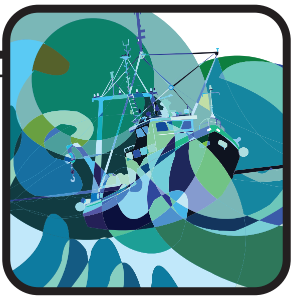

CHAPTER 8: 'In Cod we trust':

trends in gadoid fisheries in Iceland 1929–1996

CHAPTER 8. 'IN COD WE TRUST': TRENDS IN COD AND GADOID FISHERIES IN ICELAND 1929-1996

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ABSTRACT

Iceland's fishing resources have played a major role in the economy of fishing nations around the North Sea in the 20th century and before. While the decline in total landings from Icelandic waters started after Iceland expanded its EEZ in 1958, the fishing effort of the Belgian fleet continued to increase until a peak was reached in 1963. Historical data on Belgian commercial fisheries landings and fishing effort include information on vessel class and fishing rectangle. The results document the Belgian gadoid fisheries in Icelandic waters from 1929-1995 and argue that the decline in the Iceland cod stock was visible at different levels before the foreign fleets were excluded from Icelands' expanded EEZ in 1975; the decrease in the proportional importance of cod in the overall landings, the 75% decrease in the LPUE (1946-1983), the decline in the proportion of 'large' fishes, and finally the decline or shift in the definition of a 'large' specimen.

Keywords: LPUE; Historical reference; Iceland; Belgium; Atlantic cod; large fish

8.1 Introduction

Iceland and its historical importance as fishing ground

The rich waters around Iceland have sustained Icelandic and foreign nations' fisheries for gadoids (e.g. haddock, cod, saithe, hake, and ling) for many centuries (Palmadottir 1989, Jones 2000, Valtysson 2001). The Icelandic cod is one of the most important economic species in Icelandic waters and is distributed along depth gradients of 50-200m. Spawning takes place in late winter mainly off the southwestern coast, although smaller spawning components were observed in other areas (ICES Advice 2012b). At the end of World War II (1939-1945), the English, Scottish, French and German fishers returned to the rich Iceland fishing areas.

In 1950 Iceland extended the boundary of its territorial waters from 3 nautical miles (nm) to 4 nm from the coastline in the northern territories and prohibited all trawling, *Danish seine* (including Icelandic) and foreign herring fisheries within this Exclusive Economic Zone EEZ. In 1952 the 4 nm was extended to the entire area of Iceland (Valtysson 2001). There was no objection to this regulation on behalf of the foreign fleet until in 1958 the EEZ was extended from 4 nm to 12 nm because this second extension restricted their access to the major fishing grounds. The British-Icelandic conflict arising from this new regulation lasted until 1961 and is known as the first modern 'cod war' (Valtysson 2001). In 1972 -in part fuelled by the concern over the state of the main fish stocks- the boundaries of the EEZ were extended, again, to 50 nm and finally to 200 nm in 1975 (the last modern cod war). The British fleet left the Icelandic waters in 1976, followed by the West German fleet in 1977. However, Belgian, Faroese and Norwegian boats were allowed to continue fishing in the EEZ (ICES Fishstat). Similar to the cod stocks in the northwest Atlantic which showed first signs of overfishing in the late 1950s and collapsed in the 1970s (Kenneth et al. 2005), the spawning stock biomass SSB of Icelandic cod reached a historic low in the 1970s (Figure 8.1., ICES Advice 2012b).

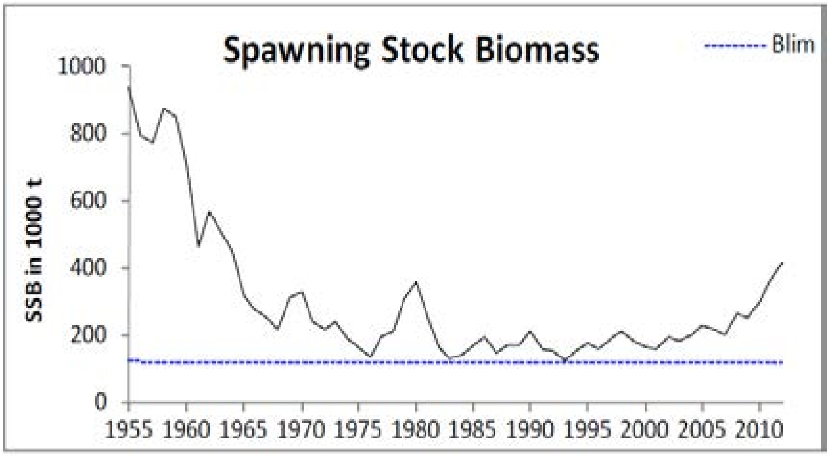

Figure 8.1.: Cod in Division Va (Icelandic cod). Spawning Stock Biomass SSB (weights in thousand tonnes).

In spite of the great economic importance of cod and other gadoid species for Iceland and the foreign commercial fleets fishing in Icelandic waters in the first half of the 20th century, little information is available on the composition of cod and other gadoid landings, on the fishing effort, vessel type and spatial dynamics of the fleet. Estimates of biomass, recruitment, landings and fishing mortality of Icelandic cod are available from 1955 onwards (for other gadoids from the 1970s), but earlier information is scarce or unavailable. The SSB of Icelandic cod is now increasing and at its highest value since decades, while fishing mortality is currently at a historical low and believed to be below safe limits (F_{lim}). Historical information on commercial fishing activities can provide valuable information to reconstruct the evolution for the earlier decades and serve as a reference for other species' restoration and management plans.

DATA AND INFORMATION ON ICELAND (COD) FISHERIES DURING THE 20TH CENTURY

In spite of its historic and economic importance, the data on Icelandic fishing in the early 20th century is scarce. The Iceland Marine Research Institute (MRI) collected scientific survey data on cod and other species, on a continuous basis since 1928. In 1995 a major effort was initiated to recover this historical data and make it available digitally. British survey vessels conducted research in Icelandic waters in the 1950s and 1960s (Goodwin et al. 2001). The Danish public record office holds ca. 20 logbooks from scientific surveys from 1906 to 1920 with information on location and catches of species such as cod and halibut (ICES 2008).
Historical landings of commercial fishing from the Icelandic waters are available from 1903-1949 in the ICES *Bulletins Statistiques*, although incomplete (not all species not all ports/countries) and from 1950 available in a digital format (ICES Fishstat). Data on the Icelandic fisheries (effort, catch, landings, and catch by fleet, season, month and port) are available from the MRI in printed format from 1957 although reporting format is inconsistent and prior to the WWII there is no detailed data on fishing activity by the Icelandic fleet (ICES 2008). Engelhard (2005) inventoried a set of archived maps from the series 'British Sea Fisheries Statistical charts' which also refer to catch and effort in Icelandic waters by the English fleet and by statistical squares. This series of maps gives unique fine-scale information on geographical distribution of the foreign fishers in Icelandic waters during the first years of the 20th century (ICES 2008).

