Assessing the response of the German Baltic Small-Scale Fishery to changes in the abundance and management of fish resources during 2000-09

Developing and applying a spatial database to quantify the impacts of changes in resource abundance and management during 2000-09 on the structure and operation of the German Baltic Small-Scale Fishery

Dissertation

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Ich erkläre, dass die vorliegende Arbeit gemäβ den Grundsätzen zur Sicherung guter wissenschaftlicher Praxis der Deutschen Forschungsgemeinschaft erstellt wurde.

Kiel,

Eva Papaioannou

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Abbreviations / Acronyms

BfN	German Federal Agency for Nature Conservation
BITS	Baltic International Trawling Survey
BLE	German Federal Office for Agriculture and Food
CBD	Convention on Biological Diversity (UN)
CCRF	Code of Conduct for Responsible Fisheries (FAO)
CFP	Common Fisheries Policy (EU)
CFR	Community Fleet Register (EU)
EAF	Ecosystem Approach to Fisheries
EFH (s)	Essential Fish Habitat(s)
EUROSTAT	Statistical Office of the European Union
FAO	Food and Agriculture Organization (UN)
FPN	Stationary uncovered poundnets (fishing gear type) (EU CFR and FAO)
FPO	Pots (fishing gear type) (EU CFR and FAO)
FWR	Barriers, Fences, Weirs etc. (fishing gear type) (FAO)
GIS	Geographic Information System
GND	Driftnets (fishing gear type)
GNS	Gillnets (fishing gear type) (EU CFR and FAO)
GT	Gross Tonnage (metric)
HELCOM	Baltic Marine Environment Protection (Helsinki) Commission
IBSFC	International Baltic Sea Fishery Commission
IBTS	International Bottom Trawl Survey
ICES	International Council for the Exploration of the Sea
ICES Rect.	ICES Statistical Rectangle
ICES SD(s)	ICES Subdivision(s)
LOA, LoA	Length overall (metric) (EU CFR and FAO)
LSF(s)	Large-Scale Fishery(ies)
MSY	Maximum Sustainable Yield
MPA(s)	Marine Protected Area(s)
MV	German Federal State of Mecklenburg-Western Pomerania
NOAA	National Oceanic and Atmospheric Administration (USA)
OTB	Single bottom ottertrawls (EU CFR and FAO)
PTB	Bottom pairtrawls (EU CFR and FAO)
PTM	Midwater pairtrawls (EU CFR and FAO)
RAC(s)	Regional Advisory Council(s)
SH	German Federal State of Schleswig Holstein
SSF(s)	Small-Scale Fishery(ies)
STECF	Scientific, Technical and Economic Committee for Fisheries
TAC(s)	Total Allowable Catch(es)
UNEP	UN Environment Programme
UNESCO	UN Education, Scientific and Cultural Organization
VDS	Vessel Detection Systems
VMS	Vessel Monitoring System
VtI	Thünen Institute, German Federal Research Institute for Rural Areas, Forestry and Fisheries

Abstract

In the German Baltic, Small Scale Fisheries (SSFs) are important elements of the region's natural and human environment. However, data available for the German Baltic SSF sector are scarce and characterised by inherent limitations which prevent the sector's determination and quantification. Furthermore, few studies have been conducted to evaluate how the sector responded to past changes in fishery resource abundance and management. The previous conditions have resulted in the sector being frequently neglected within the context of fishery governance and management, which has in turn compromised its profitability and further development. This situation could further lead to local resource overexploitation and a series of other adverse social and environmental conditions that extend beyond the (confined) limits of the SSF.

The major aim of this thesis is to assess how the German Baltic SSF adapted to changes that took place in the wider Baltic region in fish resource abundance and management during 2000-2009. An important objective of the research is to explore how resource abundance and management changes impacted the structure (vessels, gears, etc.) and operation (catches, target species, etc.) of SSFs; for that matter, a thorough literature review was conducted to determine SSFs fundamental characteristics and how these characteristics affect SSFs' catches, profits, the natural environment and social dynamics of coastal communities. The research also sets forward a novel methodology for the characterisation, definition and subsequent quantification of the sector's key variables (vessels and technical characteristics, weight of landings, target species, etc.). The methodology combines disparate information and overcomes a series of limitations inherent in primary data. A major outcome is the development of a spatial regional database for the German Baltic SSF, which enables the assessment of the sector's spatial dynamics with reference to investigated changes. The research constitutes the first known quantitative definition and characterisation of the German SSF and one of the few extensive spatial databases developed specifically for SSFs globally.

Results indicate that the German Baltic SSF sector is heterogeneous (i.e. vessels and practiced fishing strategies) and targets numerous different species. The sector covers a broad geographic area (large number of home ports) while secondary harbors located at rural areas exhibit high concentrations of vessels and catches (landings) (decentralisation). The sector has a confined range of operation with respect to the extent of fishing areas. These characteristics were shown to be fundamental for the sector and clearly differentiated it from the larger scale sector. Moreover, these characteristics

determined to a large degree its adaptation potential to changes that occurred in the region's fish resource abundance and management.

Changes in fish abundance and the management of fisheries have had a marked impact on the German Baltic SSF. The sector's landings followed closely the quotas allocation for cod and herring for the German Baltic area. Trends in landings along the area's harbors were determined by proximity of ports to productive fishing grounds. Trends in the sector's key variables (vessel numbers, fishing strategies, landings, species composition) along the study area have been influenced by the local combination of the natural and human environment [local abundance of fish stocks, presence of target species, suitability for practicing specific fishing strategy, infrastructure (e.g. processing facilities), livelihood diversification potential]. Likewise, the impact of stipulated regulations differed between the western and eastern parts. Results also indicate the importance of access to resource for the SSF, in terms of catch (landings) and revenues. The SSF has been responsive to management changes directed to the activity of the larger scale, active fishery (e.g. Odra closure to active gear). However, it only partly accommodated for the declines in the catch of the active fishery, while the latter did adapt relatively fast to the changes brought about by management alterations.

The research provides an in-depth account of SSFs, their key characteristics and the limitations in their further development, while also highlighting the need for regional assessments. Although the analysis was restricted to the German Baltic, the methodology set forward by the research can be adapted to other regions. Results highlight the benefits of such an approach in the context of fisheries governance and management, while the methodology set forward can enable the extrapolation of how the SSF sector will respond to future management changes or incidents of environmental variability.

Zusammenfassung

Im deutschen Teil der Ostsee stellt die kleinskalige Fischerei ein wichtiges Element der regionalen natürlichen und anthropogenen Umwelt dar. Allerdings stehen Daten über diese Fischerei nur begrenzt zur Verfügung, wodurch die genaue Abgrenzung und Quantifizierung des Sektors nur schwer möglich ist. Darüber hinaus wurden nur wenige Studien durchgeführt, die die Auswirkungen von Veränderungen im Fischvorkommen oder im Management auf die kleinskalige Fischerei analysieren. Diese Bedingungen haben dazu geführt, dass der Sektor sowohl in der Fischereipolitik als auch in der Verwaltung regelmäßig vernachlässigt wurde. Diese Situation könnte zukünftig möglicherweise zur Übernutzung lokaler Ressourcen führen und damit eine Reihe von gesellschaftlichen und ökologischen Auswirkungen haben, die über den (begrenzten) Umfang der kleinskaligen Fischerei hinausreichen.

Das Hauptziel dieser Arbeit ist die Auswertung möglicher Auswirkungen auf die deutsche kleinskalige Fischerei durch Veränderungen im Vorkommen von Fischressourcen (Menge und Verteilung) und im Fischereimanagement in der erweiterten Ostseeregion im Zeitraum 2000-2009. Dabei wurde das Hauptaugenmerk auf die Struktur (Fahrzeuge, Ausrüstung, etc.) und die Fangaktivität (Fangmenge, Zieltierarten, etc.) gelegt. Dafür wurde zuerst eine umfassende Literaturrecherche durchgeführt, um die wesentlichen Eigenschaften des Sektors identifizieren zu können, und darauf aufbauend untersucht, inwiefern diese Eigenschaften die Fänge, den Erlös, die natürliche Umwelt und die sozialen Dynamiken von Küstengemeinden beeinflussen. Die Arbeit stellt außerdem eine neue Methodik vor, die die Charakterisierung, die Definition und die darauffolgende Quantifizierung der Schlüsselvariablen des Sektors erlaubt (Fischeifahrzeuge und technische Eigenschaften, Gewicht der Anlandung, Zielarten, etc.). Die Methode kombiniert verschiedenartige Informationen und überwindet eine Reihe von Primärdaten immanenten Einschränkungen. Ein wesentliches Resultat ist die Entwicklung einer regionalen, räumlichen Datenbank der kleinskaligen Fischerei in der deutschen Ostsee, die eine Beurteilung der für den Sektor typischen Dynamik ermöglicht. Die Arbeit stellt die erste den Autoren bekannte quantitative Definition und Charakterisierung der deutschen kleinskaligen Fischerei dar und ist eine der wenigen umfangreichen räumlichen Datenbanken, die weltweit existieren.

Die Ergebnisse zeigen, dass die deutsche kleinskalige Fischerei sowohl in Bezug auf die Fahrzeuge als auch auf Fangmethoden sehr heterogen ist und dabei eine große Zahl an verschiedenen Zielarten hat. Gemessen an der Zahl und Verteilung der Heimathäfen deckt der Sektor eine große geographische

Fläche ab, wobei kleinere Häfen in ländlichen Gegenden eine große Anzahl von Fahrzeugen und hohe Anlandemengen aufweisen (Dezentralisierung). In Bezug auf die Ausdehnung der Fischgründe hat die kleinskalige Fischerei allerdings nur einen eingeschränkten Einsatzbereich. Diese Eigenschaften haben sich als elementar für den Sektor erwiesen und machen ihn klar abgrenzbar gegenüber industrieller Fischerei. Darüber hinaus bedingen diese Charakteristika in großem Maße das Anpassungspotenzial gegenüber Veränderungen der Fischressourcen und des Managements.

Veränderungen der Fischbestände und im Fischereimanagement hatten einen deutlichen Einfluss auf die deutsche kleinskalige Fischerei. Die Anlandungen des Sektors waren eng mit der Quotenaufteilung für Dorsch und Hering für die westliche Ostsee verbunden. Die Entwicklung der Anlandemengen in den Häfen der Region wurde durch die Nähe der Häfen zu ergiebigen Fischgründen bestimmt. Die Entwicklung der Schlüsselvariablen des Sektors (Anzahl der Fischereifahrzeuge, Fangtechniken, Anlandungen, Artenzusammensetzung) innerhalb des Untersuchungsgebietes wurde durch lokalspezifische Kombinationen der natürlichen und anthropogenen Umwelt [lokaler Fischreichtum, Vorhandensein der Zielart, Eignung für die Anwendung der konkreten Fangtechnik, Infrastruktur (z.B. Verarbeitungseinrichtungen), Potential zur Diversifizierung des Lebensunterhaltes] beeinflusst. Die vorgeschriebenen Regelungen im östlichen und westlichen Teils der deutschen Ostseeküste wirkten sich unterschlich auf den Sektor aus. Die Ergebnisse deuten darauf hin, dass die Zugänglichkeit zu Ressourcen, ausgedrückt durch Fang (Anlandungen) und Einkommen, für die kleinskalige Fischerei von großer Bedeutung ist. Die kleinskalige Fischerei reagierte auf Managementänderungen, die in erster Linie für die industrielle Fischerei von Relevanz waren (Schließung von Fanggebieten im Bereich der Oder für aktive Fanggeräte). Allerdings konnte die kleinskalige Fischerei nur einen Teil der entgangenen Fänge ausgleichen, wohingegen sich die industrielle Fischerei relativ schnell auf diese Managementmaßnahme einstellen konnte.

Die Arbeit beschreibt ausführlich die kleinskalige Fischerei, ihre zentralen Merkmale und die Grenzen für ihre zukünftige Entwicklung, und stellt den Handlungsbedarf hinsichtlich regionaler Bewertungen dar. Auch wenn sich die vorliegende Analyse auf den deutschen Teil der Ostsee beschränkt, kann die Methodik, die durch die wissenschaftliche Untersuchung entwickelt wurde, zur Untersuchung des Themas auch in anderen Regionen angewendet werden. Die Ergebnisse zeigen die Vorteile dieser Herangehensweise auch im Kontext von Fischereipolitik und –management auf, während die Methodik Voraussagen ermöglicht, die Aussagen darüber zulassen, wie der Sektor in Zukunft auf Änderungen im Management oder auf Ereignisse in der natürlichen Variabilität reagieren wird.

1. Introduction

Small-Scale Fisheries (SSFs) are an integral part of global fisheries, affecting the livelihood of about 357 million people and employing more than 90 percent of the world's capture fishers (FAO, 2012a). It is estimated that the number of large-scale fishing vessels worldwide is 355,000, with the remaining 3.94 million vessels classified as small-scale (Sumaila et al., 2012). The SSF sector contributes about half of global catches, with catches used primarily for direct human consumption (FAO, 2012b) ['SSF sub-sector', as opposed to the 'Fishery sector' has also been used to describe the organizational level of the entire SSF. However, in the present thesis, 'sector' is used to denote highest organizational level, an aggregation of the sum of all comprising individual SSFs (see also: Chapter 2)]. SSFs are dynamic and geographically diverse (FAO, 2012b), operating at widely differing organizational levels ranging from single operators to formal sector businesses (FAO, 2004; Béné et al., 2007). Although it is difficult to give a precise definition of SSFs (Béné et al., 2007), terms such as small-scale, traditional, subsistence and artisan are used to denote the counterparts to large-scale, industrialized fisheries (Madau et al., 2009).

Contrary to an ever-growing number of studies for the large-scale fishery, little research has been conducted in the past to quantify the SSF sector's key structural and operational characteristics (catch, fleet composition etc.). This situation has resulted in the sector being underestimated with reference to its contribution to the livelihood of coastal communities and its socio-economic significance, both at a local but also global context (FAO, 2012a). Moreover, few studies have been conducted to assess the sector's response to changes in the abundance and management of fish resources. Such changes frequently have adverse impacts on the catch and profitability of SSFs, already challenged by the small capital of fishers and the general unpredictability of the fishing profession.

1.1. Topical focus of the thesis

The primary aim of the present thesis is to assess how the German Baltic SSF responded to past changes in resource abundance and management (e.g. quotas, technical measures etc.) that took place in the wider Baltic Sea region during 2000-09. German Baltic SSFs have long been considered as key elements of the region's natural and human environment (Döring, 2003) and provide a compelling case study for an in-depth assessment of relevant issues.

There is a growing need for better information on the state and development of small-scale fisheries in the German Baltic. Their contribution is often measured by the number of jobs [An estimated 2,500 labourers are directly employed in the German marine fishery sector (Strehlow, 2010)] and generated income; while this approach provides important information, it does not enable estimating how the SSF sector is affected by changes in fish resource abundance and management. Moreover, although competent authorities [German Federal Office for Agriculture and Food, BLE; fisheries' authorities of the federal states of Mecklenburg-Western Pomerania (MV) and Schleswig-Holstein (SH); the German Institute for Baltic Sea Fisheries] have provided some insight on the sector's structure (vessel numbers) and catches (t), there exist gaps in available information. Information on the sector's structure and catches has not been linked to changes that took place in the region's fish resource abundance and management. Also, information is usually provided on an aggregate level that does not enable more refined estimates or the determination of the location where major changes took place. Within the context of research, a major objective has been the definition, characterisation and quantification of the German Baltic SSF, using various sources of fisheries-related information. A central objective has been to analyse relevant information both on a temporal and spatial context. For this reason, a major part of the work has involved the development and use of a spatial database tailored to the specifications of the German Baltic SSF (Papaioannou et al., 2012). The database has been employed to investigate the response of the sector to major changes that took place in the wider region's fish resource abundance and management between 2000-09 (Papaioannou et al., 2014a, submitted).

1.2. Background

The following sections provide a general background on the state of marine fisheries, including past and recent advancements in their management and governance, with a focus on SSFs and their role in facilitating fisheries' sustainability. The different methodologies used for assessing fish resources and fisheries, with special reference to SSFs are discussed. The overview aims to emphasize the need of overcoming SSF data scarcity and the novelty in developing databases tailored to regional SSFs. A description of the Baltic marine environment and its fish stocks is also provided. Finally, the aims and major objectives of the thesis and the structure of its different sections are presented.

1.2.1. The governance and management of fish resources and fisheries

Major institutions (UNEP, 2011; European Parliament, 2013a) are now recognising the need for a shift towards sustainable fisheries. Globally, approximately 29.9% of fish stocks are overexploited (FAO, 2010; 2012a) (figure 1-1). Overfishing has resulted in dramatic declines in fish stocks and significant changes in the structure and function of marine ecosystems. It is estimated that a more effective management of fisheries could result in higher profits, with an additional ~51 billion USD generated annually (World Bank, 2009).

One of the key players in fisheries' governance is the Food and Agriculture Organization (FAO) of the United Nations (UN), dealing with several fisheries-related issues and having a strong commitment in ensuring fisheries' sustainability. The Organisation is involved in relevant data compilation, collation, analysis and integration and the development of information products and packages that are easily accessible to end-users, thus serving as the main repository in fisheries statistics globally (FAO, 2013a).

