesis has been able to inform the management process and a clearer biological picture of the local ecosystem has been established.

6.2 Is the MSC approach an effective fisheries management tool?

Although the MSC programme has now been operational for 13 years and adoption trends have risen markedly over the past 2-3 years, there still remains doubt about its effectiveness as a fisheries management tool. Using the Stornoway fishery as a case study, it is possible to consider whether MSC certification has generated benefits more effectively than statutory non-participatory legislation.

The Stornoway MSC *Nephrops* trawl fishery is still in the early years of its certification period, and therefore any evidence for improvements in terms of environmental benefits will not yet be evident. The scientific programme completed during the first three years does however provide a sound foundation for a long term data set, necessary to monitor ecological changes over the longer term. The introduction of the self-sampling scheme has brought about more involvement from the fishermen into the process and although there is reluctance from some of them to participate, most acknowledge the importance of collecting biological data. Certification has also allowed the monitoring of three sensitive species, adding to the scientific knowledge that already exists, which is important when it comes to identifying local conservation measures. For example the biological information concerning the life-history aspects of spurdog have been widely reported in the scientific literature but information on local migratory movements or the effects of demersal fishing activities on local discrete populations is lacking and poorly understood. Using the bycatch data from this project can supplement the broad knowledge that already exists but also provide contemporary data upon which management measures can be taken that may allow populations to recover. Using an ecosystem-based approach to fisheries management enables specific biological knowledge gaps to be targeted, and can address current local conservation issues on sensitive species through applied research.

After many months of independent assessment the MSC chose to certify a group of trawlers in Stornoway provided they agreed to a work plan aimed at improving their impact on the non-target bycatch species within a certain timeframe. If, after four years, certification alone has prompted the use of more selective gears and improved management then one could say that the MSC offers an effective approach to fisheries management. At this stage it is too early to comment. However, what the MSC has achieved indirectly in this case study is the creation of a successful partnership between industry and a scientific organisation, both of whom are focused on successfully establishing a sustainable, well managed fishery. Fishermen alone cannot produce the scientific evidence needed to prove their sustainability credentials, whilst scientists can only produce so much research based on a limited time in the field, which may have elements of uncertainty. This project has allowed data to be gathered from “real” commercial fishing operations over a sustained period of time as opposed to time-limited research cruises which may not be truly representative of actual fishing behaviour.

Whilst the number of fisheries successfully achieving MSC accreditation has risen substantially in recent years, issues remain about certification. The client, Young’s Seafood Ltd., has invested a substantial amount of time and money in order to ensure that the fishery meets its obligations for continued certification. Fees for pre-assessments, full assessments, annual surveillance audits, re-certifications, premium payments for fishermen and research costs make this an expensive process. There is also the problem of certifying a group of vessels, and of expecting wider ecological benefits accrue when other vessels not belonging to the certified group are permitted to fish in the same waters without the need to change their behaviour. The certified vessels are often a subset of an entire fleet of fishers within the fished region. Therefore any management measures applied to the MSC vessels which are proven to reduce their environmental impact could potentially be offset by other non-MSC vessels which continue to fish as normal.

Certification is a long term commitment and given the level of expense and the other associated problems one may question the worth of seeking or retaining the MSC accreditation. However, as Kelleher (2005) suggests, the problem of discarding bycatch must be addressed fishery by fishery, with there being no “one size fits all” solution. MSC certification presents an opportunity for this proposal to be implemented whereby individual certified fisheries can undertake their own (scientific) programmes focusing on area-specific bycatch issues highlighted through the assessment process.

6.3 Conclusions

This case study has highlighted how the Marine Stewardship Council’s standard for sustainable fishing has the potential to generate considerably more benefits than current non-participatory legislation. Participation in the scheme has created a successful partnership between industry and science, providing important biological information for informing fisheries management.

However, the ecosystem approach alone, as exemplified by the MSC certification scheme, is unlikely to resolve the problems concerning overfishing and associated issues with bycatch. Rather it can be used as an effective fisheries management tool in conjunction with a suite of other management tools, including a reformed and improved EU common Fisheries Policy. This will hopefully lead to the long term goal of productive, environmentally sound and sustainable fisheries.

References

AGNEW, D., C. GRIEVE, P. ORR, G. PARKES AND N. BARKER (2006) Environmental benefits resulting from certification against MSC's Principles and Criteria for Sustainable Fishing. MRAG UK Ltd and Marine Stewardship Council, London. 134 pp.

