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REDFISH (*Sebastes marinus*) IN MARINE PROTECTED AREAS WEST OF ICELAND

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ABSTRACT

Redfish *(Sebastes marinus)* is one of the most important fish species in Icelandic fishing grounds and has been highly exploited. In recent years the number of redfish caught has decreased as a consequence of decreasing stock size. A Marine Protected Area (MPA) was established in 1994 to protect juvenile redfish. This project focuses on this area west of Iceland. The data collected in this report is from 1985-2002. After the MPA was established, the mean length of redfish has increased by about 1-2 cm. From the three first years to the three last years of the period the number of species in the MPA has increased by three. Biodiversity has increased after the MPA was established and the ecosystem seems to have returned to the way it was in 1985-1986.

Key words : Marine Protected Area (MPA), redfish

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1 INTRODUCTION

Marine Protected Areas (MPAs) are now widely distributed throughout the ocean, not only in tropical waters, but also in temperate and arctic waters (Jamieson and Levings 2001). The International Union for the Conservation of Nature and Natural Resources (IUCN) defines MPAs as "any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which have been reserved by law or other effective means to protect part or all of the enclosed environment" (Kelleher and Kenchington 1992). For marine environment, there are two general categories of protected areas: those that were primarily established to preserve habitats and ecosystems and those that are focused on the protection of individual species or groups of species (Jamieson and Levings 2001). Studies on the effects of area protection have been mostly associated with tropical regions. They have typically been associated with the preservation of long-lived species and particularly vulnerable ecosystems, such as coral reefs (Jamieson and Levings 2001).

In 1986, the Government of Vietnam established a National Park on Cat-Ba Island. This park occupies 9800 ha of forest and 5400 ha of marine area. In 1987 the National Park of Con-Dao Island was established, which also included a marine area.

These marine areas in Cat-Ba and Con-Dao are the first MPAs in Vietnam. MPAs are a new concept in Vietnam. In 1999 the Ministry of Fisheries created an MPA system in Vietnam. Due to lack of experience and financial constraints no effective management measures have taken place in the marine areas of the park. Now Vietnam is going to establish an MPA network system but an assessment on biodiversity in these areas needs to take place in order to select areas to be protected. Vietnam's coastal and marine areas contain important geological features that are significant in terms of national conservation priorities. Several MPA sites are mentioned in the Biodiversity Action Plan (BAP) as priority areas. Also mentioned as a priority programme in the BAP is the development of a national MPA system. The project will assist Vietnam in implementing priority programmes under the BAP (Support to the Marine Protected Area Network in Vietnam 2002).

Part of the Government of Vietnam's response to perceived decline in the country's fish and other marine resources has been to consider the development of a national MPA network. The Cat Ba National Park, as well as the newly created National Park on Phu Quoc Island, are both located in marine areas but they focus almost exclusively on the terrestrial environments that are managed by the Ministry of Agriculture and Rural Development (MARD) and its provincial-level line agencies. In Con Dao National Park the terrestrial park is combined with a large marine environment and both are managed as an integrated whole (Support to the Marine Protected Area Network in Vietnam 2002).

The Vietnamese Ministry of Fisheries (MoFi) has identified three categories of MPAs for Vietnam. There are no specific criteria for these categories but instead there are recommendations for a management structure for each type. The categories are: (1) national parks, (2) species/habitat reserves, and (3) marine resources conservation zones. None of the proposed MPA sites have actually been gazetted in terms of these categories. (Support to the Marine Protected Area Network in Vietnam 2002).

Through work carried out at the MoFi research laboratories and research institutions, considerable progress has been made in developing alternative forms of income from marine products. Marine culture operations (marine farming or culture of resources) have been a special area of interest at different institutes and special centres for aquaculture.

The scope of this report is an MPA located west of Iceland. An area was closed in the autumn of 1994 as a consequence of discussions between fishermen that had been fishing in that area for more than 20 years with bottom trawls and fisheries scientists at the Marine Research Institute in Reykjavik as well as people from the Directorate of Fisheries. The goals for closing the area were primarily to decrease the fishing effort of golden redfish (*Sebastes marinus)* and to protect juveniles of the same species. At that time, a large amount of juveniles were located in the area. There is no information available on species composition prior to when fisheries started in this area in the early 1950s and therefore there is no information on the species composition, both in terms of fauna and flora at that time. One of the problems of documenting community effects many years after full exploitation of local species has occurred, is that contemporary community dynamics may not be representative of what existed in the preexploitation period. Important species may have been extirpated from a local environment and both the resulting community structure and the dominance of species may now be significantly different from those that used to occur (Jamieson and Levings 2001). Nevertheless, monitoring a closed area for a long time could, after a given time, indicate how the situation might have been before exploitation began.

The main objectives of this project are to investigate how fish composition changed with time and to study the advantages and disadvantages of MPAs: The aims are therefore to:

a) Investigate the biodiversity in the MPA based on data from the Marine Research Institute database.
b) Study changes in the fish community within the MPA west of Iceland.
c) Compare biodiversity in the MPA before and after 1994.

1.1 Redfish stocks in Icelandic waters

As the golden redfish is the reason for the closure of the area in 1994, an overview of redfish species in Icelandic water is provided. There are three separate species of redfish around Iceland, i.e. golden redfish (*S. marinus)*, deep-sea redfish (*S. mentella)* and *S. viviparus*. The smallest of these, *S. viviparus*, is not caught in significant amounts and is as yet of little commercial importance.

Golden redfish and deep-sea redfish are caught all year round. Fishing is often best in late winter and the richest fishing areas are in the west and southwest at an ocean temperature of 3 - 8 °C. Golden redfish is mainly caught at depths of 100 - 300 m but can be found as far down as 500 m. Deep-sea redfish is more common at depths below 500 m. Oceanic redfish, which is also of the species *S. mentella* is mainly caught in the spring and summer months in the Irminger Sea, within the EEZ of Iceland and Greenland and in international waters (Figure 1). Common weight in landings of these redfish species is 0.5 to 1.5 kg with a body length of about 32-40 cm. Redfish is caught by bottom trawl in waters of the Icelandic continental shelf and slope but by pelagic trawl in the Irminger Sea (International Council for the Exploration of the Sea, 2002 report.

Figure 1: Irminger Sea within the EEZ of Iceland and Greenland.

Redfish mate in late autumn to early winter, the female carries the sperm and the eggs are fertilised in January to February. The larvae are hatched in April or May in remote areas in the southwest. The fry stays near the bottom off east Greenland and at the edge of the Icelandic continental shelf. North of Iceland redfish grows slowly and research shows an annual growth of less than 2 cm from the age of two years to the age of maturity, which is around 12-13 years. Age determination is, however, difficult (International Council for the Exploration of the Sea, 2002 report.).

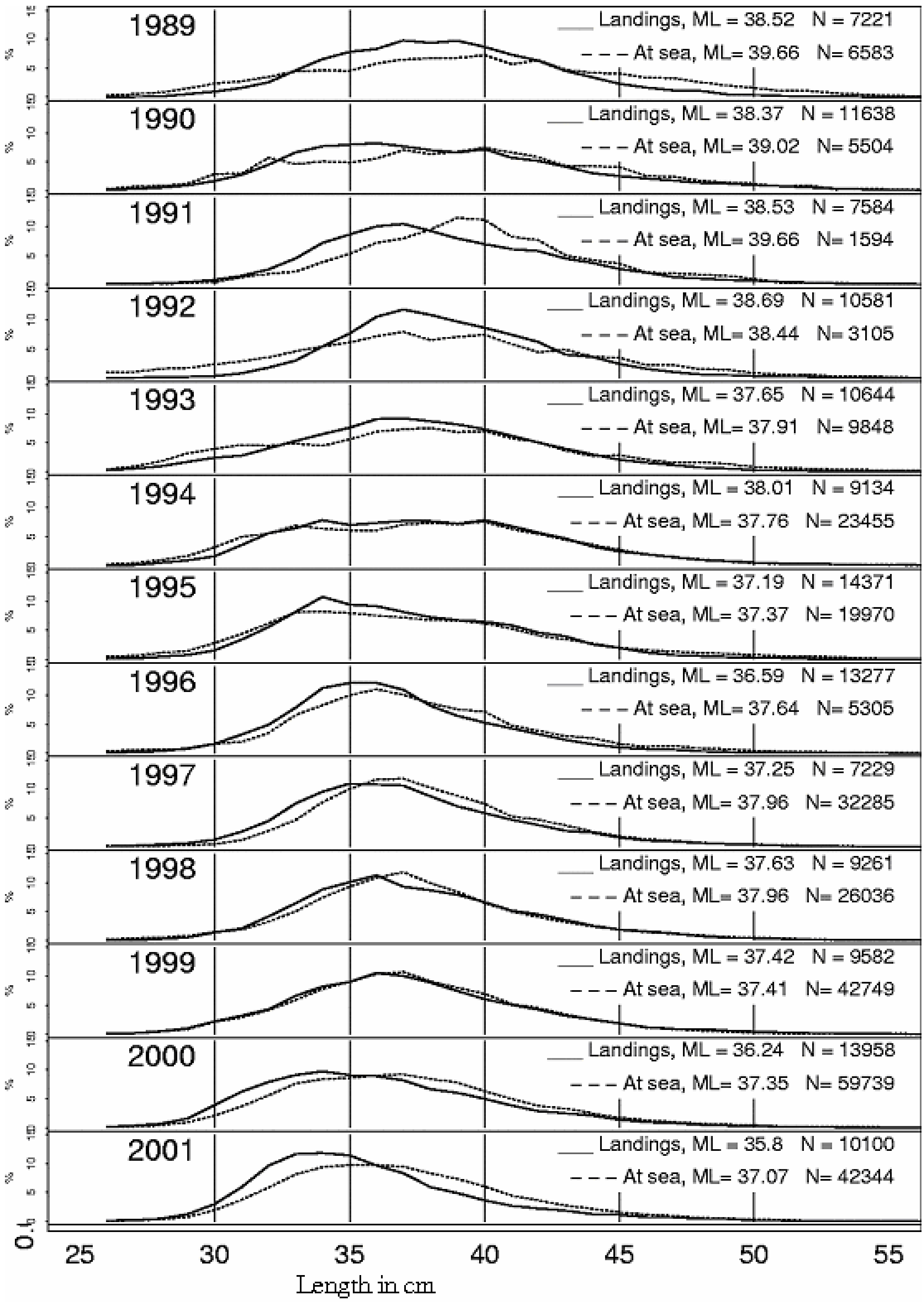


Figure 2: *S. marinus* length distribution from Icelandic landings and from samples taken at sea from the trawler fleet 1989-2001 (International Council for the Exploration of the Sea, 2002 report.).