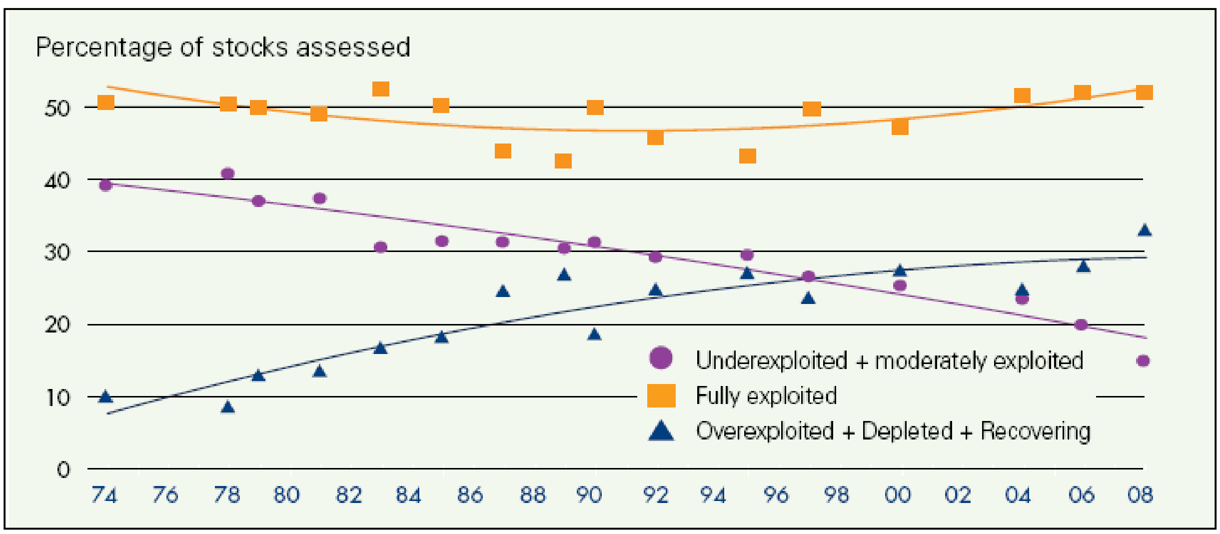

Figure 1-1: Global trends in the state of world marine stocks (1974-08) (Source: FAO, SOFIA 2010)

In Europe, the principal institution for the management and governance of fish resources is the European Union (EU), with relevant regulations incorporated within the national legislation of Member-States. Major institutions for the assessment of fisheries include the International Council for the Exploration of the Sea (ICES) and the Scientific, Technical and Economic Committee for Fisheries (STECF), a group of independent scientists established to advise the EU Commission. ICES and STECF provide scientific advice to the EU on various issues relating to fisheries. The role of

Regional Advisory Councils (RACs) in the process is also increasingly important. The EU Common Fisheries Policy (CFP) is the overarching governing legislation for fisheries management in Europe. The CFP has recently been reformed (European Parliament and Council, 2013) and Member-States are required to start implementing relevant provisions as of 1 January 2014.

A series of past events resulted in environmental and social considerations also entering into perspective within the framework of fish resource exploitation, highlighting that environmental, social and economic sustainability are equally important in fisheries governance and management. Figure 1-2 presents major landmarks in fisheries' governance and management. An earlier reference to the need of conserving biological diversity and promoting the sustainable use of natural resources, including fish, was made within the framework of the Convention on Biological Diversity (CBD) (open for signatures: 1992 Rio 'Earth Summit'; entry into force: 1993). In 1995, FAO member countries adopted the Code of Conduct for Responsible Fisheries (CCRF; FAO, 1995), which sets out principles and methods applicable to all aspects of fisheries and aquaculture; the Code shared numerous common objectives with the CBD (FAO, 2013b). The Code outlined ways to achieve the sustainable development and management of fisheries and aquaculture, while it also introduced the concept of the Ecosystem Approach to Fisheries (EAF) as a principal target in management. Following that, in 2001, 57 countries issued the 'Reykjavik Declaration on Responsible Fisheries in the Marine Environment' where their intention of managing fisheries' resources, also accounting for ecosystem considerations, was clearly declared (FAO, 2013c).

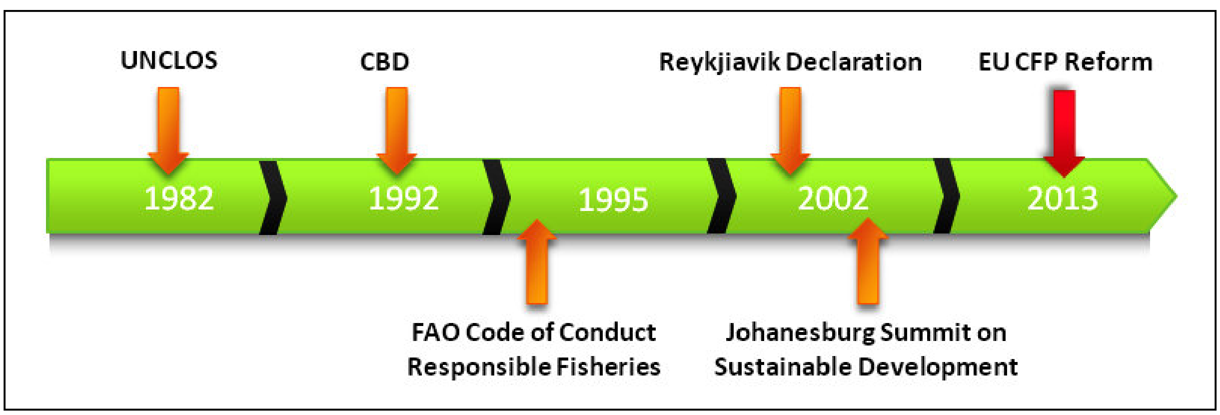

Figure 1-2: Major landmarks in fisheries' governance and management (Crooked black line indicates time interval)

In 2002, at the Johannesburg World Summit on Sustainable Development, participants, including the EU, made the commitment to (i) manage fish stocks according to the concept of Maximum Sustainable Yield (MSY) and (ii) apply the Reykjavik Declaration as one of the essential for ensuring sustainable fisheries (FAO, 2013b). The MSY concept, enshrined as early as the UN Convention on the Law of the Sea (UNCLOS) (1982), denotes the optimal catch that may be taken from a fishing stock year after year without endangering its capacity to regenerate in the future (European Commission, 2013a). The previous led eventually to the formulation of the EAF approach framework. The EAF dictates that management must not focus on single-species but on the principle that all ecosystems have certain limits that should not be exceeded in order to prevent adverse impacts occurring on them (European Council, 2002). Another important advancement in marine resource governance, also integrating aspects of fisheries sustainability was the recent Rio +20 Summit on Sustainable Development (2012).

Commonly practiced measures in fisheries management include either restricting catches (i.e. the output of the fishery) or limiting fishing effort (i.e. the input to the fishery) (World Ocean Review, 2010). The former include the concept of Total Allowable Catches (TACs), namely a threshold in the maximum catch of a particular species (European Commission, 2013b), whereas the later focus on controlling the input to the fishery, for instance technical restrictions to the use of certain fishing practices. Another important element in fisheries' management is marine spatial planning with closures to fishing; designation of Marine Protected Areas (MPAs) etc. being implemented on both national and regional levels.

1.2.2. Fisheries' Assessment and Analysis

Data required for assessing the state of fish stocks and fisheries, include data collected through the fishery itself ('fishery-dependent data') and data collected independently from the fishery ('fishery-independent data').

Fishery-dependent information include landings statistics (namely the fraction of the catch that ends up being sold, e.g. auctions), market sampling and logbook or vessel-trip reports (Johnson and van Densen, 2007). Fishery-independent techniques use fishing surveys (e.g. trawls or other nets), underwater surveys and tagging experiments. Other data that are important for the assessment of the state of fish stocks include information on key abiotic and biotic variables, especially within the framework of ecological models and Essential Fish Habitat (EFH) modelling techniques.

Scientific fish surveys are usually conducted by national fisheries authorities and research institutions; technological advancements and improved cooperation among countries, resulted in a thorough assessment of the state of the stocks of most commercially-exploited fish species. Relevant surveys include the International Bottom Trawl Survey (IBTS) in the North-eastern Atlantic and the Baltic International Trawl Survey (BITS). These surveys, coordinated by the ICES have been conducted for a substantial period of time and have been stratified and standardized for more efficient and meaningful information to be obtained. ICES member-countries are required to report fisheries' catches per ICES Statistical Rectangle (30' in latitude by 1° in longitude) (figure 1-4), which enables a compatible method of collecting and sharing fisheries data.

Most national fisheries authorities require fishers to provide them with information relating to their fishing activity. Catch data and other information (e.g. price of landings, position etc.) are usually recorded by fishers in logbooks. More elaborate frameworks of data acquisition have lately been developed that make use of measures and techniques such as electronic logbooks; Satellite-based Vessel Monitoring Systems (VMS) and Vessel Detection Systems (VDS). These measures contribute to the improvement and harmonization of approaches used by different countries to assess the state of their fishing industries. In Europe lately the role of CCTV in vessels is also promoted for dealing with discards (European Parliament, 2013b) [Discarding being the practice of throwing back to the sea unwanted fish catches].

A wealth of primary fisheries data and fisheries' databases is now available from an ever increasing number of institutions (e.g. FAO; ICES; the Community Fleet Register of the EU etc.) and science centres (e.g. The Sea Around us Project, etc.), while numerous elaborate programs and software for data analysis and manipulation have also been developed (e.g. Riolo, 2006; Hintzen et al., 2012).

A multitude of modelling techniques for the assessment of the state of fish stocks has been developed and is constantly being updated to integrate new considerations and latest advancements on the field. Many models also integrate spatial frameworks (e.g. the ECOSPACE module of the EwE software, Pauly et al., 2000; Le Quesne et al., 2008); for a general review on the topic see the work of Plagányi (2007). Progress is also made in fisheries bio-economic and ecological-economic modelling (e.g. Voss et al., 2011), with models also reviewing the impacts of management strategies on fisheries' resources (Riolo, 2006; Bastardie et al., 2010). Models have also been implemented to assess the impacts of environmental variability and climate change on fisheries (Keyl and Wolff, 2008).

The need to understand the spatial relationships between marine-coastal environments and access 'location' makes the use of GIS particularly important within the context of fisheries management. Several institutions globally are increasingly using GIS for assessing fisheries-related issues, such as for instance the GISFish Internet Site, especially for aquaculture and inland fisheries developed by FAO (2013d), HELCOM's Map and Data Service (2010) etc.

The main applications of GIS in fisheries include among others matching fish distributions to environmental parameters; modelling fish activity and movement; analyzing fisheries catch and effort; and establishing regional and national fisheries databases (Meaden, 2000). GIS applications are considered especially important within the context of the EAF approach to the management of fisheries (for a review on the topic see: FAO, 2009a). Past GIS applications in fisheries research include determining key indices of fishing activity for regional fisheries and local fleets (e.g. Daw, 2008; Dunn et al., 2010; Stewart et al., 2010); modelling and determining the habitats of commercially important species (Eastwood et al., 2001; Valavanis, 2004; 2008); evaluating the impacts of management changes on fisheries (Scholz, 2003; Forcada et al., 2010). Elaborate applications also integrate remote sensing, clearly manifesting the immense scope GIS have on the management of marine resources.

1.2.3. SSFs governance and management framework

A background on the definition of SSFs and how the sector has evolved in recent years is provided in Chapter 2. Figure 1-3 depicts major landmarks relating to the sector's policy framework. The different approaches in assessing SSFs are presented in Chapter 2 whereas Chapter 3 discusses primary data for SSFs, assessment methodologies and limitations in data.

In Europe, SSFs represent the vast majority of fishing activities in all Member States, account for the majority of the European fleet (vessels of <12-15 m in length), while at the same time they comprise the main employment provider in the entire fishing sector. Until now the definition of SSFs in an EU context includes vessels smaller than 12 m Length overall (LoA) not using towed gear (European Commission, 1998; European Council, 1999; 2006a). Vessels smaller than 12 m LoA are not required to possess VMS and can provide information in the form of logbooks (paper format) (European Council 2009; European Commission, 2011) (Prior to 2012 vessels between 12-15 m LoA could instead fill in electronic logbook data information but they are now obliged to possess VMS).

Within the context of the Parliamentary vote for the Reform of the CFP (European Parliament, 2013a) it was suggested that the definition of SSF should be widened to also consider additional criteria other than boat size, including the impact of fishing techniques on the marine ecosystem, the time spent at sea and the characteristics of the economic unit exploiting the resource. *'SSF and artisanal fisheries ... means fisheries undertaken by vessels which have an overall length equal to or less than 15 metres, and/or which spend less than 24 hours at sea and sell their catch fresh, with the exception of those vessels fishing with towed gear'* (Amendment 42, Part I, Article 5). Within the framework of the reformed CFP, SSFs received increased attention and are now of alleged priority in the policy's implementation (European Parliament, 2013a; European Parliament and Council, 2013). Among the major aims of the CFP is to contribute to *'a fair standard of living for the fisheries sector, including small-scale fisheries'* [OJL 354, p. 22, (4); p. 29, point (f)]. As such, Member States '*should endeavour to give preferential access for small-scale, artisanal or coastal fishermen*' within their 12 nm zones [OJL 354, p. 24, (19)].

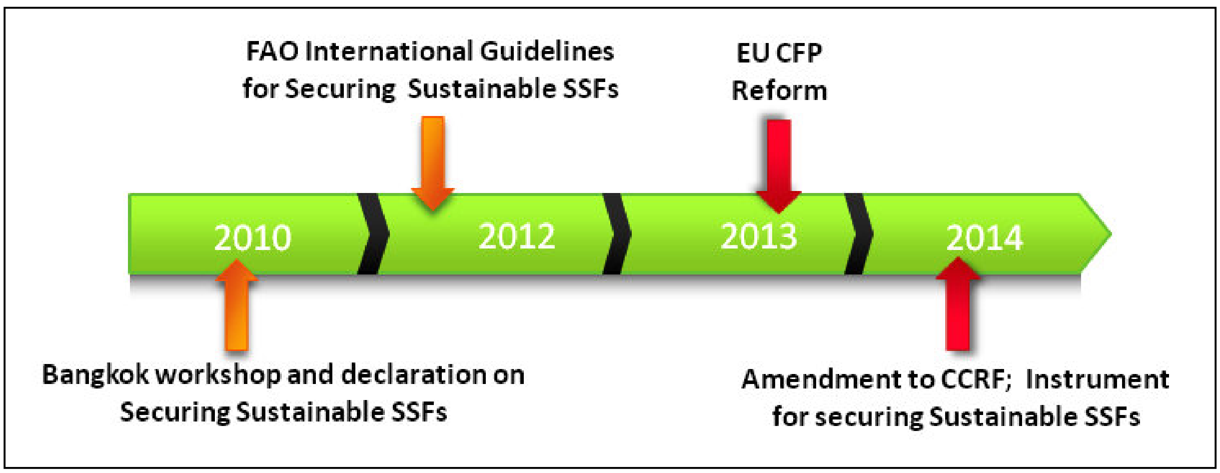

Figure 1-3: Major landmarks in SSFs policy framework (in addition to figure 1-2) (Crooked black line indicates time interval)

1.3. Research focus area - The Baltic marine coastal environment and the German Baltic Small-Scale Fishery

The Baltic Sea is a semi-enclosed, brackish water body with strong horizontal and vertical gradients in salinity, temperature and oxygen concentration that determine the distribution and reproductive patterns of fish species. Primarily due to its low salinity that imposes a physiological stress to both marine and freshwater species (MacKenzie et al., 2007), the Baltic is characterized by comparatively low species richness (ca 100, European Environment Agency, 2002; MacKenzie et al., 2007). Unique hydrographic processes that occur in the area and in particular North Sea inflow events of saline water, lead to rapid and pronounced impacts on the distribution of fish species (MacKenzie et al., 2007). The Baltic has been divided to subdivisions based on prevailing geographic and hydrological conditions (Hüssy, 2011) (figure 1-4). Most of the commercially important species of fish in the Baltic, including cod, herring and sprat, have been shown to be susceptible to changes in the area's hydrographic conditions. Important habitats for cod (nurseries, spawning areas etc.) are shown in figure 1-5.

Fisheries in the Baltic have a coherent framework of management and governance including TACs and quotas for most commercial species (cod, herring, flounder etc.); other regulations limit the use of specific gear and relate to gear technical characteristics (see Chapter 3; 4). Commercial fish species in the Baltic, including cod and herring, are assessed and managed according to where they have been caught, namely either as western (ICES Subdivisions 22-24) or eastern (ICES Subdivisions 25-32) stocks.

The German SSF is governed by the management framework of fisheries of the EU and the wider Baltic. At a national level, the management of fish resources and fisheries is divided between the Federal States of Schleswig-Holstein (SH) in the west and Mecklenburg-Western Pomerania (MV) in the east (see Chapter 3; 4). Major resource and management changes that have taken place in the wider Baltic region and their implications on the German SSF are presented in Chapter 4.