ALVERSON, D. L. F., M.H.; POPE, J.G.; MURAWSKI, S.A (1994) A global assessment of fisheries bycatch and discards. No. 339. Rome, FAO. 1994. 233p. *FAO Fisheries Technical Paper*.

ANDREWS, J. W., CHAPMAN, C.J., LOCKWOOD, S.J. (2009). Certification report for Stornoway *Nephrops* trawl fishery Client: Youngs Bluecrest Ltd. Moody Marine Ltd.

BAILEY, N., BAILEY D, M., BELLINI L, C., FERNANDES P, G. F., C., HEYMANS, S., HOLMES, S., HOWE, J., HUGHES, S., MAGILL, S., MCINTYRE, F., MCKEE, D., RYAN, M., R., SMITH, I. P., TYLDESLEY, G., WATRET, R. & TURRELL, W. R. (2011) Marine Scotland Science Report 09/11: The west of Scotland marine ecosystem: a review of scientific knowledge. Available URL: http://www.scotland.gov.uk/Topics/marine/science/Publications/publicationslatest/Science/MSSR/2011Reports/MSSR0911

BEDDINGTON, J. R., AGNEW, D. J. & CLARK, C. W. (2007) Current problems in the management of marine fisheries. *Science,* 316**,** 1713-1716.

BELL, M. C., ELSON, J. M., ADDISON, J. T., REVILL, A. S. & BEVAN, D. (2008) Trawl catch composition in relation to Norway lobster (*Nephrops norvegicus* L.) abundance on the Farn Deeps grounds, NE England. *Fisheries Research,* 90**,** 128-137.

BELLIDO, J., SANTOS, M., PENNINO, M., VALEIRAS, X. & PIERCE, G. (2011) Fishery discards and bycatch: solutions for an ecosystem approach to fisheries management? *Hydrobiologia,* 670**,** 317-333.

BENNETT, D. & HOUGH, A. (2008) Public certification report for Loch Torridon *Nephrops* Creel Fishery. Derby: Moody Marine, Moody International Certification. 114pp.

BERGMANN, M., WIECZOREK, S. K., MOORE, P. G. & ATKINSON, R. J. A. (2002) Discard composition of the *Nephrops* fishery in the Clyde Sea area, Scotland. *Fisheries Research,* 57**,** 169-183.

BRIGGS, R. P. (1985) Catch composition in the Northern Ireland *Nephrops* fishery. *Fisheries Research,* 3**,** 47-60.

CAMBRIDGE, T., MARTIN, S., NIMMO, F., GRIEVE, C., WALMSLEY, S., HUNTINGTON, T., CAPPELL, R. & AGNEW, D. (2011) Researching the Environmental Benefits of the MSC certification programme. Project no: GB1337. Issue ref: Final report: MSC environmental benefits August 2011. MRAG Ltd, Poseidon Aquatic Resource Management Ltd, Meridian Prime Ltd.

CAPAPE, C. & REYNAUD, C. (2011) Maturity, reproductive cycle and fecundity of the spiny dogfish *Squalus acanthias* (Chondrichthyes: Squalidae) off the Languedocian coast (southern France, northern Mediterranean). *Journal of the Marine Biological Association of the United Kingdom,* 91**,** 1627-1635.

CARLETON, C., MEDLEY, P., SOUTHALL, T. & GILL, M. (2010) MSC Sustainable Fisheries Certification: St Helena pole & line and rod & line tuna fisheries for albacore, bigeye, yellowfin and skipjack tuna. Public Certification Report October 2010.

CATCHPOLE, T. L., FRID, C. L. J. & GRAY, T. S. (2005) Discards in North Sea fisheries: causes, consequences and solutions. *Marine Policy,* 29**,** 421-430.

CATCHPOLE, T. L., FRID, C. L. J. & GRAY, T. S. (2005) Discarding in the English north-east coast *Nephrops norvegicus* fishery: the role of social and environmental factors. *Fisheries Research,* 72**,** 45-54.

CATCHPOLE, T. L., FRID, C. L. J. & GRAY, T. S. (2006) Resolving the discard problem - A case study of the English *Nephrops* fishery. *Marine Policy,* 30**,** 821-831.

CATCHPOLE, T. L. & GRAY, T. S. (2010) Reducing discards of fish at sea: a review of European pilot projects. *Journal of Environmental Management,* 91**,** 717-723.

