

CHAPTER 9: General Discussion and Conclusions.

CHAPTER 9. GENERAL DISCUSSION AND CONCLUSIONS

9.1. THE SHIFTING PERCEPTION ON THE STATUS OF MARINE ECOSYSTEMS

Human activity has been impacting marine ecosystems for millennia, and the concept of 'pristine' ecosystems is merely a theoretical one (Myers and Worm 2003). Fishing is considered to be a human activity with major impact in the marine environment, both on regional and global scales (Salomon 2009), and it is the activity that is most often seen as the cause of overexploitation and depletion of marine biological resources (Myers and Worm 2003). Concern about overexploitation of fish stocks is certainly not a recent phenomenon (Mann 1777, Du Bus and Van Beneden 1866, Olsen 1883, Garstang 1900) and measures to regulate fishing intensity and mitigate fishing impact on the exploited stocks were established as early as 1289 in the Southern North Sea (Roberts 2007).

There is a wealth of recent studies illustrating how our perception of pristine conditions in the seas and oceans has shifted over generations. In reference to fisheries management, depleted fisheries have often been evaluated by using the state of the fish and fisheries at the start of the data collection as a baseline, rather than the fish stocks in untouched state or under conditions of low impact or subsistence fisheries (Pauly 1995, Saenz-Arroyo et al. 2005, McClenachan et al. 2012). In fact, the concept of the 'shifting baseline syndrome' was developed by Pauly (1995) in reference to fisheries management, who signposted the risks associated with this shifting perception and the challenge this represents for the sustainable management of marine ecosystems. A shifting baseline (also known as sliding baseline) is defined as a change to how a system is measured, usually against previous reference points (baselines), which themselves may represent significant changes from an even earlier state of the system.

Fuelled by current policies in support of a sustainable management of the marine environment, evidence is being built about (pre) historical reference conditions and early baselines (Pinnegar and Engelhard 2008, section 1.1.). This evidence has increased the awareness on the limitations associated with the current scientific methods in determining appropriate reference conditions against which current targets for conservation and management are set, in particular for fisheries. It is acknowledged that environmental reference conditions and targets must strive to integrate all available and relevant data and information for improved assessments, including incorporating historical data into conservation and management frameworks (Pinnegar and Engelhard 2008, McClenachan et al. 2012). Historical data can contribute in explaining underlying cause-effect relations in changes in the ecosystems, but they can also potentially reveal information and knowledge from past conditions (Jackson et al. 2001) and help defining reference conditions and achievable targets for environmental management today. In other words, historical data can counter the 'shifting baseline syndrome'.

The present thesis focuses on quantitative data to extend the timeframe of current analyses on fisheries (landings, fleet dynamics, spatial dynamics, indexes of productivity of the fleet and impact of fishing), and on historical time-series to expand our knowledge on historical references for the Belgian sea fisheries.

The conclusions presented here, are structured according to the topics addressed in the different chapters of this thesis:

- General conclusions in relation to data sources to reconstruct historical time-series for Belgian Sea Fisheries
- 'Shifting Baselines' applied to the Belgian Sea fisheries: an overview of trends observed in the reconstructed time-series:
 - o Landings, species, fishing areas

- Fleet dynamics
 - Landings per unit of effort and landings per unit of power
 - Changes in targeted fish stocks
- Potential use of the HiFiDatabase in other fields of application
 - Next steps in data management and analysis of data

9.2. DATA ON COMMERCIAL SEA FISHERIES IN BELGIUM

9.2.1. THE POLITICS BEHIND THE STATISTICS

A number of authors have published reviews of available data and information sources for the Belgian sea fisheries: Cloquet (1842), De Zuttere (1909), Vilain (1962), Omey (1982), Poppe (1977), Hovart (1985). Although these reviews are instrumental to obtain an overview of potential (data) sources on the history of sea fisheries in Belgium, the sources remained fragmented and disperse. This was particularly the case for historical quantitative datasets describing fisheries dynamics. Information sources consulted in the context of the present thesis were documented in the Integrated Marine Information System IMIS (VLIZ) and - where possible - disclosed full-text and open access to the public. Sources in archives and literature databases were specifically screened for:

- i. **numerical data**
- ii. **metadata** needed for a correct interpretation thereof (e.g. minimum legal mesh sizes of nets, landing sizes of species, ancient reporting units),
- iii. elements that triggered the **onset of systematic and centralized data collecting systems** in Belgium (e.g. international cooperation, subsidies, etc...), and
- iv. **marking events and legislation** that provide context for understanding observed trends and sudden changes in time-series.

A few generalised conclusions are drawn specifically in relation with the driving forces behind the data collection on sea fisheries both in Belgium and in the other fishing nations bordering the North Sea. Because data sources are incomplete and the search was not exhaustive, the conclusions related to data sources must be considered as indicative.

Different drivers interact to shape data collection systems on fisheries throughout history

The search in the literature, archives and databases has illustrated how different driving factors have interacted to facilitate – in some cases hamper – the data collection on sea fisheries in Flanders/Belgium since the 15th Century (Figure 9.1. and text box). Depending on the period in history these driving factors were economic power, regional politics and national security (e.g. during warfare), the fisheries policies and the administration enforcing the policy requirements, the fisheries sector itself (economic interests e.g. to obtain subsidies), the research community, environmental policy targets, or a combination of two or more of these drivers. It is not the purpose of the present thesis to conduct an exhaustive study of the literature. Nevertheless, the most important events were documented in an on-line application on the Belgian sea fisheries that can be consulted in chronological order (www.vliz.be/cijfers_beleid/zeeverij/timeline.php, VLIZ 2010) (Appendix). The timeline provides an overview of the historical events that describe the Belgian sea fisheries since the earliest years and integrates different topics. It is based on the sources identified, inventoried and screened for the purpose of the present thesis. The tool is available to the wider public and is continuously updated.

Drivers for Data Collection on Fisheries in Flanders-Belgium 15th-21st Century

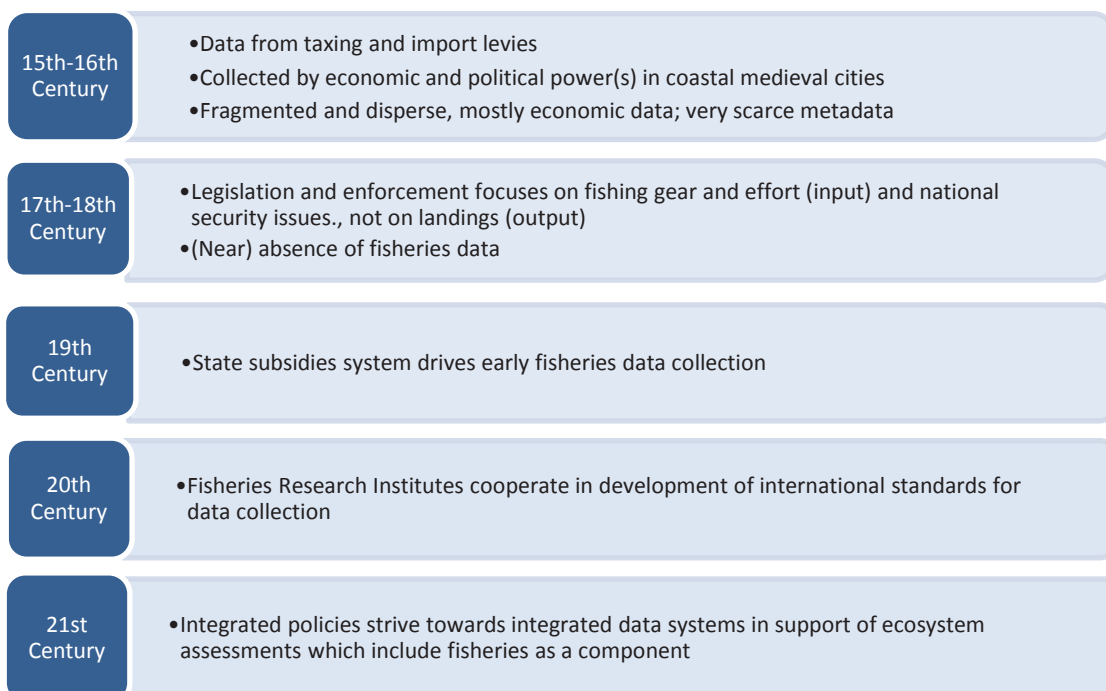


Figure 9.1.: Main drivers for data collection on sea fisheries in Flanders-Belgium 15th-21st Century

THE POLITICS BEHIND THE STATISTICS

In the Late Middle Ages (15th – 16th century) fishing was basically a free enterprise all over Europe (Hovart 1985). Data on commercial sea fisheries in Flanders were collected by cities and port authorities using local accounting systems that focused on the production of the salted herring and codfish industry for taxing purposes. The gains from taxing were crucial to sustain the established political powers of medieval cities such as e.g. Nieuwpoort, Brugge and Oostende.

Political turmoil during the 17th and 18th century affected the Flemish ports and their fisheries in different ways: Flanders' fisheries benefited from the conflicts between England and France. Subsidies or indirect support were implemented to the local fisheries e.g. through tax levies or straight prohibitions on foreign import of herring or cod (Cloquet 1842, De Zuttere 1909, Hovart 1985). The Compagnies of Oostende and of Nieuwpoort were established but did not persist in these unstable conditions. Numerical information is scarce and patchy, fragmentary records were preserved from individual company owners accounts (e.g. Schreurs Grootboek from 1771, facteurboek Serweytens from 1814-1820, Parmentier 2001). Governmental information on fishermen and fisheries was often collected from the perspective of warfare and security and maritime control. Interestingly, in terms of fisheries management a number of technical measures and regulations were established because of the alleged negative effects on the juvenile fish and larvae (Appendix III: overview historical fisheries measures and laws). These were mainly oriented to mesh size and the prohibition of trawling in the coastal waters (e.g. Ordinance 30/04/1752).

Information is particularly scarce for the French (1794-1815) and Dutch periods (1815-1830) and additional efforts were conducted to identify data sources. The 'City of Ghent Newspaper' (1666-1940) contains data on ship movements in the ports of Oostende for these periods. Landings of salted codfish in Oostende were also

reported in the newspaper of Ghent. These data were inventoried with the aim to reconstruct indices of fishing effort and productivity, however because of the fragmentary nature of the data they could not be integrated in the time-series reconstruction. For cod and herring, partial reconstructions were conducted including the salted cod and herring data from the 19th century (Lescrauwaet et al. 2010a, Lescrauwaet et al. under review).

To subsidise or not...economic incentives to the fisheries in the 19th Century

In 1815 (Congress of Vienna) the United Kingdom of the Netherlands was established and Flanders was annexed as the 'southern provinces'. Governmental subsidies were tailored to the particular fishing gear, techniques, and corporate structures of the northern Dutch fisheries. With the establishment of the Kingdom of Belgium in 1830 the subsidies were adapted to local characteristics of the Flemish fisheries (see Chapter 2 for details on this period). The system of state subsidies is the driver for early fisheries statistics collected in the 19th century. The period between 1860-1900 is of particular interest because of the interplay between the government and administration, scientists, and the private sector. Interestingly, upon a parliamentary inquiry about the usefulness of subsidies to the fisheries and the issue of overexploitation that was brought under the attention of a vessel owner and skipper, scientists defended the infinity of renewable resources of the sea. It was a period during which liberal views were advocated in economic models, and e.g. in The Netherlands fisheries were set fully free of regulations in 1857 (Du Bus and Van Beneden 1866). The first International Conferences were organised around the North Sea region – e.g. Convention of The Hague in 1882 - and the issue of overexploitation of fish resources and commonly agreed regulations to access resources were on the agenda. To underpin the debate, the first nation-wide detailed surveys and stocktaking were commissioned. Today, this early stocktaking provides an interesting baseline for fisheries as an economic sector in 19th century Belgium.