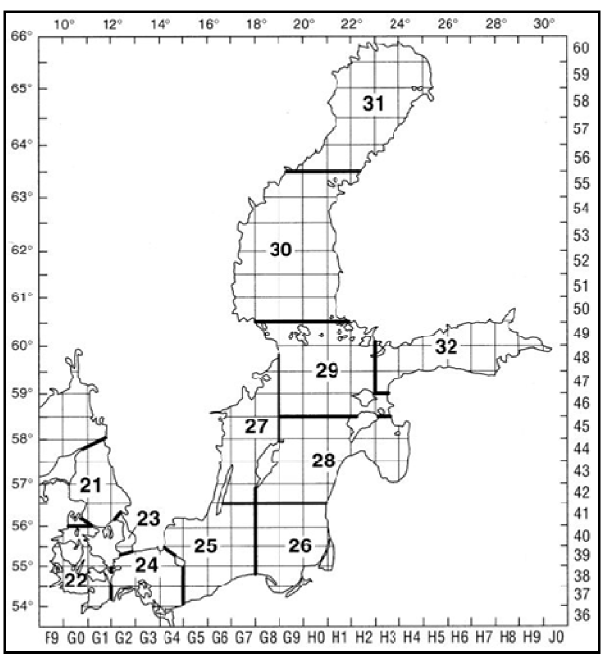

Figure 1-4: Map of Baltic Subdivisions (SDs) and ICES Statistical Rectangles (Source: HELCOM, 2010)

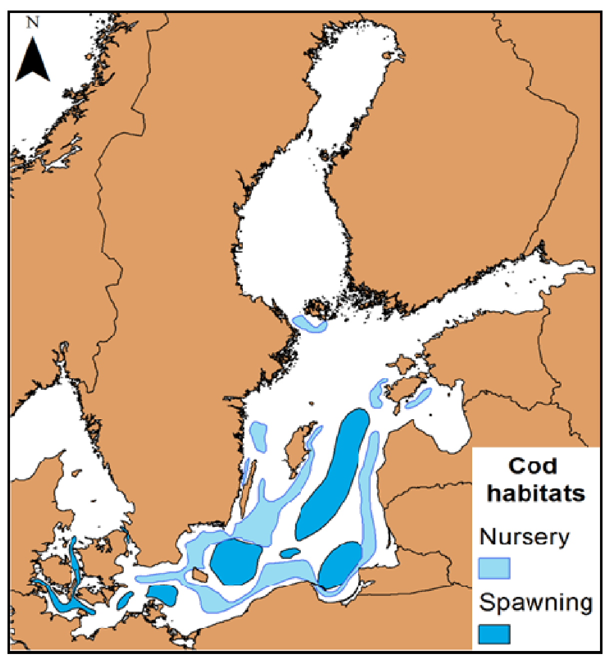

Figure 1-5: Map of Baltic Sea major cod habitats (Source: HELCOM, 2010)

1.4. Aims and Objectives of the study

The primary aim of the research was to quantitatively assess the structural (vessel numbers, gears, etc.) and operational (landings, operational distance, target species, etc.) changes in the German Baltic SSF in the period 2000-2009 and link them with environmental and management changes that took place in the wider Baltic Sea region during the same period.

The present thesis is based on a series of articles that have been submitted for publication or published in peer-reviewed scientific journals. The thesis' chapters consist of the respective original articles as these have been submitted for publication and/or published.

Q1. Which are the key characteristics of the SSF sector and how do they relate with its catches and profits? How can the sector's environmental and socio-economic sustainability be facilitated? <u>(Determining the key characteristics of SSFs; facilitating the SSF sector's sustainable development)</u>

To determine the variables that would be used for the purpose of the analysis, we reviewed these characteristics which generally define SSFs and differentiate them from larger-scale fisheries (Chapter 2). A central focus was on how these characteristics affect the SSF sector's catches, profits, the natural environment and social dynamics of coastal communities. We also investigated how the sector's further sustainable development can be facilitated.

Q2. How can the state and development of the SSF be determined? How should key variables be assessed and analyzed? <u>(Formulating a methodological framework for the characterization and assessment of the SSF)</u>

Globally, the SSF sector is often data deficient and this situation has in the past compromised its assessment and inclusion within policy and management. A central aim of the study was (i) the formulation of a methodology for characterizing and defining the German Baltic SSF and (ii) the development of a regional database tailored to the sector's specifications that would enable the integration of primary fisheries data for the quantification of the sector. The data that were used and how these were combined in order to compile the spatial database are presented in Chapter 3. Since changes in the distribution, abundance and assemblages of fish resources are spatially differentiated (Keyl and Wolff, 2008) a major objective in the development of the database was to also assess the sector spatially. Thus, the database was integrated within GIS to enable the investigation of the sector's spatial dynamics with reference to changes in resource abundance and management (e.g. locating affected areas).

Q3. How have past changes in fish resource abundance and management impacted the structure (vessels, gears, etc.) and operation (landings, target species etc.) of the German Baltic SSF? <u>(Assessing the adaptation potential of the German Baltic SSF to changes in resource abundance and management)</u>

Major changes in fish resource abundance and management have taken place in the wider Baltic region between 2000-09. The main aim of the study was to evaluate the response of the German Baltic SSF to past changes in the region's resource abundance and management between 2000-09 (Chapter 4). We employed the spatial database to assess how past changes impacted the structural and operational characteristics of the German Baltic SSF.

1.5. Structure of the thesis

The thesis starts with a general overview of SSFs (Chapter 2) and then focuses on the German Baltic SSF (Chapters 3 and 4). Thus, while it underlies the significance of SSFs globally, it highlights the importance of assessing SSFs at a context-specific, regional level. The structure of the thesis enables an in-depth understanding of SSFs, their unique characteristics and the limitations that exist in their further development.

Chapter 2 comprises an extensive literature review of disparate reference material, which aims to determine the key structural and operational characteristics of the SSF and common traits that exist among SSFs globally. The relation between these characteristics and the sector's catches, profits, the natural environment and social dynamics of coastal communities is investigated while suggestions are made on how the sector's sustainability can be facilitated [The chapter has been submitted for publication as a Review Article. Papaioannou E.A., Quaas, M.F, Schmidt, J.O., and Vafeidis, A.T. 2014b].

Chapter 3 presents the development and use of the spatial database for the determination and characterization of the German Baltic SSF. The chapter presents the methodology of the database development and describes the structure of the database and its comprising elements. Limitations in the use of primary data are discussed. Finally, it provides results of applying the database to assess the German Baltic SSF in 2008, with respect to weight and price of landings and other parameters [The chapter has been published as an Original Research Article in the ICES Journal of Marine Science. Papaioannou E.A., Vafeidis, A.T., Quaas, M.F., and Schmidt, J.O. 2012. IJMS. 69: 1480-1490 (© OUP)].

Chapter 4 describes the response of the German Baltic SSF to past changes in the region's resource abundance and management. The chapter investigates temporal and spatial trends in the sector's key variables (weight of landings, target species, etc.) with reference to major changes in management. It spans along 2000-09 and thus provides an account of the sector's adaptation potential to external factors [The chapter has been submitted for publication as an Original Research Article. Papaioannou E.A., Vafeidis, A.T., Quaas, M.F., Schmidt, J.O., and Strehlow, H.V. 2014a].

Chapter 5 contains the discussion of key findings and results from the research while major conclusions are drawn. The potential for further research is discussed and the links with ongoing project work are summarized. The Appendix contains material which was included as supplementary material in the manuscript versions of the chapters. For matter of consistency, the numbering of figures and references has changed with respect to the manuscript versions of the chapters, where relevant.

2. Small-Scale Fisheries: key characteristics, challenges and constraints to development

The chapter has been submitted for publication as a Review Article. Papaioannou E.A., Quaas, M.F., Schmidt, J.O., and Vafeidis, A.T. 2014b.

2.1. Abstract

Small-Scale Fisheries (SSFs) are deemed central in securing sustainable fisheries and progress has taken place regarding their assessment and analysis; yet, limitations still exist in the SSF sector's characterization and integration within policy and management, thus challenging its further development. Defining characteristics of the sector include: operational distance, heterogeneity, selectivity, diversity of target species and livelihood diversification of individual fishers, households and communities. The chapter thereby addresses the problem of disentangling frequently antagonistic properties, while accounting for the sector's lack of harmonized definitions and data scarcity. The present review examines how these fundamental characteristics affect its catches, profits, the natural environment and social dynamics of coastal communities and derives implications for management and governance frameworks. Also, the review suggests how the sector's further sustainable development can be facilitated. We further conclude that in the forthcoming years SSFs will be in the institutional spotlight, especially with respect to poverty alleviation and food security, and their scientific assessment needs to be prioritized.

2.2. Introduction

SSFs are progressively being recognized as central in promoting fisheries' sustainability. For achieving the general objective of a 'green economy', measures put forward include '*incentives to promote changes to more sustainable uses, such as … small-scale fisheries'* (IOC/UNESCO et al., 2011). The progress in the integration of SSFs within policy can be attributed to various reasons: public engagement, for instance through consumers' initiatives for certified seafood, is increasing government mandate whereas both institutions and the fishing industry are recognizing that the increased participation of fishers and their integration as key stakeholders in decision-making and governance are necessary prerequisites for effective management (Veitch et al., 2012). SSFs communities are increasingly engaging in collective management strategies to deal with risk from resource and market fluctuations [initiatives include the local catch network[1] in the USA; the '27 percebeiros' in Galicia, Spain; pesca (fishing) tourism initiatives in Var, France[2] etc.].

Progress is also made in the SSF sector's assessment, with a rising number of studies covering the entire globe, addressing different aspects, ranging from quantitative analyses to descriptive accounts (Caddy and Carocci, 1999; Bundy and Pauly, 2001; Salas et al., 2004; Cinner and McClanahan, 2006; Zeller et al., 2007; 2011b; Dunn et al., 2010; Forcada et al., 2010; Stewart et al., 2010; Wielgus et al., 2010; Hicks and McClanahan, 2012; García-Flórez et al., 2014), and employing methodological approaches that involve the development of databases (Chuenpagdee and Pauly, 2008; Papaioannou et al., 2012). There is also a rising number of studies on the sector's economic status and profitability (Rueda and Defeo, 2003; Daw, 2008; Madau et al., 2009; Cinner et al., 2009; Cinner and Bodin, 2010). The socio-economic importance of the sector, especially with reference to poverty alleviation and food security, is now recognized by major institutions (FAO, 2012b; 2013e) and as such qualitative analyses of the social characteristics of the sector are also performed (e.g. Allison and Ellis, 2001; Strehlow, 2010; Teh et al., 2012).

Although there has been substantial progress in reducing the sector's exposure to different types of risk (e.g. extreme weather events, management changes etc.) and increasing its adaptation potential (e.g. technological advancements, infrastructure), the sector is still prone to the negative impacts of reduced fish stocks (Béné et al., 2007) and poor access to global markets of fish. In addition to the general constraints imposed by natural resource limitations, SSFs frequently face a lack of capital and assets, a low level of technological development, limited access to fishing grounds, poor infrastructure and handling facilities and high post-harvest losses.

In the present review we examine how the SSF sector's fundamental characteristics (i. technological, operational and structural; ii. social, demographic) affect its catch and profit and the natural environment and social dynamics of coastal fishing communities. Findings are critically evaluated to suggest ways by which limitations in the development of the sector can be overcome in order to achieve SSFs environmental and socio-economic sustainability.

Although past studies have provided insight on SSFs fundamental characteristics (e.g. FAO and WorldFish Center, 2008), there still exists a need for a thorough review of relevant characteristics and

[1] www.localcatch.org (accessed: 15.1.2014)
[2] https://webgate.ec.europa.eu/fpfis/cms/farnet/farnet-good-practices-project-examples-country (accessed: 15.1.2014)

an assessment of how these relate with issues of abundance and profitability and welfare of coastal communities. To that end, we believe the present work will come to bridge existing gaps.

The chapter is structured as follows: Section 2.3 describes the methodological approach of the present study and reviews the selection criteria of the sources used for the purpose of the analysis. Section 2.4 presents the major constraints to the sector's development. In sections 2.5 and 2.6, we address the fundamental characteristics of the sector (e.g. heterogeneity) and how they affect its catch, profit and the ecology and dynamics of coastal communities, further suggesting how potential limitations can be overcome. Section 2.7 investigates ways though which the sector's environmental and socio-economic sustainable development can be facilitated.

2.3. Methodological approach – Studies selection

Globally, SSFs are considered too diverse and complex to generalize about their characteristics (Evans and Andrew, 2009; Jentoft et al., 2011). However, SSFs share a set of key characteristics, especially in comparison with the larger-scale sector; these common traits make it feasible to speak of SSFs collectively (Charles, 2011a). In the present review we use the term 'small-scale fishery' to describe:

- The individual '**enterprise**' or '**unit**', which, for SSFs, frequently coincides with the level of the individual fisher, bound by its unique technical (e.g. vessel) and operational characteristics (e.g. location of fishing activity, gear etc.). Likewise, in the case of SSFs, the individual enterprise typically coincides with the **'household'** level.
- The **'activity', 'operation'** or **'tactic'** that the 'unit' or fisher engages in, either limited to a single temporal incident or expressed as a sum of temporal and spatial activities/operations.
- The **'community'** of many individual fishers in a location, for example a village or other small administrative unit.
- The overall **'sector'**, referring at either a global, domestic, or local level, as specified accordingly, i.e. the set of all individual agents in the SSF.

The review is based on the assessment of publications from both natural and social sciences to determine recent advancements regarding the sector, both from an ecological and socio-economic perspective. Records include scientific publications, grey literature, policy documents and institutional reports to enable reviewing the emerging (institutional and research) focus, at an international, regional and local level. Studies were selected on the basis of containing a profile assessment and/or evaluation of the respective SSF dealt with therein. Primary data availability and quantification of SSFs key variables were important criteria in the selection of studies. In this context, the assessment of institutional reports was essential because for certain areas they may contain the only source of concrete information. For instance, for western African SSFs '*a detailed evaluation of the economic and social preferences of a sector as SSFs needs data, tools and human expertise that were unfortunately not available in most … participating countries'* (Kébé, 2008).

Studies were also selected to be indicative of the different degrees of SSFs complexity with reference to resource use, exploitation patterns, distribution of catch and range of social, ecological and economic conditions (Cinner et al., 2009). To access the role market pressures exert on SSFs (Béné et al., 2007) we reviewed studies for both artisanal, subsistence SSFs (e.g. McClanahan and Cinner, 2008; Cinner et al., 2012; DuBois and Zografos, 2012) but also SSFs targeting high-valued resources (e.g. Defeo and Castilla, 2012); both rural SSFs where catch is distributed locally/domestically and export-oriented SSFs were investigated. Livelihood diversification options (Muallil et al. 2011) available to fishers and how these affect the sector's state and further development were central considerations in studies' selection. Another key aspect in the process was for respective fisheries to have a wide geographic distribution while at the same time being geographically representative. Competition with large-scale, industrial fisheries (Horta and Defeo, 2012) was also an important criterion for studies selection.

Selected studies were narrowed down according to relevance with the afore-mentioned criteria and evaluated to establish the sector's fundamental features (technological, operational, structural; social and demographic). Studies were subsequently classified according to relevant information contained; a meta-data table was compiled, where studies were categorically grouped according to insight provided on fundamental characteristic(s). Supportive studies were given as entries of the meta-data table; see Appendix, table S2-1.

Selected studies are not exhaustive of all issues that pertain to the sector. A wealth of studies reviewing the applicability of management and governance regimes for SSFs is emerging (McClanahan et al., 2009; Gutiérrez et al., 2011; Hall et al., 2013) an issue that is not within the scope of the present review. Also, although studies are widely distributed and geographically representative, not all locations and SSFs globally have been assessed. The review is tailored to marine coastal fisheries and freshwater SSFs, though comprising some of the world's most important SSFs, have not been covered within the scope of the present review.

2.4. Background to the study – What are major constraints to the development of the SSF sector?

There exists rising consensus on the need to safeguard SSFs and overcome constraints to their development (Evans and Andrew, 2009; Hall et al., 2010; FAO, 2012b). Such constraints include among others their often remote location, limited access to social services as well as markets, low level of education and weak economic and political powers (FAO, 2012b). The present section discusses some of the major constraints to the development of SSFs.

The SSF sector's limited data availability is considered as an impediment in achieving ocean and coastal sustainability (IOC/UNESCO et al., 2011). Data scarcity and fragmentation are attributed to the sector's fundamental structural and operational characteristics, namely its large number of vessels, high degree of heterogeneity and broad geographic distribution. Also, data and statistics are not always comprehensive, resulting in underestimating its socio-economic and nutritional benefits and its contribution to livelihood and food security (FAO, 2012a). More attention is required '*to converting data from several sources into information for decision making and communicating the information to all stakeholders'* (Charles, 2011b).

For many SSFs globally, intensive extraction of coastal fish resources, in conjunction with local (habitat loss, pollution etc.) and global (international trade and globalization of markets, climate change) pressures have resulted in stock overexploitation or depletion (Defeo and Castilla, 2012). Certain SSFs have exhibited characteristics of open-access resource regimes, primarily due to the absence of an effective management framework, with an increasing number of fishers making use of a limited resource leading in turn to decreasing income (Béné, 2003; Pomeroy et al., 2009; Mondaca-Schachermayer et al., 2011) and subsequent resource overfishing (Béné et al., 2007). Local overexploitation is likely to increase in range and intensity as fishing and market pressures increase, fisheries development projects are instituted, markets develop and once existing resources are overexploited, fishers start searching for new ones (Cinner and McClanahan, 2006).