CATCHPOLE, T. L. & REVILL, A. S. (2008) Gear technology in *Nephrops* trawl fisheries. *Reviews in Fish Biology and Fisheries,* 18**,** 17-31.

CHAPMAN, C. J. (1980) *Ecology of juvenile and adult Nephrops*, Academic Press In: Cobb JS, Phillips BF (eds) The biology and management of lobsters. Vol2. Ecology and management. Acadernic Press, New York, p 143-178

CLARKE, K. R. & GORLEY, R. N. (2006) PRIMER v6: User Manual/Tutorial PRIMER-E: Plymouth.

CO-OPERATIVE (2010) Ethical Consumerism Report 2010. Available at: http://www.goodwithmoney.co.uk/assets/Uploads/Documents/EthicalConsumerismReport2010.pdf?token=d4ebbd209c94d783f5556357a8acc43ff0d2c3ae|1299754901#PDFP.

COUNCIL OF THE EUROPEAN UNION (2009) Total Allowable Catch (TACS) and Quotas for 2010. European Union, Brussels.

DAW, T. & GRAY, T. (2005) Fisheries science and sustainability in international policy: a study of failure in the European Union's Common Fisheries Policy. *Marine Policy,* 29**,** 189-197.

DREWERY, J., PIRIE, J., MAIR, J., EDRIDGE, A., KYNOCH, R., J. & O'NEILL, F., G. (2011) 45 MM Flexible Grids In a Scottish *Nephrops* Fishery. Scottish Marine and Freshwater Science Vol 02 No 05

EUROPEAN COMMISSION (2009) The Common Fisheries Policy - A user's guide. Luxembourg.

EUROPEAN COMMISSION (2011) Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions. Reform of the Common Fisheries Policy. 13.07.2011 Available URL: http://ec.europa.eu/fisheries/reform/.

FAO (2005) Guidlines For The Ecolabelling Of Fish and Fishery Products From Marine Capture Fisheries. Rome.

FAO (2010) Report of the Technical Consultation to Develop International Guidlines on Bycatch Management and Reduction of Discards Rome, 6–10 December 2010. *FAO Fisheries and Aquaculture Report*. No. 957. Rome, FAO. 2010. 32p.

FORDHAM, S., FOWLER, S. L., COELHO, R., GOLDMAN, K. J. & FRANCIS, M. (2010) *Squalus acanthias*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4. www.iucnredlist.org

FRID, C. L. J., PARAMOR, O. A. L. & SCOTT, C. L. (2006) Ecosystem-based management of fisheries: is science limiting? *ICES Journal of Marine Science: Journal du Conseil,* 63**,** 1567-1572.

FRIEND OF THE SEA (2011) Available URL: http://www.friendofthesea.org/about-us.asp Accessed 03/09/11.

GALBRAITH, R. D., RICE, A. & STRANGE, E. S. (2004) An Introduction to commercial fishing gear and methods used in Scotland. Scottish Fisheries Information Pamphlet No. 25.

GARTHE, S., CAMPHUYSEN, C. J. & FURNESS, R. W. (1996) Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea. *Marine Ecology-Progress Series,* 136**,** 1-11.

GRAFTON, R. Q., ARNASON, R., BJORNDAL, T., CAMPBELL, D., CAMPBELL, H. F., CLARK, C. W., CONNOR, R., DUPONT, D. P., HANNESSON, R., HILBORN, R., KIRKLEY, J. E., KOMPAS, T., LANE, D. E., MUNRO, G. R., PASCOE, S., SQUIRES, D., STEINSHAMN, S. I., TURRIS, B. R. & WENINGER, Q. (2006) Incentive-based approaches to sustainable fisheries. *Canadian Journal of Fisheries and Aquatic Sciences,* 63**,** 699-710.

GREATHEAD, C. F., DONNAN, D. W., MAIR, J. M. & SAUNDERS, G. R. (2007) The sea pens *Virgularia mirabilis, Pennatula phosphorea* and *Funiculina quadrangularis*: distribution and conservation issues in Scottish waters. *Journal of the Marine Biological Association of the United Kingdom,* 87**,** 1095-1103.

GREENSTREET S, FRASER H, COTTER J & PINNEGAR J (2010) Assessment Of The "State" Of The Demersal Fish Communities In Uk Waters. Scottish Marine and Freshwater Science Report Volume 1 No 3.