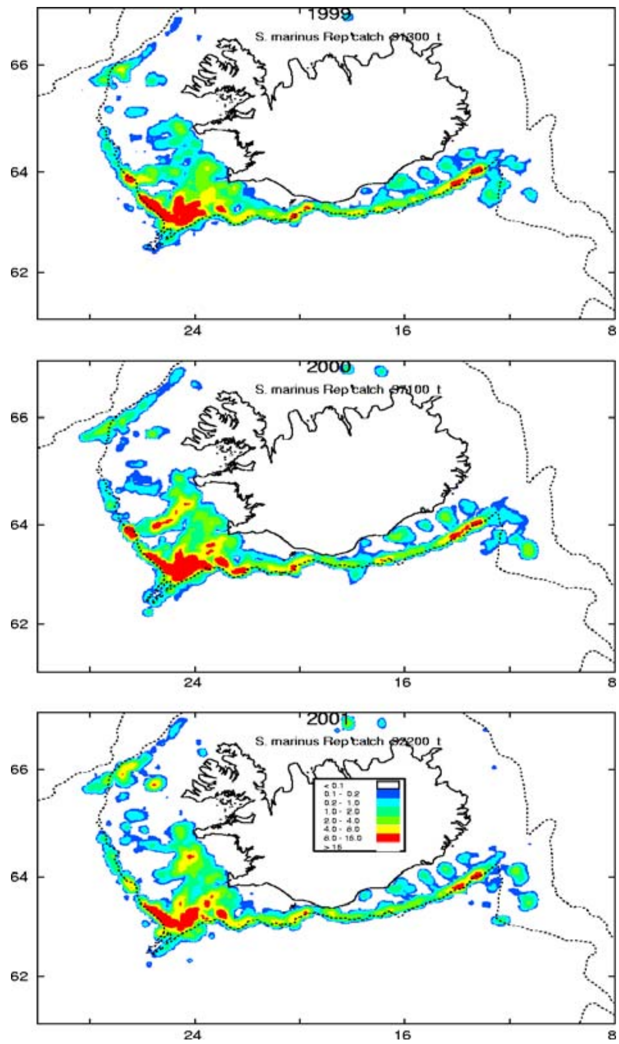


Figure 3: Distribution of *S. marinus* catches in Icelandic waters from 1999-2001 (International Council for the Exploration of the Sea, 2002 report.).

The catch of golden redfish increased between 1978 and 1983 from about 25,000 tons to nearly 100,000 tons, but decreased from then until 1994. The decrease for the catch in the period between 1984 and 1986 was a result of decreased fishing effort. The total catch for both golden and deep-sea redfish ranged from 85,000 to 100,000 tons between 1986 and 1994. The reason for this stability was that when catch decreased for *S. marinus,* catch increased for *S. mentella*. The introduction of an MPA led to a decrease in the yield from 1994 to 2002 (Figure 4). In the Icelandic Groundfish Survey (IGS) in March, an index of fishable stock size is provided. Figure 5 shows the fishable stock of redfish in the IGS from a depth of 0 to 400 m. As can be seen, the stock seems to have decreased from 1985 to 1995. After that, the stock increase due to a reduction in effort, and possibly also, because of the MPA that was established in 1994.

The low catch in 1994 was partly due to area closures imposed on the fishery by Iceland in order to reduce the catches of *S. marinus*, and to reduce the effort at the nursery grounds. However, landing in 1995 increased to approximately 42,000 tons. The length distributions in the Icelandic landings 1989 to 2001 along with measurements from the commercial trawler fleet are shown in Figure 2, and the fishing grounds are shown in Figure 3. About 90-95% of the total *S. marinus* catches in Icelandic waters have, in recent years, been taken by bottom trawlers (both fresh fish and freezer trawlers 48-65 m in length) targeting redfish. The remainder is taken partly as by-catch in the gillnet and longline fisheries (International Council for the Exploration of the Sea, 2002 report.).

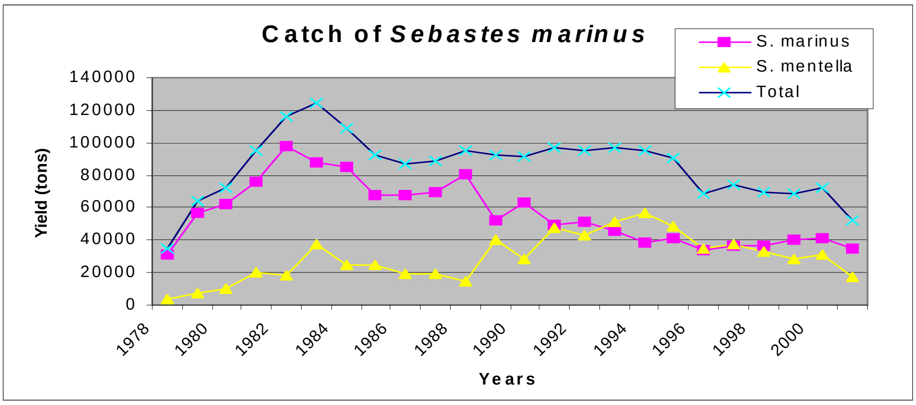


Figure 4: Catch of *S. marinus* and *S. mentella* by stock 1978-2001 (MRI 2002).

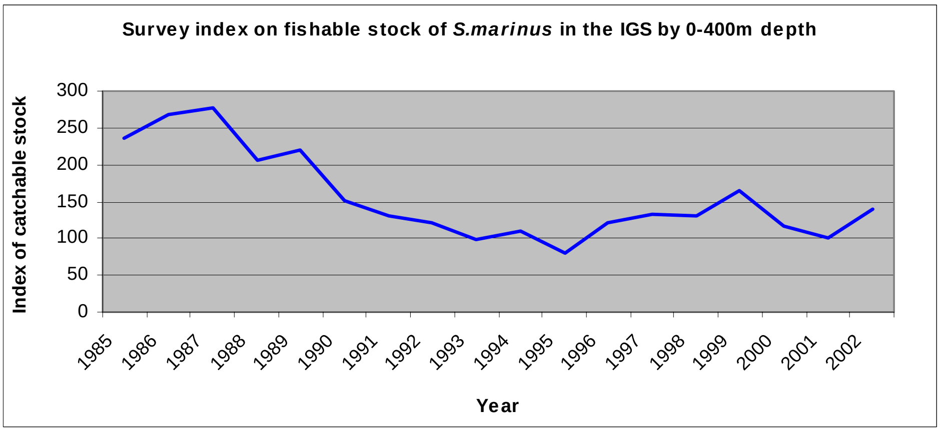


Figure 5: Redfish stock in the IGS (International Council for the Exploration of the Sea, 2002 report.).

Abundance, biomass indices, and length composition have been derived using German annual groundfish surveys covering shelf areas and the continental slope off east and west Greenland down to 400 m in depth. Due to difficult identification, juvenile redfish (< 17 cm) were only classified to genus as *Sebastes spp*. Trends in survey abundance for juvenile redfish (< 17 cm) in Icelandic waters are also used. Since 1993 *Sebastes spp* were very abundant and distributed mainly off east Greenland (International Council for the Exploration of the Sea, 2002 report.).

The IGS and the CPUE series seem to indicate a considerable decline in the fishable biomass of *S. marinus* during the period from 1986 to 1994. The stock seems to have started to recover, but it is still low according to the survey index. A large proportion of the catch in recent years is caught from two year classes (International Council for the Exploration of the Sea, 2002 report.).

2 LITERATURE REVIEW

2.1 MPAs

There is a long history of using restrictions on geographical areas as one component of a fisheries management package. The approaches range from limitations on the gear type or exclusion of certain types of vessels, seasonal or even total closure of an area. While there has been debate on the effectiveness of these procedures, the virtual cessation of fishing in the North Sea for four years during each of the two world wars demonstrated just how beneficial closure could be to the stocks (McIntyre 2002).

With the present failure of conventional fisheries management to protect commercial resources around the world, there is a demand for new options to be considered, and the interest in an ecosystem-based strategy is increasing (McIntyre 2002).

There is a growing interest in the use of MPAs as a method for protecting fish populations from excessive exploitation, particularly in developing countries. Many MPAs appear to be successful, at least in terms of increasing fish numbers within reserve boundaries. The species that are the target of exploitation respond significantly better than non-targeted species. This may occur through increased larval export from MPAs owing to increased spawning stock biomass within MPAs. MPAs are established to protect sensitive habitats and non-species, which may otherwise be damaged or depleted through recreational or exploitative use. Nevertheless, given the potential benefits of MPAs for both fisheries and conservation, it is crucial to understand the characteristics of such reverves that promote the fulfilment of these dual goals (Pastoors *et al.* 2000 and Cote *et al.* 2001)

MPAs may be divided into two general categories: those that were primarily established to preserver habitats and ecosystems, and those that are focused on the protection of individual species or species groups (Jamieson and Levings 2001). The level of habitat protection is somewhat determined by the legislative act that was used to establish it, but sometimes it is primarily determined on a site by site basis, typically in consultation with local communities and interest groups (Jamieson and Levings 2001).

In general terms, MPAs are areas set aside and closed to fishing or harvesting of other living marine recourses (LMRs). The marine environment requires a substantially different approach. Protection of marine areas can have several aims, preserving biodiversity and improving fisheries management, although other possibilities, including contributions to scientific knowledge, expansion of educational opportunities, enhancement of recreational activities, tourism, and protection of cultural heritage, are noted (McIntyre 2002). The MPAs then provide opportunities for reproduction, spawning, and recruitment of various LMRs. Moreover, the habitat of an MPA is not subjected to physical damages by fishing gear, or the noise, movements, and shadows resulting from docks, piers, vessel traffic, or transepts. The MPAs in estuaries and coastal zones can preclude dredging, filling, dock construction, pollution, ocean mining, and other physical damages so common in many coastal areas (White *et al*. 2002). Such areas may then develop more robust stocks, capable of dissemination to other, unprotected, areas. Forage species, essential to fishes, other LMRs, and marine mammals may grow and occur in far greater numbers, augmenting the diets of LMRs, and thus their growth and biomass. In many cases, the MPAs are designed to protect diversity and endangered species (Pearce 2002).