In 1902 the **International Council for the Exploration of the Sea (ICES)** was founded. ICES developed a system of subareas and divisions for use in the collection and presentation of fisheries statistics, and the first (preliminary) international fisheries statistics were published in 1903 (Hoek and Kyle 1905). Belgium acceded in 1903. Concern for some fish stocks lead to e.g. the establishment of the international Plaice-committee in 1912. Other species or stocks would follow later (herring, cod, sole). WWI severely hampered this initial process of statistical data collection, but by the onset of WWII the statistical systems were largely in place in most countries bordering the North Sea. After WWII, international territorial policies in the maritime environment were largely driven by interests in fisheries; e.g. the declaration of the 12 nautical miles as territorial sea, the establishment of the 200 nm as Exclusive Economic Zones in 1982 (Finley 2011), and the 'cod wars' in Iceland in 1958, 1972 and 1975 (Valtysson 2006). Access to marine resources is increasingly debated in the context of international agreements and models for international cooperation are set up to develop cross-border single stock management.

21st Century Fisheries in the EU policy context: the challenge to move to ecosystem-based approach requires integration of data and data systems. EU wide efforts to balance economic objectives and fishing efforts against the availability of the resources are further pursued through the establishment of the EU Common Fisheries Policy CFP (1983). The need to regulate access to economically important but declining resources becomes an important drive for data collecting. Whereas fisheries formerly competed with each other over resources between fisheries and metiers (Rijnsdorp et al. 2008), the different fisheries now need to join forces to interact with other sectoral demands to claim their spatial needs (International Conference on MSP, EU DGMARE, 26/03/2012). The UN Conferences on sustainable development (Rio 1992, Johannesburg 2002, Rio+2012) and the science-based evidence of overexploitation of most of the commercial fish stocks, support the slow transition to an ecosystem-based management of the marine environment.

In the pursuit of an ecosystem-based approach in the marine environment, Data Collection Regulations in support of the Common Fisheries Policy CFP (EU Council Regulation 1543/2000 and Commission Regulations 1639/2001, 1581/2004 and 199/2008) require EU MS to collect data on technical, biological and economic aspects of their national fisheries, and their impact on the marine ecosystem. The Commission Regulation

136/2007 requests member states to collect data and report on discards. Besides these measures related to data collection and the scientific stock assessments that need to advise the Council of Fisheries each year on the definition of Total allowable Catch (TAC) and MS quota, there is a large number of technical measures to reduce fishing effort and to implement measures, techniques and initiatives to support the development of sustainable fishing communities throughout Europe.

The reformed EU CFP (2012) is also to be aligned with the objectives as defined in the EU Marine Strategy (2008). The EU proposal for a directive on Marine Spatial Planning (COM 133/ 2013) and the Habitat and Bird directives are mechanisms to support these legal commitments by 2020. By aligning targets across policy frameworks (Fisheries, Environment, Nature Conservation, Sea Use) the transition from single stock management to a more integrated ecosystem management is pursued. The integration of policy objectives is a driver for the development of rich data environments that integrate data on living and non-living components of the marine environment and ecosystem functioning, as well as pressure and impact by human uses.

9.2.2. RECONSTRUCTING LONG-TERM DATA SERIES ON SEA FISHERIES IN BELGIUM: STRENGTHS AND LIMITATIONS

The screening of literature databases, archives and other sources indicated that in Belgium, structurally embedded reporting based on detailed taxonomic and geographical resolution started in 1929 with an acceptable degree of consistency and continuity ever since. During the second half of the 19th century and the beginning of the 20th century, efforts were conducted by government officials to achieve standardized collecting and centralized reporting on fisheries data in Belgium. In spite of these early efforts, all data on catches, landings, fleet and effort collected before 1929 are either spatially incomplete or taxonomically aggregated (Table 9.2).

The ‘Historical Fisheries Database’ (HiFiDatabase) is a product of this thesis. It is the result of a thorough search, rescue, inventory, standardization and integration of data for Belgium’s sea fisheries that were not available before in the public domain or were not available before in the appropriate format for redistribution. It is documented and stored in the Marine Data Archive MDA of VLIZ and freely available for end-users. It contains a collection of time series with standardized species names, reporting units, fishing areas and ports of landing (Lescrauwaet et al. 2010b, Chapter 2 Table 2.6.). It counts 0.7 million data rows and is a ‘living’ product in the sense that new, relevant, quality-controlled time-series can be added as they are discovered or produced.

The HiFiDatabase is a quite exceptional because it documents the sea fisheries of one country, over one century, and for a wide range of topics. Considering the relative size of the fleet, the short coastline and the limited number of fish auctions and fishing ports, it is fair to say that the present reconstruction of sea fisheries in Flanders/Belgium may depict a relatively complete picture of historical volume, value and composition of landings, fleet dynamics, fishing effort and spatial dynamics for this time period, compared to other countries. It contains unique data with advantages compared to recently developed databases (ICES Official Catch Statistics 1950-2010 (ICES 2011)). However, a number of limitations need to be taken in to account (Table 9.1). The most relevant limitations refer to the coarse scale of spatial reporting units and the patchy and discontinuous data on fishing gear and effort.

For commercially important species such as cod and herring, time-series on landings can be extended with caution towards the early 19th century (Lescrauwaet et al. 2010a, Chapter 3) and even earlier (Lescrauwaet et al. 2013, under review).

Time-series of landings and value of landings by fishing rectangle, by month, by weight or size class, by fishing effort and fishing métiers (vessel type and gear) provide unique insights at higher spatial, temporal and taxonomic resolution. Unfortunately these data are not continuous throughout the period from 1920 onwards (Chapter 2 and overview Table 9.2).

Table 9.1.: Overview of the main strengths and limitations of the HiFiDatabase

	Strengths	Limitations
General	A complete reconstruction of historical volume, value and composition of landings, fleet dynamics, fishing effort and spatial dynamics over (nearly) one century	
Taxonomic coverage	Data available at the level of: <ul style="list-style-type: none"> - 41 reported species - and 15 aggregated taxa 	Taxonomic validation for species that are difficult to identify in the field (e.g. the case of 'rays') can raise doubts
Temporal coverage	1929-1999 (and continued to present)	-
Spatial coverage	-All fishing areas where Belgian fishing fleet has operated between 1900-present, including 4 fishing areas not reported separately by ICES/FAO these are: Fladen (in ICES area IVa), North Sea central-east and North Sea central-west (in area IVb). and 'Coastal waters' (in area IVc). -All fishing ports	-No data were found on Belgian landings in foreign ports before 1950. The data from 1950-1960 however suggest that landings in foreign ports were few. -The proportion of the catch that may have been landed informally or illegally in other sites along the coast is not known
Temporal resolution	Monthly values	-
Spatial resolution (smallest reporting units)	Data available by statistical rectangle: 1946-1983	In general (except for statistical rectangles) spatial units of reporting remain coarse (= ICES fishing areas and subareas)
Thematic coverage	Economic data (value of landings) Fleet and fishing effort data: <ul style="list-style-type: none"> • Effort data (chapters 5 to 8) • Fleet characteristics (Chapter 5) • Fleet and fishing gear (Chapter 5 to 8) Employment and Education levels	Data on fishing effort and gear at statistical rectangle are often patchy, discontinuous
Other	Data by size or weight class (large, medium, small, -extra large, extra small), for commercially important species	
	More information in Chapter 2, and from Materials& Methods sections in Chapters 3-8	

The screening of archives, databases, libraries and other repositories as described in Chapter 2 has generated an inventory of data sources related to historical fisheries in Flanders-Belgium. The data contained in these sources were copied to electronic formats, quality controlled and integrated according to a priority setting by which the datasets that are feasible to be reconstructed as long-term time-series were tackled first (Chapter 2). Based on the resulting time-series a number of descriptive statistics (Chapters 3 to 5) and analyses (Chapters 6 to 8) were conducted in the context of the present thesis.

Next steps in data rescue and digitization need to focus on more fragmentary sources such as the logbooks of individual vessels. These logbooks contain detailed information for each fishing trip, including environmental data. From the logbooks, a correlation can be drawn between fishing effort, deployment of the fishing gear, spatial coverage, and catches. Logbooks have been used in different studies to reconstruct historical references (Poulsen 2008, O'Donnell et al. 2010). If the logbook is assumed to be a reliable report, and provided one or more particular vessels can be followed over time, the logbooks may potentially offer anchor points that document the change in technology over time, or provide information on the time of introduction of specific technologies that improved the efficiency of fishing and the catchability of target species. This is of particular use as a reference or to set a baseline for the datasets which are discontinuous over time, or for which gaps in spatial coverage were identified.

BELGIAN FISHERIES - BELGIAN AND FOREIGN PORTS													1750	1800	1810	1820	1830	1840	1850	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000
1. LANDINGS AND VALUE OF LANDINGS - annual data																																		
Landings (kg) salted herring by port of landing (*)																																		
Landings (kg) salted cod by port of landing																																		
Value of landings (converted to €) all species 'fresh' landings																																		
Landings (kg) all species by species by port of landing																																		
Value of landings (€) all species by species by port of landing																																		
Landings (kg) all species by species by fishing area of origin																																		
Value of landings (€) all species by species by fishing area of origin																																		
Landings (kg) all species by species, landed in foreign ports																																		
Landings (kg) all species by species by fishing area, landed in foreign ports																																		
2. FLEET AND FISHING EFFORT - annual data																																		
Number of vessels by port																																		
Number of vessels by type of engine power (sail, steam, motor)																																		
Number of vessels by port, by tonnage																																		
Total tonnage of fleet by port																																		
Number of vessels by port, KW, LOA, BOA,																																		
Fishing effort: fishing days and days at sea																																		
Fishing gear: number of vessels by fishing gear																																		
Fishing gear: number of vessels, fishing effort, tonnage, engine power, landings & value of landings by fishing effort, by fishing gear																																		
3. LANDINGS & EFFORT: HIGHER RESOLUTION																																		
Landings (kg) and value of landings (€) by species, per month																																		
Landings (kg) and value of landings (€) by species, per month: for 7 commercially most important species																																		
Fisheries practiced from the beach during WWII: landings and values by species, per month																																		
Fishing effort by fishing area, vessel class, fishery type, total landings and value of landings																																		
Fishing effort by fishing area and statistical rectangle, vessel class, fishery type, total landings and value of landings																																		
Landings (kg) and value of landings (€) by species, per month, per fishery type, vessel class, fishing effort, by fishing area																																		
Landings (kg) and value of landings (€) per month, per fishery type, vessel class, fishing effort, by fishing area + per weight class for 5 commercially important species																																		

1

Notes: Time scale: e.g. cell '1750' covers the period between 1750 and 1799
 (*): earlier data on salted herring 1398-1427 and 1492-1580 are not included in this overview;