Although many accounts agree that market pressures have a pronounced effect on SSFs (Brewer et al., 2012; Defeo and Castilla, 2012) and that over-exploitation of coastal fish resources has been aggravated by globalization of markets (Béné et al., 2007; Ortega et al., 2012) what exactly is the relevant 'market' in the context of studies may be vague. For fisheries in general 'market access' may denote the export distribution of the catch[3]. For SSFs in particular, 'market access' is frequently understood as the distance from fishing grounds to the location where the catch is sold '*distance … to the nearest local fish market, provincial capital all of which have fish markets'* (Brewer et al., 2012). In that context, for certain SSFs there is evidence that market pressures led to a large amount of catch being exchanged or sold rather than consumed by local communities (Cinner and McClanahan, 2006). Fewer studies defined and accessed the degree of connection of national fisheries' sectors (also encompassing SSFs) to external markets as the difference between exports and imports in value and the contribution in terms of foreign currency (Kébé, 2008). Certain SSFs exhibit high revenues (Gascoigne and Willsteed, 2009; Ünal and Franquesa, 2010; Defeo and Castilla, 2012; Papaioannou et al., 2012), primarily due to the high value of caught species, the high demand of fish and the tourism that increases demand. Past studies show demand functions for SSFs that unambiguously point out increasing prices at very low abundance levels triggered by high prices in foreign markets. A graphic example that demonstrates the impacts global market pressures have on SSFs is the case of high-value, Latin American and Caribbean shellfisheries (Defeo and Castilla, 2012). Past demand and increase in export prices, coupled by easy to access stocks and open access regimes triggered an exponential increase in fishing effort because of low operational costs in the fishery. Additionally, ability of mobile agents to access unmanaged stocks led to a shift in effort to formerly low-valued species; traders pushed towards the selection of individual sizes below legal marketable sizes. Subsequently, cascade effects caused several shellfishery collapses during the past three decades.

Frequently, a major constraint to the sector's development is the poverty of associated coastal fishing communities (Béné, 2003). Recent accounts highlight that problems associated with SSFs communities are not solely fisheries-related (Jentoft et al., 2011), clearly pointing to the need of reviewing SSFs within the context of wider socio-ecological problems (Chuenpagdee and Jentoft, 2011). An important contribution of these studies is the realization that poverty for SSFs is: (i) a relative concept: although SSFs in the western world may be in a better position than their counterparts in sub-Saharan Africa for instance, they are still poor in comparison to other occupations (Chuenpagdee and Jentoft, 2011; Jentoft and Midré, 2011) and (ii) not defined solely with reference to meeting basic subsistence needs but transcends to also include socio-political exclusion and marginalization of SSFs (Jentoft and Midré, 2011).

[3] Norwegian Ministry of fisheries and coastal affairs, 2013. http://www.regjeringen.no/en/dep/fkd/selected-topics/market-access-for-norwegian-seafood.html?id=1181 (accessed: 24.9.2013, 15:00)

Conflicts with LSFs can affect SSFs, especially artisanal, even more than dwindling fish stocks (Bavinck, 2005; DuBois and Zografos, 2012), particularly because in the conflict SSFs are outmatched in terms of political influence and size (DuBois and Zografos, 2012). The absence of zoning of waters for different fishery users may result in rising number of conflicts (Pomeroy et al., 2009). This situation is aggravated by the fishery interdependencies between the SSF and LSF sectors, namely the increasing probability of spatial overlap of the two fleets over time, thus the increased potential conflict for resource use (Horta and Defeo, 2012). In certain instances it was shown that the two fleets can potentially exhibit large interdependencies, particularly during important fishing seasons (reproduction, migration) and important fishing grounds, which in turn could result in resource overexploitation (Horta and Defeo, 2012).

Conventional fisheries management tools (e.g. gear/vessel restrictions, limited entry schemes) are generally difficult to enforce in SSFs and may thus not be efficient for managing the sector (Ward et al., 2004; Sathyapalan et al., 2011). Moreover, costs related with the function of a quota system (assessment, monitoring and enforcement) may be particularly high for SSFs (Charles, 2011c, Costello et al., 2012). Major fishing policies have been implemented in a top-down rather than a bottom up approach thus not providing a real incentive to the SSF to behave as a responsible agent. Few studies have reviewed the social impacts of management measures such as Marine Protected Areas (MPAs) on stakeholders and communities while MPAs' agendas have shown little concern about their impacts on coastal communities (Gasalla, 2011). Climate change is also expected to have a considerable impact on fisheries with an increase in the participation in fishing activities and a coupled decrease in productivity, primarily due to changing species distributions and declining catch potential (Harper et al., 2013). In several locations, especially in Asia, aquaculture development is emerging as a major conflicting use to SSFs.

The previous indicate that other than the implications of resource and environmental changes (stock decline, environmental variability), limitations in the sector's further development have to do with data scarcity and the general problems of coastal communities (poverty, market pressures, competition with other coastal users, e.g. large-scale fishery etc.) to highlight the need of assessing the sector not solely from a physical and ecological viewpoint but also on a socio-economic basis.

2.5. Which are the sector's fundamental characteristics and how do they relate with its state and development?

From the review of existing literature (figure 2-1; table S2-1), it was shown that the sector's fundamental characteristics (technological; operational; structural; social and demographic) include its heterogeneity; diversity of target species; (selective or unselective) fishing practices; narrow range of operation; and livelihood diversification. Other important characteristics are the uneven spatial and temporal distribution of fishing and the frequent practice of landing fish at numerous remote ports (UNEP, 2011).

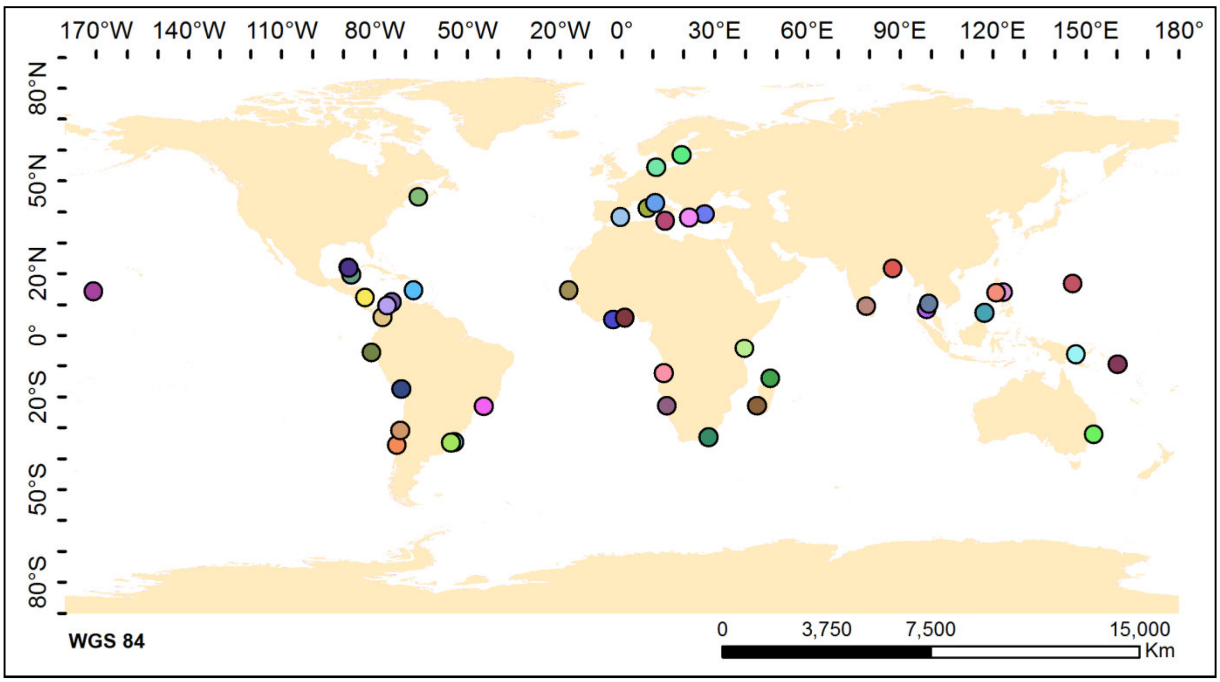

Figure 2-1: SSF studies – Location of studies that were assessed within the context of the present review (n.b. Map depicts location-specific studies) (Map data: Natural Earth, 2012)

2.5.1. Operational distance

`Fishing grounds and operational distance from shore are considered defining characteristics for a given location's SSF (FAO and WorldFish Center, 2008). Other terms used to describe operational distance are 'range of operation' (Papaioannou et al., 2012); 'fishing range' (Daw, 2008) and 'extent' (Dunn et al., 2010). Past studies that assessed the influence of distance to the operation of SSF, include Caddy and Carocci (1999), Rueda and Defeo (2003) and Stewart et al. (2010).

Determining the operational distance of the SSF is frequently a difficult task due to data scarcity and the coarse resolution of available data, while the limited budgets of competent authorities, especially in developing countries, further hinder the sound monitoring, control and surveillance of the sector's distribution and spatial dynamics. Furthermore, with increasing distance from the shore, assignment problems may arise, namely problems associated with knowing where the fishery is located and who is using it (McClanahan et al., 2009). This condition may in turn further compromise the challenged control potential by competent authorities.

As a general rule, SSFs have a confined range of operation due to their limited technical efficiency. SSFs tend to fish at grounds located nearest to home port/village (Caddy and Carocci, 1999; Cabrera and Defeo, 2001; Daw, 2008; Teh et al., 2012) in spite of potential higher yields and revenues of grounds located further. The decision to fish near or far from fishers' point of origin is often made by accounting for the trade-off between travel costs and expected higher yields, whereby economic incentives, including non-monetary considerations, are thought to determine fishers' spatial range (Caddy and Carocci, 1999; Daw, 2008; Teh et al., 2012).

Spatial distribution of fishing effort is a result of several underlying factors, including local knowledge of fishing grounds; technical considerations (e.g. depth limit, type of substrate) and innovations (e.g. monitoring); legislative and institutional constraints (e.g. spatial closures) and social factors, including the activities of other fishers (Daw, 2008). Margins of economic rent from past fishing incidents were not always a good indicator of subsequent effort allocation as fishing sites were selected on the basis of fishers' preference to be based close to port (Cabrera and Defeo, 2001; Salas et al., 2004). The distance to fishing grounds is further influenced by safety at sea considerations (Daw, 2008; Teh et al., 2012), which depend on weather conditions, vessel type and individual risk aversion (Daw, 2008), with areas located near home village/harbor usually perceived by fishers as comparatively safe (Teh et al., 2012). Possessing navigational tools (e.g. compasses, GPS) assists fishers to fish farther and in more challenging conditions while enabling them to save time and fuel by locating grounds easier. Also fishers who are willing to travel to different locations are in general more experienced from the ones not willing to change location (Teh et al., 2012). The interactions and conflicts with the larger-scale fishery also determine the spatial extent and operational range of SSFs due to the fact that the two frequently target the same resources (Horta and Defeo, 2012).

The extension in fishing range in some fisheries is often a consequence of near-shore overexploitation (Caddy and Carocci, 1999; Daw, 2008); this suggests that trends in catch per unit effort (cpue) should be evaluated along with trends in spatial effort distribution, as they may be coupled with significant changes in the productivity of fishing grounds (Daw, 2008).

2.5.2. Heterogeneity

'Heterogeneity' usually denotes the sectors' numerous and diverse types of fishing grounds, gears and target species and is determined by both ecological and social factors. The diversity of fishing practices ('fishing tactics', Cabrera and Defeo, 2001; 'métiers', Tzanatos et al., 2006) can be considered an adaptation to the large diversity of species in the fishery. The use of passive gears close to the coast, where seasonal environmental variability and spatial heterogeneity are high, has been shown to promote the diversification of fishing practices (Tzanatos et al. 2006). SSF gears usually require relatively low investments and can be used in a variety of methods and are therefore highly adaptable to changing circumstances. The short life span of fishing gears also contributes to the sector's flexibility in adapting to changing circumstances. Heterogeneity may thus have a positive impact on the sector's ability to adapt to changing circumstances, yet the presence of various different gears may also signify overcapacity. However, an apparent overcapacity in terms of boats or number of fishers may be a seasonal adaptation aimed at maximizing catches during periods of resource abundance, with the apparent overcapacity not being utilized during periods of scarcity (Allison and Ellis, 2001). Also, associating heterogeneity directly with overexploitation may be misleading, and a result of inadequate data and data assessment.

Choice of métiers is based on several factors, which include recent yield and income, the knowledge of fishing grounds and the seasonal availability of resources, the market demand, the weather conditions, the tradition as well as information and rumors about the yield of other fishers (Tzanatos et al., 2006). Changes in the biological or economic conditions and the relative profitability of métiers result in a redistribution of fishing effort whereas spatial or temporal closures and other restrictive management measures may force SSF fishers to redirect their activity to other métiers. A fisher's wealth might not permit the investment in many gears. Consequently, the originally selected gear could be used in other seasonal métiers by the skipper, despite this choice being of relatively low benefit. This inability of many SSFs fishers to afford many gears could explain in certain cases the high percentage of activity directed to low-income métiers (Tzanatos et al., 2006). The use of multiple gears to target different species according to seasonal availability can compensate for fishers with restricted livelihood diversification alternatives (Chuenpagdee and Juntarashote, 2011). Long-term commitment to a way of life and profession has been suggested to be a factor in increasing time and spatial horizons and the diversity of tools used by participants (McClanahan et al., 2009).

2.5.3. Selectivity

There is mixed evidence about the selectivity of the SSF with respect to target species and sizes: both selective (Döring, 2003; Macfadyen et al., 2011) and non-selective practices have been documented (Bundy and Pauly, 2001). As a general rule, SSFs are primarily multi-species, multi-gear fisheries (Chuenpagdee and Juntarashote, 2011), thus at the aggregate level their selectivity is relatively restricted in comparison to single-species, industrial large scale-fisheries, which has in many occasions enabled maintaining the structure and functioning of target resources. Individual, location and segment specific fishing activities can however be very selective with potential environmental benefits. For some artisanal SSFs (Cinner and McClanahan, 2006; McClanahan and Cinner, 2008) differences in fishing pressure, distance to fish markets and size of fishing grounds also affected the composition of the catch with respect to the trophic levels of target species; at locations of intense fishing pressure, the catch was comprised of very low trophic level fish, suggesting that higher trophic levels have been overfished. Thus, increasing fishing pressure could reduce fish size in catch, even when keeping gear selectivity constant.

Short-term selection of target species appears to be influenced by prior information available to the fishers (Salas et al., 2004); selection among different species may be influenced by the perception of resource availability, as expressed in previous cpue and profits from the species. Choice of species may not only be made on the basis of the species price but other considerations are important, such as the degree of method's specialization and fisher's experience in its use. It should also be reminded that SSFs usually operate in coastal environments where resources are frequently over-fished and thus decoupling the impacts of over-fishing from gear selectivity may not be a straight-forward task.

2.5.4. Diversity

Ecosystems with a higher species' richness are generally less susceptible to the anticipated impacts of overfishing and subsequent stock collapse. Anticipated enhanced recovery at high diversity is due to the fact that fishers can switch more readily among target species, potentially providing overfished taxa with a chance to recover (Worm et al., 2006).

Multi-species, multi-gear SSFs provide fishers with versatility in targeting different species and using different gears during seasonal closures (Seilert and Suchat Sangchan, 2003; Chuenpagdee and

Juntarashote, 2011); fishers can target other species and thus earn reasonable income thus enabling stocks to recover (Chuenpagdee and Juntarashote, 2011).

It is important to consider how biodiversity impacts the dynamics of the sector (Vitale et al., 2011). Higher values of biodiversity indices in catch have been recorded during specific seasons (Vitale et al., 2011); these are likely a consequence of the double effect of favorable weather conditions, which allow fishers to catch farther away from the port, and the fact that several species record a peak in reproduction in the warm season. Cinner and McClanahan (2006) showed that the size of fishing grounds determines to a large extent the composition of the catch with respect to the trophic level and relative size of species.

In certain SSFs (Gupta, 2010; Defeo and Castilla, 2012; Brewer et al., 2012) the transition in the fishery with respect to target species was directly related to the role of the market, thus highlighting the effects of economic forces on biodiversity maintenance. When a market is established, some species are likely to be in more demand than others. The loss of biodiversity is linked to the development of the market in that it leads to over-exploitation of valuable species which results in a reduction in aggregate fish biomass (Quaas and Requate, 2013). There thus may exist a conflict between profit maximization and biodiversity conservation. The fishery is exploited to meet market demand and any signals of scarcity, as reflected by increasing market prices, induces further exploitation of the fishery. Therefore, a reduction of over-exploitation of a fishery will increase not only biodiversity, but also the value of the fish catch.

2.5.5. Livelihood diversification

For SSFs communities, the option of diversifying into different economic activities at a household level is a strategy that enables to smooth the effects of resource variations (Allison and Ellis, 2001). '*Actors should consider diversifying their livelihoods if the state of the fishery resources and the environment is such that continued use patterns threaten their sustainability'* (FAO, 2012b).

Many fishers in the sector do not have only one job or do not completely exchange their job for a life as a fisher but will spread their risks in income over various activities. Fisheries and agriculture are highly interchangeable and multiple occupations are common; thus many people will be occupied as fishers to varying degree with time[4]. Livelihood diversification does not only relate to occupational flexibility, but also encompasses geographic mobility of fishers (Isaacs, 2012). A reduction of household livelihood diversity may diminish SSFs capacity to deal with change (fewer alternatives)

[4] A full-time fisher is one deriving at least 90% of their livelihood from fishing or spending at least 90% of working time on fishing (FAO and WorldFish Centre, 2008).