GOYERT, W., SAGARIN, R. & ANNALA, J. (2010) The promise and pitfalls of Marine Stewardship Council certification: Maine lobster as a case study. *Marine Policy,* 34**,** 1103-1109.

GULBRANDSEN, L. H. (2009) The emergence and effectiveness of the Marine Stewardship Council. *Marine Policy,* 33**,** 654-660.

HALL, M. A., ALVERSON, D. L. & METUZALS, K. I. (2000) By-Catch: Problems and Solutions. *Marine Pollution Bulletin,* 41**,** 204-219.

HALL, S. J. (1999) *The Effects of Fishing on Marine Ecosytems and communities*, Oxford: Blackwell Science.
HAMMOND, T. R. & ELLIS, J. R. (2004) Bayesian assessment of northeast Atlantic spurdog using a stock production model, with prior for intrinsic population growth rate set by demographic methods. *Journal of Northwest Atlantic Fishery Science,* 35**,** 299-308.
HARRIS, R. R. & ULMESTRAND, M. (2004) Discarding Norway lobster (*Nephrops norvegicus* L.) through low salinity layers - mortality and damage seen in simulation experiments. *Ices Journal of Marine Science,* 61**,** 127-139.
HE, P. & KENNELLY, S. J. (2007). Technical Measures to Reduce Seabed Impact of Mobile Fishing GearsBy-catch Reduction in the World's Fisheries. Springer Netherlands.
HILBORN, R., ORENSANZ, J. M. & PARMA, A. M. (2005) Institutions, incentives and the future of fisheries. *Philosophical Transactions of the Royal Society B-Biological Sciences,* 360**,** 47-57.
HOARE, D., GRAHAM, N. & SCHON, P.-J. (2011) The Irish Sea data-enhancement project: comparison of self-sampling and national data-collection programmes-results and experiences. *ICES Journal of Marine Science: Journal du Conseil,* 68**,** 1778-1784.
HOWARD, F. G. (1982) The Norway lobster. *Scottish Fisheries Research Report***,** 1-15.
ICES WGNSDS REPORT (2006) ICES Advisory Committee on Fishery Management ACFM13 Report of the Working Group on the Assessment of Northern Shelf Demersal Stocks.
ICES (2008) ICES Advice 2008 Book 9: North East Atlantic Spurdog (*Squalus acanthias*) in ICES Areas I-IX.
ICES (2009) Report of the ICES Advisory Committee 2009 Book 5.
ICES (2011) Report of the ICES Advisory Committee, 2011. ICES Advice, 2011. Available from: http://www.ices.dk/committe/acom/comwork/report/2011/2011/Neph-via.pdf.
INGÓLFSSON, Ó. A. (2011) The effect of forced mesh opening in the upper panel of a *Nephrops* trawl on size selection of *Nephrops*, haddock and whiting. *Fisheries Research,* 108**,** 218-222.
JACQUET, J., PAULY, D., AINLEY, D., HOLT, S., DAYTON, P. & JACKSON, J. (2010) Seafood stewardship in crisis. *Nature,* 467**,** 28-29.
JENNINGS, S., KAISER, M. J. & REYNOLDS, J. D. (2001) *Marine fisheries ecology*, Blackwell Science Ltd, Oxford.
KAISER, M. J. & EDWARDS-JONES, G. (2006) The role of ecolabeling in fisheries management and conservation. *Conservation Biology,* 20**,** 392-398.
KELLEHER, K. (2005) Discards in the world's marine fisheries. An update
KELTZ S AND BAILEY N (2010) Fish and Shellfish stocks 2010. Marine Scotland Science.
KINNEAR, J. A. M., BARKEL, P. J., MOJSIEWIEZ, W. R., CHAPMAN, C. J., HOLBROW, A. J., BARNES, C., GREATHEAD, C. F. F., ENO, N. C., MACDONALD, D. S. & AMOS, S. C. (1996) A study of the effects of *Nephrops* creels on the environment in Scotland. *A study on the effects of fish (Crustacea/mollusc) traps on benthic habitats and species: final report to the European Commission.***,** 3pp., 1-12, 16pp.
LEADLEY, P., PEREIRA, H., ALKEMADE, R., FERNANDEZ-MANJARRES, J. F., PROENCA, V., SCHARLEMANN, J.P.W & WALPOLE, M. J. (2010) Biodiversity Scenarios: Projections of 21st century change in biodiversity and associated ecosystem services. Secretariat of the Convention on Biological Diversity, Montreal. Technical Series no.50, 132 pages
LONGHURST, A. (1998) Cod: perhaps if we all stood back a bit? *Fisheries Research,* 38**,** 101-108.
LORDAN, C., O' CUAIG, M., GRAHAM, N. & RIHAN, D. (2011) The ups and downs of working with industry to collect fishery-dependent data: the Irish experience. *ICES Journal of Marine Science: Journal du Conseil,* 68**,** 1670-1678.
LOTZE, H. K., LENIHAN, H. S., BOURQUE, B. J., BRADBURY, R. H., COOKE, R. G., KAY, M. C., KIDWELL, S. M., KIRBY, M. X., PETERSON, C. H. & JACKSON, J. B. C. (2006) Depletion, degradation, and recovery potential of estuaries and coastal seas. *Science,* 312**,** 1806-1809.
MANDELMAN, J. W. & FARRINGTON, M. A. (2007) The estimated short-term discard mortality of a trawled elasmobranch, the spiny dogfish (*Squalus acanthias*). *Fisheries Research,* 83**,** 238-245.