2.2 MPAs objectives and effects

MPAs are unlikely to be effective if they are located in areas that are subject to numerous, and often uncontrollable, external stressors from atmospheric, terrestrial, and oceanic sources, all of which can degrade the environment and compromise protection. These factors should be analysed before designation and periodically re-evaluated after designation. Top priority should be given to designating MPAs in minimally impaired locations that can act as reference sites for monitoring and assessment programmes (Jameson *et al.* 2002).

Large-scale surveys of MPA users, managers and researchers paint a different picture of MPA success. It is estimated that about 35% of Caribbean MPAs and only 10–15% of Indo-Pacific MPAs are meeting their stated management objectives. Most MPAs are “paper parks” which lack compliance on the part of resource users and monitoring or enforcement on the part of management agencies; the reason for this failure can be traced to the level of community and institutional capacity. Community capacity refers to the rules, procedures and values that people hold, which predispose them to working collectively for mutual benefit. Institutional capacity is the ability of government agencies to provide public goods and services and ensure that laws and regulations are enforced.

The success of MPAs as a management tool will be greatest when communities collectively support the MPA and government agencies (or in some cases, non-governmental organisations, provide the necessary financing, monitoring, enforcement, and technical expertise to ensure that MPAs reach their management objectives. Illegal fishing is likely to occur if community capacity is high but institutional capacity is lacking (Jameson *et al.* 2002).

The management achievement of an MPA also depends greatly on the level of compliance by local resource users, who bear most of the costs of an MPA. The probability of compliance will increase if local resource users derive direct benefits from the MPA. For example MPAs with fisheries focus, f must export sufficient biomass to mitigate for the loss of fishing grounds within the MPA boundaries. To date, many studies have found substantial increases in biomass within MPAs, and several studies have shown an increase in catch-per-unit-effort in fishing grounds adjacent to MPAs. These ecological studies are cited repeatedly as evidence for the success of MPAs in fisheries and ecosystem management (Jameson *et al.* 2002).

Community based-marine protected areas (CB-MPA) involve an improvement in the resource; e.g., measurable increases in the quality and quantity of flora and fauna, including corals. Community members’ perception of the MPA’s impact on the resource is also an important indicator. It is these perceptions that will influence their behaviour regarding the CB-MPA. The degree of adherence to the rules associated with the MPA is also an indicator of success. Finally, since a CB-MPA involves empowering community members to manage their own resources, the degree to which this empowerment is realised is a component of success (Pollnac *et al.* 2001).

2.3 MPAs as a tool for sustaining ocean ecosystems

The World Conservation Union (IUCM) distinguishes between the following categories (in decreasing order of protection):

a) *Ecological Reserve* (or "no-take" zone)—an area where fishing or disturbance of any living or non-living resource is prohibited;
b) *Fishery Reserve*—a zone that precludes fishing on some or all species;
c) *Marine Reserve*—a zone where some or all of the biological resources are protected from removal or disturbance;
d) *MPA*—a discreet geographical area designated to conserve marine resources, managed by an integrated plan that includes fishery and ecological reserves within the MPA.

Currently MPAs occupy less than 1% of the marine environment, but given their multiple goals, their use is increasing throughout the world (McIntyre 2001).

The use of protected areas represents a shift in emphasis from single-species management to spatial management. It has been argued that uncertainty in assessments is too large for fisheries to be managed sustainably using conventional tools. MPAs make a convincing case for the potential of fishery reserves as a complementary approach to fishery management, pointing out that in most cases experience shows that reserves will increase the biomass of exploited fish stocks, enhance biodiversity, and allow ecosystem recovery. However, fishermen are reluctant to see spatial management on a par with conventional procedures (McIntyre 2001).

Nowadays marine resources are dwindling because of human activities. This is evident in terms of:

- Declining yields world-wide
- Too many fishers
- A growing market for seafood

Scientists, managers, and politicians seem to be unable to do much to stop this downwards trends (Pearce 2002). Extinction of species arises because of overfishing. MPAs enhance biodiversity and fish stocks (Pearce 2002). Many ecologists believe that the wild Columbia River salmon can never be saved, largely because of habitat failures, and incompetent management systems (Pearce 2002).

Use of the protected marine area is without doubt the only way to preserve certain reefs, coral heads, and associated fauna. Reserves have been shown to aid in the preservation of many tropical aquatic species as demonstrated in the Great Barrier Reef of Australia, as well as the fringing reefs of Bermuda (Rashid *et al*. 2000).

Areas closed to the harvesting of several marine species have been shown to "grow" new spawning stock (Hyrenbach *et al.* 2000). The MPAs have been demonstrated in many ways to work, and their use must be initiated if we are to conserve groundfish stocks, as well as endangered species, diversity and habitat stability (Pearce 2002 and Jameson *et al*. 2001). The MPAs may ultimately be linked to other schemes such as "corridors" and artificial reefs or islands, new tools and pathways to provide "bridges" so that stock progeny and genes may disseminate or flow from one MPA to another, or from an MPA to an unmanaged area (Hall 2001 and Pearce 2002). MPAs will be another “island tool” to aid in the verification of evolutionary change. They may also be the best way to deal with marine pollution and physical degradation (Pearce 2002).

3 MATERIAL AND METHODS

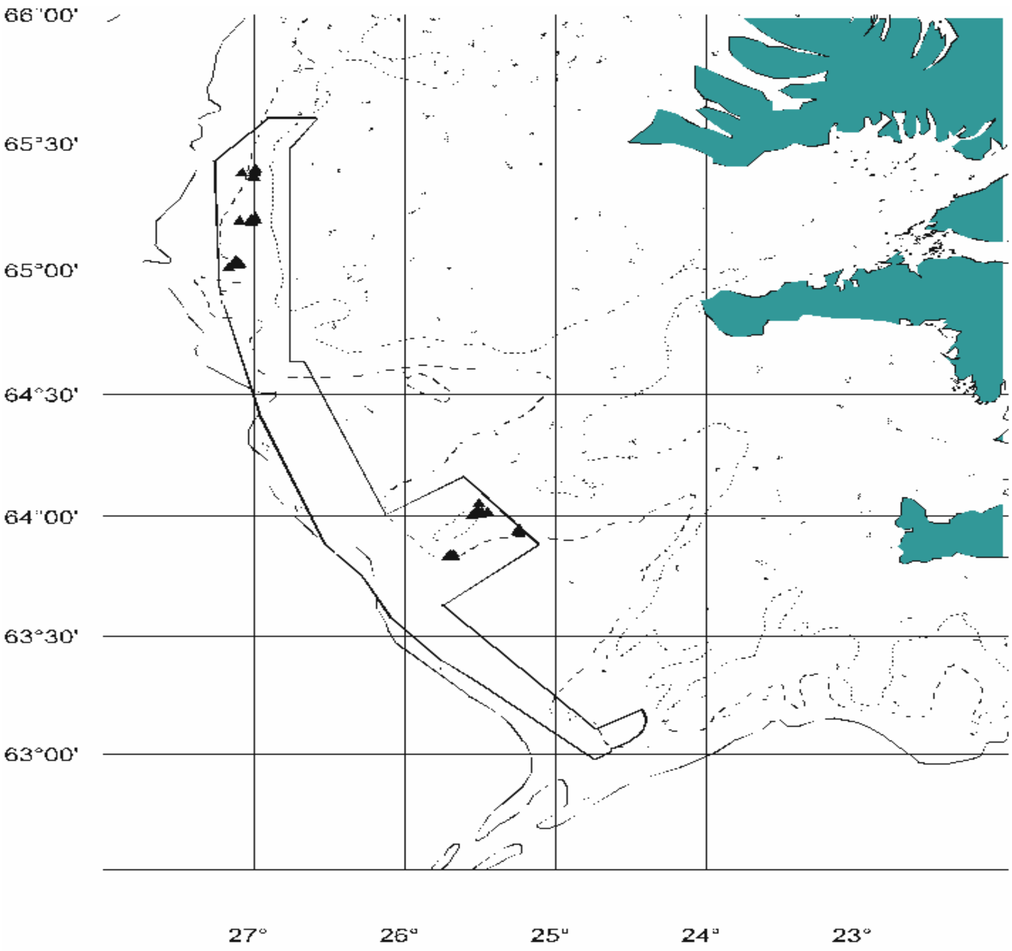


Figure 6: The MPAs west of Iceland and stations sampled in the IGS.

The MPA was established in late 1994 and since then no trawling has been allowed inside the area north of 63°30N. The location of the MPA is shown in Figure 6. Figure 6 also shows the position of stations in the IGS since 1985 that are used in the analysis presented here. The southern most part was reopened in 2002 and is therefore not included in the analysis. Data from the stations will be the main source of information in this project. Between six and eight stations were sampled in the IGS (since 1985) inside the MPA. Since 1995 the parameters sampled were number of fish per catch of each species, and length distribution for most species. Therefore the data allows us to:

- Investigate species abundance by year from 1985-2002 as an average by haul.
- See the length distribution by species per year.
- Conduct a "stock assessment" for selected species.

The primary tools used for data analysis were Excel and Primer-E5. The Primer-E5 Software package (Clarke and Warwich 1994) is a statistical package often used to analyse change in the environment. That package makes it possible to calculate similarity between stations and also between years. PRIMER (Plymouth Routines in Multivariate Ecological Research) v5 consists of a range of univariate, graphical and multivariate routines for analysing matrices of species by samples abundance (or biomass, % cover, presence/absence…) that arise in biological monitoring of environmental impact and more fundamental studies in community ecology, together with associated physic-chemical data.

The basic routines of the package cover: hierarchical clustering into sample (or species) groups (CLUSTER); ordination by non-metric multidimensional scaling (MDS) and principal components analysis (PCA) to summarise patterns in species composition and environmental variables; permutation-based hypothesis testing (ANOSIM), an analogue of univariate ANOVA which tests for differences between groups of (multivariate) samples from different times, locations, experimental treatments etc; identifying the species primarily providing the discrimination between two observed sample clusters (SIMPER); the linking of multivariate biotic patterns to suites of environmental variables (BIO-ENV); abundance distributions etc.

Cluster analysis aims to find “natural groupings” of samples so that samples within a group are more similar to each other, generally, than samples in different groups. Cluster analysis is used in the present context as described below.

One of the greatest abilities of PRIMER is to calculate biodiversity indices based on the taxonomic distinctness or relatedness of the species making up a quantitative sample or species list, indices whose statistical properties are robust to variations in sampling effort. These routines allow formal hypothesis tests for change in biodiversity structure at a location (as measured by average and variation in taxonomic ‘breadth’ of the species list), from that ‘expected’ from a larger, regional species pool. It provides the possibility of comparing biodiversity patterns over wide space and time scales, when sampling effort is not controlled.