(Cinner and Bodin, 2010). Moreover, the viability of some key occupations is sporadic and highly susceptible to disturbances such as price fluctuations or incidents of environmental variability (Cinner et al., 2009). However, alternative employment opportunities, especially in rural areas may be non-existent and many SSFs, especially in developing countries, show very little livelihood diversification alternatives and a high dependence on the artisanal SSF (Davies et al., 2009; Pomeroy et al., 2009).

It is important to note that many small-scale fishers were willing to continue fishing even when catch declined and when offered alternative attractive monetary incentives to do so (Muallil et al., 2011). This situation indicates an attachment to the fishery as a way of life (Kraan, 2011) suggesting that fishing is important not solely as a livelihood source, but also as a historically and culturally significant occupation (Muallil et al., 2011; Trimble and Johnson, 2013). Such evidence comes to question the general assumption that fishing is an occupation of last resort, with many fishers getting through the occupation job satisfaction (Muallil et al., 2011; Trimble and Johnson, 2013). Fishers' decision to exit the fishery was shown to be strongly related to years fishing, with more mature and more experienced fishers not willing to change occupation (Muallil et al., 2011).

However, willingness to remain a fisher does not necessary reflect fishers' reality. Past studies showed that although fishers were willing to continue working at the sector they eventually exited the fishery as a result of political and economic constraints. This decision was determined to a large degree by perception of wellbeing with material considerations becoming more important than in the past (Trimble and Johnson, 2013). Such a situation implies that conflicting interests may arise in fisheries with change in environmental, political and socio-economic variables (DuBois and Zografos, 2012). Another important aspect is the link between profit and level of education attainment. Certain fishers with a low educational level were unable to afford advanced technology for offshore operations (Pomeroy et al., 2009). Empirical evidence suggests that SSFs households are frequently financially constrained in their education decisions, with the chance of children being in school increasing significantly with the income of the head of the household (Noack et al., 2012).

2.6. How can major limitations in the sector's further development be overcome?

In the following section we discuss how constraints to the sector's further sustainable development can be overcome, especially with reference to its fundamental characteristics. Suggested measures are reviewed with regard to scientific, political and institutional aspects.

2.6.1. Operational distance

The determination of the range of SSFs requires dealing with the issues of data scarcity and the coarse resolution of data. Further progress is necessary, especially in developing countries. Despite the advancements in the field, fishing authorities, primarily for reasons of data confidentiality, often hesitate in providing spatially explicit fisheries' information. This approach may have a negative impact in the determination of SSFs range and subsequent quantitative analysis. It may result in the sector being excluded from policy within the framework of spatial planning, as it has been frequently the case in the past.

With evidence suggesting that a decisive factor on location selection is what other fishers are doing (Daw, 2008), how peer effects determine operational distance requires additional research. The sector's restricted range coupled with the fact that several fishing communities may be based in numerous locations with a broad geographic distribution, together with the reliance of SSF communities on home port/fishing village, should be carefully considered and accounted for within spatial planning.

Proximity to markets was shown to be a defining factor of the sector's range (Cinner and McClanahan, 2006). This situation stresses the need to enable SSFs to access nodal landing facilities and trade centers. A potential policy measure is to foster infrastructure development (Isaacs, 2011; Sowman and Cardoso, 2010). Such a development should promote the safeguarding of the fishery resource while ensuring that any extra demand does not jeopardize the special needs of local communities and the subsistence nature of the activity.

2.6.2. Heterogeneity

Overall SSFs exhibit a high degree of heterogeneity and this may enhance their ability to adapt to changes in resource fluctuations and management at the sector level. However, for an individual fisher it may be difficult to adapt inputs (vessels, gears, capitalization), suggesting that negative impacts from such changes are more pronounced at the individual level.

Gear diversification and modernization can have positive impacts on the ecological status of a locality; Panayotou (1982) argues that the control of gears and mesh size may eventually lead to more valuable species composition of catch. Gear diversification is also a possible means for governments to ensure SSFs do not to opt for larger boats and more powerful engines (Gascoigne and Willsteed, 2009). However, economic constraints in the short-term present a major obstacle to any policy put forward that would result in significant temporary decrease in market supply. As fishers adapt to new gear and new grounds they may further experience a temporal decline in earnings (Gascoigne and Willsteed, 2009). As such, conservation, development and donor organizations should consider supporting relevant efforts through programmes such as gear or mesh exchanges (McClanahan and Cinner, 2008). Authorities could provide incentives to SSFs via buyouts to fishers for reducing marine mammal bycatch and interest-free loans for shifting gears in conservation areas (Niesten and Gjertsen, 2010). Improved fishing technology is also crucial for safety at sea. FAO (2012b) stresses the need for improving sea safety in SSFs through measures involving formal and informal training also directed to gear and boat designers, boat builders, mechanics.

Implemented management initiatives should also take into account that the negative impacts resulting from the competition among different gears could potentially increase with increasing fishing effort and the addition of new and novel gears. Moreover, local gear restrictions should consider potential changes in ecosystem structure (e.g. trophic level), thus stressing the need of an adaptive management framework (McClanahan and Cinner, 2008).

The success of management practices that involve gear regulations depends on fishers' perception, with fishers frequently disregarding rules they do not consider legitimate (Evans and Andrew, 2009) or rules they are not familiar with (DuBois and Zografos, 2012). Gear limitations are likely to be ineffective without first assessing alternative options available to fishers (Davies et al., 2009). Since years of fishing experience seem to influence fisher's decision to invest in tools, efforts at professionalizing fishers are likely to have more long-term effects than any specific management addressed to gear measures, and should thus be seen as a key and cost-effective area for involvement of governments, conservation and development organizations and donors (McClanahan et al., 2009).

2.6.3. Selectivity - Diversity

With reference to SSFs certain accounts argue that a certain type of selectivity may have adverse environmental impacts (Bundy and Pauly, 2001). Solution advocate balanced exploitation patterns that could be achieved by using a wide diversity of gears (Bundy and Pauly, 2001; Misund et al., 2008; Rochet et al., 2011; Garcia et al., 2012). Maxwell et al. (2012) argue that the successful implementation of balanced harvesting depends on the development of future demand for species for which today no major demand exists, since most fishing activity is directed towards targeting high value resources. To this end SSFs could potentially play a central role, provided they are decoupled from the dynamics of international fish markets, as several SSFs target high-value species and are of export-oriented character (Defeo and Castilla, 2012). Although the applicability of balanced harvesting for SSFs could be further investigated, it is not a straight-forward task considering the multi-gear, multi-species nature of many SSFs; furthermore coastal fish resources are susceptible to a variety of different pressures that need to be taken into account before concluding on the suitability of implementing balanced harvesting. Also, a shift towards such a practice has to consider that SSFs frequently have limited access to trading centers, while catch composition may be governed by proximity to market.

SSFs discards and bycatch rates are difficult to evaluate because of SSFs diffuse character, remote landing sites and social marginalization (Chuenpagdee et al., 2006; Zeller et al., 2007; 2011b; Jacquet and Pauly, 2008; Alfaro-Shigueto et al., 2011). Research is investigating ways to increase SSFs selectivity with reference to minimizing non-target fish bycatch (Macbeth et al., 2005). Past studies have reviewed measures to mitigate bycatch with suggestions including the use of set net illumination, elimination of floats in main lines, along with fisheries closures and the designation of MPAs (Alfaro-Shigueto et al., 2011). In the process, the engagement of local communities is crucial in guaranteeing the successful implementation of plans (Gasalla, 2011). It is also envisaged that local initiatives including trained fishers contribute to ensuring the recovery of imperiled populations of non-fish bycatch (Alfaro-Shigueto et al., 2011).

2.6.4. Livelihood diversification

Providing fishers and their families with a broader range of livelihood options could both support exit from the fishery and reduce the household’s economic dependence on it (Pomeroy et al., 2009). Promoting complementary household activities, while in the meantime encouraging children to remain in education and providing information on achievable career opportunities, would increase livelihood diversity and as such help stem the flow of the next generation into fishing (Davies et al., 2009). Allison and Ellis (2001) argue that the management of SSFs should be aimed at improving rural development policy and practice by taking into account the fact that livelihood strategies exhibit seasonal and cyclical patterns.

Policies that reduce the number of fishers without creating non-fishery livelihood options may prove unsuccessful (Pomeroy et al., 2009). Buy-back schemes that did not provide training of fishers to the new livelihood were not successful, with fishers eventually selling their land to resume a lifestyle in fishing (Pomeroy et al., 2009). Moreover, livelihood diversification must be pro-active rather than reactive and management should focus on developing mechanisms and techniques to prevent poverty rather than finding alternative livelihoods once a problematic situation has already been established (Béné et al., 2007; 2010).

The allocation of financial aid should be cautious, as it has been shown to result in an increase of fishing effort in certain fisheries. Livelihood support provision is likely to be successful in reducing fishing pressure through reduction of fishing effort but may not necessarily stop fishers from fishing completely. To that end, non-sectoral interventions such as health care, education, and credit schemes can have more effective impacts on the livelihood of fishing communities than interventions targeting the resource (Isaacs, 2012). The role of women in SSFs has been in the forefront of investigation (Chuenpagdee and Juntarashote, 2011; Harper et al., 2013) signifying their important contribution to SSF households, even indirectly, such as being involved in complementary yet substantially helpful activities.

2.7. How can the sector's sustainability be enhanced?

This section discusses additional scientific, political and institutional strategies on promoting SSFs environmental and socio-economic sustainability; gaps and feasibility of implementation of relevant strategies are evaluated.

2.7.1. Environmental sustainability

Labeling and certification [e.g. via the Marine Stewardship Council (MSC)], is a potential measure to promote SSFs environmental sustainability. However, the relatively high cost of participating in these schemes continues to be an impediment for many SSFs in developing countries (Jacquet and Pauly, 2008). Some SSFs have been certified by the MSC e.g. the Dutch sea-bass SSF (2012)[5], which also shows the extrovert, entrepreneurial character that SSFs can have. Other than the direct impacts on the environment, positive outcomes from labeling include increased profit margins and a potential shift of consumer preference towards sustainable fisheries (Jacquet and Pauly, 2008), which in the longer run may balance the original investment required from the fishers to enter the labeling scheme. Initiatives such as the Responsible Fisheries Alliance in Iceland focus on the guarantee that seafood carrying the certification is produced by artisanal and SSFs using low impact or passive gear (Molyneux, 2011). Such an approach may actively contribute to limiting Illegal Unreported and Unregulated (IUU) fishing and also enhance access to resources (Gasalla, 2011).

[5] see: http://www.msc.org/get-certified/news/newsitem/first-catch-of-dutch-msc-certified-sea-bass-presented-in-brussels (accessed: 4.6.2013)

With reference to an Ecosystem Approach to Fisheries (EAF) management, although of substantial interest to the SSF sector (Mathews, 2001; Garcia et al., 2003), few projects have reviewed implementation potential, especially in a context-specific level. The implementation of EAF initiatives for SSFs is a particularly difficult task due to the scarcity and fragmentation of data and the limited budget for research agencies, especially in the developing world. Lately the topic is central within the framework of institutional policy (European Parliament and Council, 2013) and ongoing projects[6] so progress on the matter can be expected within the near future.

2.7.2. Socio-economic sustainability

As a general principle, gradually being integrated within the institutional and legislative framework of fisheries operation, the governance of SSF should be vested at the most effective local level (FAO, 2012b). More appropriate and successful forms of governance of SSFs have been suggested to include co-management (Defeo and Castilla, 2005; Gutiérrez et al., 2011; FAO, 2012b). Local self-governance or co-operative co-management enables the participation of fishers within schemes of monitoring, control and surveillance while encouraging responsible fishing, thus ensuring increased compliance with regulations (Defeo and Castilla, 2012).

Insight provided by past studies on the pressures market forces exert on SSFs (Cinner and McClanahan, 2006; Gascoigne and Willsteed, 2009; Defeo and Castilla, 2012) highlights the need for market-specific governance, for example through sustainable harvesting certification and market-specific gear and species restrictions. Brewer et al. (2012) suggested that such considerations will become increasingly important in the future.

Many argue on the need to: (i) enable SSFs access to cash and credit in order to invest in means of production and (ii) ensure improved market access that allows fishers to sell their product (Jentoft et al., 2011; Isaacs, 2012). These suggestions do not necessarily imply investment in bigger and more efficient vessels, but on basic elements of the fishing operation and meeting basic, subsistence needs; availability of health services and education for fishers and their children is key in coping with the poverty typically associated with SSFs (Davies et al., 2009; Jentoft et al., 2011; Isaacs, 2012).

As many SSFs have no involvement in the post-harvest catch distribution, there exists a need to enable fishers to be involved in the control and first scale transaction (Chuenpagdee and Juntarashote, 2011). SSF management regimes have been most successful when fishers have

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[6] see: http://www.worldfishcenter.org/ongoing-projects/taking-ecosystem-approach-small-scale-fishing-tropics (accessed: 7.1.2013) WorldFish Center, 'Implementing EAF in small scale tropical marine fisheries', E.U.-funded Project

influence in local markets by allowing specific management tactics, improved product quality, shorter intermediaries, chains, market timing coordination and eco-labeling strategies (Gutierrez et al., 2011). This situation may in turn result in multiple benefits to local communities, minimizing the probability of over-exploitation and enhancing economic revenues by higher income per unit effort (Gutierrez et al., 2011). Fishers' political participation and freedom to organize is a key element towards achieving this goal (Jentoft et al., 2011; FAO, 2012b).

The elimination of subsidies in fisheries comprises a central consideration in the process of achieving fisheries sustainability and 'investing in a green economy' (UNEP, 2011). The World Trade Organization (WTO) is currently considering eliminating fisheries' subsidies; some argue that in the new regime, SSFs, especially artisanal, should be provided with a 'Special and Differential Treatment' (S&DT) on the basis of their contribution to poverty alleviation and food security and development. However, subsidies provided to artisanal fisheries (e.g. vessel/gear modernization, incl. motorization; infrastructure; export; fuel; training and capital) can have negative impacts on both fish resources and coastal communities (for a review see: UNEP, 2011; Charles, 2011a). Recent evidence (Mondaca-Schachermayer et al., 2011) suggests that subsidies provided to SSF villages did not lead to changes in the size of landings and the income received, which challenges the assumption that subsidies necessarily result in overfishing and resource depletion. Other findings indicate that funding was higher for those villages with the highest values of landings and was primarily allocated to villages in urban areas as opposed to rural areas a situation which may indicate that such subsidies do have distortionary effects. Also, although there was evidence to suggest that better working conditions and improved access was not an incentive for new people to enter the fishery, careful analysis is required to properly understand this matter. To this end, subsidies for the SSFs should be considered cautiously and should only be provided within a management framework that controls exploitation of the stocks.

2.8. Outlook

The present study highlights the fact that the further development of SSFs requires strengthening their efficiency and sustainability, in particular by reducing over-fishing. Any obstacles that exist in the process are not simply a matter of the (small) size and engine power of individual units, thus stressing the fact that the SSF sector can transcend to a key stakeholder within fisheries' policy and management. In the context of the reform of the Common Fisheries Policy (CFP) of the European Union and its ongoing implementation, SSFs received increased attention and their needs have been prioritized (European Parliament, 2013a; European Parliament and Council, 2013). It is envisaged that the establishment of the International Instrument for securing SSFs in 2014 (FAO, 2012b) will promote the sector's capacity building and as such constitutes a major – and long anticipated - advancement.

SSFs are highly complex and diverse systems, thus governance is a challenge, as no-size fits all and context-sensitive perspectives are crucial. FAO (2012b) argues that preferential and/or exclusive access to traditional fishing grounds for SSF communities should be supported as appropriate. Most accounts agree that improving credit facilities available to SSFs is important for raising the sector's capacity. Subsidies that go beyond the provision of basic public goods have to be considered cautiously, even if they are specifically tailored to the artisanal SSF.

Other than their significant contribution to food security and poverty alleviation, SSFs also act as centers of economic activity in rural areas located away from major hubs and apart from employment and income, they also provide linkages with other industries which can constitute the basis for local-level economic development (FAO and WorldFish Center, 2008). Assessing SSFs contribution to socio-economic development should take into account the needs of the people who depend on the resource for their subsistence (Kébé, 2008; Isaacs, 2012). Linking fisheries management to the general objective of improving the economic and social reality of fishers will facilitate the sustainable development of the SSF.

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3. The development and use of a spatial database for the determination and characterization of the state of the German Baltic Small-Scale Fishery sector

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3.1. Abstract

Although substantial progress has been made in the acquisition and analysis of fishery data, the small-scale fishery (SSF) sector is frequently data deficient, with relevant primary data often being fragmented and incomplete. Also, in contrast to the case of the larger scale sector, a coherent methodological framework for the assessment of the SSF has, in most cases, not been formulated. In the present study, the methodology of developing a database for the German Baltic SSF sector is presented. The aim of the database is to combine fishery primary data effectively and enable the sound determination and characterization of the German Baltic SSF sector. Data used include, among others, fleet data derived from the European Community Fleet Register (CFR) database and logbook data from the German Federal Office for Agriculture and Food (BLE). The database includes information on the technical specifications of SSF vessels (length, engine power etc.); the sector's operational range; main target species; fishing grounds; landing ports; and weight and price of landings. Results of employing the database for profiling the state of the SSF sector (in 2008) are presented. The results demonstrate the benefits of such an approach within the framework of managing coastal fish resources and fishing activities.

3.2. Introduction

Small-Scale Fisheries (SSF) are associated with practices that favour the use of less energy-intensive, primarily static, fishing gear and are considered potentially more sustainable than large-scale fisheries (Jacquet and Pauly, 2008).