From ICES stock assessments, landings and fishing mortality, total and spawning stock biomass and recruitment are available for the Icelandic cod stock from 1955 onwards, for other species (e.g. haddock, saithe) time series go back as far as 1979 (ICES Advice 2012b). The importance of historical information in current management issues has been evidenced by, e.g., the documented large-scale migration of cod originating from West and East Greenland stocks into Icelandic waters (Harden Jones 1968, Schopka 1993) affecting the stock abundance at Iceland. In the past, low weights-at-age of cod have been related to a low biomass of capelin linked to hydrographical changes in Icelandic waters, and historical time-series of landings of haddock supported the hypothesis of the positive effect of increased water temperatures on the stock biomass of haddock in Icelandic waters (ICES 2012b).
After Iceland extended its EEZ to 50 nm (1972) and later to 200 nm (1975), respectively 19 and 12 Belgian vessels were permitted to continue fishing under the condition of a phase-out. In 1995, the last Belgian trawler stopped fishing in Iceland. An effort was conducted to recover historical fisheries data from the Belgian fisheries (HiFiData) including detailed statistics collected from its fleet operating in Icelandic waters between 1929 and 1995 (Lescrauwaet et al. 2010a). The data presented here add detailed spatio-temporal information on trends in fisheries by the foreign fleet, for a period for which limited information is available.

8.2. METHODS AND MATERIALS

Data on fishing effort and landings by Belgian commercial fisheries in Icelandic waters (fishing area Va) were recorded between 1946 and 1983, while general data on landings are available from 1929 (incomplete data from 1905). The data related to fishing effort include, per year, per month, per type of fisheries and per vessel class: the number of vessels, the number of fishing trips, number of days at sea, number of days fishing, landings (tonnes, t), value of landings (Belgian francs BEF), hours at sea, hours spent fishing, HP (Horsepower or *paardenkracht PK*) *hours at sea, HP*hours fishing and since 1972 also Gross tonnage (GT)*hours at sea and GT*hours fishing. From 1956 until 1983 the monthly reported data on landings and LPUE are spatially explicit by rectangles (Figure 8.2.). These rectangles are spatial aggregations of the ICES statistical rectangles that are currently in use. The reporting formats cover 19 rectangles numbered 1201-1219, although data were only reported for rectangles 1201-1204, 1206, 1210-2014 and 2016-1219 (no data for numbers 1205, 1207-1209 and 1215). Additionally these monthly data were reported by vessel class and by rectangle between 1961 and 1963. Fishing effort (PK * hours fishing or PKHF) after the 1970s was mainly concentrated in rectangles 1212, 1216, 1214 and 1211 in the southern and western part of the island (Figure 8.2.). Before the 1970s also 1202 to the north and 1204 to the east were important rectangles. Based on these historical data for Belgium, estimates of LPUE by rectangle were calculated and monthly composition of the landings was obtained.

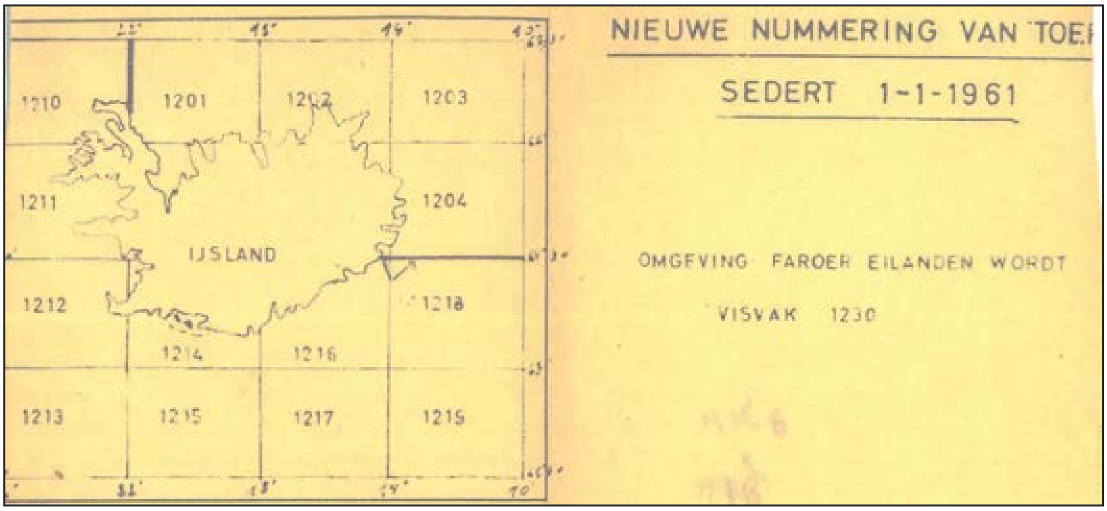

Figure 8.2.: Fishing area Iceland (Va) and its rectangles 1201-1219. To the right of the map, says: *'New numbering operational as from 1/1/1961'* and *'Area of Faroer Islands becomes rectangle number 1230'*. Map recovered from the archives of the Fisheries Service- Flemish Government.

For the most important commercial species between 1929 and 1981 (cod, haddock, hake, brill, plaice), monthly landings were also reported by size class (small, medium, large) or size categories (1 to 5). The data on size classes are available from 1929-1933 on an annual basis and from 1947 to 1981 on a monthly basis. The boundaries of classes are species-specific, and these boundaries change as time progresses (Table 8.1.). Metadata on these class boundaries are scarce, but available for a number of anchor points 1909, 1947 and 1972 (Table 8.1.). For cod, size class boundaries are based on weight (kg): whereas 'large' specimens were classified as such if >8kg in 1909, a cod in 1947 would be classified as 'large' if weighing >5kg, and in 1972 this boundary was lowered to >4kg, with an additional class for 'largest' cod >7kg. Similarly, 'medium' sized and 'small' cod have had decreasing class boundaries. In terms of length classes, a cod was classified as 'large' if >95cm in 1909, and if >84cm in 1954.

Table 8.1.: Weight class boundaries for cod landings based on weight (kg); anchor points 1909, 1949-1959 and 1970. Based on metadata collected from different data sources by VLIZ

Year	**Weight Class**											
Cod 1909	**Large**									large		
	Medium						**medium**					
	Small					Small						
Cod 1947	**Large**						large					
	Medium				medium							
	Small			small								
Cod 1972	**Size 1**								largest			
	Size 2					Large						
	Size 3			medium								
	Size 4		small									
	Size 5	smallest										
weight class (kg)		**0-<1kg**	**1- <2**	**2- <3**	**3- <4**	**4- <5**	**5- <6**	**6- <7**	**7- <8**	**8- <9**	**9-<10**	**+10kg**

Similarly decreasing class boundaries were described for haddock (*Melanogrammus aeglefinus*). In 1947, 'large' specimens were >2kg, medium between 0.75- <2kg and small under 0.75kg. In 1970 'largest' is >1kg, large is 0.4-1kg, medium 0.25 to <0.4 kg and small <0.25kg. The data for cod and haddock were included in the present analysis because of their importance in the Iceland landings. The data for the other species are available for further analysis. The data were digitized, quality controlled, standardized and integrated. For more information regarding the QC and integration the authors refer to previous work (Lescrauwaet et al. 2010b).