1. Different sites can be seen to have differing community compositions by noting that replicate samples within a site form a cluster that is distinct from replicates within other sites. This can be an important hurdle to overcome in any analysis; if replicates for a site are clustered more or less randomly with replicates from every other site, further interpretation is likely to be dangerous.
2. When it is established that sites can be distinguished from one another (or, when replicates are not taken, it is assumed that a single sample is representative of that site or time), sites or times can be partitioned into groups with similar community structure.
3. Cluster analysis of the species similarity matrix can be used to define species assemblages, i.e. groups of species that tend to co-occur in a parallel manner across sites.

In addition to PRIMER, Microsoft Excel in used for mean length distributions to calculate mean length and fitting the trendline to various data points.

4 RESULTS

4.1 Length distribution in the MPA west of Iceland

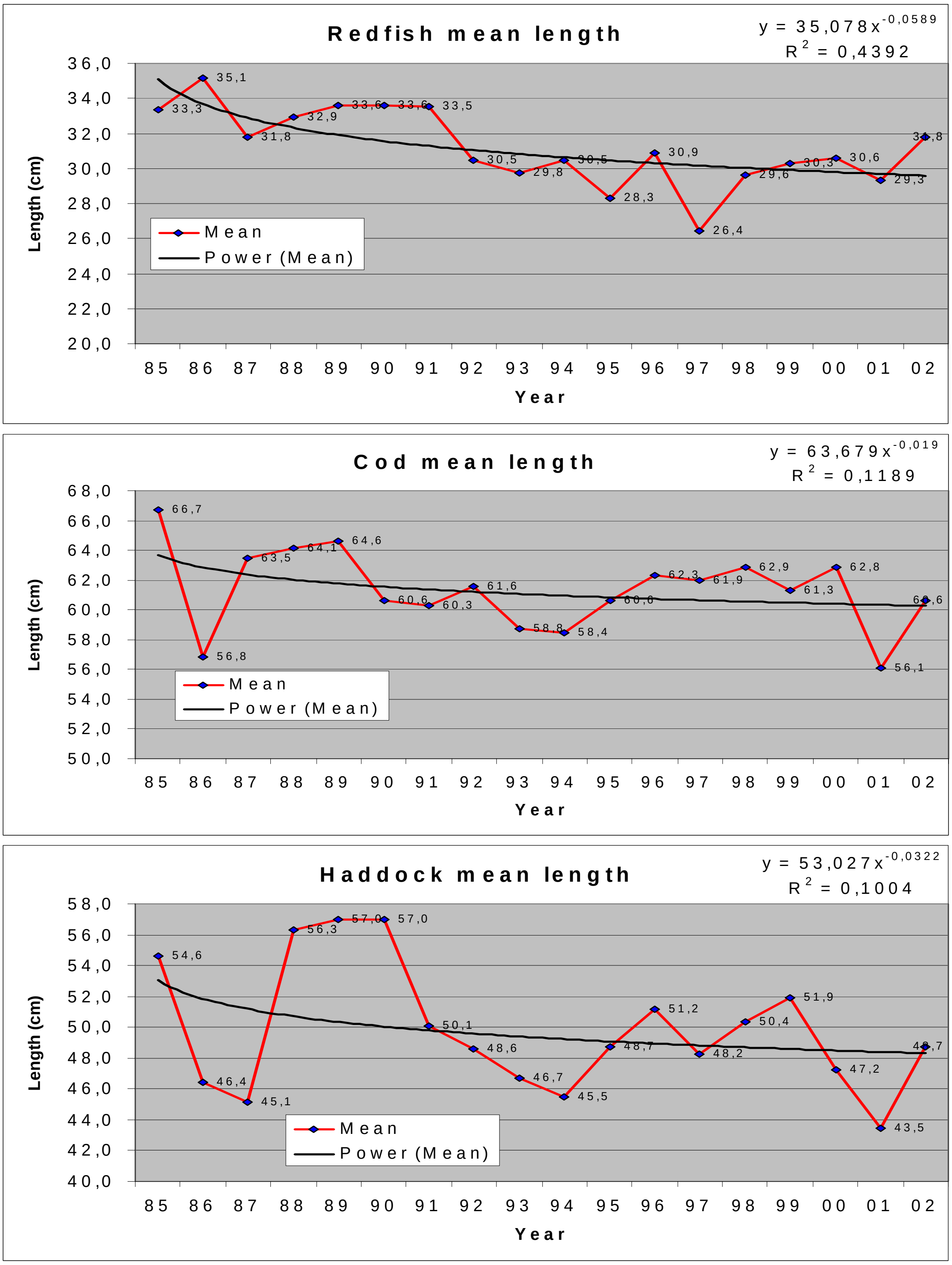


Figure 7: Mean length of the main species in the MPA.

In addition to comparing differences in the MPA before and after the closing time by using the biological diversity method, species distribution by year, and length distribution of species in the community is also important. In the MPA there are several commercial species such as redfish, cod and haddock. Mean length is one factor that might show the success of an MPA. In this case the focus is on the number of fish not biomass.

Figure 7 shows the mean length of three of the main exploited species that are found in the MPA. Mean length indicates the growth condition of the fish, food and environmental factor in the MPA correspond and high biodiversity.

Golden redfish was the most important commercial species in the MPA between 1985 and 1994. The mean length of redfish decreased slightly ($y = 35.078x^{-0.0589}$ with $R^2 = 0.4392$) over the whole period, but has increased since 1994.

Before 1994, when the MPA had not yet been established a decreasing mean length was observed. The reason for this might be high fishing effort during that time within the MPA, so the individuals did not have time to grow to a mature size as well as some differences in the natural condition. Since the MPA was established, there has been a tendency for the mean length to increase from 30.5 cm in 1994 to 30.9 cm in 1996 and reached 31.8 in year 2002. However, from 1994-2002 the mean length did not always increase and for the entire period the mean length decreased (Figure 7). Similarly the other commercially important species (cod, haddock) show a decreased mean length from 1985-2002.

The mean length of cod increased from 58.4 cm in 1994 to 60.6 cm in 2002.

The mean length of haddock increased from 45.5 cm in 1994 to 48.7 cm in 2002.

In summary the mean length of the main commercial species in the MPA increased from 1994-2002.

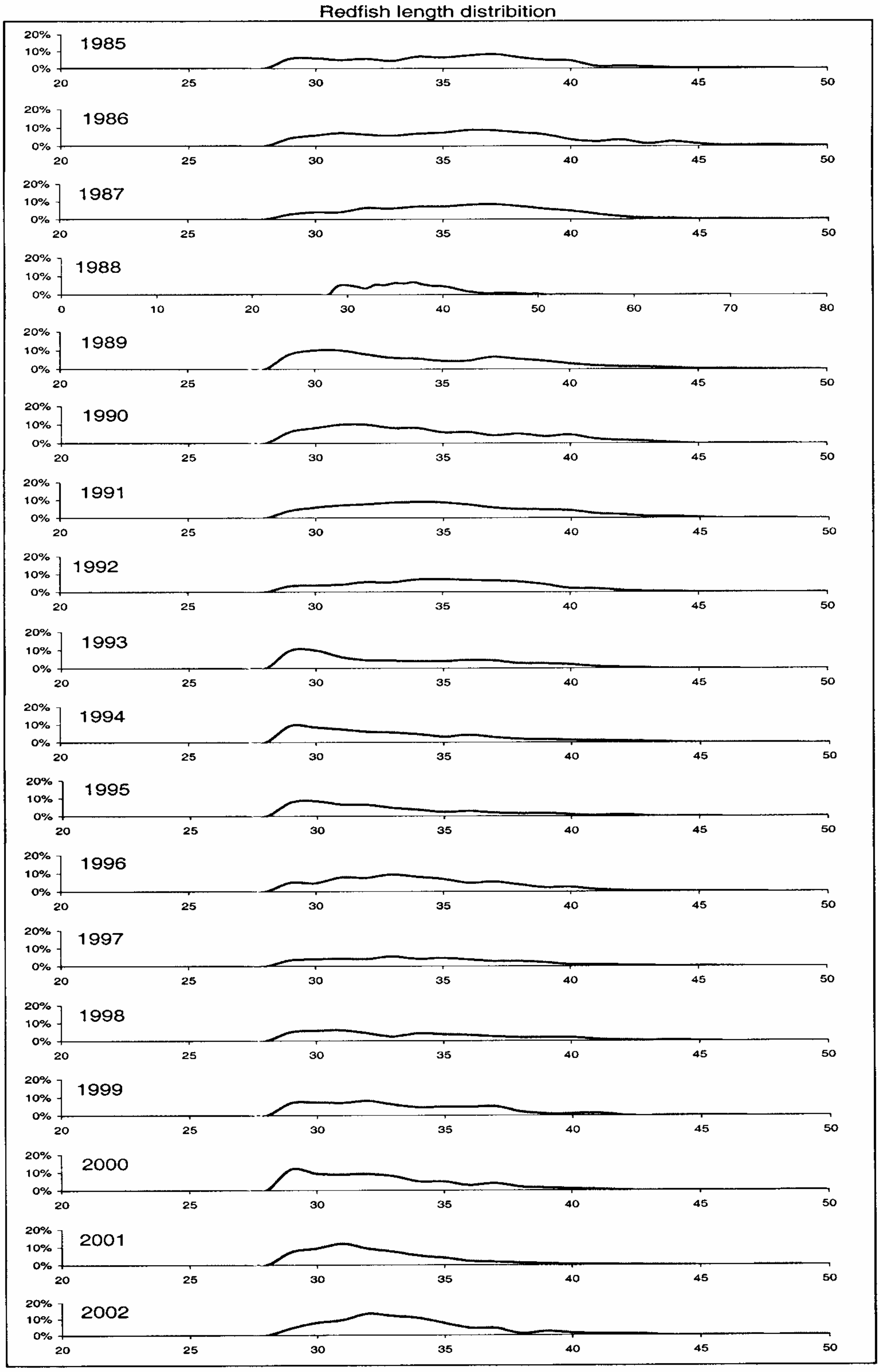
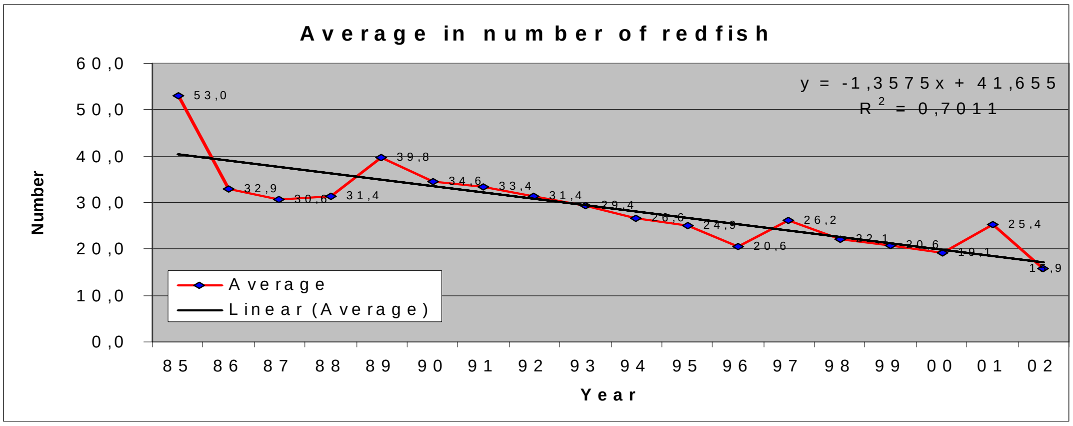


Figure 8: Redfish length distribution in the MPA from 1985-2002.