Annual data: systematic, formal and centralized reporting
Annual data: incomplete coverage (not all ports or taxa)
Data does not cover entire decade, but is part of time-series
Discontinuous, fragmented data sources
No data reported

Table 9.2. Overview and chronology of data and time-series on fisheries

9.3. RECONSTRUCTED TIME-SERIES: SHIFTING BASELINES IN BELGIAN SEA FISHERIES

9.3.1. RESCUE AND MANAGEMENT OF HISTORICAL DATA IN SUPPORT OF AN ECOSYSTEM-BASED ASSESSMENT

Many countries have invested great efforts to systematically collect scientific data and statistics. This is also the case for Belgium. Initially, most of the raw data was recorded on paper, at the best summarized for storage and reporting purposes and kept in punch cards or other 20th century technologies that are not available anymore. In some cases the data were analysed and published in summarized form to be transferred to new, digital carriers while the raw or underlying data were discarded. A few decades ago, computing capacities were still limited and even until recently raw data were encoded and stored on paper, limiting their redistribution and accessibility. Many of these potentially valuable datasets and sampling designs are now archived in libraries and institutions where they are at risk of being lost for science. As libraries and institutions occasionally clean up their holdings, this may lead to loss of archived data (Zeller et al. 2005). Today, computing technology and infrastructure is not the limiting factor. Data are electronically encoded in standardized and exchangeable formats so they can theoretically be shared and exchanged all over the world. Web based search engines increase efficiency and speed of harvesting and exchanging of data and information. Spatial Data Infrastructures allow sharing spatial data from web-based clients worldwide. Although important progress is made in this direction, further improvements can still be achieved in sharing and accessing data and information:

- **Establishing institutional Data policies and Data management procedures**

Universities and research institutes, private companies, government services are paying increasing attention to aspects of data management and ethics, responsibility in managing and sharing data that are collected with taxpayers' money. Academic institutions as well as other scientific research institutes are developing data policies, including regulations for the recording and storing of data associated to graduate and pre-graduate research.

- **Developing a Vision for the future**

Data that may seem of limited relevance today may be of crucial importance in the future. It is important to invest in data sharing infrastructures and capacity building to safeguard data, information and knowledge for future use and to pass it on to the next-generation of data infrastructures (Matthews 1993).

- **Society's perception on data ownership**

Despite marine research and monitoring being largely paid by tax money, environmental and fisheries related data are often perceived to be owned by the public institutions and academic and research institutes that generate them (Russ and Zeller 2003). This issue of perceived ownership of data (Matthews 1993) has been a continued cause for hampering access to and use of data, in many cases even the definite loss of valuable datasets. One of the most important responses to the latter is the global Open Access Movement (www.openarchives.org/).

In the present thesis, a case is made for the importance of the rescue and integration of historical fisheries data, demonstrating the need for historical fisheries data and its potentialities for the analysis of and assessment of historical marine reference conditions in the 20th century. In the process, an important number of trainees, internships and students participated were trained in the basic aspects of data management and the principles of Open Access.

9.3.2. LANDINGS, VALUE OF LANDINGS, MAIN SPECIES, MAIN FISHING AREAS

The concept of shifting baselines can be applied in different environments. In the reconstruction of time-series on commercial fisheries, the trends in landed volumes are often most conspicuous. The reconstructed time series indicate that landings reported by the Belgian sea fisheries both in foreign and in Belgian ports over the period 1929-2008 amounted to 3.3 million t, of which 90% was landed in Belgian ports. After a maximum of 80,000 t in 1947 (rounded figures), annual landings declined steadily to only 26% of this peak by 2008 (Lescrauwaet et al. 2010a). Currently (2010), landings are below those achieved in 1929.

The most important species over the observed period in terms of landings were cod (17% of all landings) and herring (16%), closely followed by plaice (14%), sole (8%), whiting (6%) and rays (6%) (Table 3.1. and Figure 3.8.). In terms of economic value and based on values corrected for inflation, sole (31%) and cod (15%) were the most valuable, closely followed by plaice (11%), brown shrimp (5%), rays (5%) and turbot (3%). Near to 73% of all landings originated from 5 of the 31 fishing areas (Table 3.3. and Figure 3.9.). Twenty percent of all landings originated from the 'coastal waters', while these waters contributed nearly 60% of all landed pelagic species and 55% of all landed 'molluscs and crustaceans' (Chapters 3 and 6.1). The North Sea (south) and the Iceland Sea are next in importance with 17% and 16% of all landings respectively. The eastern and western part of the central North Sea, contributed each with approximately 10% of the total landings (Lescrauwaet et al. 2010a).

Interestingly, three groups of targeted species have explained on average 75% of all landings between 1929 and 1990 (red line, Figure 9.3.) These are:

- a) the pelagic fisheries for herring and to a lesser extent sprat,
- b) the roundfish fisheries targeting mainly cod but including also other species (haddock, saithe, whiting, ling, redfish, monkfish)
- c) the flatfish fisheries targeting plaice and sole.

Before and during WWII the bulk of the landings consisted of herring (and sprat): this component explains 52% of all landings before 1946 and up to 100% of all landings during WWII. On average, herring and sprat represent 66% of the landings of the 3 major components before 1946. After WWII, the large-scale herring fisheries in the central North Sea quickly resumed and after 1950 these fisheries take an industrial dimension (Chapter 7). Mortality in the North Sea herring stocks increased significantly, affecting also the Downs herring, which was targeted by the Belgian fishers on the post-spawning sites on the Flemish banks, before and during WWII (Chapter 7).

After WWII and until the mid 1980s, 47% of all landings consist of the group of gadoid and other roundfishes, mostly from Icelandic waters. Towards the second half of the 1960s, when the Belgian fisheries in Icelandic waters was at its peak in terms of fishing effort, this group of species represented up to 80% of the 3 main components (Figure 9.3.). In the wider context of the Belgian fisheries, the landings of cod and other roundfish represented 66% of all landings in 1968.

Between 1980 and 2000, the proportional importance of the 'gadoid' component and the 'flatfish' component within the sum of these 3 large components, were reverted: sole and plaice increased from approximately 30% to 70% while the relative importance of the 'gadoid' component – except for the smaller peak at the end of the 1990s - decreased from 70% to 30% (Figure 9.3.).

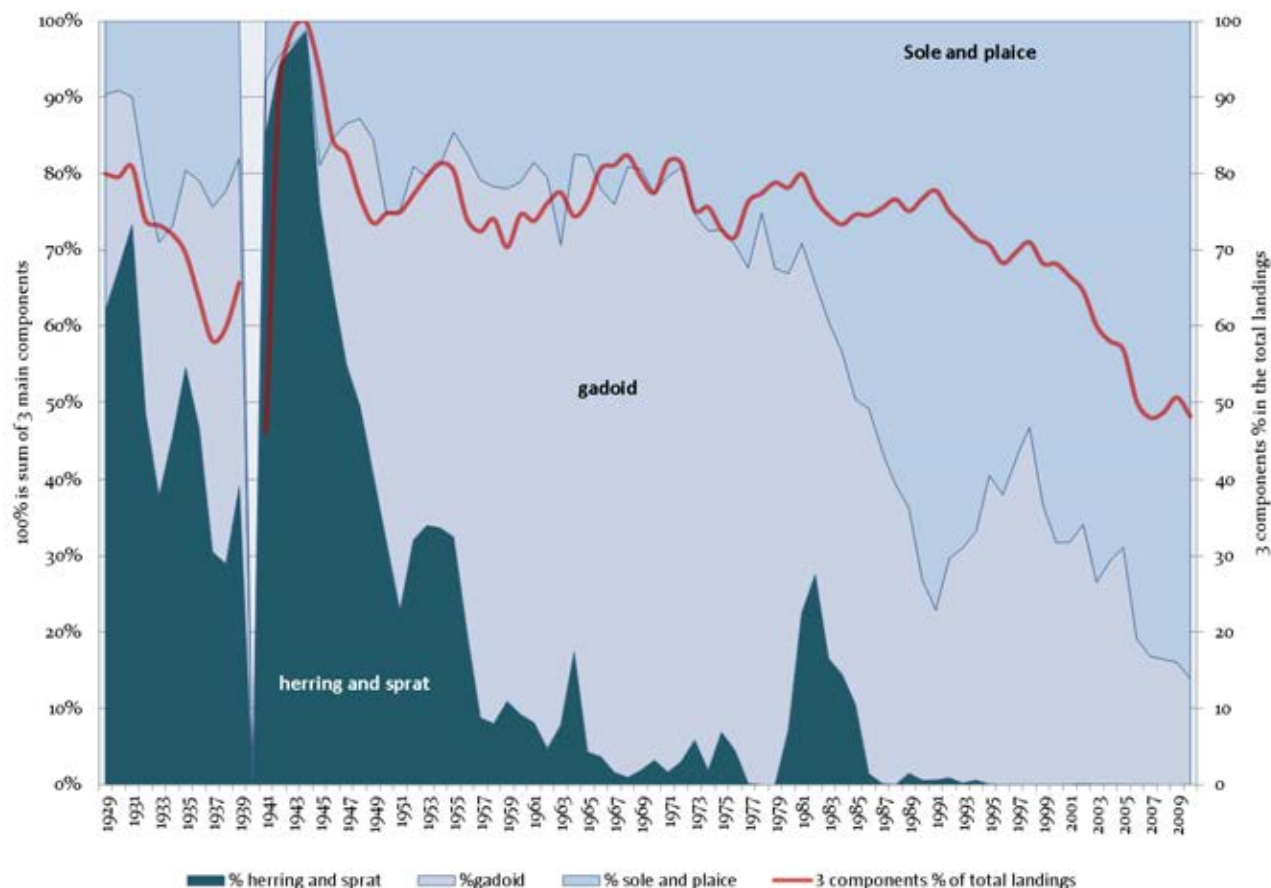


Figure 9.2.: Landings of the 3 main components (herring and sprat, gadoid and other roundfish, sole and plaice). The sum of these 3 main components as a percentage of the total landings, is indicated in the red line. The relative proportions of each of these 3 components are indicated as areas (%).

After 2000, plaice and sole make up 70%-85% of the main components. However, from 2000 onwards the importance of these 3 major components in the total landings decreased from 70% to less than 50%. This decrease suggests that the proportional composition of landings (weight-based) became more diverse after 2000 (Figure 9.2, red line). Important landings of anglerfish (*Lophius piscatorius*), cuttlefish (*Sepia officinalis*) and scallops (*Pecten maximus*) are also reported in recent years (Tessens and Velghe 2012).

The reconstructed time-series suggest that the Belgian fisheries have followed a development of 3 successive exploitation phases in which 3 major target species or target species groups were exploited until events or processes triggered a transition to a new phase. This pattern of successive exploitation was also described by Pauly et al. (2005) for the fisheries worldwide. For Belgium we can distinguish – simplification permitted – a ‘herring’ period between 1929 and 1950, a ‘cod’ period between 1950 and 1980 and a period marked by plaice/sole between 1980 and 2000 (and after). This successive exploitation of targeted species was also associated with exploited fishing grounds, successively the Coastal waters for herring, the Icelandic Sea for cod, the North Sea south and the North Sea central (east and west) for sole/plaice, later also joined by the ‘western waters’ (English Channel, Bristol Channel, Irish Sea) for the flatfish fisheries (Figure 9.3.).