MARINE SCOTLAND (2009) The Scottish Governments response to the European Commision's Green paper on reform of the Common Fisheries Policy.
MARINE SCOTLAND (2010) Marine and Fisheries Regulations:Management Arrangements 2010.
MARINE STEWARDSHIP COUNCIL (2007) Developing a Strategic Plan for the MSC. Available at http://www.msc.org/about-us/governance/strategic-plan.
MARINE STEWARDSHIP COUNCIL (2010) MSC Fishery Standard. *Principles and Criteria For Sustainable Fishing.* Available at http://www.msc.org/documents/scheme-documents/msc-standards/MSC_environmental_standard_for_sustainable_fishing.pdf.
MARINE STEWARDSHIP COUNCIL (2012) Marine Stewardship Council - Vision and Mission/Numbers Available URL: http://www.msc.org/about-us/vision-mission, http://www.msc.org/business-support/key-facts-about-msc Accessed: 05/01/12.
MILLIGAN, R. & NEIL, N. (2010) Bycatch In the North Minch *Nephrops* fishery: Year 2 Report. University of Glasgow 2010.
MILLIGAN, R., WATTS, A., NEIL, D. & SMITH, P. (2009) Bycatch In the North Minch *Nephrops* fishery: Year 1 Report. University of Glasgow 2009.
PAWSON, M. G., ELLIS, J. R. & DOBBY, H. (2009) The Evolution and Management of Spiny Dogfish (Spurdog) Fisheries in the Northeast Atlantic. *In Biology and management of dogfish sharks* ch. 31, pp. 373–390. Bethesda, MD: American Fisheries Society.
PETERMAN, R. M. (2002) Ecocertification: An incentive for dealing effectively with uncertainty, risk, and burden of proof in fisheries. *Bulletin of Marine Science,* 70**,** 669-681.
PIKITCH, E. K., SANTORA, C., BABCOCK, E. A., BAKUN, A., BONFIL, R., CONOVER, D. O., DAYTON, P., DOUKAKIS, P., FLUHARTY, D., HENEMAN, B., HOUDE, E. D., LINK, J., LIVINGSTON, P. A., MANGEL, M., MCALLISTER, M. K., POPE, J. & SAINSBURY, K. J. (2004) Ecosystem-Based Fishery Management. *Science,* 305**,** 346-347.
PINN, E. H., ROBERTSON, M. R., SHAND, C. W. & ARMSTRONG, F. (1998) Broad-scale benthic community analysis in the Greater Minch Area (Scottish west coast) using remote and nondestructive techniques. *International Journal of Remote Sensing,* 19**,** 3039-3054.
ROCHET, M. J., PERONNET, I. & TRENKEL, V. M. (2002) An analysis of discards from the French trawler fleet in the Celtic Sea. *Ices Journal of Marine Science,* 59**,** 538-552.
RULIFSON, R. A. (2007) Spiny dogfish mortality induced by gill-net and trawl capture and tag and release. *North American Journal of Fisheries Management,* 27**,** 279-285.
SCOTTISH NATURAL HERITAGE (2011) Priority Marine Featrures In Scottish Territorial Waters (Draft List). Available URL: http://www.snh.gov.uk/protecting-scotlands-nature/safeguarding-biodiversity/priority-marine-features/priority-marine-features/
STEVENS, J. D., BONFIL, R., DULVY, N. K. & WALKER, P. A. (2000) The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. *Ices Journal of Marine Science,* 57**,** 476-494.
STRATOUDAKIS, Y., FRYER, R. J., COOK, R. M., PIERCE, G. J. & COULL, K. A. (2001) Fish bycatch and discarding in *Nephrops* trawlers in the Firth of Clyde (west of Scotland). *Aquatic Living Resources,* 14**,** 283-291.
SUURONEN, P. (2005) Mortality of fish escaping trawl gears. *FAO Fisheries Technical Paper,* 478**,** i-xii, 1-72.
THORSTEINSSON, G. (1991) Experiments with square mesh windows in the *Nephrops* trawling off south-Iceland, ICES CM 1991/B:3.
THRANE, M., ZIEGLER, F. & SONESSON, U. (2009) Eco-labelling of wild-caught seafood products. *Journal of Cleaner Production,* 17**,** 416-423.
UHLMANN, S. S., BIERMAN, S. M. & VAN HELMOND, A. T. M. (2011) A method of detecting patterns in mean lengths of samples of discarded fish, applied to the self-sampling programme of the Dutch bottom-trawl fishery. *ICES Journal of Marine Science: Journal du Conseil,* 68**,** 1712-1718.
WARD, T. J. (2008) Barriers to biodiversity conservation in marine fishery certification. *Fish and Fisheries,* 9**,** 169-177.
WORM, B., HILBORN, R., BAUM, J. K., BRANCH, T. A., COLLIE, J. S., COSTELLO, C., FOGARTY, M. J., FULTON, E. A., HUTCHINGS, J. A., JENNINGS, S., JENSEN, O. P., LOTZE, H. K., MACE, P. M.,