Data were reported by vessel class between 1959-1983, with vessel classes 4-7 reported for Iceland fisheries. Vessel class 4 comprised medium-sized trawlers with motor engine power between 240 and 349 Dutch Horse power HP. Vessel classes 5 and 6 are large-sized trawlers with engine power between 350-499 HP and >500HP respectively. Vessel class 7, which disappeared from the Iceland fisheries reporting after 1963, refers to steam-engine powered vessels >439 and up to 800 indicative HP. The classes 4-7 are respectively referred to as 'medium' (4), 'large' (5), 'large >500HP' (6) and 'steam' (7) trawlers. The HP were not converted to kilowatt (kW) because it is uncertain whether the reported HP refer to Dutch horsepower (736 Watt) or - though unlikely – the English HP (745,7 Watt).

To test whether the LPUE was mainly determined by factors other than changes in the fish stocks, the monthly data for vessel class and for fishing rectangles were compared over the period 1962 and 1963, when all vessel classes contributed to effort and landings. A univariate PERMANOVA test Type III using a 2-factor model design (factors: 'fishing rectangle' (re), and 'vessel class' (ty) with Euclidean distance to calculate resemblance, was conducted on the untreated data, in PERMANOVA+ for PRIMER. The main factor test was followed by an a posteriori pair-wise comparison for 'rectangles' for each 'vessel class' with a Monte Carlo (MC) permutation of the data.

8.3. Results

Trends in landings of (cod) fisheries in Iceland waters, Belgium sea fisheries (1929-today)

Fisheries data collected from 1929 until today illustrate the sharp increase of the total landings by Belgian vessels after World War II (Lescrauwaet et al. 2010a). This sharp increase was to a large extent explained by the fisheries in Iceland which increased steeply after WWII to reach a maximum of 23,260 t in 1955 (Figure 8.3.).

The Iceland Sea has provided approximately 502,800 t of reported landings of fish products (dead weight) for the Belgian fisheries industry (Figure 8.3.) and was third in importance as fishing area for the Belgian fisheries throughout the 20th century. The Iceland Sea has been predominantly a provider of gadoids. Cod (*Gadus morhua*, 29%) and saithe (*Pollachius virens,* 17%) were important species throughout this period. The landings of cod decreased after the last peak in landings in 1963. While haddock (*Melanogrammus aeglefinus*, 16%) was important until 1963, redfish (*Sebastes* sp., 15%) became an important component of the landings from 1964 onwards. Together these 4 species sum 77% of all landings from this area over the entire reported period. Pelagic species (mainly herring in the early 1980's) and shellfish are minor components of the landings. The Iceland waters were also fished for Norway lobster (*Nephrops norvegicus*) by Belgian vessels.

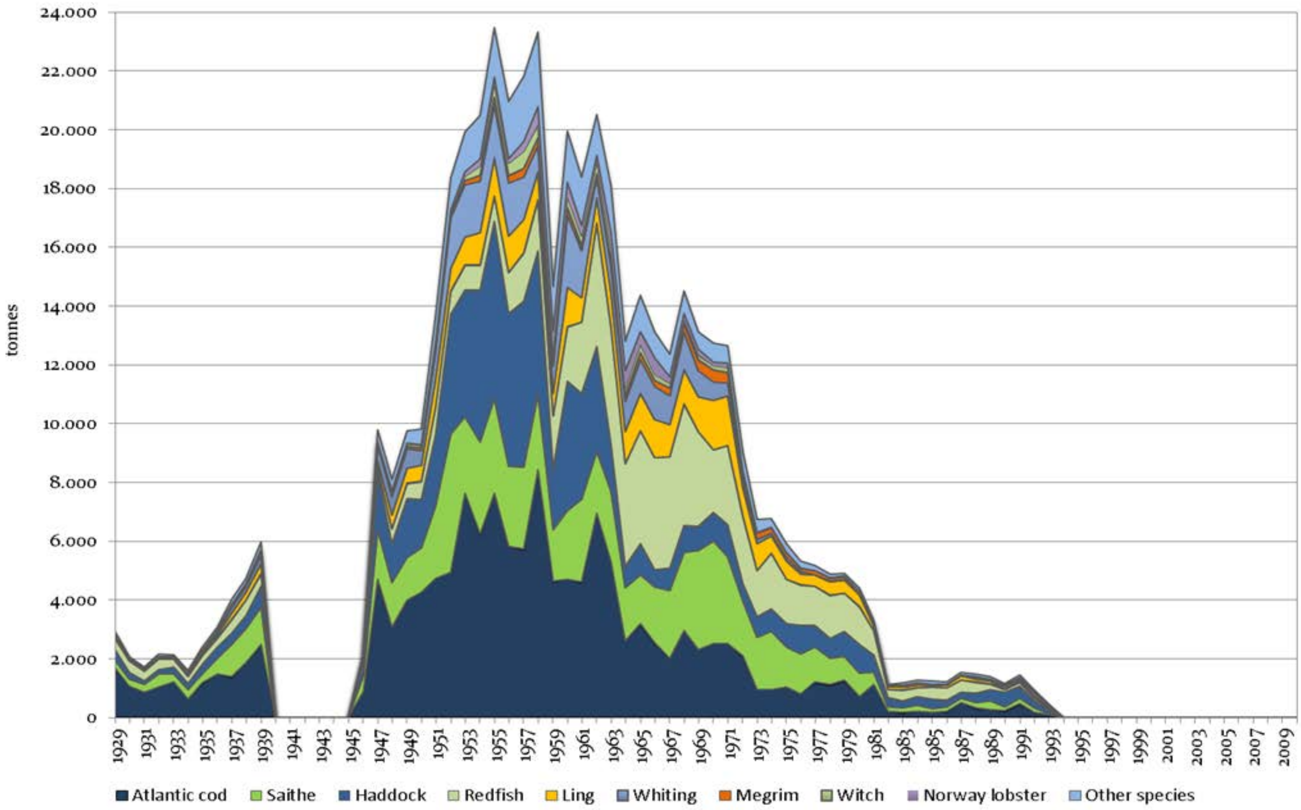

Figure 8.3.: Landings (t) by Belgian sea fisheries from Icelandic waters in 1929-2010; landings by species for the 9 most important species, remaining species were aggregated as 'other species' for visualization purposes.