The length distribution of redfish from 1994 does not indicate that the redfish remain in the MPA (Figure 8), as the number of adult fishes (>33cm) does not increase from the time of the closure. Therefore it seems that as the redfish grow, the majority migrate away from the MPA.

Length distribution is a criterion for assessing stock in the MPA. Figure 8 shows redfish length distribution between 1985 and 2002. In the beginning of the period, the fishing effort was not very high but from 1992 to 1996, when the fishing effort was very high, the mean length decreased sharply to 30 cm. High fishing effort and the increased fishing of juveniles was the main reason for establishing the MPA in 1994. From 1998 to 2002 the length distribution was increasingly similar to the situation 1985-1986.



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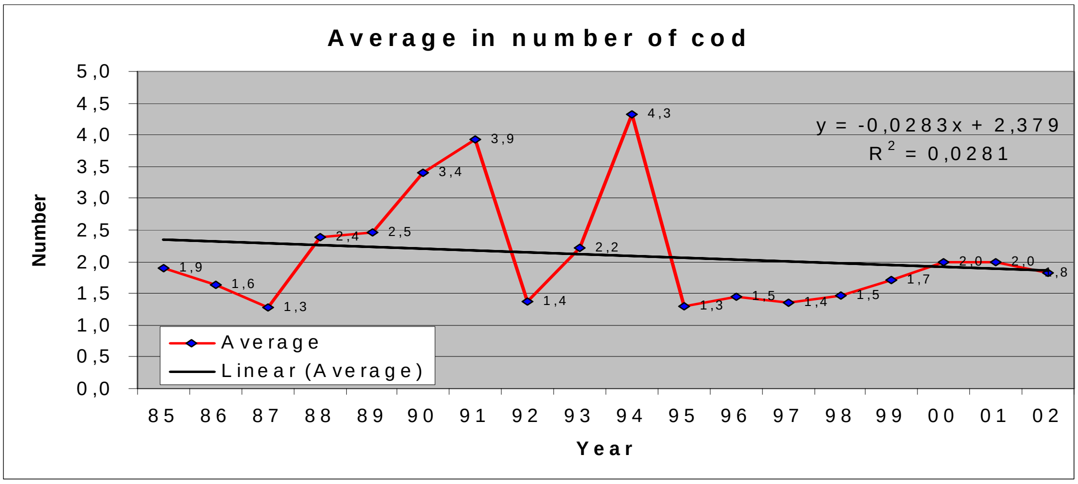

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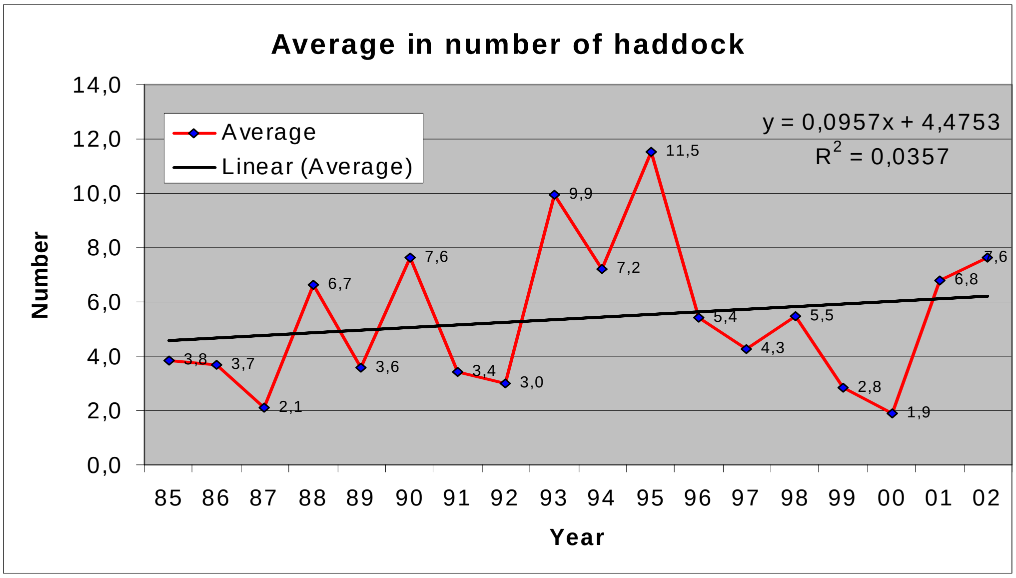

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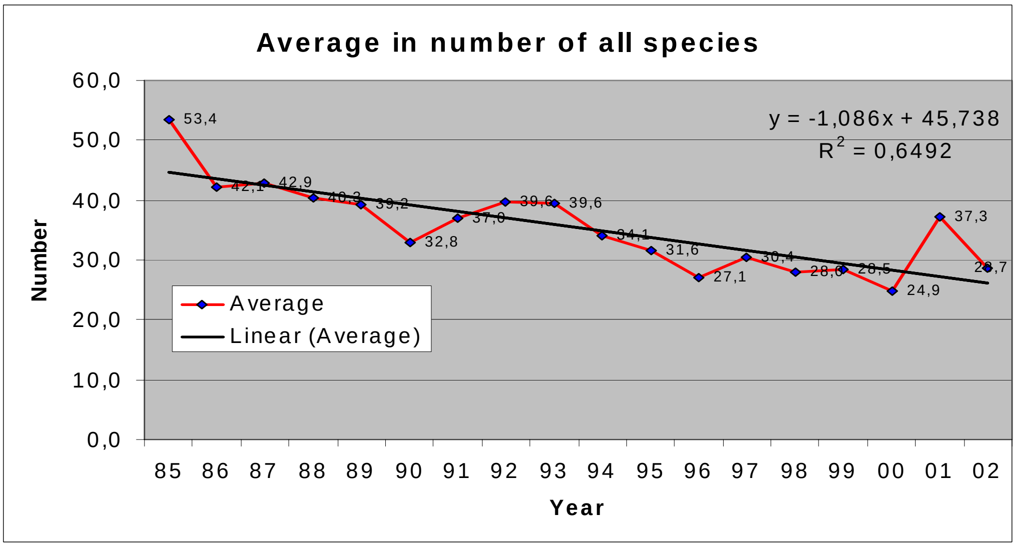


d)

Figure 9: Average number of main species in the MPA west of Iceland.

Figure 9 shows the average number of fish caught in the MPA of some important species and also of all species caught in the MPA. In general, the number of individuals decreased year by year from 1985 to 1994, before the MPA was established. In the years before 1994 the decrease was not clear, but after 1994 the average number of redfish decreased sharply. Like the redfish, some species such as haddock and cod also decreased. However, the decrease was not stable because those species were in small numbers in the MPA (0.2% and 0.8%). All species average number per year in the MPA decreased, especially after 1994. This is the same situation as was reported in the MRI report in the status of marine stocks (MRI 2002). The catch of redfish (*S. marinus and S. mentella*) decreased sharply after 1994 (Figure 4) as the index on fishable stocks of *S. marinus* in the IGS depth decreased sharply between 1984 and 1994. After 1994 the redfish catch increased slightly (Figure 5).

4.2 Changes in the species community in the MPA west of Iceland

4.2.1 Species composition

Table 1 gives an overview of sampling stations within the MPA. Not all stations were sampled every year.

Table 1: Overview of the stations in the MPA west of Iceland.

Year	324-3-12	375-1-11	375-2-1-	376-2-1-	425-3-12	425-4-12	476-1-12	477-2-11	526-3-12	527-2-1-	527-4-11	527-4-12	576-3-13	Grand Total
1985	X	X	X	X	X				X	X	X		X	9
1986	X	X	X	X	X				X	X	X		X	9
1987	X	X		X	X				X	X	X		X	8
1988	X	X	X	X	X				X	X	X		X	9
1989	X	X	X	X	X			X	X	X	X			9
1990	X	X	X	X	X				X		X		X	8
1991	X	X		X	X				X	X	X		X	8
1992	X	X	X	X	X	X			X	X	X		X	10
1993	X	X	X	X	X				X	X	X		X	9
1994	X	X	X	X	X				X	X	X		X	9
1995	X	X		X	X				X	X	X		X	8
1996	X	X		X	X				X	X	X		X	8
1997	X	X		X	X			X	X	X	X		X	9
1998	X	X	X	X	X				X	X	X		X	9
1999		X	X	X	X		X		X	X	X			8
2000	X	X		X	X			X	X	X	X			8
2001	X	X		X	X				X	X	X		X	8
2002	X	X		X	X					X	X	X		7
Total	17	18	10	18	18	1	1	3	17	17	18	1	14	153

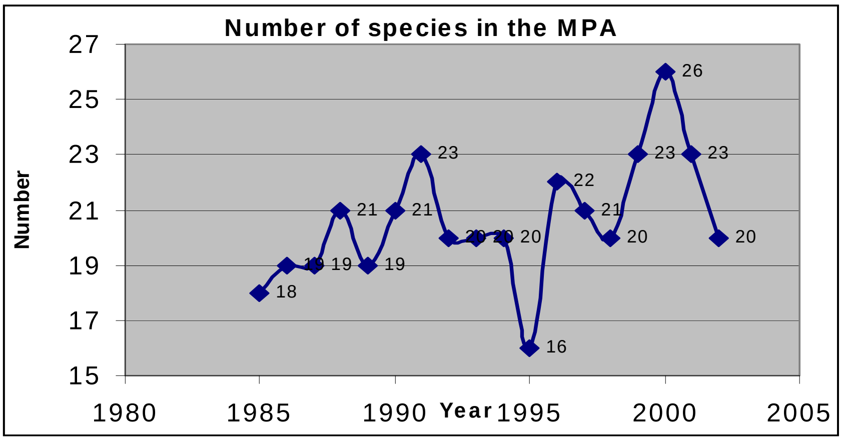
Six stations in which data was collected less than 10 times are omitted from the PRIMER Software Analysis (Stations 375-2-1, 425-4-12, 476-1-12, 477-2-11, 527-4-12 and 324-3-12).