SSF are also of great social significance, employing the largest number of fishing workers (FAO, 2009b) and accounting for most of the world's fishing operations. In the future, the SSF sector is expected to play a central role in resolving the global fishery crisis; Hall et al. (2010) consider the support of its continued operation and development, and the increase in its adaptive capacity, as cornerstones in the process of sustainable fisheries. However, SSFs have been systematically ignored and marginalized through government policies in both developing and developed countries (Berkes, 2003; Ünal and Franquesa, 2010). Although there now exists a rising consensus on the need to promote the interests of the sector, as manifested by the increased attention of international and regional institutions (for instance, within the framework of the ongoing reform of the EU CFP), the sector has yet to overcome decades of a non-favourable management regime. The absence of a clear definition; its high degree of heterogeneity (Freire and García-Allut, 2000; Tzanatos et al., 2008; Forcada et al., 2010); and its exclusion from national policy and the benefits that the larger scale sector may have (Madau et al., 2009); all account for the SSF sector being frequently neglected and not adequately assessed and analysed.

An important limitation in the definition, assessment, and analysis of the state of the SSF sector is that primary data are frequently absent, fragmented and/or incomplete. Besides the general limitations inherent in fishery primary data that pose difficulties in the sound assessment of the state of fisheries (e.g. source fragmentation/variability, various levels of stratification, etc.), the SSF sector's fundamental characteristics (i.e. a large number of vessels, heterogeneity, and lack of clear definition) further hinder the acquisition of reliable and meaningful data. Moreover, while in the medium and large-scale sectors substantial progress is being made in data collection [e.g. the use of vessel monitoring systems (VMS) in the EU] and in the development of elaborate programmes for fishery data analysis (for reviews see: Plagányi, 2007; FAO, 2012c), the same does not hold true for the SSF sector, which remains data deficient and lacks a coherent methodological approach for data analysis.

Past attempts to assess the SSF sector include the work of Zeller et al. (2007) for certain US flag-associated island areas in the western Pacific, and Dunn et al. (2010) for coastal fisheries in the wider Caribbean; SSFs were of central consideration in the assessment of Colombian marine fisheries by Wielgus et al. (2010) and within the work of Zeller et al. (2011a) concerning the reconstruction of Arctic Sea fishery catches. These studies formulated methodological frameworks for the analysis of a diversity of data sources (e.g. landings/catch time-series data, literature review, and expert consultation) that eventually enabled the evaluation of the state of the SSF sector. A recent study by the European Parliament (Macfadyen et al., 2011) analysed and assessed the structure and economic performance of SSFs in Europe, by primarily assessing data contained within the EU CFR and EUROSTAT. However, most past studies of the sector primarily involve local applications that focus on a particular segment; for instance, many of these studies review the impact of the designation of MPAs on the area's SSF (e.g. Madau et al., 2009; Forcada et al., 2010). In the absence of complete primary data sources, past research has made use of different methods to acquire data for a certain part of the SSF, such as conducting questionnaire/interview surveys (Otero et al., 2005; Forcada et al., 2010; Strehlow, 2010), visual observations (Gonzalvo et al., 2011) and on-board sampling (Forcada et al., 2010). Larger analyses (Katsanevakis et al., 2010) include the assessment of logbook data, coupled with survey data. These examples demonstrate the variety of methodological approaches that exist for assessing the SSF sector, especially in the absence of primary data. Each of these approaches discloses valuable information on different aspects of the SSF, and the adoption of a particular method relies, among others, on the defined objectives of research, the nature and extent of available data, and the spatial extent of the study area. It should be noted, however, that such approaches are helpful when assessing local segments of the SSF, but may be difficult to implement, from a logistical perspective, when the entire fleet is considered.

3.2.1. German Baltic Small-Scale Fishery

In the Baltic Sea, coastal fish communities have long been recognized as important components of the natural ecosystem (HELCOM, 2006 a, b), while SSFs that target the resource account for the majority of fishing vessels in the area (IFREMER, 2007) [According to E.U. legislation, small-scale coastal fishing is defined as fishing carried on by vessels of an overall length of less than 12 m, not using towed gear; Council Regulation (EC) No 2792/1999 and Commission Regulation (EC) 2090/1998; Council Regulation (EC) No 1198/2006]. The Baltic region is one of the few areas with a coherent legislation for the technical measures of fishing practices (European Parliament, 2007; Council Regulation (EC) No 2187/2005) and the limits of total catch and fishing effort for certain species of commercial importance (e.g. Council Regulation (EC) No 1124/2010, for the year 2011), also governing the activity of the SSF sector.

The coastal fishery in the German Baltic region is long considered an integral element of the broader area, having historically shaped regional economies (the Baltic herring fishery was a cornerstone of the Hanseatic League trade alliance), providing employment opportunities and being a tourist attraction (Döring, 2003). Also, the fishery exploits the coastal fish resource in a moderate way, while relevant fishing practices usually include the use of static, comparatively selective gear, resulting in small amounts of non-target fish species bycatch (Döring, 2003). Furthermore, as opposed to the case of the offshore fishing sector, non-target caught fish species are frequently returned by fishers to the sea alive (Döring, 2003).

There has been marked progress in the Baltic area in the acquisition, collation, analysis and dissemination of fishery data. Catch statistics for the Baltic area are contained within the EUROSTAT/ICES database (2011), while other elaborate databases of fishery statistics have also been developed and are publically available, such as the HELCOM Map Service and GIS Data (2010); web-based data applications such as FISHFRAME (ver. 5.0, 2008); or the German 'Fish Stocks' Online web-portal (Institute of Baltic Sea Fisheries, 2010). Furthermore, past studies (Rossing et al., 2010; Zeller et al., 2011b), have also accounted for unreported removals and discards and the contribution of the recreational fishery to the area's total fishery removal, thus also addressing fundamental gaps in official fishery data. Outcomes of these studies present an improved dataset of catch time-series and results are freely available to the public (see Sea Around Us Project, 1999).

However, the state of the German Baltic SSF has not been extensively evaluated. The 2010 Annual Economic Report of the European Union fishing fleet (STECF, 2010) provides an overview of the German fleet. Within this overview, information relating specifically to the Baltic Sea is presented, including insights and quantitative information on the SSF (STECF, 2010). The ICES Baltic Fisheries Assessment Working Group has partly assessed the state of the German Baltic SSF (ICES, 2009a), providing data on the total number and average technical specifications of vessels per gear-type category (length, tonnage capacity, and engine power). Other projects have reviewed the catch weights from the recreational fishery (see Institute of Baltic Sea Fisheries, 2012). Overall, however, there have been relatively few case studies conducted to assess the Baltic SSF in general and the German Baltic SSF sector in particular (e.g. Lappalainen et al., 2002; Delaney, 2007; IFREMER, 2007), and relevant data are restricted to the extent of each specific application (e.g. certain geographic region, segment of the fleet, or a particular métier).

Moreover, available datasets lack information that is important for the assessment of the SSF sector. For example, HELCOM's database, which contains the most thorough and complete information on fisheries for the area, does not currently include information on the number of landing operations and the weight of landings per harbor, which could enable the extrapolation of additional indicators of fishing activity (e.g. distance from fishing grounds to landing harbors). Also, the harbors that are present in the relevant database include major ports and commercial harbors but are lacking information on secondary fishing harbors, which appear in the EU CFR (European Commission, 2004; 2006) and are important for the SSF sector. Furthermore, HELCOM data are stratified per ICES Rectangle and are in aggregate form for all Baltic countries; however, the catch composition among different countries and different segments/length classes of the fleet remains unknown.

The primary aim of our research was the development of a database for the German Baltic SSF sector that would enable the detailed identification and analysis of the state of the sector. The database aims at making primary data consistent, thus enabling the assessment of various attributes relevant to the German Baltic SSF sector and the assessment of data reliability [Data reliability has been a central consideration for past projects in the Baltic that are also of relevance to fishing (e.g. the EMPAS project, ICES 2008; Pedersen et al., 2009), and demonstrates the need to know the 'confidence limits' of fishery data (i.e. the degree of trusting the data]. The database is integrated within a GIS where data are related to features such as fishing harbors and fishing areas. The database includes information on several of the sector's attributes (e.g. fishing harbors, number of vessels, landings, fishing grounds, target species etc.), thus enabling its detailed evaluation. Our study provides an overview of the state of the sector during 2008, which is the year that has the most up-to-date, complete available data.

3.3. Study area, data and methods

3.3.1. Description of the study area

The German Baltic has a coastline of ~ 2,350 km and includes the coastline of the states of Mecklenburg-Western Pomerania (MV) and Schleswig-Holstein (SH). Within the area, there exists a multitude of commercial ports, secondary fishing harbors and shelters that extend along the whole length of the coastline. This situation results in the establishment of local markets for fish of commercial importance, especially in rural areas. Our study area encompasses the geographic area that corresponds to the operational range of the German Baltic SSF. This extends along the German Exclusive Economic Zone and is within Baltic Area Subdivisions 22 ('Belt Sea') and 24 ('Arkona Sea') of the Baltic Proper (figure 3-1).

The German Baltic marine coastal area is home to numerous coastal fish species and includes spawning areas of major commercial fish species (cod, herring). The important ecological features of the area's marine coastal environment have resulted in the establishment of an extensive network of areas of special conservation status, such as NATURA 2000 network areas, Ramsar sites and the designation of fishery closures, all within the extent of the coastal band. Major bays in the area include, from west to east, the bays of Kiel, Lübeck and Greifswald.

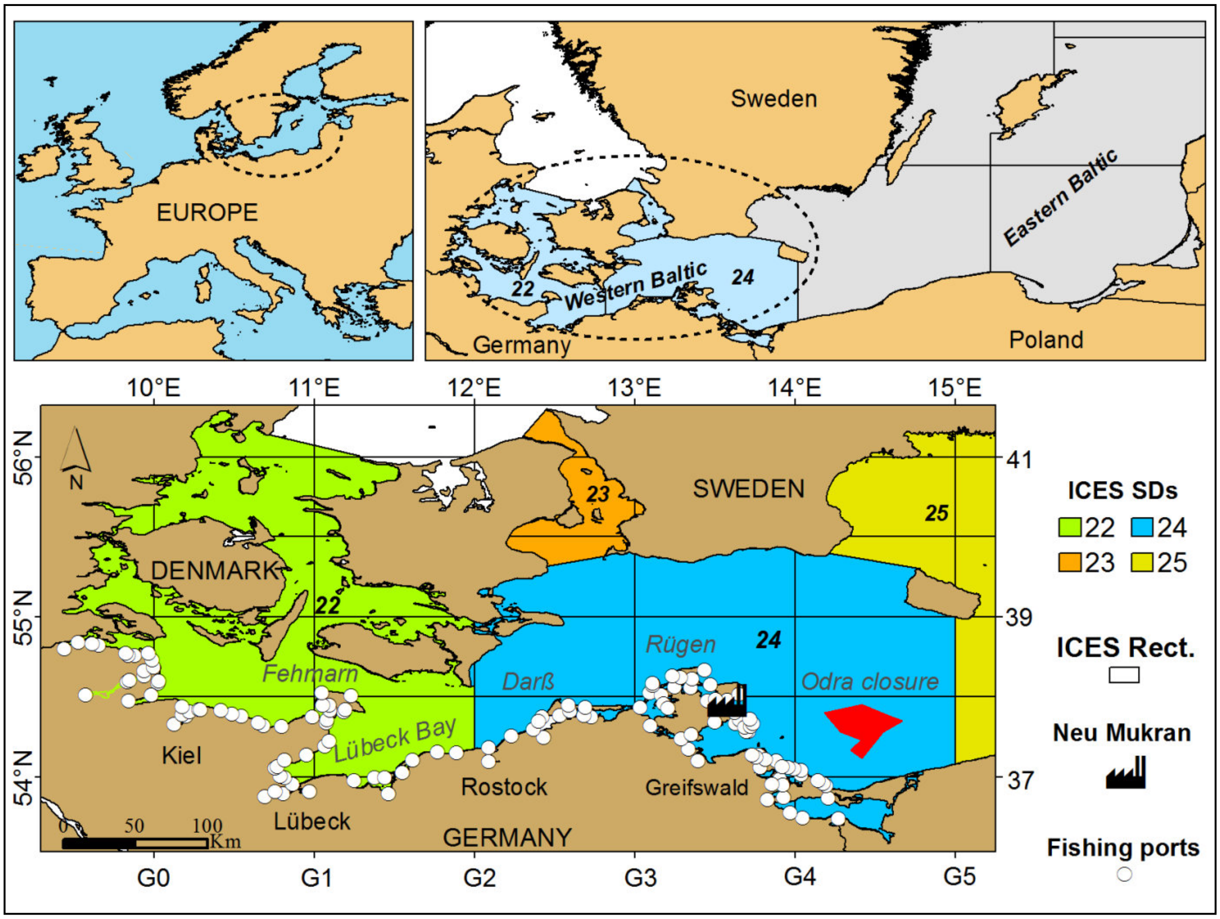

Figure 3-1: Map of the German Baltic coastal marine region (Adapted after Papaioannou et al., 2012; 2014a). ICES Subdivisions (SDs) are shown as colored areas and are divided into fishing areas (ICES Rectangles); fishing harbors, Neu Mukran herring processing plant (newly established in 2003) and Odra closure indicated (Data source: DIFRES, 2006; ICES, 2010; HELCOM, 2010).

3.3.2. Data description

We acquired, assessed, edited and analysed available primary fishery data, which included information on ports and harbors of the study area, fleet register data for Germany (European Community Fleet Register, CFR, 2010) and German logbook data (BLE, 2010).

3.3.2.1. German Baltic fishing harbor data

The dataset for the area's fishing harbors was compiled by combining existing datasets for ports and harbors and updating these according to additional information present within the other datasets (logbooks, fleet register, see 'Methods'). Primary sources were the HELCOM map and data service (2010) and data from the Pennsylvania State University libraries (2009). Relevant data include information on the name of each port, its position (x, y coordinates); and its administrative area (see Appendix, table S3-1).

3.3.2.2. Fleet register data

Information regarding the SSF fleet was derived from the European Community Fleet Register (2010). The CFR (see Appendix, table S3-2) is the official record of technical details, characteristics and activities of all Community fishing vessels based on the national registers of the EC Member States since 1991 and includes information on boat length, engine power, tonnage, homeport and permitted fishing gear (Gonzalvo et al., 2011).

3.3.2.3. Logbook data

Logbook data used in this study (BLE, 2010, see Appendix, table S3-3) were in the form of annual datasets of relevant quantitative and qualitative fishery data that included, among others, information on the date and time of the landing operation, the target species (e.g. cod), the weight of landings (kg), the price of landings (€), the fishing area where landings originated (ICES Rectangle), and the landing harbor [According to Council Regulation (EC) No 1224/2009 and Commission implementing Regulation (EU) No 404/2011 vessels smaller than 12 m LoA are not required to possess a VMS so as to present the exact co-ordinates of the fishing grounds, and can report fishing areas in terms of ICES Rectangle(s)].

Logbook data were in the form of spreadsheets that corresponded to two length classes of vessels, namely vessels smaller and vessels larger than 10 m (LoA) respectively. It should be noted that according to the current legislative framework, the length class category <10 m LoA is not obliged to provide logbook-related information, but German logbooks, unlike the case with other European counties, do include information for this segment.

3.3.3. Methods

3.3.3.1. Database development

The development of the database for the German Baltic SSF sector consisted of a series of analytical steps, which resulted in the integration of all data described above and in the determination of the state of the sector. First, an extensive dataset of primary and secondary German Baltic fishing harbors was compiled. Second, the CFR was assessed, to develop the dataset of the German Baltic SSF fleet. The third step involved the use of the logbook datasets to acquire information on the relevant indices included therein. The subsequent integration of the database within GIS (Environmental Systems Research Institute, 2008) enabled the visualization and analysis of the relevant attributes. The relationships between the modules making up the database are presented in figure 3-2.

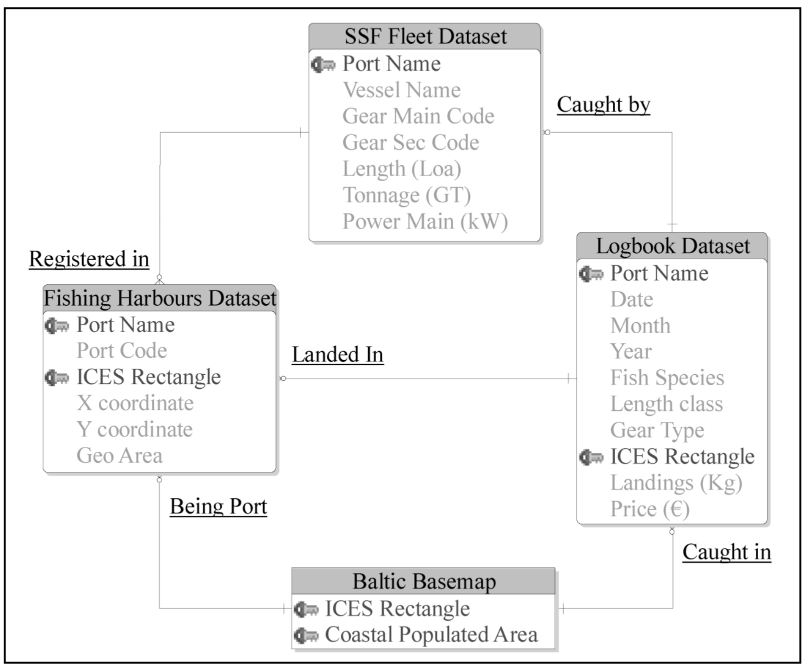

Figure 3-2: Entity-Relationship (ER) diagram of the German Baltic SSF database. Diagram developed within Toad Data Modeller Ver.4.1 software [2011 Quest ©, Freeware version]. The common attributes of the various comprising datasets (e.g. port name, ICES Rectangle etc.) were used to join together all relevant datasets.