Trends in fishing effort and LPUE in Icelandic waters for Belgian fisheries (1946 - 1983)

Data on the landings and the effort of commercial otter trawl fisheries (fishery type I) by vessel class of Belgium in Icelandic waters were available from 1946 to 1983 and reported by rectangle from 1959. The fishing effort (PK*hours fishing, PKHF) and landings per unit of effort LPUE (kg per PKHF) were reconstructed for the period 1946 to 1983 for trawl fisheries (all vessel classes aggregated) (Figure 8.4.). Fishing effort ranged between 5 and 45 million PKHF, with a peak in the early 1960s at a time when total landings from the Icelandic waters were already in decline (see also Figure 8.3.). It must be noted however that fishing effort may have reached up to 130 million PKFH per year in the first half of the 1950s (Chapter 4, Figure 4.5. Lower panel).

The total fishing effort increased from approximately 11 million PKHF in the period 1947-1950; from 1956 it further increased from 30 million to a maximum of 45 million PKHF in 1963. The latter is entirely explained by the increase in the fishing effort of large (>500HP) trawlers. At that time, the Belgian fleet conducted 820 fishing trips/year to Iceland summing a total of 16,000 days at sea of which 8,500 fishing. Total fishing effort then gradually decreased from 45 to 5 million PKFH. In particular the decrease after 1971 corresponds to the 'phase-out' for Belgian vessels allowed fishing within Iceland's EEZ.

LPUE values decreased from 0.95 kg per PKHF in 1946 to 0.24kg per PKHF in 1983. A few temporary peaks in landings of cod, haddock and redfish (1965 and 1968) combined with a sudden decline in effort (PKHF) in these years, explain the temporary increase in LPUE in the late 1960s (Figure 8.4.). The overall decrease in LPUE between 1953 and 1963 is explained by the decrease in obtained landings, since overall effort is still on the rise in that period.

The reconstruction suggests that LPUE - a measure used to indicate relative efficiency of fisheries and often used as a proxy for relative abundance of fish and the state of fish stocks - has decreased by 75% over a period of 4 decades (1946-1983). The polynomial trend regression (4 orders – 'Poly LPUE', Fig. 8.4.) underlines the overall declining trend in LPUE.

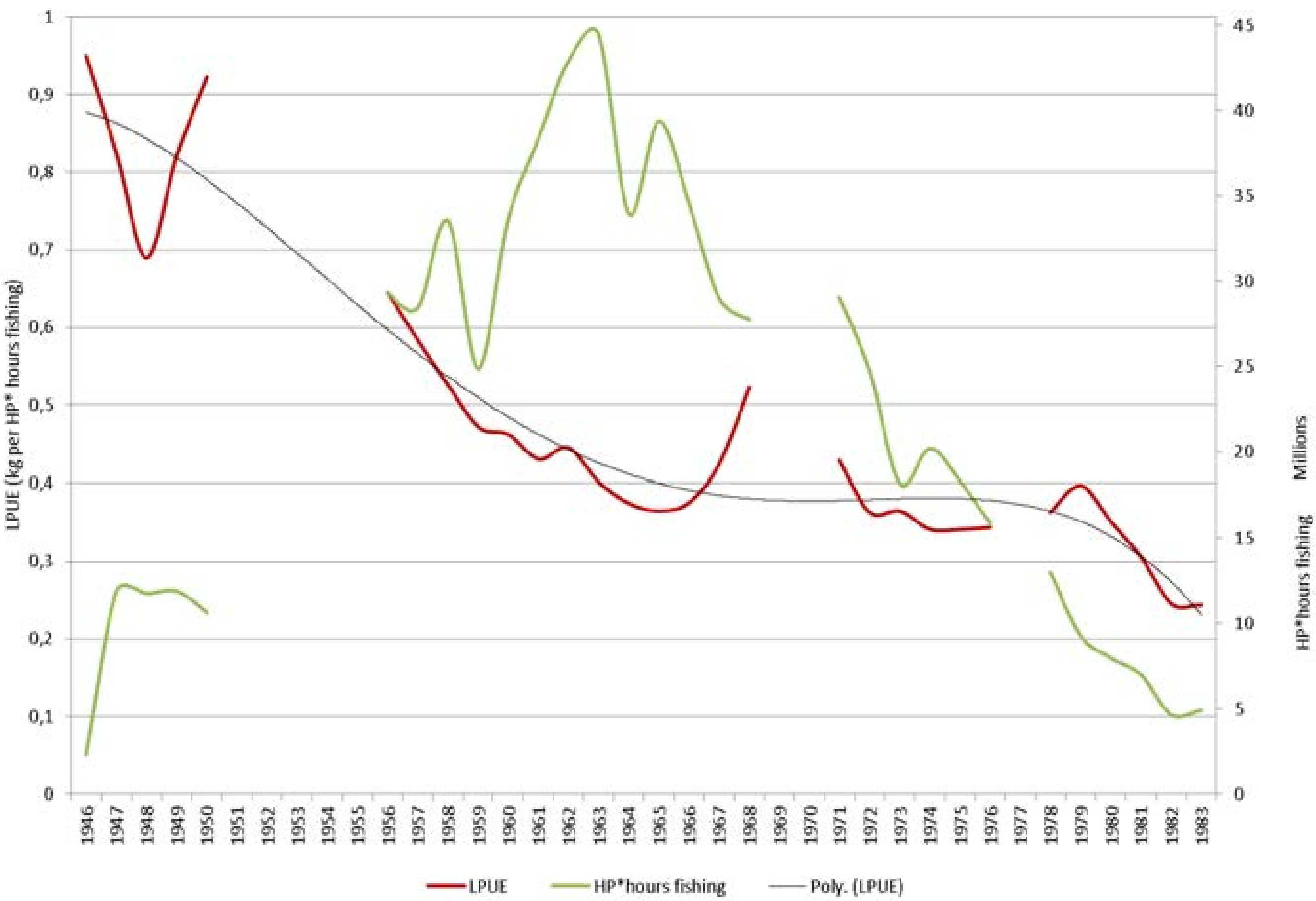

Figure 8.4.: Reconstructed effort (PK*hours fishing, PKHF) and cod landings per unit of effort LPUE (kg per PKHF) and the polynomial regression LPUE (Poly LPUE) from 1946 to 1983 aggregated for all rectangles 1201-1219 and all trawler classes, Belgian fisheries in Iceland.

However, the index of LPUE must be considered with care if interpreted as a measure of relative abundance of fish stocks, and a number of conditions must be met: the index must be used in the context of a particular fishery, fishing area, vessel class and fishing gear. Fishing potential must always be used to a maximum, catchability is to remain constant or increasing as a consequence of increasing technological improvements, the proportion of the catch reported as landings should be constant and market prices should not be the main drivers for decisions leading to decreases in the total reporting. Also, it is important to take into account technological improvements that affect fishing efficiency over time. To test whether these assumptions were met in the LPUE dataset, a separate analysis was conducted for vessel class, fishing rectangle, and species composition.