Table 2: Number of stations where species occurred from 1985-2002.

No	English name	Latin name	Number of station where species occurred
1	Atlantic hookear sculpin	*Artediellus atlanticus Jordan & Evermann, 1896*	1
2	Capelin	*Mallotus villosus (Müller, 1776)*	1
3	dab	*Limanda limanda (Linnaeus, 1758)*	1
4	Greenland halibut	*Reinhardtius hippoglossoides (Walbaum, 1792)*	1
5	rabbitfish (rat fish)	*Chimaera monstrosa Linnaeus, 1758*	1
6	skate	*Raja (Dipturus) batis Linnaeus, 1758*	1
7	snake blenny	*Lumpenus lampretaeformis (Walbaum, 1792)*	1
8	spotted snake blenny,	*Leptoclinus maculatus (Fries, 1837)*	1
9	spinetail ray, spinetail skate	*Bathyraja spinicauda (Jensen, 1914)*	1
10	angler, monkfish	*Lophius piscatorius Linnaeus, 1758*	2
11	spurdog, spiny dogfish	*Squalus acanthias Linnaeus, 1758*	2
12	twohorn sculpin	*Icelus bicornis (Reinhardt, 1840)*	2
13	jelly cat, arctic wolffish	*Anarhichas denticulatus Kröyer, 1845*	3
14	moustache sculpin	*Triglops murrayi Günther, 1888*	3
15	deepwater redfish	*Sebastes mentella Travin, 1951 (105)*	4
16	arctic rockling,	*Onogadus argentatus (Reinhardt, 1837)*	7
17	Vahl´s eelpout, checker eelpout	*Lycodes vahli Reinhardt, 1831*	7
18	plaice	*Pleuronectes platessa Linnaeus, 1758*	9
19	round ray, round skate	*Raja (Rajella) fyllae, Lütken, 1888*	9
20	whiting	*Merlangius merlangus (Linnaeus, 1758)*	9
21	lumpsucker, lumpfish	*Cyclopterus lumpus Linnaeus, 1758*	11
22	blue whiting	*Micromesistius poutassou (Risso, 1826)*	12
23	herring, Atlantic herring	*Clupea harengus Linnaeus, 1758*	16
24	witch, witch flounder	*Glyptocephalus cynoglossus (Linnaeus, 1758)*	16
25	blueling, European ling	*Molva dipterygia (Pennant, 1784)*	21
26	halibut, Atlantic halibut	*Hippoglossus hippoglossus (Linnaeus, 1758)*	27
27	megrim	*Lepidorhombus whiffiagonis (Walbaum, 1792)*	36
28	spotted wolffish, leopardfish	*Anarhichas minor Olafsson, 1772*	44
29	greater argentine,	*Argentina silus (Ascanius, 1775)*	47
30	lemon sole	*Microstomus kitt (Walbaum, 1792)*	54
31	Norway pout	*Trisopterus esmarki (Nilsson, 1855)*	67
32	ling	*Molva molva (Linnaeus, 1758)*	72
33	starry ray, thorny skate	*Raja (Amblyraja) radiata Donovan, 1808*	78
34	Norway haddock	*Sebastes viviparus Kröyer, 1845*	81
35	tusk, torsk, cusk	*Brosme brosme (Ascanius, 1772)*	89
36	saith, pollock	*Pollachius virens (Linnaeus, 1758)*	105
37	Atlantic wolffish, catfish	*Anarhichas lupus Linnaeus, 1758*	109
38	cod, Atlantic cod	*Gadus morhua (Linnaeus, 1758)*	109
39	haddock	*Melanogrammus aeglefinus (Linnaeus, 1758)*	112
40	long rough dab	*Hippoglossoides platessoides limandoides (Bloch, 1787)*	118
41	redfish, golden redfish	*Sebastes marinus (Linnaeus, 1758)*	120

Table 2 gives a list of species and their occurrence in the MPA. In total, there were 41 species recorded. Golden redfish was recorded in all 120 stations within the MPA. Other common species were long rough dab, which was recorded at 118 stations, haddock at 112 stations, cod and catfish at 109 stations and pollock at 105 stations.

The number of species increased from 18 in 1995 to 26 species in 2000. The change in the number of species in the MPA includes the environmental condition that the MPA could favour the biological characteristics of species. Before 1994, the number of species did not change much with 18 species in 1985, 23 species in 1991 and 20 species in 1994 (Figure 10).



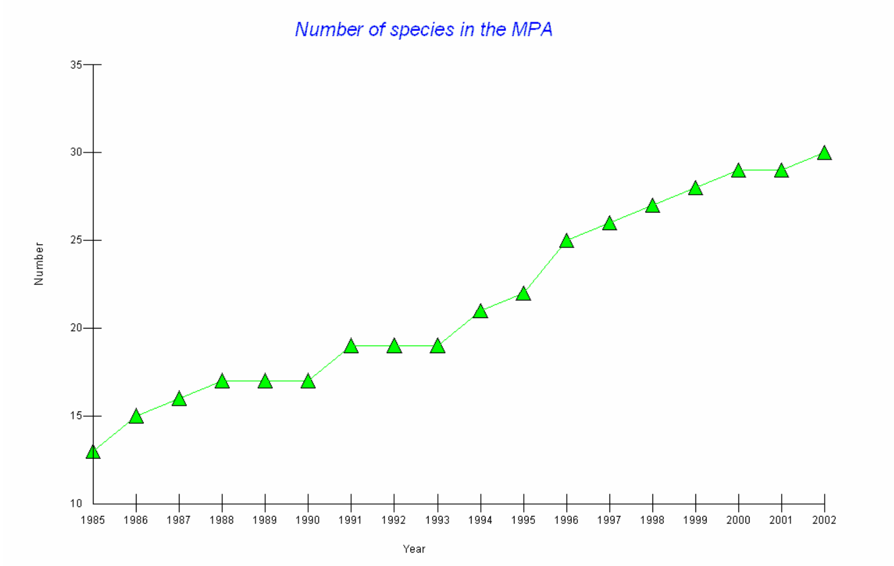


Figure 10: Number of species by year in the MPA.

4.2.2 Analysis of change in the community

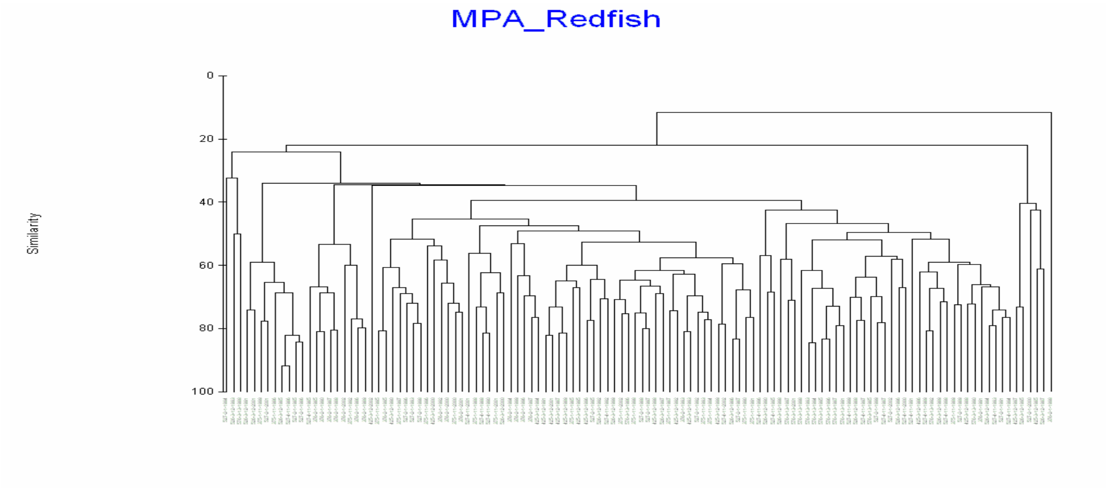


Figure 11: Dendrogram for hierarchical clustering for 120 sites.

Figure 11 shows a dendrogram for hierarchical clustering for each of the 120 samples taken since 1985. The data were square root transformed before the clustering. The data were further regrouped at about 35% similarity level. There was no clear pattern that could be read from the figure although the same indication of a sub-structure was found. Therefore, some factors such as position, depth etc. were looked at and an analysis carried out to see if those factors would clear the clustering. The factors that are considered for the relationship include: sea wave level as an indicator for weather, time of the day, depth and the geographical position. Below are the results of the analysis.

4.2.2.1 a) Configuration in sea wave level factor

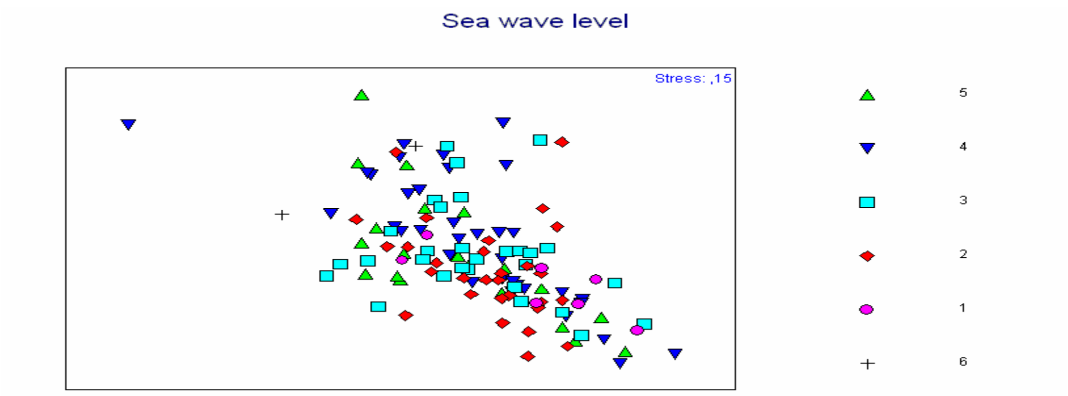


Figure 12: MDS analysis of the sea wave level factor.