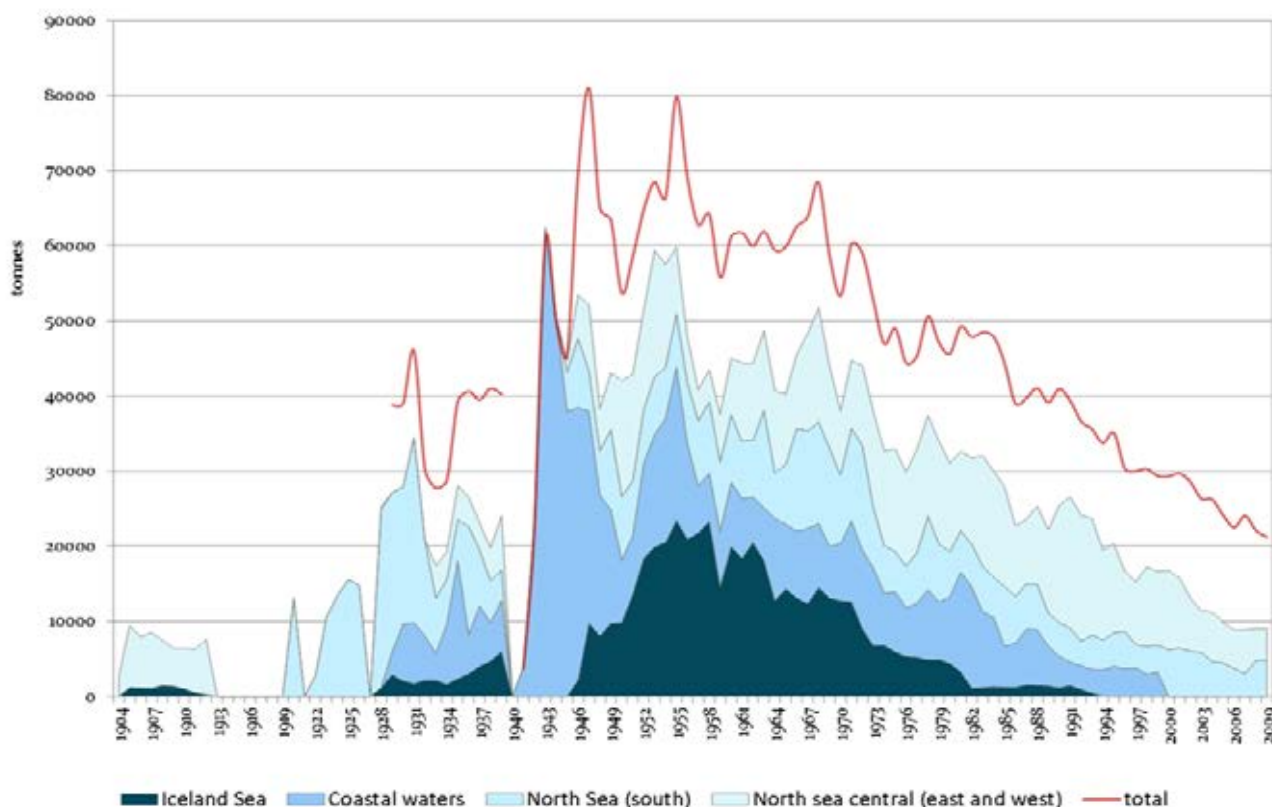


Figure 9.3.: Landings in the 4 main fishing areas of historical importance and associated to the landings of the 3 main components as represented in Figure 9.2. (herring and sprat, gadoid and other roundfish, sole and plaice). The total landings are indicated as a reference (red line).

9.3.3. FLEET DYNAMICS AND VESSEL CHARACTERISTICS

Although the volume of landings shows a decline of -74% since 1947, this decline cannot be interpreted as an indicator of change in the biomass of targeted fish stocks. To understand and interpret the trends in landings and changes in target species (groups) as described above, it is crucial to look at trends and changes in the fishing fleet and the fishing sector inserted in a wider socio-economic and political context. Most time-series on the fleet dynamics start after the 1980s, at times when major changes in fleet characteristics had already taken place. In the present thesis work, a reconstruction was made of the fleet size (from 1830), tonnage (from 1842) and engine power (kW from 1912) of the Belgian sea fisheries fleet. The time-series show a 85% decrease in fleet size and a 5% decrease in overall engine power (kW). This decrease was compensated by a 10-fold increase in average tonnage (GT) per vessel and a 6-fold increase in average engine power (kW) per vessel, from an average of 100kW after WWII to approximately 600kW in the mid- 2000s (Figure 9.4. and Chapter 5 for details on fleet dynamics).

During the WWII, the Belgian fisheries benefited a 10-fold increase in catches and 5-fold increase in LPUE of Downs herring. These increased catches can be explained by the combined effects of a major increase in catch power thanks to improved technologies that were implemented after WWI (motor engine, fish detecting devices), and by the effects of strong pre-WWII year classes (e.g. 1936 and 1938) which joined the adult Downs herring during WWII on the post-spawning resting areas that were targeted by the Belgian fisheries

(Lescrauwaet et al. under review, Chapter 7). This was associated with an apparent almost zero mortality Z in the North Sea herring stocks, because of the 6-years cessation in fishing efforts on the herring feeding grounds in the central North Sea. In spite of the severe damage that the fishing fleet suffered during the WWII, the Belgian (coastal) fisheries benefited economically from this unintended 6-year temporary closure to fisheries in the North Sea that triggered a period of rapid expansion and investments in the Belgian fleet in the years to follow.

After the cessation of the fishing activities during WWII, the sector was severely hit by an economic crisis in 1948. According to local fisheries experts, the North Sea showed marks of depletion of its fish stocks again by 1950 (Poppe 1977, Omeij 1982). In only 10 years time after WWII, the fleet size decreased from approximately 550 to 450 vessels (Lescrauwaet et al. 2012). This decrease in fleet size is reflected in the decrease in total GT and total kW of the fleet (Figure 9.4) and by the sudden drop in landings between 1948 and 1950 (Figure 9.3.).

Between 1955 and 1970, major structural changes took place in the Belgian sea fisheries fleet (Figure 9.4.). These changes were driven first by the larger otter trawling vessels that shifted their fishing activities to the Icelandic waters to ensure profitability and in the early 1960s by the governmental subsidies for the purchase of new steel-hulled medium-sized motor trawlers and the introduction of the beam-trawl (Poppe 1977, Lescrauwaet et al. 2012). From 1955 to 1970 the total kW of the fleet increased while the total GT remained stable, which is explained by the increase in average kW per vessel as a consequence of the events described above (Figure 9.4.). This led to less but more powerful vessels: between 1960 and 1975 the fleet size declined from 430 to approximately 250 vessels (-42%). The decline in fleet size was exacerbated when Iceland demarcated its territorial waters from 12 nm to 50 nm in 1972 and when the presence of Belgian fishermen within the declared 200 nm EEZ of Icelandic waters became subject to a 'phase-out' in 1975 (Chapter 8 and Lescrauwaet et al. under review).

Although the peak in fishing effort by the Belgian fleet in Icelandic waters was situated in 1963, various of the indicators were already in decline by then: the total landings, the relative importance of target-species cod in the total landings from Icelandic waters, the LPUE, and the proportion of larger cod in the total landings (Lescrauwaet et al. ms under review, Chapter 8). As a consequence of the loss of the Icelandic waters towards 1980, Belgian vessels shifted their activities again towards the central part of the North Sea (Omeij 1982) and - to a lesser extent - towards the English Channel, Bristol Channel, South and West Ireland and the Irish Sea.

Before 1974, the Belgian fisheries fleet remained largely free of restrictive measurements except for aspects related to minimum mesh sizes and minimum landing sizes MLS of the fish, as e.g. established by royal decree of 30 December 1950 (<http://www.vliz.be/imis/oma/imis.php?refid=204569>). In 1975 the 'total allowable catches' or TAC were introduced for the first time by the North East Atlantic Fishery Commission NEAFC, and this system was later followed-up by the EU Common Fisheries Policy. Two years later, on 22 September 1977, the 12nm was established as a zone for coastal fisheries where beam-trawling was prohibited for vessels with engine power above 221kW (<http://www.vliz.be/imis/imis.php?module=ref&refid=207089>). Although in spirit this law was issued to favour the 'protection of marine biological resources', an EEC subsidy scheme implemented from 1980 onwards stimulated the construction of new 'Eurocutters' or vessels with engines <221kW and LOA < 23.99m to be able to exploit the 12nm zone. This is reflected in a temporary stabilization of the fleet size (number of vessels) at least until the 1990s. This period also coincided with an increase in the overall kW of the fleet and in the average kW of a vessel (Figure 9.4.).

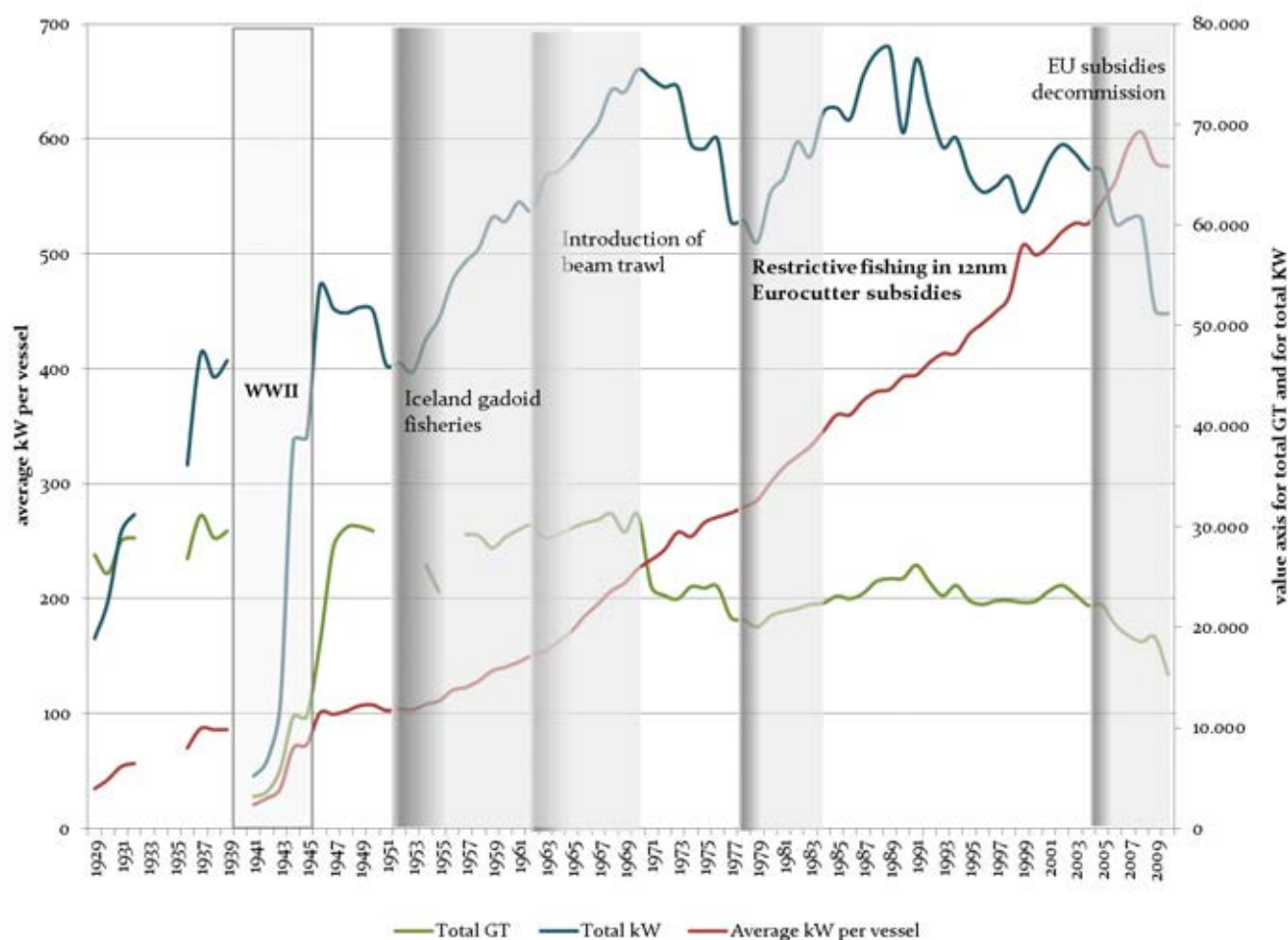


Figure 9.4.: Landings of the 3 main components (herring and sprat, gadoid and other roundfish, sole and plaice) as a percentage of total landings (red line). The relative proportions of each of these 3 components are indicated as areas (%).