VESSEL CLASS
Over time, vessel classes with a lower LPUE could have become proportionally more important, therefore explaining the observed changes in LPUE. We therefore statistically compared LPUE values between vessel classes. The monthly data by vessel class (available for 1960-1967) were compared over the period 1962 and 1963, when all vessel classes contributed to effort and landings. PERMANOVA test showed that LPUE of medium-sized and steam-trawlers are similar (p>0.05) and have a significantly higher LPUE than those of the large trawlers (class 5 and 6).

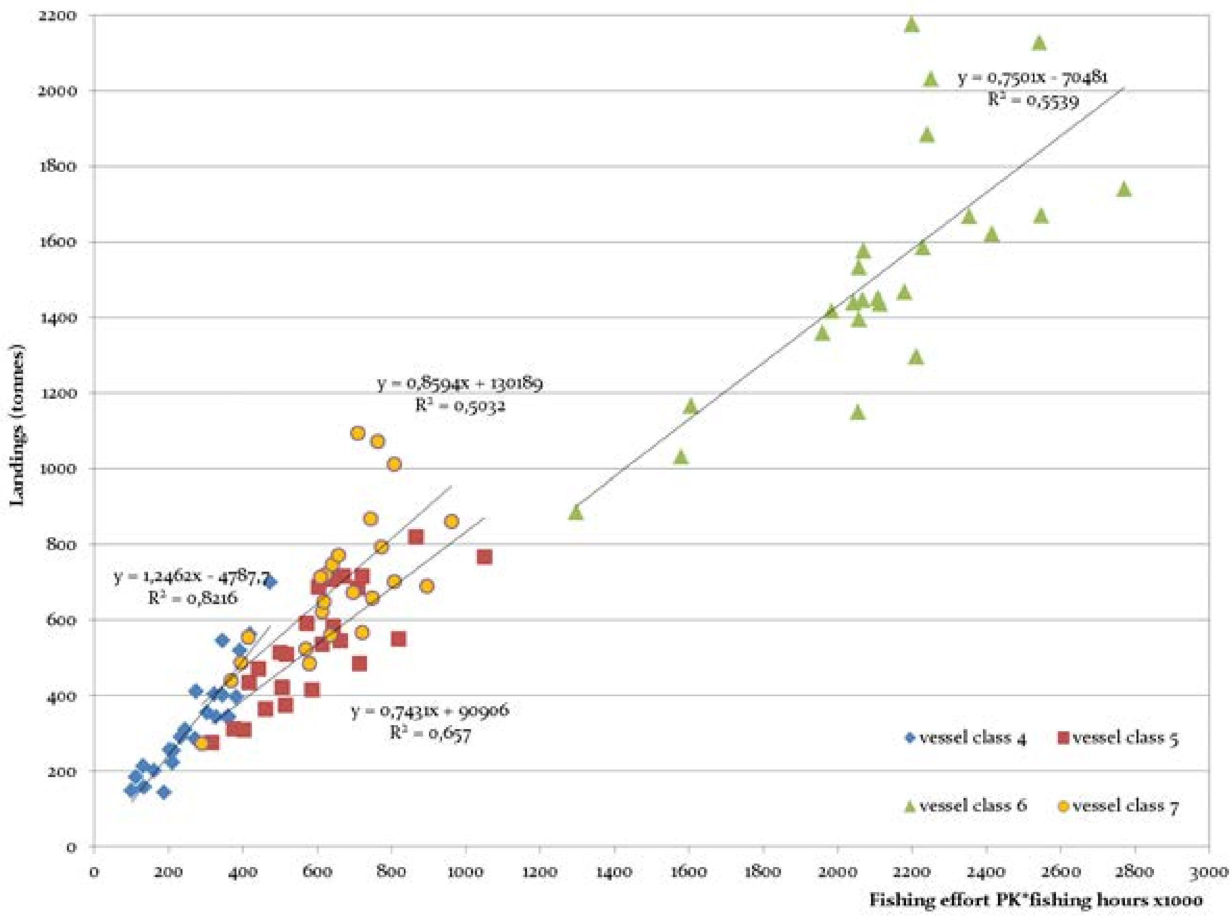

Figure 8.5.: Reconstructed effort (PK*hours fishing, PKHF, x-axis) and landings (kg, y-axis) for 1962-1963, by vessel class , aggregated for all rectangles 1201-1219, Belgian fisheries in Iceland.

Steam-trawlers represent on average 15% of all fishing effort in 1960-1963 however, this class stopped participating after the peak in effort in 1963. Medium- and particularly the large trawlers (class 5) also gradually phase-out from 30% to less than 10%. Large (>500HP) trawlers are the dominant class throughout the period 1960-1983. However, even a simulation of a transition from a 100% fishing effort by vessel class with the highest LPUE to a 100% fishing effort by a vessel class with lowest LPUE could not explain the observed decline in LPUE.

As a conclusion, the data do not seem to support the hypothesis that observed changes in LPUE were due to change in proportional importance of vessel classes.
Although there is no data on vessel class for the period 1946-1960 in Iceland fisheries, the detailed reconstruction of the Belgian fleet dynamics (Lescrauwaet et al. 2012) showed that the maximum in steam-powered vessels occurred in the 1920s. Between 1947 and 1950 less than 20 steam-powered vessels remained,

and between 1950 and 1960 this number decreased to around 5-6 steam trawlers. The data on average GT however show that it were particularly the larger steam-trawlers that remained operational, and it were the smaller steam-trawlers that were taken out of the fleet.

Fishing rectangles

Monthly data on fishing effort (PKHF) by fishing rectangle is available from 1956-1983. Fishing effort was also reported by vessel class and by rectangle between 1961 and 1963. After the 1970s, fishing effort was mainly concentrated in rectangles 1212, 1216, 1214 and 1211 in the southern and western part of the island (Figure 8.2.). Before the 1970s also 1202 to the north and 1204 to the east were important rectangles. Interestingly the rectangles 1213-1215-1217-1219 that are located at further distance from the southern coastline of Iceland have not been of particular importance throughout the time-series, also not after the EEZ of 50nm (1972) and 200nm (1975) were declared by Iceland. This suggests that the movements of the Belgian fleet were not significantly affected by the new Icelandic EEZ regulations, in terms of access of foreign vessels to Icelandic fishing areas.