Figure 12 is a non-metric multi-dimensional (MDS) plot. The purpose of MDS is to construct a "map" or configuration of the station, in a specified number of dimensions, which attempts to satisfy all the conditions imposed by the rank similarity or dissimilarity matrix, e.g. if station 1 has higher similarity to station 2 than it does to station 3 then station 1 will be placed closer on the map to station 2 than to station 3.

Figure 12 shows MDS analysis for all samples of the wave level factor in the MPA. The sea wave level factor was used to test if the weather could affect sampling. There was no clear significance depending on the weather, which means that the assumption that the weather (sea level) affects the catch composition is rejected. Thus the sea wave level does not seem to affect the abundance of species diversity correlation. A summary of the ANOSIM analysis is given below:

- Sample statistic (Global R): 0,048
- Significance level of sample statistic: 3,3%
- Number of permuted statistics greater than or equal to Global R: 32

4.2.2.2 b) Configuration in the time of day factor

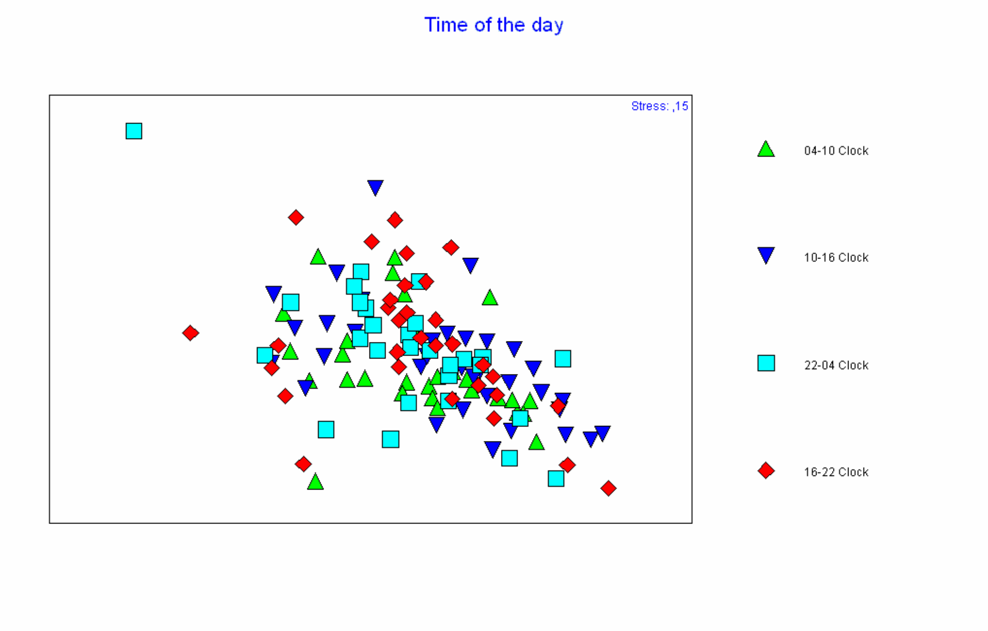


Figure 13: MDS analysis of the time of day factor.

Figure 13 shows an MDS analysis of the time of the day factor in the MPA. The time given is the time of the day (in six hour intervals) when the trawl is launched. As for the weather, the results did not show any indication that the time of the day factor affects the catch and catch composition in the MPA. This factor does not contribute significantly to the change in the marine community. There fore this factor can not be used to assess biodiversity in the MPA, ANOSIM statistic analysis gives the following results:

- Sample statistic (Global R): 0,022
- Significance level of sample statistic: 5,8%
- Number of permuted statistics greater than or equal to Global R: 57.

4.2.2.3 c) Configuration in the sea depth level factor

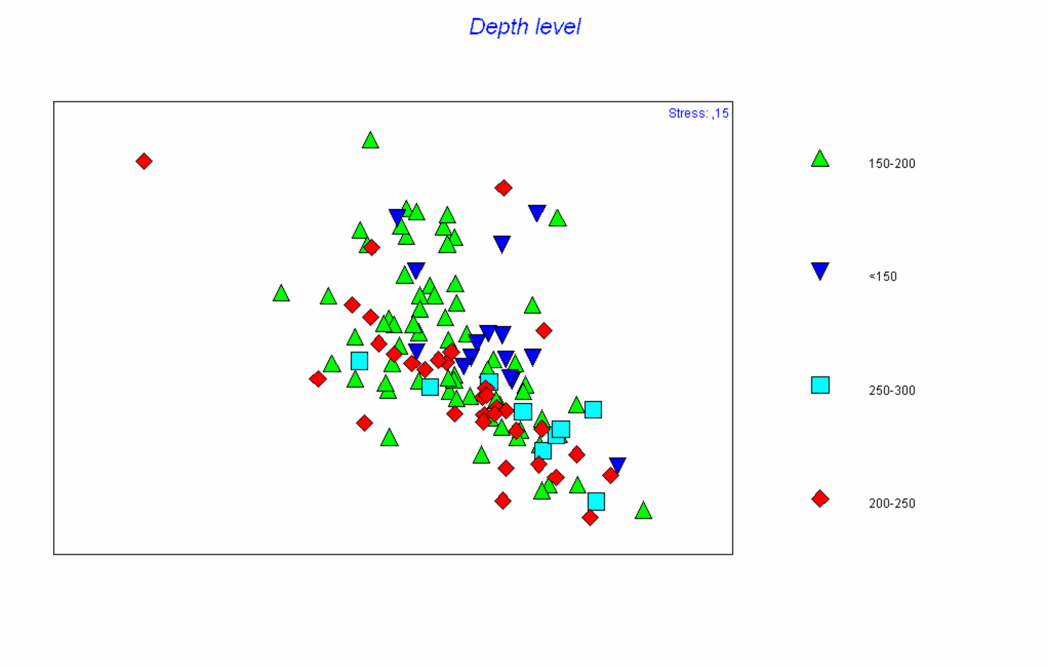


Figure 14: MDS analysis of the depth level factor.

Figure 14 shows an MDS analysis for the depth level factor in the MPA. As before, the results indicate that this factor is not significant:.

- Sample statistic (Global R): 0,042
- Significance level of sample statistic: 15,5%
- Number of permuted statistics greater than or equal to Global R: 154

4.2.2.4 d) Configuration in the geographic position factor

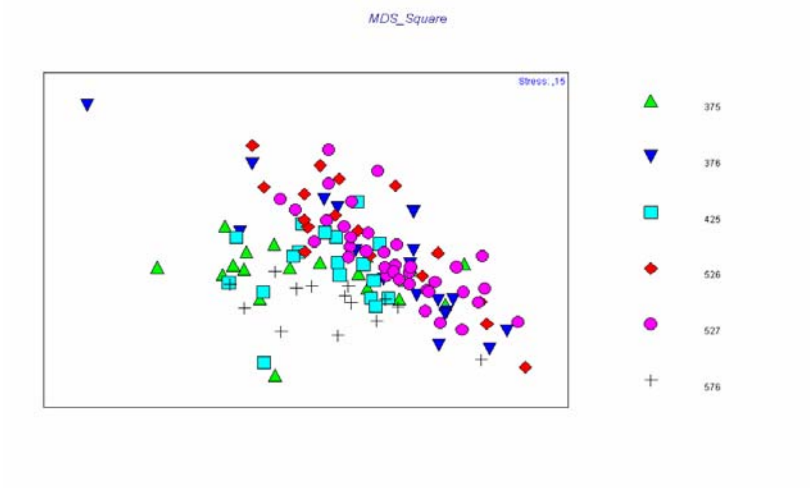


Figure 15: MDS analysis of the geographic position factor in the MPA.

A further MDS analysis using statistical square was conducted. The square factor can represent the area factor. The MDS plot in Figure15 shows squares as different symbols. Square 527 and square 576 which are located in the north of the MPA are different from the each other. However the statistical analysis is not significant:

- Sample statistic (Global R): 0,229
- Significance level of sample statistic: 0,1%
- Number of permuted statistics greater than or equal to Global R: 0

In summary the geographic position factor analysis is not significant.

4.2.2.5 e) Configuration of the southern and northern stations

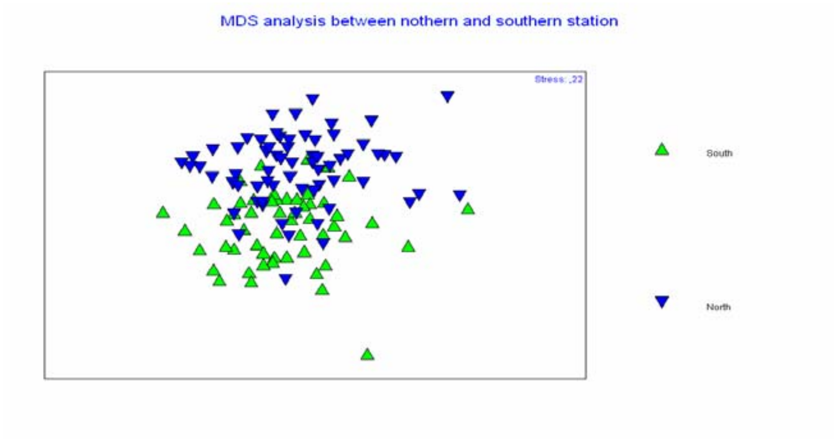


Figure 16: MDS analysis of the group factor in the MPA (north and south stations).

Based on this classification, the data was further divided into two groups, north and south (Figure 16). The MDS plot shows a construction between northern and southern stations. Although visually there seems to be a grouping, the statistical analysis does not show a significant difference between the northern and southern stations:

- Sample statistic (Global R): 0,094
- Significance level of sample statistic: 0,1%
- Number of permuted statistics greater than or equal to Global R: 0

4.2.2.6 f) Comparison of year groups in the MPA

After having rejected detailed analysis of the data with respect to all the factors mentioned above, the whole set of stations within the MPA was pooled by year. The results of the cluster are shown in Figure 17 and an MDS plot based on those results is shown in Figure 18. The MDS plot is based on a threefold separation of the cluster, at around 78% similarity level. The years 1985, 1986, 2001 and 2002 are grouped as A, or the first two years and last two years of the series. Statistical analysis on this clustering also shows this grouping of the years as group B: 1990, 1999, 1996, 1994, 1997, 2000, 1989, and 1998. And years 1992, 1995, 1991, 1993, 1988, and 1987 as group D.