MCCLANAHAN, T. R., MINTO, C., PALUMBI, S. R., PARMA, A. M., RICARD, D., ROSENBERG, A. A., WATSON, R. & ZELLER, D. (2009) Rebuilding Global Fisheries. *Science,* 325**,** 578-585.
WWF (2009) The Scottish Conservation Credits Scheme: Moving fisheries managemnt towards conservation. WWF Scotland, Dunkeld.

Appendices

Appendix A. List of Species recorded during trawl surveys

Appendix B. *Nephrops* carapace lengths (CL) obtained from random sub-samples

Appendix C. Number of male, female and ovigerous "berried" *Nephrops* recorded in each sub-sample

Appendix A. List of Species recorded during trawl surveys

ROUNDFISH

Agonus cataphractus (Linnaeus, 1758)
Alosa alosa (Linnaeus, 1758)
Callionymus lyra (Linnaeus 1758)
Capros aper (Linnaeus, 1758)
Chelidonichthys cuculus (Linnaeus, 1758)
Clupea harengus (Linnaeus 1758)
Conger conger (Linnaeus, 1758)
Dicentrarchus labrax (Linnaeus, 1758)
Enchelyopus cimbrius (Linnaeus, 1766)
Family Triglidae
Gadus morhua (Linnaeus 1758)
Gaidropsarus vulgaris (Cloquet, 1824)

Labrus bimaculatus (Linnaeus, 1758)
Lophius piscatorius (Linnaeus, 1758)
Melanogrammus aeglefinus (Linnaeus 1758)
Merlangius merlangus (Linnaeus 1758)
Merluccius merluccius (Linnaeus 1758)
Micromesistius poutassou (Risso, 1827)
Molva molva (Linnaeus, 1758)
Phycis blennoides (Brünnich, 1768)
Pollachius virens (Linnaeus, 1758)
Scomber scombrus (Linnaeus, 1758)
Trachurus trachurus (Linnaeus, 1758)
Trisopterus spp.
Zeus faber (Linnaeus, 1758)

FLATFISH

Buglossidium luteum (Risso, 1810)
Glyptocephalus cynoglossus (Linnaeus, 1758)
Hippoglossoides platessoides (Fabricius 1790)
Hippoglossus hippoglossus (Linnaeus, 1758)
Lepidorhombus whiffiagonis (Walbaum, 1792)
Limanda limanda (Linnaeus, 1758)
Microstomus kitt (Walbaum, 1792)
Pleuronectes platessa (Linnaeus, 1758)
Scophthalmus rhombus (Linnaeus, 1758)