The overall results of the PERMANOVA test confirm that the observed differences in LPUE between fishing rectangles are co-determined by 'vessel class'. The main factor test was followed by an a posteriori pair-wise comparison for 'rectangles' for each 'vessel class' with a Monte Carlo (MC) permutation. The results of this analysis suggest that significant differences may exist in LPUE between fishing rectangles, for the medium-sized and steam-trawlers. However, for the medium-sized and large (>500HP) trawlers there are no significant differences in LPUE between fishing rectangles. The large trawlers (>500HP) represent the dominant vessel class in terms of number, in fishing effort and in landings - Therefore, the analysis does not support the hypothesis that a change in fishing rectangles explains for the decline observed in LPUE observed (Figure 8.4.). The data by rectangle presented here provide valuable information to compare fishing activities and LPUE between rectangles. However, the data can not distinguish for the effects of environmental factors (e.g. depth, currents, temperature, sediment type).that may occur within rectangles and influence LPUE, as a consequence of spatial shifts in the core area of fishing activities of the fleet within rectangles.

Fishing gear, Species composition

The minimum allowed mesh size for groundfish and midwater trawls in Iceland was increased from 110 mm in 1954, to 120 mm in 1963, 135 mm in 1976 and finally to 155 mm in 1977, the largest minimum mesh size in the North Atlantic (Gilis 1957, Halliday and Pinhorn 1996). Trawling with 135 mm is however still allowed in some areas in the south, mainly for redfish (ICES 2012). The increase in mesh size - under unchanged conditions in the population structure – is expected to increase or at least not to decrease the average size/weight of specimens in catch.

Although selectivity data are not available for the period, area and gear under study, it must be noted that Belgian fisheries in Iceland have targeted cod, whereas the other species were regarded as bycatch. This is sustained by the significantly higher market value of cod compared to the other species landed (HiFiDatabase, VLIZ 2009). Changes in the species composition of the landings may indicate a change in fishing gear, fishing technique, targeted species or environmental changes.

From the monthly data on landings by species, there is a clear shift with increased catches of redfish during the mid 1960s, while the landings of cod and haddock decreased. Whereas the pattern in landings of redfish followed that of cod in e.g. 1961-1962 (high in summer with peaks in June-August, and low in winter), the landings in 1966-1967 in contrast show clear peaks in redfish catches in March-April and September-October while the much decreased landings of cod remain highest in June-August. This suggests that a targeted and seasonal fishery for redfish occurred from the second half of the sixties. Although it remains unclear whether this shift is due to changes in seasonal patterns in abundance of cod in Iceland, or whether other (environmental) variables influenced this shift, it probably did not correspond to a market-driven fishing strategy as fishermen received on average 3 times higher value for Iceland cod than for Iceland redfish in the Belgian market in the 1960s (HiFiDatabase, VLIZ 2009).

TRENDS IN PROPORTION OF LARGE SPECIMENS IN LANDINGS OF COD AND HADDOCK IN ICELAND WATERS (1947-1971)

Data on landings by weight classes for cod and haddock from Belgian commercial fisheries in Icelandic waters were collected for 1929-1933, 1947-1971 and 1972-1981. Different boundaries were applied to the categories 'small', 'medium' and 'large' over these 3 periods. After 1972, a system of 5 size classes was implemented for cod. The 'downsizing' of the class boundaries (Fig. 8.6. and text boxes, Table 8.1.) is an example of what Pauly (1995) identified as 'shifting baselines'. Although the weight classes are too broad to detect trends over shorter periods, the breaks generated in the time-series when class boundaries change (i.e. 1947 and 1972) allow drawing some conclusions related to the second period 1947-1971, and in particular related to the 'large' class. Firstly, what was considered a 'medium' weight cod (5kg-8kg) before 1947 was classified as 'large' (>5kg) after 1947. Although in 1947 approximately 83% of the cod landings were classified as 'large', we could presume that at the beginning of this period 1947-1971 approximately 30% of the this large cod was actually >8kg. Over the second period, the proportion of cod classified as 'large' (>5kg) decreased from 85% in 1947 to 35% in 1971. However, from the class boundaries in 1972, we may conclude that by 1971 hardly any cod was >7kg. The observed trends for the period 1929-1981 (Fig. 8.6.) are based on commercial catches and confirm the SSB estimations based on scientific surveys available from 1955 (Fig. 8.1.)..

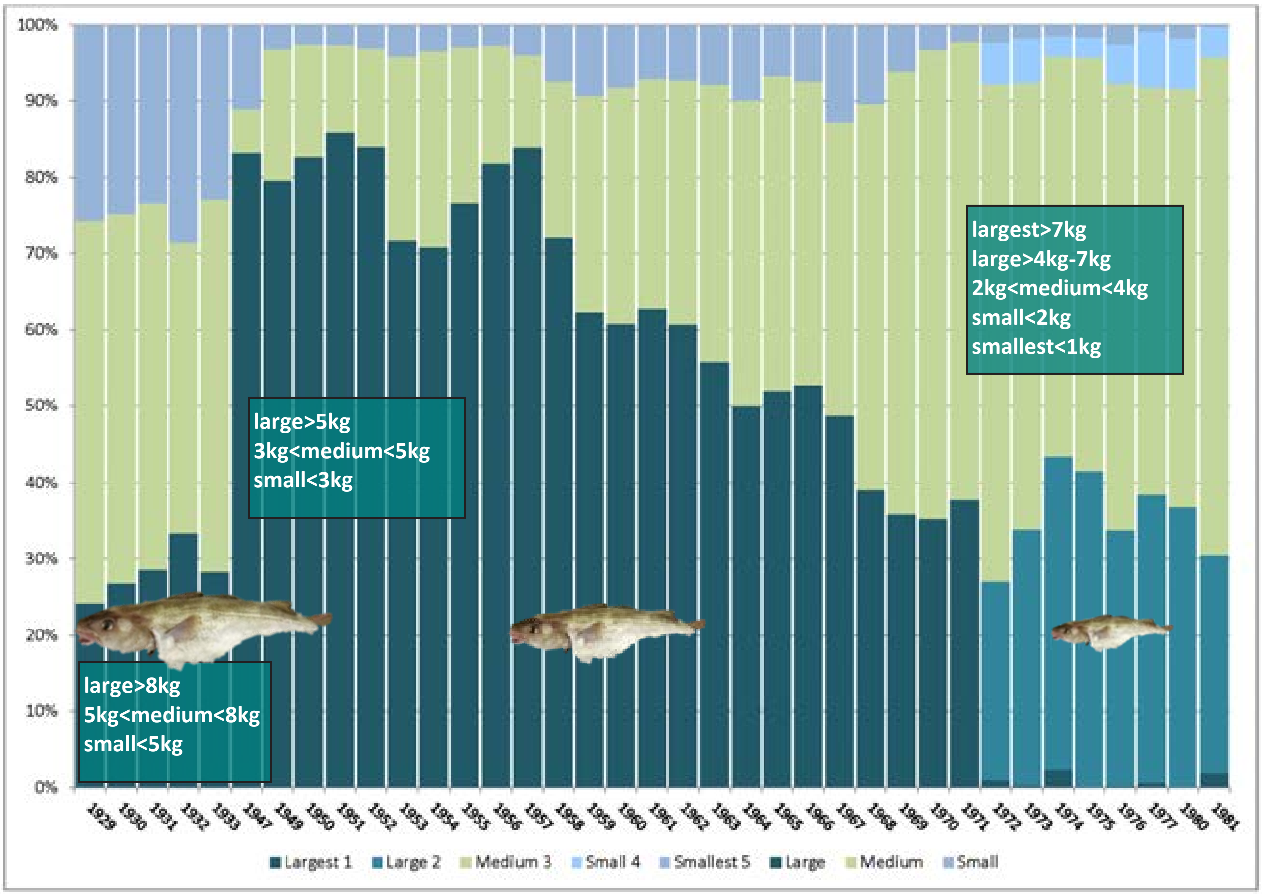

Figure 8.6.: Proportion of cod landings by different weight classes, Belgian commercial fisheries, Iceland 1929-1981.The changes in weight class boundaries over time are documented in the text boxes in the figure.