As was the case for the Dutch fleet (Rijnsdorp et al. 2008), this management restriction generated a bifurcation in the Belgian fleet between the Small Fleet Segment SFS and the Large Fleet segment LFS which persists until today. For the case of the Belgian LFS, the continued increase in average engine power is related to a gradual introduction of *technological creep*, e.g. the size of the gear, the towing speed, the number of tickler chains rigged in the net-mouth of the beam-trawl, and which required more engine power (Polet et al. 1998, Rijnsdorp et al. 2008).

The structural changes as a consequence of technological developments in the 1960s, the loss of access to the Icelandic waters as fishing grounds, the energy crisis and the increasing fuel costs in the early 1970s (and later), have contributed in different degrees to these changes in the fleet and spatial dynamics of fisheries (Chapter 4 and Chapter 5, Lescrauwaet et al. 2012). From 2000 onwards specific programmes of the EU CFP were established, oriented to the decommissioning of ships with the aim to reduce fleet capacity although this did not directly led to a decrease in average kW per vessel. In Belgium, the royal decree of 29 June 1984 already foresees decommissioning for vessels of at least 12m LOA and which had spent at least 100 days fishing the previous year. The increasing trend in average engine power (kW) in a declining fleet size was legally capped by measures establishing a maximum of 1,200 kW per vessel. Finally, the decline in total engine power (kW) in recent years is both due to the decline in the fleet size and the gradual replacement of larger vessels by smaller

ones (Figure 9.4.). In 2012, the Belgian commercial sea fishing fleet counted 86 ships, with a total engine capacity of 49,135 kW and gross tonnage of 15,326 GT (Roegiers et al. 2013).

These shifts in the overall fleet and fleet dynamics are generally not perceived at the level of individual fishers or vessel crews and difficult to perceive unless visualized over longer periods. To interpret the trends correctly, information from a political, socio-economic and/or cultural context proves indispensable. In an analysis of external factors affecting the Dutch bottom trawling fleet from 1945- 2005, Rijnsdorp et al. (2008) found a direct correlation between changes in the fleet and periods during which species availability – expressed as biomass per unit of engine power - was well above average. Rijnsdorp and co-workers (op.cit.) also found that changes in engine power of the fleet showed a significant positive correlation with the net economic results with a time lag of 1 year, and a periodicity with a period of 6.6 year in the change in engine power. Although different mechanisms explain the change in engine power of the Belgian fleet, the data suggest that the fleet responded very quickly to external factors (see Chapter 7).

9.3.4. LANDINGS PER UNIT OF EFFORT LPUE

At the level of the Belgian fleet, the total number of days spent at sea has decreased from approximately 91,800 days in 1938 to 15,100 days in 2010 (-84%; Figure 9.5 second panel from below). Trends in productivity can be expressed in terms of fishing effort: landings per day at sea or per fishing day, landings per fishing hour FH, or per kW*FH. The total landings decreased with total fleet size (number of vessels), with total fishing effort (days at sea and days fishing) and with kW*FH. Interestingly, the average price of landings (all species, all areas, all fisheries aggregated) is negatively correlated with the decreasing fishing effort and decrease in overall landings. This suggests that the Belgian sea fisheries compensated for the losses by targeting species that achieve better prices in the market (Figure 9.6. second panel from above; Figure 9.9).

Trends in productivity can also be expressed in terms of fishing effort per vessel. Changes at this level are generally perceived by individual fishers and crews, over decades (Saenz-Arroyo et al. 2005). Fishing crews spent on average 88% of the days at sea as effectual fishing days, with a minimum of 79% in 1963-64 when the distant Iceland fisheries were at their peak effort. A vessel spent on average 171 days per year at sea. During WWII, when fishing was only allowed during daytime breaks and in coastal waters, a day spent at sea was actually spent fishing. Expressed as landings (kg) per vessel per day at sea or per day fishing, the average amount has doubled from approximately 400kg in 1938 to 1,000kg in 2010 (Figure 5.7., Chapter 5). At least 4 successive events or periods are observed. The first event (1939-1945) is marked by WWII and the increased landings of herring in coastal waters. The exceptionally high landings per unit of effort are partly explained by the cessation of large-scale herring fisheries in the North Sea during WWII combined with the effects of two strong year classes (Chapter 7). The second period is situated in 1951-1955 and coincides with the steep increase in landings from Icelandic waters. Thirdly, an increase in landings is observed between 1960 and 1967, which largely coincides with the state subsidies to introduce the beam trawl firstly in shrimp vessels (1959-1960) and later for flatfish fisheries. A final conspicuous increase concerns the period of increased levels of landings per vessel per day between 1977 and 1986. The trend in landings (t) per vessel (Figure 9.5., central panel) largely confirms this, and shows an additional period of sustained increases in the early 2000s.

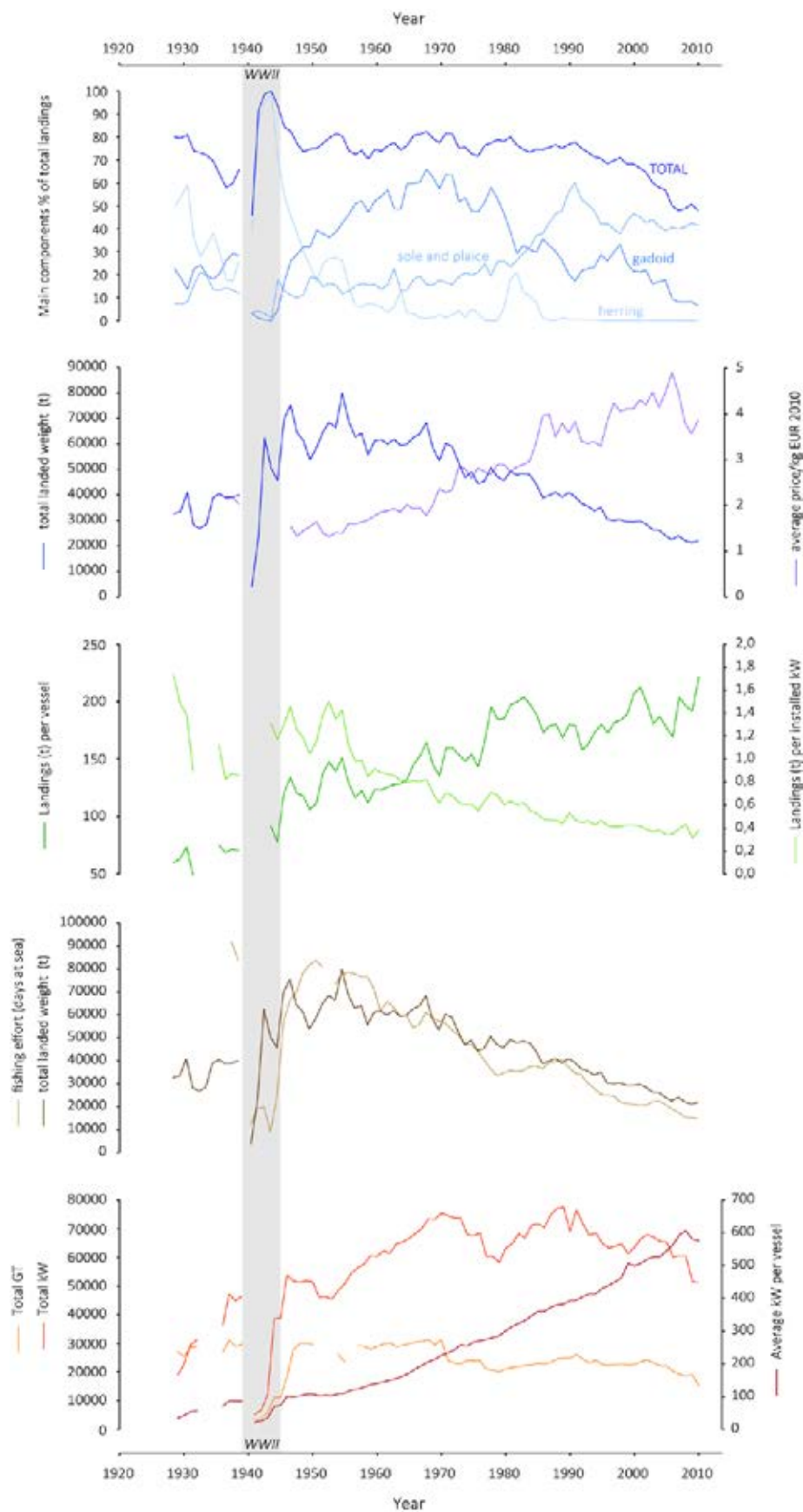


Figure 9.5.: Overview of the main trends in Belgian sea fisheries 1920-2010: fleet dynamics (GT, kW, average kW per vessel, see lower panel), fishing effort (days at sea) versus overall landings (t) (second panel from below), landings per vessel and per installed unit of engine power (kW) (central panel), average price (Euro/kg) expressed as values 2010 corrected for inflation, second panel from above), proportion of landings (%) for the 3 main components of target species. (drawing T. Verleye)

9.3.5. LANDINGS PER UNIT OF POWER LPUP

The annual landings per operational unit of the fleet (vessel) increased from 119 t per year in 1946 to 220 t per year in 2010 (Figure 9.5. central panel). However, if expressed as LPUP to account for the average increase (x6) of engine power per vessel, the landings have decreased by 74% from an average 1,3 t /installed kW in 1944-1947 to 0,38 t /installed kW in 2009-2010 (Figure 9.5. central panel).