3.3.3.1a. German Baltic fishing harbors

We assessed existing datasets of coastal populated areas (e.g. Pennsylvania State University libraries, 2009; HELCOM Map Services, 2010) that typically coincide with major ports and commercial harbors. A total of 130 additional harbors - from information contained within the fleet register and logbook datasets - were added to the initial dataset. We also considered ports/harbors situated within inland waters (e.g. bays, estuaries etc.) and at a distance <12 nm from the sea, which is typically considered as the maximum range of operation of SSF. The German Baltic fishing harbors are shown in figure 3-1.

Landing harbors located outside the study area (e.g. German North Sea and Denmark) and their corresponding information were excluded from the analysis. From the comparison of the logbook data with the respective initial harbor data, it was found that there are harbors in the latter that derived from the fleet register dataset and are not included as landing harbors in the logbooks, which implies that some of the ports of registration of SSF vessels are not used as landing harbors. The resulting fishing harbors dataset has been compared and validated against alternative data sources (e.g. Pennsylvania State University Libraries, 2009; HELCOM, 2010; World Port Source, 2010), and comprises an improved dataset of operational fishing harbors along the German Baltic coastline.

3.3.3.1b. Fleet Register data – determination of SSF

To determine the German SSF fleet, data for the year 2008 were retrieved from the CFR (2010) and analysed. Data were specified as 'active at date' for 31 December 2008, so as to cover the entire year. Although SSF vessels are officially defined as vessels <12 m not using towed gear, the SSF sector is heterogeneous. It includes vessels with various technical specifications that practice different fishing strategies. Thus, we initially categorized vessels according to the combination of their primary and secondary gear and established the various different gear-type combination categories present in the dataset. In order to account for seasonal shifts between primary and secondary gear, both gear types were considered and all possible combinations of the two gears were determined. This was done in order to estimate the exact number of static-geared vessels that can be operational at any given time and their technical characteristics. Three major gear combination categories were identified, namely the 'static' category (both primary and secondary gears static), the 'mixed' category (one gear static and one gear active) and the 'active' category (both primary and secondary gear 'active').

The second step was to determine the SSF sector based on the length (LoA), engine power (kW) and carrying capacity (GT) for each of the different gear-type categories. Four criteria were set as threshold limits for the definition of the SSF. All these criteria had to be met for a vessel to qualify as 'small-scale':

- The length of the vessel (LoA) should be <12 m (according to the legislative and institutional framework).

- The carrying capacity of the vessel should be <20 GT (to correspond with the average GT of the EU SSF fleet for the particular length class; after: López Benítez, 2010).
- The engine power should be <100 kW (to correspond with the average kW of the EU SSF fleet, after: i. ICES (2009a) (according to which the engine power of the German coastal cod fleet <=100 HP ~ 75 kW); and ii. López Benítez (2010).
- It should possess at least one static gear.

It must be noted that the values of the above threshold limits were intentionally selected to be high, in order for SSF vessels of the 'mixed' category not to be excluded from the analysis while ensuring that they truly qualify as SSFs.

We then focused on the 'static gear' category and assessed all respective segments where both gears are static, to determine the small-scale fleet (see Appendix, table S3-4 for relevant gear combinations). This assessment also provides a first-order estimate of the degree of heterogeneity of fishing practices of the German Baltic SSF sector. All vessels with relevant gear combinations were then integrated into the dataset. Vessels with secondary gear 'unknown' were assessed individually and allocated into an active/static category based on the combination of other technical attributes.

3.3.3.1c. Logbook data

Logbook data were fundamental in the development of the present database, as the type of information they include (landings, target species, fishing area etc.) could not be retrieved from alternative data sources (such as VMS data or the HELCOM database). Logbook information was not available at the level of individual vessels (in the manner of the fleet register data), but only in aggregate form ('fishing operation vs. time vs. day vs. landing harbor vs. species vs. fishing area caught'). Also, data do not include information on the duration of each fishing operation, and information on the type and amount of gear deployed (e.g. m^2 of nets, number of hooks and lines, etc.).

In this study, logbook data on weight of landings (kg) have been aggregated per annum to enable linking relevant information to the respective fleet register dataset that also has an annual level of aggregation. This level of analysis takes into account potential shifts between primary and secondary gears in the area, including gears used on a part-time basis. We assessed each segment of the SSF sector, as these appear in the logbook datasets (<10 m; 10-12 m). Active gear vessels were omitted. All data that corresponded to the <10 m LoA category (generic gear type 'static nets') were found to belong to the SSF sector (carrying capacity <20 GT, static gear, length <12 m) and were included in the dataset.

The assessment of the logbook data of the category 10-12 m LoA initially involved the analysis of non-gillnet fishing strategies. The SSF fleet from those records was defined based on the gear type and fishing strategies (non-GNS, >10 m LoA) practiced in the area during the year 2008 (see Appendix, table S3-5). For the SSF segment of 10-12 m LoA it should be noted that since data are aggregated annually, the representation of all small-scale fishing strategies is possible, as the use of secondary static gears does not overlap with that of primary active gears. Therefore, in the final results the (part-time) activity of SSF vessels with secondary gear 'static' is also included, provided those vessels follow the specifications set during the analysis of the fleet register data.

The exact weight of landings and the extent of the operation of the 'gillnets 10-12 m length' segment of the SSF could not be determined precisely. The length of the vessels is not explicitly stated in the logbook data, while it was demonstrated from the assessment of the CFR that several GNS vessels have specifications that do not qualify them as small scale (namely LoA > 12 m, GT > 20, engine power > 100 kW). To account for these limitations, we excluded the landings deriving from fishing areas (ICES Rectangle) located at a distance to the respective landing harbor, much greater than the range that corresponds to small-scale fisheries [This distance was set at 100 km, and is a general estimate of the range of operation of the German SSF sector, in line with the specifications of the institutional framework for the area's SSF (ICES, 2009a) and also includes the instances of SSF operating within inland/sheltered waters]. Thus, landings that pertain to fishing harbors located at a distance >100 km from the ICES Rectangle of origin were omitted from the database. This also included landings originating from the Danish and Swedish coastal bands, at a distance >100 km from their respective German landing harbors, and landings taking place in other countries' ports located at a distance >100 km from the respective fishing area of origin. This procedure partly corrects the data, with the weight of landings excluded most likely accounting for the larger scale (>12 m LoA) segment of the gillnets' fishing strategy. As such, the present analysis significantly refines the primary data, and provides a good estimate of the 'gillnets 10-12 m length' segment. However, in contrast to the rest of the analysis, the weight of landings that correspond to the gillnets 10-12 m length segment should only be considered as an approximation.

3.3.4. Data limitations

The inherent limitations in primary fishery data may limit our definition of the SSF sector, as also demonstrated by previous research (e.g. ICES, 2008; Madau et al., 2009; Pedersen et al., 2009; Forcada et al., 2010; Wielgus et al., 2010; Gonzalvo et al., 2011). Although the CFR could provide a good overview of the SSF sector, insight is restricted by the fact that vessels of the CFR may not operate during the entire year and/or may not use the same gear type throughout. This restriction does not enable the estimation of the exact number of SSF fishers active in the area. This is further complicated by the fact that in the German Baltic area, many of the registered vessels that qualify as small-scale do not actually operate as such, but are in reality 'helping-hand' vessels for the offshore fishery sector (Institute of Baltic Sea Fisheries, pers. comm.). This discrepancy between the number of vessels of the CFR and the actual number of active operational vessels has been reported to occur in other countries, and has also been observed during surveys in Germany.

Another drawback in the use of CFR data is that a given vessel's corresponding fishing harbor of registration is not necessarily the harbor from where the vessel began its fishing operation. This aspect may have implications for the assessment of the spatial distribution of the sector, its range of operation, and therefore estimates of fishing intensity. Furthermore, after assessing the logbook data, it was discovered that the CFR was not exhaustive in terms of the fishing gears active in the area. For instance, some fishing gears associated with SSF (e.g. poundnets) were absent from the CFR dataset but present in the logbook dataset; this is most likely due to strategies that do not involve the use of vessels for gear deployment, an example that clearly demonstrates the aforementioned fragmentation of fishery data. Importantly, as has also been suggested in the past, it was found that determining the SSF sector using the gear-type as the sole criterion was not always sufficient, as it did not account for other factors (GT, engine power, and travel distance to fishing grounds).

The quality of the logbook data is limited as fishers in the area may misreport catches/landings (Institute of Baltic Sea Fisheries, pers. com.) or fishing grounds (ICES Rectangles). This misreporting may be either accidental, i.e. unfamiliarity with the Rectangle codification scheme, or deliberate, i.e. to reduce taxation and avoid strict regulations (e.g. area's quota system, designated areas, seasonal closures), as it has been shown to be the case in other areas (Bearzi et al., 2008; Gonzalvo et al., 2011). This can hinder the estimation of the exact number of records that pertain to the SSF. Although the exact degree of misreporting cannot be estimated, the present analysis partly corrects for this, by excluding North Sea harbors and unrealistic records. Another drawback associated with the use of logbook data, is that they include information on landings and, in the absence of data on 'Illegal, Unregulated and Unreported' (IUU) catches and discard data (Wielgus et al., 2010; Rossing et al., 2010; Zeller et al., 2011a; 2011b), they cannot be used to reconstruct catch estimates. However, the German Baltic SSF is relatively selective and is usually associated with small amounts of fish discards (Döring, 2003).

3.4. Results

Results of the analysis enable the characterisation of the state of the German Baltic SSF for the year 2008 and provide a detailed overview on: (i) the size of the fleet; (ii) the technical characteristics of vessels; (iii) the distribution of fishing ports; (iv) major target species; (v) the sector's range of operation; (vi) the distribution of landings per fishing area (ICES Rect.) and (vii) the weight and price of landings per harbor.

3.4.1. Structure of the German Baltic SSF fleet

The entire German Baltic fleet consists of a total of 1,825 registered fishing vessels of diverse technical characteristics and gear combinations. The number of SSF vessels is 1,349, thus the SSF accounts for the overwhelming majority of the fleet (74%). Most of the SSF vessels (1,335 vessels, 99% of total SSF vessels) employ static primary and secondary gear and a relatively small number of vessels (14 vessels, 1% of total SSF vessels) falls within the 'mixed' category having an 'active' secondary gear (see Appendix, table S3-6) [Gear types present in the logbook dataset that were not included in fleet register were driftnets (GND), barriers, fences and weirs (FWR) and poundnets (FPN)]. Thirteen distinct fishing strategies were determined which corresponded to the SSF sector (see Appendix, table S3-7). The distribution of registered SSF vessels in the various different harbors along the German Baltic coastline is shown in figure 3-3.

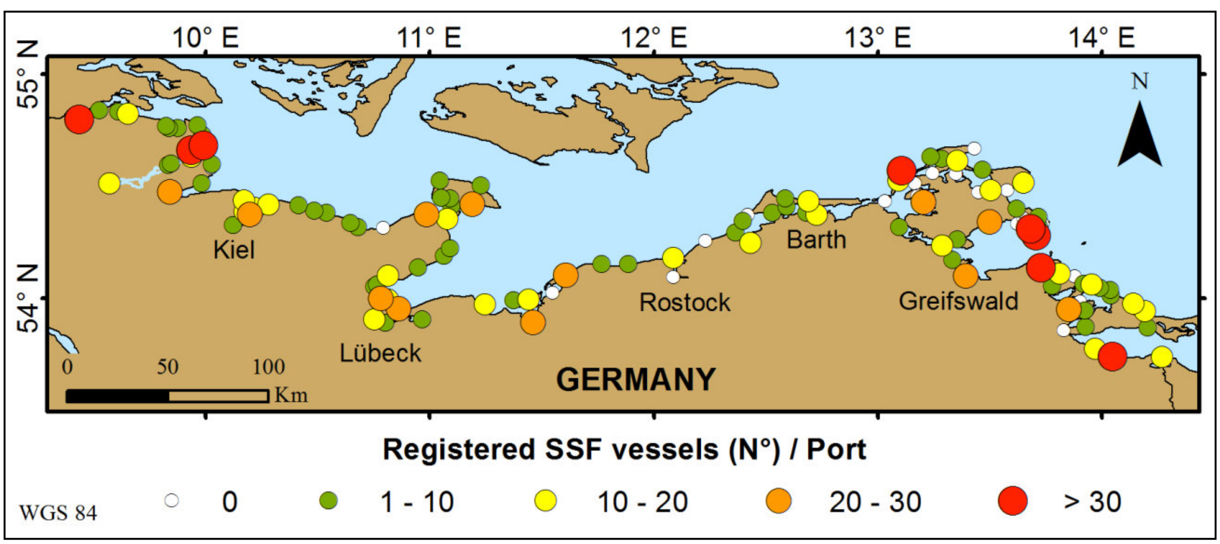

Figure 3-3: Total number of registered SSF vessels in German Baltic harbors. Primary data source: EU CFR, 2010 ('Active at date: 31/12/2008'); vessel specifications are as presented in section (3.3.3.) (Adapted after Papaioannou et al., 2012).

3.4.2. Spatial extent of German Baltic SSF

The completed database includes a total of 133 fishing harbors. This number is significantly higher than the respective number of ports contained in other databases (e.g. World Port Source database, 2010, ~20 ports). It should be noted that a particularly high density of landing harbors is located in the easternmost part of the study area, along the coastline of the state of MV. Furthermore, the assessment of the fishing grounds from which landings originated (ICES Rectangles) shows the operational range of the SSF sector for the year 2008 (figure 3-4).

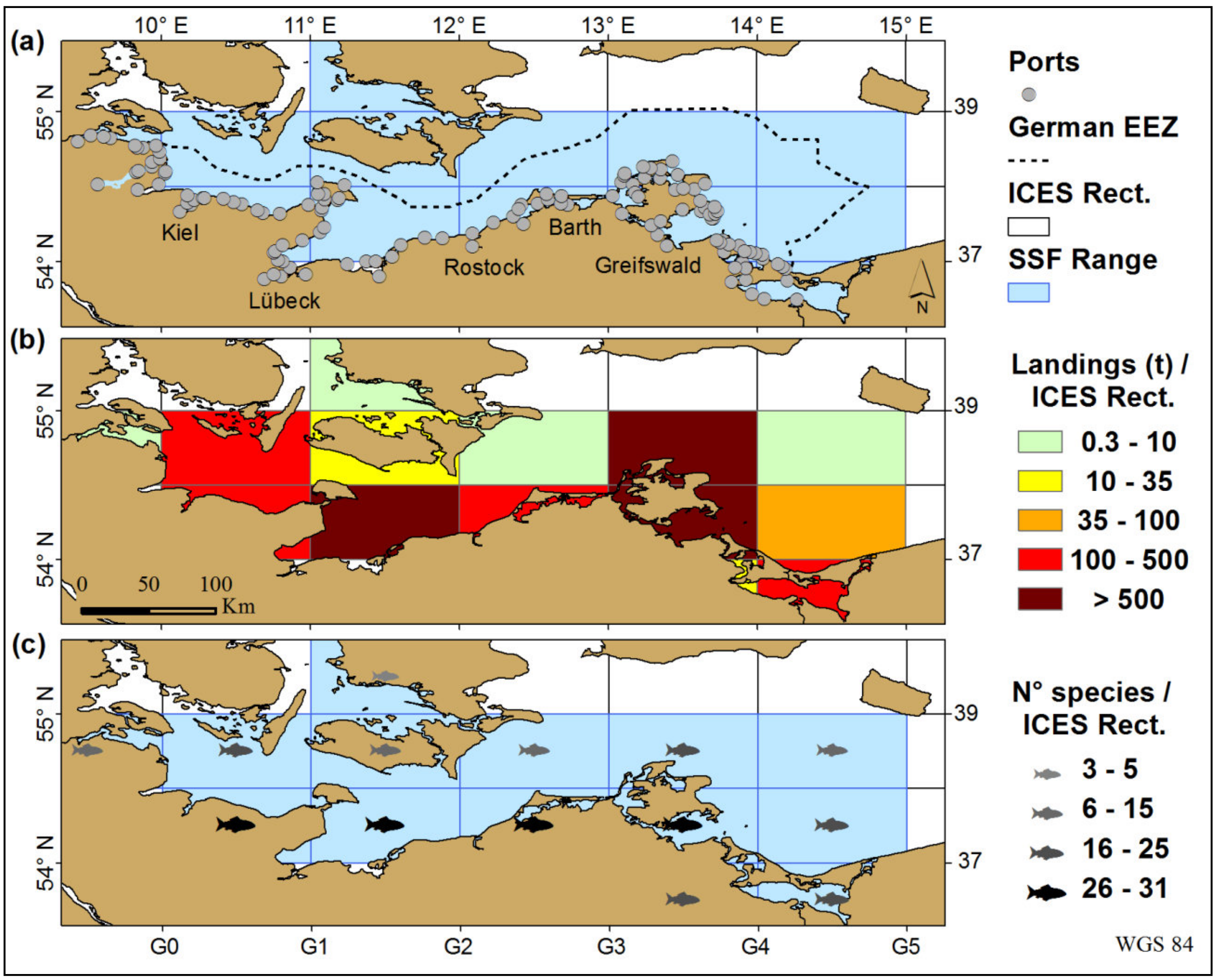

Figure 3-4: SSF across German Baltic fishing grounds (ICES Rect.) (year 2008): (a) Geographic extent of German SSF. (b) Weight of total SSF landings (t) / ICES Rect. of origin. Values represent total landings per ICES Rect. of segment '<10 m LoA' (aggregated annually, for total n^{o} of fishing operations and for total n^{o} of target species). (c) Number of species (landings) / ICES Rect. of segment '<10 M LoA' (Modified after Papaioannou et al., 2012).