The data in Figure 8.7. show the monthly/seasonal fluctuations for cod (a) and for haddock (b) for the period 1947-1971. Monthly data also exist for the first and third period, but were not included in Figure 8.7. The decrease in the proportion of larger specimens was gradual for cod, and set in particularly after 1957. The proportion of large haddock (>2kg) decreased from 53% to 13%, with a temporary increase in 1958-1961.

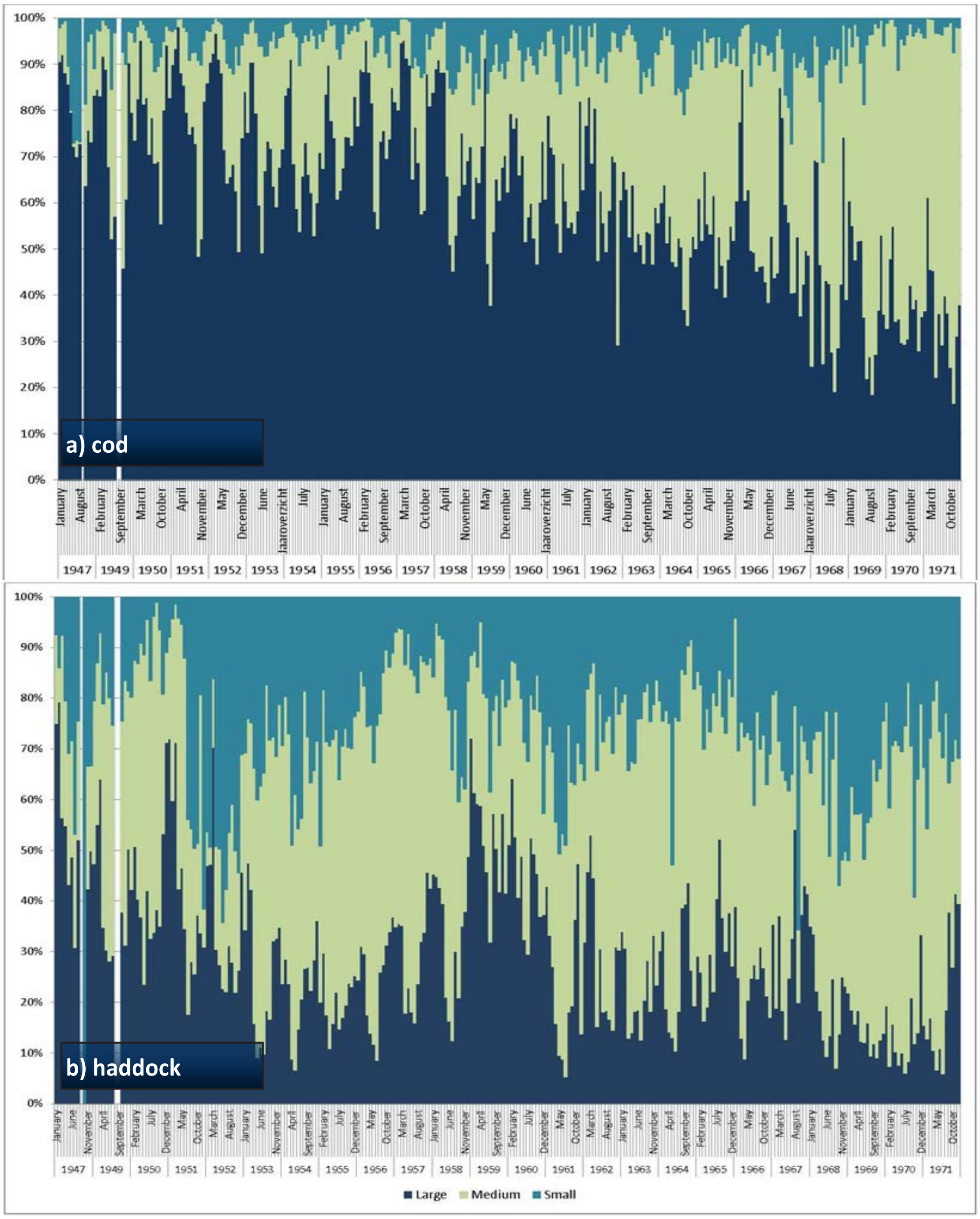

Figure 8.7.: Proportion of cod (a) and haddock (b) landings by different weight classes, Belgian commercial fisheries, Iceland 1947-1971.

8.4. Discussion and Conclusions

Cod, and Iceland's fishing resources, have played a major economic role for Belgium and other fishing nations around the North Sea in the 20th century (Palmadottir 1989, Jones 2000, Robinson 2000, Valtysson 2001) . The fisheries in Icelandic waters represented approximately 40% all landings by the Belgian commercial fisheries in the late 1950s, and over the entire reporting period 77% of these landings were composed of only 4 species (cod, haddock, saithe and redfish). While the total landings from Icelandic waters clearly started to decline from 1958, the fishing effort continued to increase until a peak of 45 million PKHF was reached in 1963. It must be noted however that effort-data were not available for the first half of the 1950s when effort in Icelandic waters was probably at a historic high. The reconstructed time series of LPUE in Icelandic waters by Belgian commercial otter trawlers refers to a homogeneous situation in terms of fisheries type (demersal, bottom trawling), fishing gear (otter trawl) and main target species (cod, gadoids). The data suggest that a decline of 75% occurred in LPUE between 1946 (0.95 kg/PKHF) and 1983 (0.24kg/PKHF). The reconstructed LPUE time-series confirms the decline in the biomass of fish stocks, in particular in cod, as demonstrated by the ICES stock assessments that are currently available from 1955 onwards. Moreover, the data on weight classes presented here (Figure 8.7.), suggest that a decline in the proportion of 'large' fish in the stocks of cod and haddock, may have started as early as 1947. The data on 'large cod' indicate that 'double erosion' took place in the targeted Icelandic cod stocks by which not only the biomass declined but also the proportion of larger fishes declined simultaneously. Superimposed on these processes, we also document the shift in the definition of 'large' fish, which took place over the 50 years observed in this time-series.