When normalized for installed unit of engine power (kW), only the first peaks in increased landings per vessel referring to WWII and the Iceland fisheries are visible, suggesting that the peaks in landings per vessel are explained as the effect of increasingly powerful vessels (see Chapter 5 on Fleet dynamics, Fig. 7.5. central panel). Again, from the vessel or crews' perspective, the landings per vessel will be perceived as real changes and shifts, whereas the changes in LPUP may go unnoticed except for the vessel owner who invested in additional engine power or received state subsidies to do so.

The historical reconstruction presented here does not take into account other relevant enabling technologies that significantly enhanced fishing power, and that are commonly referred to as 'technological creep'. Marchal et al. (2003) estimated an annual increase in catchability as a consequence of 'technological creep' of up to 10% in North Sea surveys, while Rijnsdorp et al. (1996) reported an annual increase of 1.8-2.6% in beam trawl fisheries for sole and plaice in the North Sea.

Although the LPUP are illustrative of the changes in the productivity of fisheries, they can not be interpreted as a proxy of change in biomass of commercial fish stocks, because the Belgian fisheries have targeted different species and fishing areas over time (Figure 9.3. and 7.4.). Trend analysis to study change in fish stocks must be conducted at the level of different métiers or fisheries, taking into account issues such as specificity and selectivity of gear, environmental conditions in the targeted fishing area, seasonality of fishing and behavior of target species.

9.3.6. IMPACT OF FISHERIES AND CHANGE IN FISH STOCKS

In Chapter 6 of the present thesis, a closer look is taken at the impact of sea fisheries. In a first part, a quantitative approach is taken to reconstruct total removals by Belgian sea fisheries by including the unreported and misreported landings of commercial and recreational fishing, as well as an estimation of discards. This reconstruction covers 6 fisheries with historical or current importance for Belgium (Lescrauwaet et al. 2013). Total reconstructed removals were estimated at 5.2 million t or 42% higher than the 3.7 million t publicly reported over this period. Unreported landings and discards were estimated to represent respectively 3.5% (0.2 million t) and 26% (1.3 million t) of these total reconstructed removals.

Chapter 7 brings an analysis of the exceptional situation of sea fisheries in Belgium during WWII (1939-1945) when unusually high landings of herring (*Clupea harengus*) were achieved under restricted fishing conditions. The data presented in the context of this thesis show a 10-fold increase in the Belgian 'autumn spawning herring' catches and a 5-fold increase in landings per unit of effort of Downs herring during WWII. It is argued that these increased catches are explained by a combination of factors including the sustained effect of a major increase in catch power, the effects of strong pre-WWII year classes and the effects of decreased fishing mortality during the 6-years cessation in fishing on the herring feeding grounds in the central North Sea and in the English Channel (Lescrauwaet et al. revised manuscript under review).

A third subchapter focuses on the otter trawl fishery in Icelandic waters targeting cod. This fishery was of great economic importance in Belgium but decreased with the 'cod wars' (1958 and 1972) coming finally to a complete end in 1996. 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. The reconstructed time-series on Belgian commercial fisheries landings and fishing effort include information

on vessel type and fishing rectangle. The results show that the decline in the Iceland cod stock was visible at different levels; 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. The three cases analysed in Chapter 6 document substantial changes in LPUE for specific fisheries, or in targeted stock biomass.

9.3.7. BELGIAN PART OF THE NORTH SEA

As a result of this thesis, unique data are presented on the trends in volume and composition of landings for the Belgian part of the North Sea (BNS). Since the Middle Ages, Flemish fisheries have targeted a variety of fishing grounds, many of which were distant fishing areas (Faroe, Iceland, White Sea, Labrador, etc., Chapter 2-4). Still, in spite of its limited extension, the BNS has been historically the most important fishing area for Belgian fisheries, representing over 20% of the total Belgian landings (Lescrauwaet et al. 2010a). The waters of the BNS are considered as the most important fishing area in terms of source of food for local population, but also as the most stable provider of food (Chapter 4). The BNS and in particular the ecosystem of shallow underwater sandbanks is also important as (post)spawning and nursery area (Leloup and Gilis 1961, Gilis 1961, Leloup and Gilis 1965, Rabaut et al. 2007). The data also suggest that since the 2000s, approximately 50% of all Belgian removals from the BNS are unreported landings and discards (IUU) and total fish discarded by the Belgian fisheries on the BNS may range between 30-40% of all Belgian landings from the BNS. These numbers do not take into account the non-commercial benthic species and the catches by the French and Dutch fleets that also have a long-standing tradition of fishing in the BNS (Depestele et al. 2011).

Commercial catch per unit of effort (CPUE) - and its variant LPUE - is widely used as an index of abundance of fish, although the factors that may potentially bias this index are well documented and the index may be less suitable for pelagic species that display schooling behaviour (Hilborn and Walters 1992). The index needs to be used for specific métiers and particular fishing areas, in order to be interpreted as a relative index of abundance. This analysis is conducted for the demersal fisheries in the BNS, targeting mainly flatfish. Similar as for the overall Belgian sea fisheries, the time-series for LPUE of the demersal (flatfish) fisheries shows a period of higher LPUE just after WWII, with a decrease of 50% in the decade after WWII, suggesting a decrease in biomass of targeted species (Figure 9.6., Lescrauwaet et al. in prep.).

From the beginning of the 1960s until 1967, in the period coinciding with the transition from the otter trawl to the more efficient beam trawl and an increase in fishing effort, the LPUE remain around 0.35 kg/HP*Fishing Hour with a slight increase to 0.4 kg/HP*FH in 1967. During the 1970s the fishing effort increases, however the LPUE remains at lower levels (0.15-0.25 kg/HP*FH). As a reference, the analysis conducted for the Belgian fisheries in Iceland, indicated that LPUE values decreased from 0.95 kg/HP*FH in 1946 to 0.24kg/HP*FH in 1983.

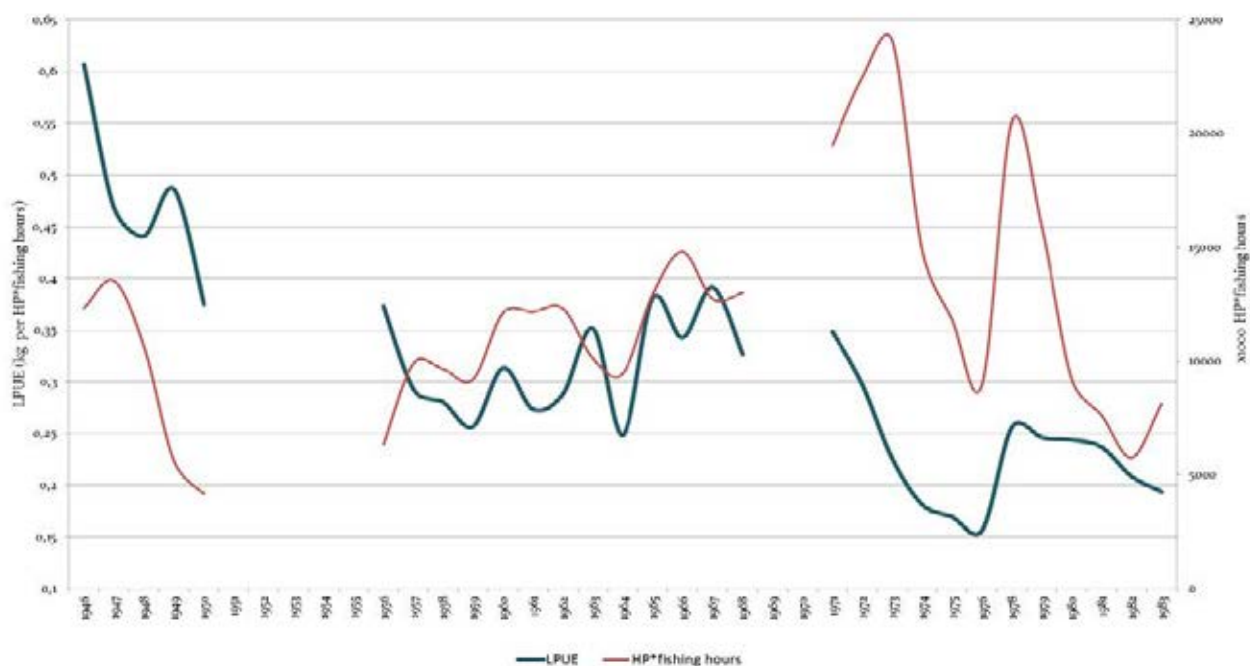


Figure 9.6.: Landings per unit of effort (kg/kW*fishing hour), left-hand axis and total fishing effort (kW*fishing hours) by the demersal trawl fisheries on the Belgian part of the North Sea, 1946-1983.

9.4. HISTORICAL TIME SERIES AND POLICY RELEVANCE IN SUPPORT OF POLICY OBJECTIVES AND TARGETS

9.4.1. HISTORICAL TIME-SERIES IN SUPPORT OF FISHERIES POLICIES

Awareness on the shifts in perception of the status of stocks or the health of marine ecosystems has influenced current marine ecological research and its methods and assumptions (McClenachan et al. 2012). Historical baselines are extremely valuable as reference conditions for marine ecosystems, to assess their status and set goals for sustainable management. This is particularly true for fish populations and commercial fish stocks that have long been exploited and the baselines for rebuilding depleted fish stocks typically refer to strongly exploited situations (Pitcher 2001). There is now on-going research to reconstruct and study reference conditions or historical baselines that date from before the onset of industrial or large-scale intensive fishing practices (Pauly 1995, Rijnsdorp et al. 1996, Roberts 2007, Pinnegar and Engelhard 2008, Cardinale et al. 2009). Evidence is available about the shift in the 'centre of gravity' of the main commercial fish stocks over the last 80-90 decades (Pinnegar et al. 2010, Kerby et al. 2013). Although some of these shifts may be (partly) due to climate change, it is not possible to exclude fisheries and modifications in habitat and trophic structure as a factor influencing these shifts. New fisheries have developed for a number of warmer-water species including seabass, red mullet, anchovy and squid (Pinnegar et al. 2010).

Landings from commercial fisheries were used in a number of applications and models and can be accepted as a proxy for fishing mortality (Daan et al. 1994, Walker and Heessen 1996, Zeller and Pauly 2007, Eero et al. 2008). Landing statistics served as a basis for analyses conducted in the present thesis focusing e.g. on estimating the historical losses of valuable resources through the IUU in Belgian fisheries (Chapter 6) or exploring the potential yield of fish stocks under different, lower intensities of exploitation (e.g. Downs herring, Lescrauwaet et al. revised manuscript under review, Chapter 7). Of particular interest are the datasets in which landings are reported in conjunction with fishing effort for particular segments of the fleet, fisheries type, high

temporal and spatial resolution, as was the case of Iceland (cod) fisheries. In the two latter cases, the reconstructed data contributed with new knowledge for a period in which a gap exists in the current time-series for the stock assessments (Downs herring and Iceland cod) or information on spatial components of fish stocks that were 'lost' (Downs herring).