ELASMOBRANCHS

Galeus melastomus (Rafinesque, 1810)
Scyliorhinus canicula (Linnaeus, 1758)
Squalus acanthias (Linnaeus, 1758)
Galeorhinus galeus (Linnaeus, 1758)
Dipturus oxyrinchus (Linnaeus, 1758)
Leucoraja naevus (Müller & Henle, 1841)
Raja clavata (Linnaeus, 1758)
Raja brachyura (Lafont, 1873)
Raja montagui (Fowler, 1910)

INVERTEBRATES

Cnidaria
Actinauge richardi (Marion, 1882)
Adamsia carciniopados (Otto, 1823)
Alcyonium digitatum (Linnaeus, 1758)
Aurelia aurita (Linnaeus, 1758)
Cyanea capillata (Linnaeus, 1758)
Cyanea lamarcki (Linnaeus, 1758)
Family Caryophylliidae
Funiculina quadrangularis (Pallas, 1766)
Pennatula phosphorea (Linnaeus, 1758)
Urticina sp.

Mollusca
Aequipecten opercularis (Linnaeus, 1758)
Aporrhais pespelicanis (Linnaeus, 1758)
Arctica islandica (Linnaeus, 1767)
Eledone cirrhosa (Lamarck, 1798)
Family Sepiolidae
Loligo vulgaris (Lamarck, 1798)
Neptunea antiqua (Linnaeus, 1758)
Order Nudibranchia: Species 1
Scaphander lignarius (Linnaeus, 1767)

Annelida
Aphrodita aculeata (Linnaeus, 1761)

Crustacea
Atelecyclus rotundatus (Olivi, 1792)
Cancer pagurus (Linnaeus, 1758)
Crangon crangon (Linnaeus, 1758)
Family Magidae
Family Pandalidae
Goneplax rhomboides (Linnaeus, 1758)
Infra-order Caridea: Sp. 1
Liocarcinus depurator (Linnaeus, 1758)
Macropipus tuberculatus (Roux, 1830)
Munida rugosa (Fabricius, 1775)
Pagurus bernhardus (Linnaeus, 1758)
Pagurus prideaux (Leach, 1815)
Palinurus elephas (Fabricius, 1787)
Pasiphaea sivado (Risso, 1816)

Echinodermata
Asterias rubens (Linnaeus, 1758)
Brissopsis lyrifera (Forbes, 1841)
Echinus sp.
Luidia ciliaris (Philippi, 1837)
Marthasterias glacialis (Linnaeus, 1758)
Order Euryalida
Parastichopus tremulus (Gunnerus, 1767)
Porania sp.
Sub-class Ophiuroidea