Our findings coincide with those of recent authors who have taken a broader historical view on changes in commercial fish stocks. Thurstan et al. (2010) found a 94% reduction in LPUP over 118 years of UK industrial bottom trawl fisheries in the North Sea, Cardinale et al. (2009b) reported an 86% decline in biomass of turbot (*Psetta maxima*) in the Kattegat-Skagerrak based on standardized research surveys extending back to 1925. Similar conclusions were drawn for the large predatory fishes in the North Atlantic, evidencing a decline by 90% since 1900 (Christensen et al. 2003) and for predatory fish worldwide since the onset of industrial fisheries (Myers and Worm 2003). In exploited fish stocks, larger fish generally suffer higher fishing mortality, affecting the size distribution of the stock. Systematically extracting the larger specimens in a population of fishes affects reproductive and growth parameters, and has shifted maturation towards younger and smaller animals (Rijnsdorp and Milner 1996, Rijnsdorp et al. 2003, Mollet et al. 2007, Garcia et al. 2012). The importance of large fishes in the ecosystem is acknowledged in current EU policies (2008/56/EU). There is evidence that a change in the size distribution of fish communities in the North Sea has taken place (OSPAR 2008) and the OSPAR Ecological Quality Objective for the restoration and conservation of the size-structure of the fish community of the North Sea sets as target that the proportion (by weight) of fish greater than 40 cm in length should be greater than 0.3, based on the ICES International Bottom Trawl Survey series (OSPAR 2008). The undesirable effects of selective fishing on the equilibrium in the trophic web and wider ecosystem have also been questioned by García et al. (2012).

There are different factors that may potentially have affected this proportional decline in large cod, and ultimately in biomass, in Iceland. Begg and Marteinsdottir (2003) investigated the effects of fishing on the composition of the cod SBB in Icelandic waters and found that SBB and relative fishing mortality were spatially unevenly distributed. They concluded that changes in stock structure and demographic characteristics caused by changes in spatially explicit exploitation patterns can significantly affect stock productivity through differential loss of reproductive potential. Petursdottir et al. (2006) found that populations of Icelandic cod from adjacent spawning areas within the main spawning area at the southwest coast, can be discriminated based on otolith growth and shape. They suggested the existence of different populations in the coastal and offshore areas, underlining the importance of special protection for the large and fast growing cod spawning in the coastal area, given their significance to the overall productivity of the stock. Historical data on commercial fisheries with a high temporal and spatial resolution are scarce. The data by rectangle presented here provide valuable information to compare fishing activities and LPUE between rectangles. However, the data can not elucidate whether cod and other gadoids were caught in deeper or shallower parts, in particular for rectangles which cover a wide depth gradient and both inshore and offshore habitats within the main spawning areas (e.g. 1212, 1214). Possibly, different populations may have been exploited over time; targeting first the larger and faster growing cod in the coastal area and later, after these became less abundant or after access to coastal areas became increasingly restricted, targeting other populations.

It has been well documented that cod in Icelandic waters form a unit stock marked by very little emigration, but migrations of cod also take place from the West and East Greenland stocks into Icelandic waters (Harden-Jones 1968, Schopka 1993). The large-scale immigrations which occur in particular years, may affect the stock abundance at Iceland and in the past have resulted in the overestimating of the Iceland stock size. While catch-at-age for Icelandic cod peaks at ages 4 or 5, in years with large-scale immigrations from the Greenland stock the catch-at-age peaks again at 7-9 years (Schopka 1993). Between 1941 and 1990, Schopka found some strong year classes emigrated from Greenland, in particular the 1945-year class which appeared in large quantities from 1953 onwards on the spawning grounds off the southwestern coast of Iceland. Schopka (1993) related the origin of this strong year-class to drifting mechanisms of larvae/eggs from Iceland, hence demonstrating the strong linkage between the larval drift and immigration mechanisms, and hence the linkage between Greenland and Iceland stocks in different stages of the life cycle. It is believed that these migrations occurred more frequently before the 1970s (Schopka 1993) and that this migration decreased due to the poorer state of the stock at (West) Greenland after 1970. In spite of the fact that the data presented here do not show evidence of an increased proportion of large(r) cod specimens in 1953, and following years, it may well have been that these ‘Greenland immigrants’ consistently strengthened the weight class of the large cod (>5kg) before 1970, and large (>8kg) before 1947.

As a cold-water fish which thrives in temperatures of 4°-7°C, cod has been used as an indicator species for climate change in different studies (Cushing 1976, Jones et al. 1999, Drinkwater 2009). During the warming which occurred in the Icelandic and Greenland waters in the 1920s and 1930s, changes in fish distributions were observed (Jones et al. 1999) and Sæmundsson (1934) documented a marked episode of massive spawning of cod off the northern and eastern waters in Iceland in addition to the known spawning areas in the southwest. In the late 1960s, water temperature and salinity and air temperature decreased again while drift ice increased. This cooling had an impact on zooplankton community and changed the marine species composition in Icelandic waters from boreal to arctic (Jakobsson 1978). Drinkwater (2009) compared the responses of Atlantic cod in Iceland during two major warm periods in the North Atlantic; a first period from the 1920s to the 1960s, and a second which started in the 1990s. While the author found that abundance in cod stocks from West Greenland, Iceland, and the Northeast Arctic increased and individual growth and recruitment were high during the first warm period, this did not seem to be the case during the second warming. The author attributed these different responses to the effects of intense fishing pressure and possibly the added effects of environmental changes in the ecosystem. In particular, abundance of Icelandic cod has remained low during the second warming, when spawning stock biomass and total biomass were at near-record low values.

Taken together, the historical data from Belgian commercial landings of trawl fisheries in Iceland, correspond with a period for which there is scarce information. The results document the Belgian gadoid fisheries in Icelandic waters and argue that the decline in Iceland cod stock was visible at different levels, even long before the peak in fishing effort of the Belgian fleet -and other foreign nations- was achieved in 1963 (or earlier). This decline is observed in terms of the decrease of the proportional importance of cod in the overall landings, the decrease in the landings per unit of fishing effort, the decline in the proportion of ‘large’ fishes, and finally the decline or shift in the definition of a ‘large’ specimen. The evolution of the Icelandic cod fisheries show a certain similarity with the northwest Atlantic cod fishery which suddenly collapsed in 1992, following years of overfishing since the late 1950s, and after a first sign of collapse in the 1970s (Kenneth et al. 2005). After trusting for centuries in the infinite reproductive capacity of the Icelandic cod stocks, the long-standing traditional fisheries in distant waters by the Belgian fleet and other foreign nations gradually came to an ending due to overfishing and changes in environmental conditions, and ended abruptly after the last political turmoil, dictated by a once mighty fish.

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