After having carried out an analysis for significance using the factors mentioned earlier, the results showed no significance. A further method was resorted to in order to assess the significance by year. There was some correlation between the years 2001- 2002 when related to 1985-1986.

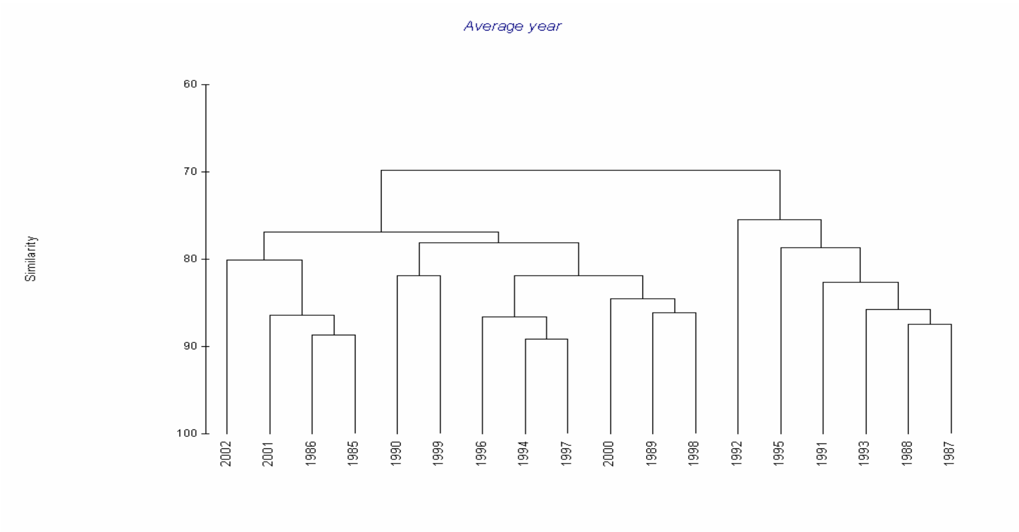


Figure 17: Dendrogram for hierarchical clustering for 18 years.

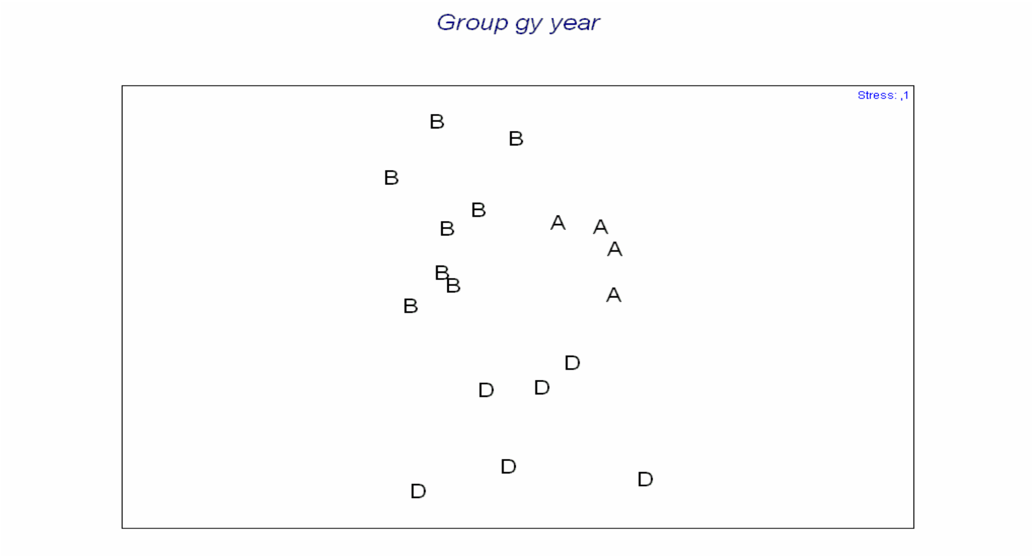


Figure: MDS analysis of the year groups.

The results of a SIMPER analysis of the similarity percentage within each year group identified that the same fish species within each group contributed to the similarity proportion to a large extent. The total within year groups is similar. The main species, which contribute to the similarity, are redfish, haddock and cod. While very few other species were important contributors to year group similarity of distribution. In terms of species contribution, redfish formed over 50% of the total contribution in the similarity within the MPA (Tables 4, 5, 6).

Table 3: ANOSIM analysis pairwise.

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations
D, B	0.85	0.2	3003	999
D, A	0.746	0.5	210	210
B, A	0.572	0.2	495	495

Table 4: Average similarity within group D.

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%
redfish, golden redfish	1643.19	42.67	8.16	53.37
haddock	36.14	5.48	3.08	6.85
saith, pollock	34.54	4.54	1.89	5.68
Norway haddock	29.18	4.49	3.25	5.62
Atlantic wolffish, catfish	12.93	3.70	5.31	4.63
long rough dab	11.88	3.64	7.81	4.55
cod, Atlantic cod	10.51	2.61	3.67	3.26
tusk, torsk, cusk	4.39	2.17	7.87	2.71
starry ray, thorny skate	4.40	2.08	4.77	2.60
greater argentine	48.48	1.69	0.67	2.12

Table 5: Average similarity within group B.

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%
redfish, golden redfish	5946.72	55.48	13.39	68.32
Norway haddock	54.28	4.78	5.00	5.89
haddock	29.80	3.86	4.24	44.75
saith, pollock	52.12	2.63	1.96	3.24
long rough dab	12.62	2.35	3.38	2.89
cod, Atlantic cod	11.08	1.98	4.37	2.44
Atlantic wolffish, catfish	8.60	1.98	3.31	2.44
greater argentine	23.55	1.65	2.68	2.03

Table 6: Average similarity within group A.

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%
redfish, golden redfish	3682.35	45.48	16.88	54.37
Norway pout	268.95	9.61	2.67	11.49
saith, pollock	81.28	5.71	9.57	6.83
greater argentine	80.14	4.03	1.33	4.82
haddock long rough dab	35.45	3.90	6.82	4.66
Norway haddock	33.07	2.94	2.20	3.51
long rough dab	11.36	2.33	13.50	2.79
cod, Atlantic cod	8.96	2.19	10.34	2.62

5 DISCUSSION

The mean length of commercial species in the MPA has been increasing since 1984. This could be attributed to natural conditions, environmental factors, decreased fishing effort, no fishing of juveniles and good conditions for juvenile growth. The time that the MPA has been closed is not long enough (eight years) to show length increases clearly.

The length distribution shows that the numbers have increased in the MPA since the closure took place. The results support theories that have been put forward that the golden redfish moves south as it grows and becomes mature (International Council for the Exploration of the Sea, 2002 report.). This distribution pattern is also supported by mean length distribution in the autumn ground fish survey (MRI 1996). This migration pattern has also been shown in the east Greenland areas (International Council for the Exploration of the Sea, 2002 report.). Therefore the MPA has succeeded in preventing the fishing of juveniles. By doing so, it might also have increased the yield from the stock, reduced discard and other hidden mortality.

These analyses have allowed us, for the first time, to compare directly the diversity of the demurral fish assemblage of the MPA west of Iceland using data collected by beam trawl surveys (IGS). The results show that the contribution was dominated by a few species, which occurred in large numbers and wide distribution. The high level of dominance of contribution by redfish, cod and haddock, and the limited total number of species present, were partly responsible for the generally low diversity of demurral assemblages in the groups, compared to those in the MPA (Figure 18 and Tables 3-5). One of the few species, which helped to differentiate between these populations in the MPA, was the lesser weaver, which occurred in low abundance.

After the three first years it seems there was a stable situation in terms of the number of species in the MPA. After the closure in 1994 there was, on average, about one new species observed every year (Figure 10). One would not expect an immediate increase in the number of species when the MPA was established because the closing time has not been long enough. Until 2000, the number of species had increased but it decreased in 2001 and 2002. However, there has been an important increase in the number of species after the MPA was established. Especially as there are some new species:

- Blue whiting *Micromesistius poutassou* (Risso, 1826)
- Dab *Limanda limanda* (Linnaeus, 1758)
- Angler, monkfish *Lophius piscatorius* (Linnaeus, 1758)
- Skate *Raja (Dipturus) batis* (Linnaeus, 1758)

From the cluster analysis we can see that the two first and the two last years are grouped together. This might indicate that the environment has started to show a reaction to the closure of eight years, although the situation is now at a similar level as it was at the beginning of the series. This is not unexpected, as it is well-known that once the nature has been changed, it takes time before it returns back to it is "virgin" situation (Jameson *et al*. 2002, McIntyre 2001). We don't know what the situation in the area was like before the fishery started. It is known that there was substantial fishing in the area in the 1970s and 1980s. Therefore, it could be concluded that the situation in 1985-1986 is not likely to have been a "virgin" situation. One could therefore conclude from these results that after having been closed for eight years, the first sign of recovery in terms of biodiversity might have started. It will be of great interest to follow these changes in years to come in order to verify the changes that seem to be taking place.

The cluster analyses groups the most recent years together with 1985-1985. This means that since the introduction of the MPA there has been a resurgence of species diversity as opposed to the decline during the early 1990s. This is shown in Figure 17. The species diversity was almost balanced in early 2000 and the mid 1980s. The diversity between the late 1980s and the late 1990s (as seen in Figure 17) was also related. This can be attributed to the juveniles picking up in the late 1990s replacing the decline of the mature stock before the introduction of MPA. The ANOSIM statistic analysis shows that the year affect is significant in the study (R=0,736). Table 3 shows similarity and dissimilarity between years in the MPA. Group D and Group B are very different (R=0.85) and the significance is 0.2%). Group D and Group A are different (R=0.746) and the significance is 0.5%. Group B and Group A are different (R=0.572) and the significance is 0.2%.

6 CONCLUSIONS

1. The mean length of redfish in the MPA decreased from 1985-2002 but from 1994 the mean length increased from 30.5 cm in 1994, 30.9 cm in 1996 and reach 31.8 in 2002.
2. Redfish length distribution indicates that the fish migrates from the MPA when it reaches a fishable size.
3. The average catch number decreased sharply after the MPA was established.
4. The number of species in the MPA increased from 16 species in 1995 to 26 species in 2000.
5. Since the MPA was established eight years ago the community has been changing. For example in terms of: mean length, length distribution, average of catch number and number of species. The situation in 2001 and 2002 is very similar to the situation in 1985 and 1986.
6. Although the MPA in Iceland and MPAs in Vietnam are different this project is useful in assessing the MPAs in Vietnam.

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