The historical time-series for the Belgian sea fisheries can further contribute to local fisheries management and the fisheries policy targets through:

- Reconstruction of historical LPUE to support recovery or management plans for fisheries practiced in the past (e.g. *Nephrops* fisheries).
- Analysis of deployed gear and fishing effort in the past
- Documenting and estimating technological adaptations of the fleet and fishing techniques through time
- (Re)utilization of 'forgotten' fishing gear and fishing techniques
- Seasonality in historical occurrence, distribution and abundance of target species
- Proportional importance of landings by weight classes and reconstruction of historical weight classes of target species
- Descriptive historical statistics of 'Coastal fisheries' in Belgian waters and their relative importance in the past
- Estimates of historical and current unreported and recreational fisheries on the BNS and in other fishing areas, as an unaccounted component in EU quota and stock management. In particular the catches of plaice and sole on the BNS.
- Literature references and metadata for current fisheries research e.g.
 - o Qualitative reference conditions for species for which no formal assessments are available such as brill and turbot).
 - o Historical references on discard rates for current or future management measures

Efforts to expand assessments further back in time by analyzing historical biological material such as otoliths and bones, have yielded crucial insights in patterns of fishing and exploitation of fish stocks (Barrett et al. 2011, Orton et al. 2011).

Fishing with improved technologies

An important aspect in reconstructing historical fishing effort and catch rates is the adaptation of new technologies to improve efficiency of fishing ('technological creep'). There is evidence that the efficiency of fishing vessels has increased through technological creep (see Marchal et al. 2007 for a review). Fishing effort is estimated by combining available physical measurements of fishing capacity (fixed production inputs) and fishing activity (variable production inputs). Fishing capacity is generally measured as a physical attribute of the operating vessel (engine power, gross tonnage), but is also dependent on other factors, including gear technology and on-board equipment, which are often ignored (Marchal et al. 2007). The introduction of new gear and technology includes new inventions such as acoustic fish-finding equipment, electronic navigation tools, but also refers to smaller and gradual improvements to the gear e.g. different netting materials and changes in the design of the nets or trawling devices. Although the latter may go unnoticed in the reporting on fishing capacity, they may cause a significant increase in fishing capacity over time. Fishing activity is typically estimated by the duration of fishing trips, therefore not taking into account important factors that define fishing pressure such as the number and the sizes of gear deployed, or the effective time used for fishing (Marchal et al. 2007). Marchal et al. (2003) estimated an annual increase in catchability of up to 10% as a consequence of 'technological creep', in North Sea surveys, while Rijnsdorp et al. (1996) reported an annual increase of 1.8-2.6% in beam trawl fisheries for sole and plaice in the North Sea. For the case of the Belgian

fleet, an important example of technological creep is the introduction of tickler chains rigged in the net-mouth (Polet et al. 1998).

Studies to evaluate time variations in fishing efficiency while taking into account the processes of technological creep in the analysis of CPUE, are often restricted by data availability. Historical data on fishing capacity of the commercial fleet are typically collected from vessels' logbooks. Although this includes information on engine power, vessel length, and/or gross tonnage, historical sources may contain other descriptors of fishing effort that are often overlooked (gear type, duration of tow, length of net used per day, crew size). Adjusting the estimates of changes in fishing effort by taking into account technological improvements and changes in the deployment of gear - based on these historical descriptors - can help improve the assessments of change in fishing capacity, in CPUE estimates and therefore improve (stock) assessments.

9.4.2. HISTORICAL TIME-SERIES IN SUPPORT OF ENVIRONMENTAL POLICIES

Current needs for a sustainable management of our coasts and seas have to deal with a number of uncertainties and knowledge gaps. To judge properly these uncertainties, long-term series and historical data are crucial. By rescuing and integrating time-series for policy-relevant datasets, research outcomes can inform about the condition of the North Sea in the past and relate these changing conditions with long-term changes in fishery, in fish assemblages and other ecosystem components (benthic species, pelagic species). Long-term or historical time-series allow the development of instruments in support of policies for the sustainable development and management of the North Sea and enhance our knowledge and understanding of changes in the diversity, distribution and abundance of fish and targeted benthic species (in fishery), the changes in fishing effort and their socio-economic and environmental implications.

From an ecosystem perspective, historical information is valuable in the context of the GES targets as set forward for the descriptors on fish stocks and biodiversity in the MSFD (2008/56/EG). The MSFD is the cornerstone of marine environmental policy within the EU Integrated Maritime Policy, and aims to establish an ecosystem-based approach in management of the EU marine waters. It also aims to strengthen the environmental targets and objectives as set forward in other EU policies for coasts and seas (MSP and ICM, Habitat directive, WFD, CFP), support the objectives of the CFP (managing fish stocks at levels above maximum sustainable yield MSY), and to achieve a favourable conservation status FCS for the species and habitats protected in marine and coastal Natura 2000 sites.

In spite of the remaining gaps and uncertainties, historical time-series, and in particular the data for the BNS, can support the wider debate about the role of small-scale fisheries, about how to move to more sustainable fisheries, how to achieve the agreed policy targets in Belgian marine waters and in particular in the marine areas protected under the EU Habitat and Bird directives.

The contribution of historical time-series has also proven valuable for environmental policies, specifically by means of:

- Information on the shift in distribution of species to different latitudinal and depth ranges in response to changes in environmental parameters (e.g. cod, whiting).
- Historical catches of 'southern' species. Examples are developed in the HiFiDatabase for
 - o *Trachinus draco* – Greater weever
 - o *Chelidonichthys lucerna* – Tub gurnard
 - o *Dicentrarchus labrax* – European sea bass
 - o *Sepia officinalis* - cuttlefish
- Predictive studies on the impact of climate change

- (commercial) extinction of fish and other species, and the recovery thereof (e.g. sturgeon) changes in local abundance of non-target species (Greater weever).
- Data on non-endemic species(e.g. *Micropogonias undulatus*)
- Trends in biodiversity indicators

9.4.3. HISTORICAL TIME SERIES IN OTHER FIELDS OF APPLICATION

The results of the reconstruction of historical time-series in the present thesis focus on the dynamics of the sea fisheries fleet, trends in volume and composition of landings and parameters related to the output per unit of effort. However, though far from being exhaustive, in this reconstruction effort also other types of data and information were collected and integrated as time-series. These data cover different fields of socio-cultural and societal aspects such as employment in fisheries, age structure of the fishers population, population of fishers by function (skipper, mechanic, sailor,...), number of students in educational institutions for the maritime and fisheries sectors etc. Examples on the historical employment in fisheries are included below, (Figure 9.7 and Figure 9.8.)

Very little work is, e.g., conducted on the socio-economic effects of environmental changes and climate change on the fisheries. In fishing communities where strong traditions persist to use particular fishing gear and target specific - economically interesting - species, these studies are needed. This is of particular importance in communities that depend on species that are directly affected in their distribution and abundance by these environmental changes, e.g. the effect of ocean acidification on molluscs. Historical time-series may offer new perspectives by illustrating or re-discovering forgotten fishing traditions, gear and target species, and their economic potential.

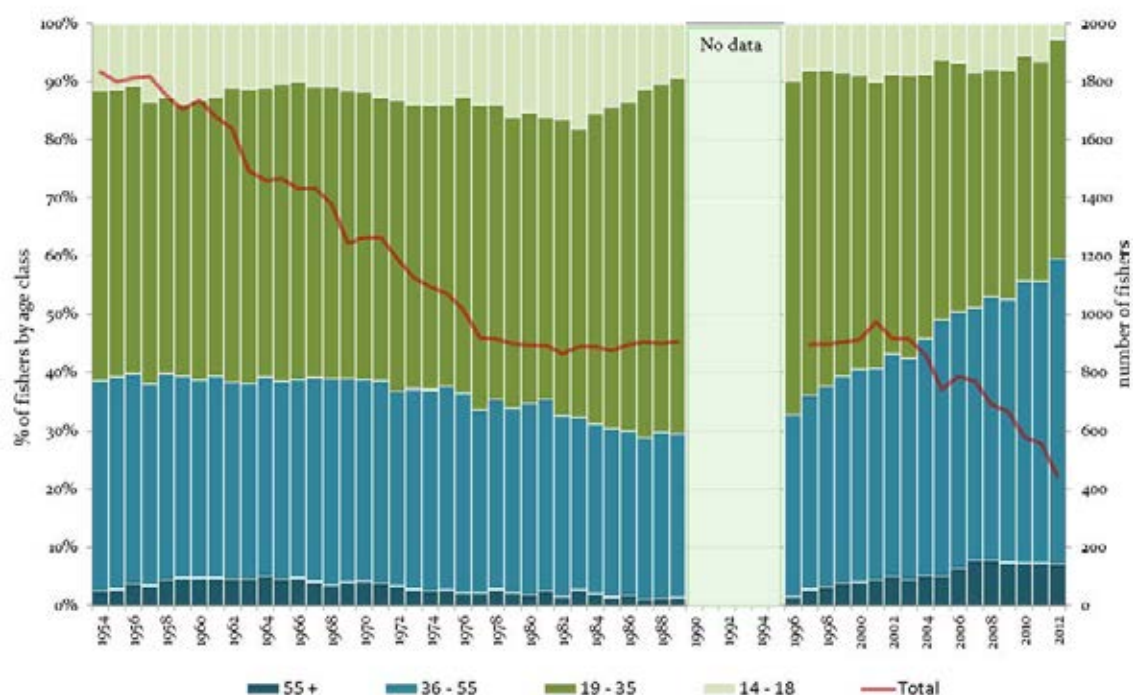


Figure 9.7.: Direct employment in fisheries in Belgium: absolute number of fishers, and proportion by age class, 1954-2012.

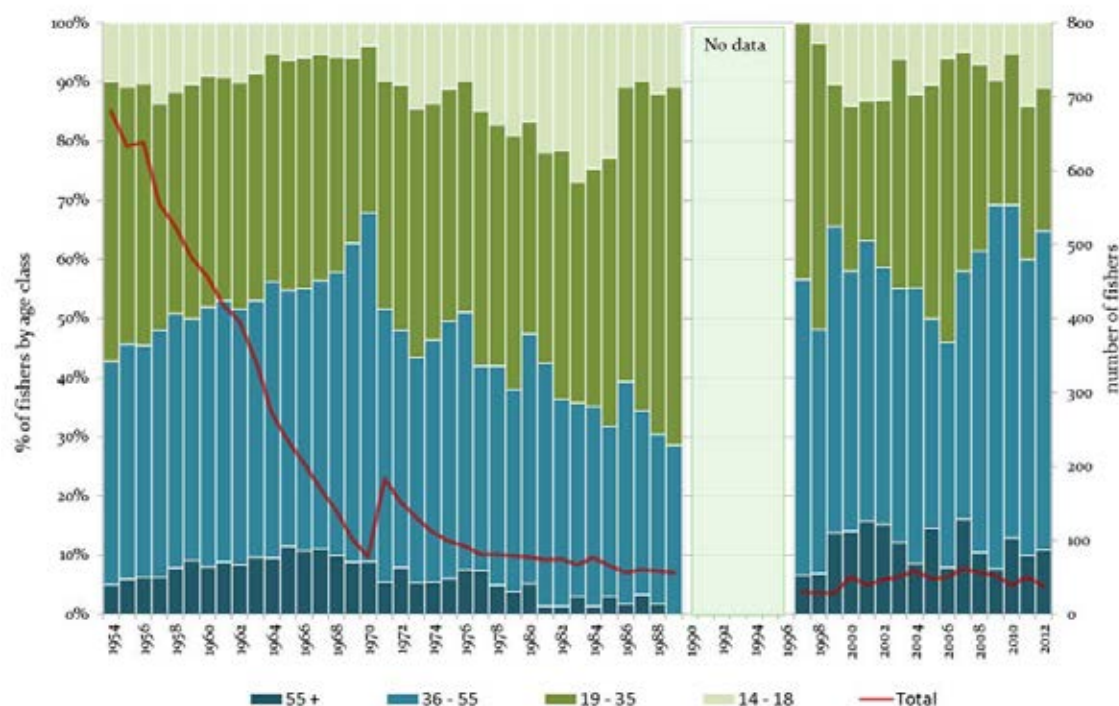


Figure 9.8.: Direct employment in coastal fisheries in Belgium: absolute number of coastal fishers, and proportion by age class, 1954-2012. Note: The sudden increase of coastal fisheries in 1971 is largely due to the change in the definition of 'coastal fisheries'. Whereas this contained the vessel classes I and II (up to 120HP) before 1971, it was modified to contain all vessels smaller than 35GT in 1971 and later expanded to vessels with engine power <221kW and 70GT that conduct fishing trips of 24 hours maximum (recently expanded to 48 hours)

Historical time-series such as landings and catches or fleet parameters can also serve as the basis for the estimation of historical baselines by involving diversity of sources and data (surveys, oral history and interviews, historical population data, fish consumption etc.). In this sense, the results of the reconstruction of time-series of landings were used in a local Belgian project to reconstruct historical ecology of the Belgian part of the North Sea and the Southern North Sea from 1930-1980, through interviews with elder fishermen (Project "Yesterday's Sea"). The HiFiDatabase also served as reference material in the efforts to valorize Local Ecological Knowledge of fishermen on the historical ecology of the Belgian part of the North Sea (LECOFISH project).