Tunicata
Class Ascidiacea

Appendix B. *Nephrops* carapace lengths (CL) obtained from random sub-samples

Trawl ID	Month	Mean CL	stdev	Min CL	Max CL	Mean CL	stdev	Min CL	Max CL
		Males				Females			
Trawl 1	Aug-10	28.8	7.4	16.2	48.3	28.3	4.0	23.7	44.4
Trawl 2	Aug-10	31.6	5.4	30.2	46.8	31.5	3.4	20.3	41.6
Trawl 3	Jun-10	34.6	3.9	23.6	53.9	34.1	4.7	24.9	49.3
Trawl 4	Sep-10	38.2	4.8	24.6	41.2	36.8	4.7	23.1	41.7
Trawl 5	Sep-10	31.5	6.7	15.0	45.5	30.3	2.2	29.7	38.9
Trawl 6	Sep-10	35.1	4.5	26.1	45.6	29.4	3.6	22.0	38.9
Trawl 7	Sep-10	32.3	5.1	23.2	46.4	31.9	3.5	20.6	40.5
Trawl 8	Oct-10	34.8	5.5	18.8	47.8	31.5	6.1	21.9	47.5
Trawl 9	Oct-10	32.2	4.4	20.2	42.3	29.7	3.2	18.8	37.6
Trawl 10	Oct-10	29.1	7.5	21.7	48.5	26.8	5.0	22.4	37.2
Trawl 11	Dec-10	32.8	5.7	19.2	45.8	25.3	4.3	18.1	35.3
Trawl 12	Nov-10	30.8	6.3	18.5	43.2	24.8	3.5	18.4	32.4
Trawl 13	Nov-10	28.3	5.8	16.9	50.6	24.2	3.2	17.1	35.5
Trawl 14	Jan-11	28.0	4.0	21.3	38.8	25.7	3.2	21.9	30.5
Trawl 15	Jan-11	32.4	6.7	20.0	54.7	26.4	3.2	19.9	34.3
Trawl 16	Jan-11	29.7	6.7	19.4	52.2	24.3	3.8	18.2	38.3
Trawl 17	Jan-11	34.3	7.9	21.5	54.7	25.3	3.7	19.9	34.9
Trawl 18	Mar-11	28.6	5.9	20.2	45.3	25.0	2.8	19.6	31.6
Trawl 19	Mar-11	27.9	6.0	20.2	49.1	26.8	4.1	18.4	34.3
Trawl 20	Mar-11	27.9	4.6	20.8	40.0	24.3	2.6	18.9	31.6
Trawl 21	Mar-11	37.0	6.7	18.8	53.6	30.7	3.7	22.7	36.7
Trawl 22	Apr-11	32.9	8.1	18.2	52.8	25.8	3.9	19.3	36.8
Trawl 23	May-11	30.6	6.1	21.3	45.4	28.7	4.2	20.6	35.7
Trawl 24	May-11	27.1	6.0	19.1	46.9	25.9	4.5	16.5	35.7
Trawl 25	Jun-11	30.7	6.3	19.1	48.2	30.6	3.3	20.3	40.1
Trawl 26	Jul-11	28.3	6.3	19.5	42.2	29.8	4.7	18.3	39.7
Trawl 27	Jul-11	31.2	4.7	21.5	46.9	32.6	3.4	22.0	43.3
Trawl 28	Jul-11	31.5	5.9	20.9	47.0	32.3	4.6	21.1	48.8
Trawl 29	Oct-11	27.4	4.7	15.5	48.6	24.7	3.8	15.0	34.2
Trawl 30	Oct-11	29.0	4.4	19.9	45.9	25.5	3.1	18.2	36.1

Appendix C. Number of male, female and ovigerous "berried" *Nephrops* recorded in each sub-sample

Trawl ID	Month	Males	Females	"Berried" Females	Males (% total)	Females (% total)	"Berried" (% total)	"Berried" (% Females)
1	Aug-10	25	67	1	27.2	72.8	1.1	1.5
2	Aug-10	68	178	9	27.6	72.4	3.7	5.1
3	Jun-10	66	145	2	31.3	68.7	0.9	1.4
4	Sep-10	44	27	15	62.0	38.0	21.1	55.6
5	Sep-10	43	63	41	40.6	59.4	38.7	65.1
6	Sep-10	50	50	30	50.0	50.0	30.0	60.0
7	Sep-10	52	46	15	53.1	46.9	15.3	32.6
8	Oct-10	72	30	11	70.6	29.4	10.8	36.7
9	Oct-10	74	46	19	61.7	38.3	15.8	41.3
10	Oct-10	31	17	2	64.6	35.4	4.2	11.8
11	Dec-10	68	19	0	78.2	21.8	0.0	0
12	Nov-10	43	21	1	67.2	32.8	1.6	4.8
13	Nov-10	462	308	1	60.0	40.0	0.1	0.3
14	Jan-11	40	21	0	65.6	34.4	0.0	0
15	Jan-11	215	52	0	80.5	19.5	0.0	0
16	Jan-11	174	72	2	70.7	29.3	0.8	2.8
17	Jan-11	104	35	0	74.8	25.2	0.0	0
18	Mar-11	73	53	0	57.9	42.1	0.0	0
19	Mar-11	36	12	0	75.0	25.0	0.0	0
20	Mar-11	103	75	0	57.9	42.1	0.0	0
21	Mar-11	69	16	3	81.2	18.8	3.5	18.8
22	Apr-11	129	48	1	72.9	27.1	0.6	2.1
23	May-11	38	27	0	58.5	41.5	0.0	0
24	May-11	99	133	2	42.7	57.3	0.9	1.5
25	Jun-11	76	253	6	23.1	76.9	1.8	2.4
26	Jul-11	41	114	0	26.5	73.5	0.0	0
27	Jul-11	88	224	2	28.2	71.8	0.6	0.9
28	Jul-11	75	167	4	31.0	69.0	1.7	2.4
29	Oct-11	290	226	16	56.2	43.8	3.1	7.1
30	Oct-11	175	111	8	61.2	38.8	2.8	7.2