Other historical time-series and parameters that were reconstructed for Belgian sea fisheries at the same spatial, temporal and taxonomic resolution as for the landings, are the economic data associated to the commercial landings (total value, price per kg) (Table 9.2.). This data is available for further socio-economic research and applications.

The example included below shows how average price per kg (corrected for inflation) of the commercial fisheries (all species, all fisheries, all fishing areas aggregated) has continuously increased. It illustrates how, in spite of the decrease in landings, Belgian fisheries compensated for the losses by increasingly targeting economically more valuable species.

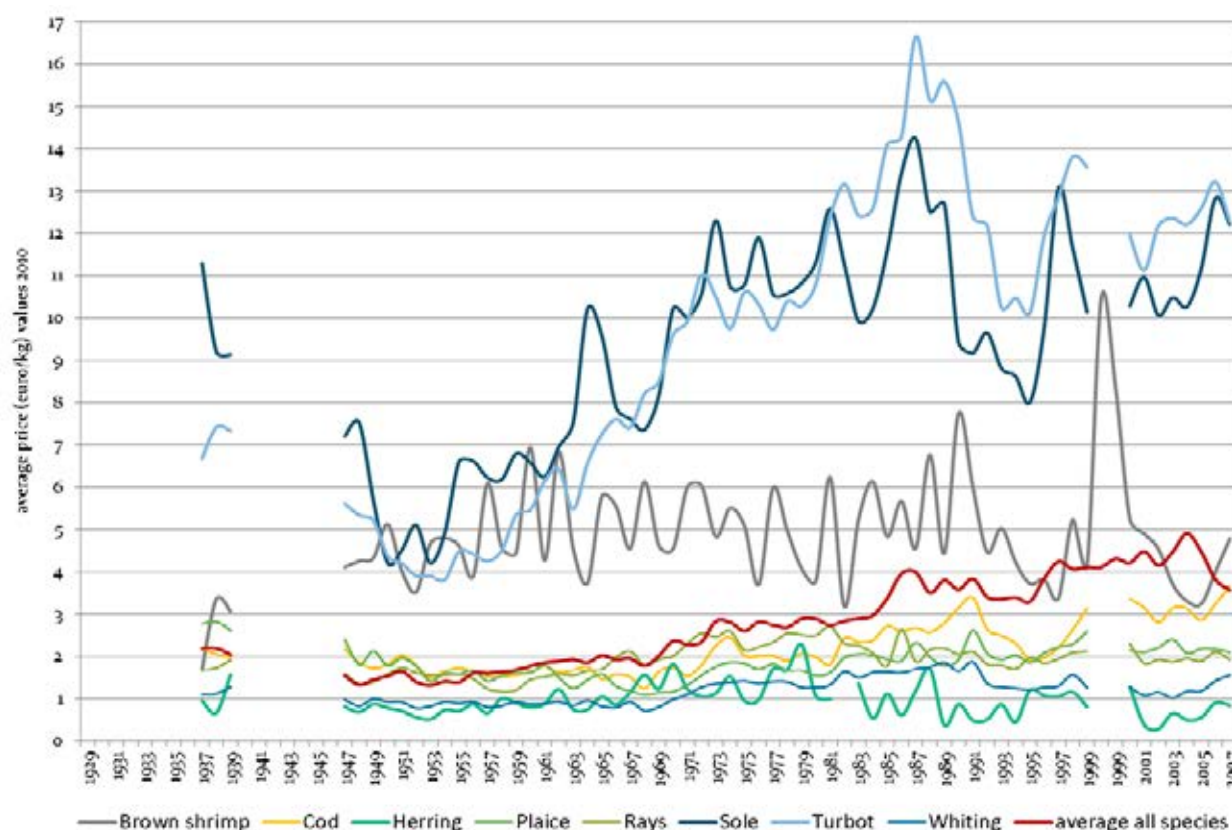


Figure 9.9.: Average price (euro/kg, prices corrected for inflation expressed as values 2010) of total commercial landings, and prices for the most important species in terms of landings or income, Belgian sea fisheries.

9.5. CONCLUSIONS AND OUTLOOK

The purpose of the present thesis is - as a first step - to reconstruct time-series in the Belgian Sea Fisheries based on standardized quantitative parameters in terms of input (fleet, effort) and output (landings, economic value), and explore trends in these parameters trends over one century.

The results of the current efforts to reconstruct these time-series are described in Chapter 2 and 3, and the strengths and weaknesses of the overall database are summarized in Table 9.1. The usefulness of the HiFiDatabase is commented in Chapter 2, and an overview of applications and uses of the HiFiDatabase is included (Appendices).

Next steps and priorities in data integration and analysis include:

- Conduct trend analysis (landings, effort, LPUE) by type of fisheries (métier) and by fishing area of origin at the highest temporal, spatial and taxonomic resolution. Where available, the analysis can be expanded with landings by weight class and improved by taking into account the impact of technological improvements in LPUE estimates..
- Collect evidence and indications to improve the present historical estimates of IUU in Belgian sea fisheries, and improved estimates to complement the current landing statistics (e.g. on sea angling).

- Explore the relevance of collected data, in combination with other time series, for further use in policy making, i.a.:
 - for the description of historical baselines for the Belgian part of the North sea and the wider North Sea area;
 - for inferences related to trophic level of sea fisheries, and for validating or challenging the concept of fishing down the food web (Pauly et al. 1998) in the context of Belgian fisheries.
- Explore with neighbouring countries (The Netherlands, UK, France), the feasibility of reconstructing historical fishing effort and an analysis of flatfish fisheries (sole and plaice) in the otter and beam trawl fisheries in the North Sea: integrating fishing effort, market drivers (including oil prices), policy drivers, and landing statistics (by month, by rectangle, by weight class), and introduction of new technologies;
- Explore with neighbouring countries (The Netherlands, France, UK) the reconstruction of reported and unreported removals (which include discards) in the Belgian coastal waters by the foreign fleet, to obtain an improved assessment of the cumulative impact of fisheries on the BNS.

The reconstructed time-series underline the decline in landings since the start of systematic reporting and quantify the patterns of successive exploitation of target species and fishing areas by the Belgian sea fisheries, changes in species composition and origin of landing, changes in the fleet and vessel characteristics. By integrating the different parameters, general indices were reconstructed that describe the Belgian fisheries in terms of spatial dynamics, sustainability (tkm of catch), diversity of composition (Hill indices of diversity, Chapter 4), fleet dynamics (Chapter 5), LPUE, LPUP.

In a second step, indicators of the impact of fisheries, both on the targeted commercial fish stocks as on other marine resources were reconstructed from some of these long-term data series. By means of specific cases, the concept of 'shifting baselines' was applied in Belgian sea fisheries for important fishing métiers: the spent herring fisheries (1930-1960) and the cod fisheries in Iceland (1947-1996). A historical reconstruction of the IUU for Belgian sea fisheries was conducted for the period 1929-2010 and an estimate of the current unreported fisheries catches on the BNS provided. Again here, the historical time-series demonstrate the profound changes in fishing and in fish stocks, over the last ten decades (Chapter 6, 7 and 8).

The impact of fisheries on the marine biodiversity and on the marine ecosystem functioning is a key concern in marine conservation strategies, especially in areas where fisheries with traditional high-impact are or have been practiced, e.g. shrimp fisheries, *Nephrops* fisheries, beam trawl fisheries. The HiFiDatabase broadens the historical view on fisheries, underlines the decline in landings since reporting started, and serves as a basis for further (fisheries) research, management applications, and policy-making. In particular, the time-series provide unique historical reference conditions of fishing in the Belgian part of the North Sea and a potential baseline for fisheries management in the territorial sea or for the coastal fisheries. The latter is useful in the context of the MSFD and the proposal for Maritime Spatial Planning on the Belgian part of the North Sea.

Particular attention should be drawn to the case of the unreported removals of fish in the BNS. Discarding on the BNS (Chapter 6) represents a substantial waste of resources, is unacceptable from a perspective of environmental impact and sustainable management and is to be considered unethical from a societal viewpoint. The data presented here provide a first assessment of IUU on the BNS and suggest that besides the discards from commercial fishing operations, the recreational fisheries are taking important proportions. Currently, the impacts of the recreational fleet are not taken into account in fisheries or environmental management. In spite of the small vessel size, these impacts nevertheless may be quite substantial due to the employed gear (trawls) and the size of the fleet. Furthermore, from the point of view of ensuring safe

and secure jobs, the recreational fisheries represent unaddressed challenges. Urgently, ways must be explored to include the activities and impacts of the recreational fleet in current fisheries and environmental management schemes for the BNS, while looking at specific measures that can stimulate the development of small-scale low-impact fishing activities on the BNS that are economically viable for professional fishermen.

However, the results of the data aim to reach beyond informing and supporting fishery and environmental research and policies. It is expected that the data, time-series and trends presented in this thesis, may lead to a greater awareness about the profound changes that have taken place in marine ecosystems, and the effects of humans on the marine ecosystems. At the same time, the data aim to elucidate how unregulated activities or activities that are not supported by sound science and following an ecosystem-based approach, are affecting our environment, and opportunities for jobs and income. It is aimed that the results of the thesis work are used in a wider range of educational activities and outreach.

Finally, in the present thesis work, important efforts were dedicated to approach the history of fisheries from different disciplines of work. The results underline the importance of collecting economic data, inventorying historical archives and historical legislation, historical economy and politics, in order to improve the interpretation and analysis of results. In this way, the present thesis work hopes to have contributed to the need for integrated approaches in marine sciences. As advocated by the current integrated policies for the marine environment, both the challenge of the task and the richness of the results rely on a multidisciplinary approach.