3.4.3. Target species

We assessed the species present in the area; the weight of landings per species and their distribution in each ICES Rectangle. Fish species present in the area were expressed as target species comprising the landings and a list of species was compiled. The distribution of the number of caught species per ICES Rectangle is shown in figure 3-4. A total of 39 different species of diverse origin, both marine and freshwater (fw), are present in the landings of the SSF <10 LoA for the year 2008. The seven species with total landings >100 t per annum, accounting for the vast majority of landings, are in descending order herring (*Clupea harengus*), cod (*Gadus morhua*), roach (fw; *Rutilus rutilus*), European flounder (*Platichthys flesus*), common bream (fw; *Abramis brama*), pike-perch (fw; *Stizostedion lucioperca*) and European perch (fw; *Perca fluviatilis*) (see Appendix, figure S3-1).

3.4.4. Landings across German Baltic fishing grounds (ICES Rectangles)

For the year 2008, the total weight of landings from the SSF segment <10 m LoA, amounted to ~7,380 t, the majority of which (4,633 t, 63%) was accounted for by herring. The highest weight of landings per fishing area (ICES Rectangle) from the segment is situated in the vicinity of Greifswalder Bay (ICES Rect. 37G3, 4,712 t, 64% of total landings for the segment) and is mostly accounted for by herring (4,150 t, 88% of the area's landings) (figure 3-4). Landings here are significantly higher than elsewhere. The second highest weight also occurs in the immediate vicinity of Greifswald Bay (ICES Rect. 38G3, 731 t). High landings also occur in Lübecker Bay (ICES Rect. 37G1, 515 t, 7% total landings for the segment), and primarily consist of cod (277 t) and flounder (125 t). The total weight of landings from the SSF segment 10-12 m LoA, using gillnets was estimated at ~5,920 t, of which the vast majority (4,420 t, 75%) was accounted for by herring. Again, the highest weight of landings derived from the fishing grounds of Greifswalder Bay (ICES Rect. 37G3, 4,585 t, 75% of total landings for the segment). The total weight of landings from the SSF segment 10-12 m LoA, using other static gear than gillnets, was estimated at ~785 t (of which 593 t, or 75% of total weight for the segment, originating from ICES Rectangle 37G3).

3.4.5. Landings in German Baltic fishing harbors

The highest weights of landings per fishing harbor from the SSF segment <10 m LoA occur in the eastern part of the study area (MV: 69 landing harbors, 6,551 t landings, 89% of total weight of landings; SH: 45 landing harbors, 813 t landings, 11% of total weight of landings) (figure 3-5) [As mentioned above, part of the landings originating from the area are also landed at ports located outside the study area; therefore the total weight of landings per harbor does not add up to the respective total weight per ICES Rectangle. Also, not all of recorded fishing harbors of the database are used in the particular year for the landing of catch for the particular segment].

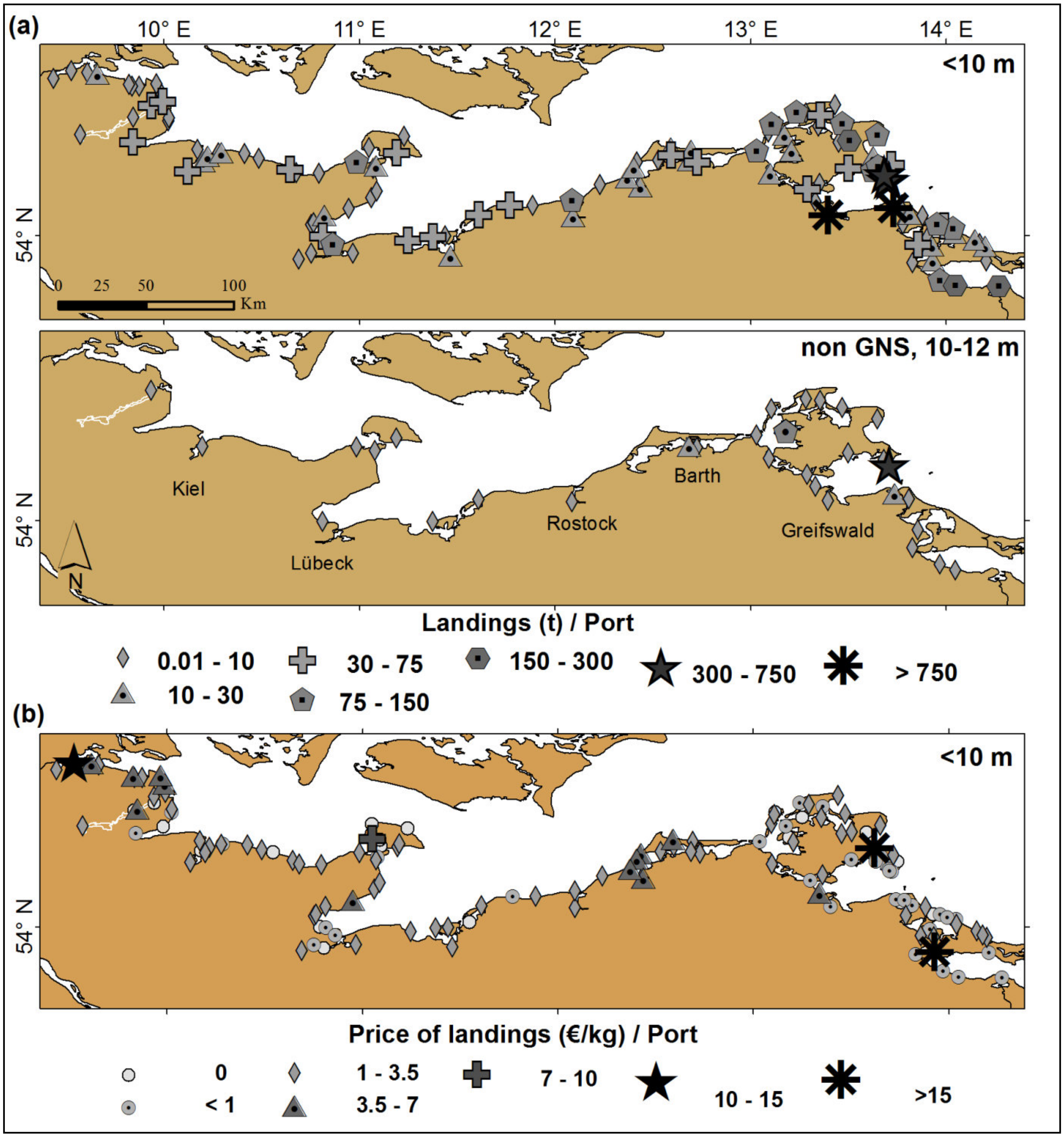

Figure 3-5: SSFs along German Baltic landing harbors (year 2008): (a) Distribution of total SSF landings (t) / landing harbor (Segments '<10 m LoA' and 'static, non-gillnet, 10-12 m LoA'). (b) Price of landings (€/kg) / landing harbor (Segment '<10 m LoA') (Modified after: Papaioannou et al., 2012).

The same holds true for the segment ‘Non-gillnets, 10-12m LoA’, with landings per harbor again primarily located at the eastern part of the study area (MV: 25 landing harbors, 780 t, 99.4% total weight of landings; SH: 6 landing harbors, 4.7 t, 0.6% total weight of landings) (figure 3-5). The analysis was inconclusive about the exact weight of landings per harbor from the 10-12 m LoA ‘gillnet’ segment, for the reasons discussed above.

Figure 3-5b depicts the average price of landings per landing harbor (€/kg) for the <10 m LoA segment. The average price of landings for different harbors is estimated at 2.23 €/kg for the eastern (MV) and 2.04 €/kg for the western part (SH) of the study area. High prices of landings also occur for individual landed species: for cod, the average price of landings is estimated at 1.94 €/kg for the eastern (MV) and 1.74 €/kg for the western part (SH) of the study area. The respective values for herring are 0.70 €/kg (MV) and 0.98 €/kg (SH). These figures indicate that the prices obtained by the SSF fleet are much higher than average fish prices obtained on aggregate by Baltic fisheries, which are ~2.1 €/kg for the relatively valuable cod, but only ~0.25 €/kg for herring (STECF, 2010). In the major ports along the German coastline (Kiel, Rostock, and Lübeck), prices of landings are smaller (1.8, 1.83 and 1.7 €/kg respectively) than the average per port for the broader areas, with secondary landing harbors having a higher price. The highest recorded prices of landings (i.e. > 10 €/kg) occur at harbors located at the eastern [(Usedom and Binz, with prices of landings of 18.5 and 48.3 €/kg respectively) (non-refined by the constituent species; by season; or by fishing area / ICES Rect. of origin. The high prices obtained in Binz mostly account for landings of flounder P. flesus and correspond to few landing operation incidents] and western ends (Glücksburg, prices of landings 12.7 €/kg) of the study area.

3.5. Discussion

3.5.1. Structure of the German Baltic SSF

Results show that the German Baltic SSF (reference year 2008) accounts for the majority of the total number of German Baltic fishing vessels. The sector is heterogeneous, made up of vessels that target numerous (39) different species (fw and marine), exhibit diverse technical specifications and involve the use of different fishing gears. The fishing gears of the sector are primarily gillnets, and to a lesser extent static long-lines and pots and traps. Other fishing strategies involve the use of poundnets and barriers, fences and weirs. The results show that the use of such strategies does not span the whole range of the sector, but is confined within particular fishing areas with appropriate habitat characteristics (depth, presence and abundance of target species, etc.), as also demonstrated by local-scale assessments (Döring, 2003; Strehlow, 2007). It should also be mentioned that although the use of driftnets is banned in the region [Article 9, Council Regulation (EC) No 2187/2005)], the gear was present in the logbook database for the year.

The analysis showed that defining SSF vessels solely by the type of gear (static) is not adequate, as several vessels with both gears 'static' had GT and kW specifications and operational ranges that do not qualify them as SSF. This finding was also supported by the results of the logbook data: cases of single landing incidents from vessels with static gear, derived from ICES Rectangles at a large distance to landing port, were also found to have a too large weight of landings to qualify as small-scale (carrying capacity>>20 GT). We argue that the results of the fleet register analysis can be used as a proxy of fishing capacity; namely the thresholds in the technical characteristics and in particular the GT and kW could constitute a qualitative method for assessing the SSF sector's fishing capacity (as also defined in EC 2930/86 and EC 2371/2002, European Council, 1986; 2002).

3.5.2. Spatial extent of the German Baltic SSF

The sector is based in a multitude of ports and shelters, along the whole extent of the German Baltic coast, as has also been shown to be the case with other countries (Forcada et al. 2010) with a more extensive coastline than Germany. From figure 3-3 it appears that there is an increase in the number of small-scale vessels along the fishing harbors from west to east, but there does not seem to be any agglomeration of vessels in particular localities, which suggests that the sector is important for the entire German Baltic coastline. It should also be mentioned that for several ports with a large number of registered SSF vessels, no landing operations occur according to the logbook data. This may indicate the localities' historical significance for the SSF sector, namely that it continues being used as a port of registration of SSF vessels, although it may not possess favourable landing facilities. From the present analysis it appears that the sector's range of operation is restricted to the German Baltic marine coastal strip. According to EU law, German fishing vessels have access and can fish for certain species within the territorial waters of Sweden and Denmark. It was found, however, that landings that originate from fishing grounds (ICES Rectangles) within the territorial waters of Denmark and Sweden correspond to minor target species.

3.5.3. Landings across German Baltic fishing grounds (ICES Rectangles)

The high weight of landings from the SSF segment <10 m LoA originating from the fishing area situated in the vicinity of Greifswalder Bay (ICES Rect. 37G3), and mostly accounted for by herring, is due to the fact that the particular area is a spawning ground for the western herring Baltic stock (Strehlow, 2007; Döring, 2003). High weights of landings also originate from Lübecker Bay (ICES Rect. 37G1), and are primarily made up of cod and flounder, partly due to the proximity to the cod's spawning grounds in the Belt Sea Area, and partly due to the absence of herring spawning grounds in the proximity. Also, the area is closer to major commercial hubs that enable the shipment of high-valued cod landings to the next steps of the distribution network.

3.5.4. Landings in German Baltic fishing harbors

For the <10 m LoA segment of the fleet, the highest concentrations of landings per harbor are found in the eastern part of the area. This is primarily due to the fact that most of the weight of landings is made up of herring and the majority of the species' catch originates from fishing grounds located in the area. Furthermore, the particular segment has a confined range of operation; the area hosts major fish-processing facilities and therefore high weights of landings are to be expected. It should be noted that the processing capacity of facilities is smaller than the total weight of landings of herring in the area's ports. The landings per harbor of the segment 'non-gillnets, 10-12 m LoA', are confined to the eastern part of study area, which is also related to the fact that the respective strategies target primarily species that are present in this part of the German Baltic coastal environment.

Many of the SSF vessels are active within inland waters and it is envisaged from the results of the logbook data (landings originating from ICES Rectangles) that the catches are subsequently landed in neighbouring ports in the fishing areas' immediate vicinity (i.e. overlapping of high landings/ICES Rectangle with landings/harbors in the immediate vicinity of the Rectangle). This observation indicates that the SSF stays within these waters and does not leave the immediate vicinity. The relatively high prices of landings towards the edges of the study area, and in particular on the eastern side, dictate the sector's significance for those coastal communities, as an important income-generating activity, particularly in rural areas that are distant from the main industrial centres, including cities with major ports.

3.5.5. Target species

The analysis enabled the deduction of the target species' distribution of the SSF within the area where the sector is operational. The target species' information and the area(s) where the species' landings originate, indicate that the extent of a species catch area (in terms of ICES Rectangle) is part of its broader distribution range. Many of the species will have a broader distribution range;

however, the small weight caught by numerous SSF vessels suggest that even species with a very low abundance are caught by the particular sector in certain localities of the coastal band of Germany. The database also enabled the estimation of the total number of species present (species' richness) per fishing area (ICES Rectangle) which could constitute an index of the area's diversity.

3.6. Outlook

The merging and subsequent analysis of the data included within the database enabled us to overcome some of their inherent limitations and also allowed the calculation of new indices (e.g. fishing capacity of various segments/fishing strategies of the SSF). We are exploring the possibilities of further combining and integrating these data, to enable additional insights into the state of the German SSF fleet, such as: the estimation of the total landings contribution of each length class of the gillnets, based on their respective carrying capacity; the determination of the fishing effort of the fleet and its component segments, provided that additional information is acquired on the duration of fishing operation and the amount of deployed gear; and the estimation of the German Baltic SSF catch per unit effort, (i.e. landings per amount of gear for a particular gear type), in a similar manner than catch per unit effort is traditionally estimated in the area.

Although the results presented in this study are not exhaustive of all aspects that pertain to the SSF, the proposed methodology, if extended, could present a complete profile of the state of the sector: we have determined the sector's range of operation; the major fishing areas where the sector is active; the major fishing strategies performed and their fishing areas; and the fishing harbors of importance in terms of registered vessels and weight of landings. Further analysis would allow the investigation of spatial and temporal trends in the various indices that have been incorporated in the developed spatial database, which could have practical implications for the management of fish resources. Such an analysis would identify the spatial entities that exhibit significant changes and which should be given priority in the future, in the event of management regime changes (e.g. quota allocation, fishing closures, establishment of protected areas, gear restrictions).

Our methodology can provide a quantitative estimate of the quota that corresponds to the SSF [The German framework for fish quota allocation follows the division of allocated quota per vessel (for fish species of relevance)]. For example, initial results indicate that for the case of herring, the quota that pertains to the SSF for the year 2008 is < 10,000 tons, when the total German quotas for the species for the study area (ICES SDs 22-24) amounted to 24,579 tons. Yet, small-scale vessels made up the vast majority of the fleet, which could imply that the quota is not equitably allocated between the small-scale and large-scale sectors. This is contrary to the aspirations of the area for the equitable distribution of fishery resources between the open and coastal fishery (Baltic Agenda 21, 1998).

3.7. Conclusions

The present analysis constitutes (to our knowledge) the first quantitative definition and characterisation of the German SSF, and simultaneously the first known attempt to assess logbook data for the German Baltic SSF and construct a database tailored to the specifications of the sector. The absence of such data analysis has been highlighted by past studies and projects in the area (ICES, 2008; Pedersen et al, 2009; Žydelis et al., 2009), therefore our work addresses a major limitation in the evaluation of the interaction among the fishing industry and other users of the coastal zone. It also builds on the information available from other data sources and in particular the HELCOM database, where the data provided, should be seen as supplementary, namely the distinction between the various segments of the fleet.

It is envisaged that further analysis of the available data, specifically the linkage of particular fishing grounds with their respective landing harbors, can refine these estimates, for example by determining the maximum travel distance of SSF vessels (e.g. figure 3-6, range of operation of SSF assuming a 100 km mean travel distance).

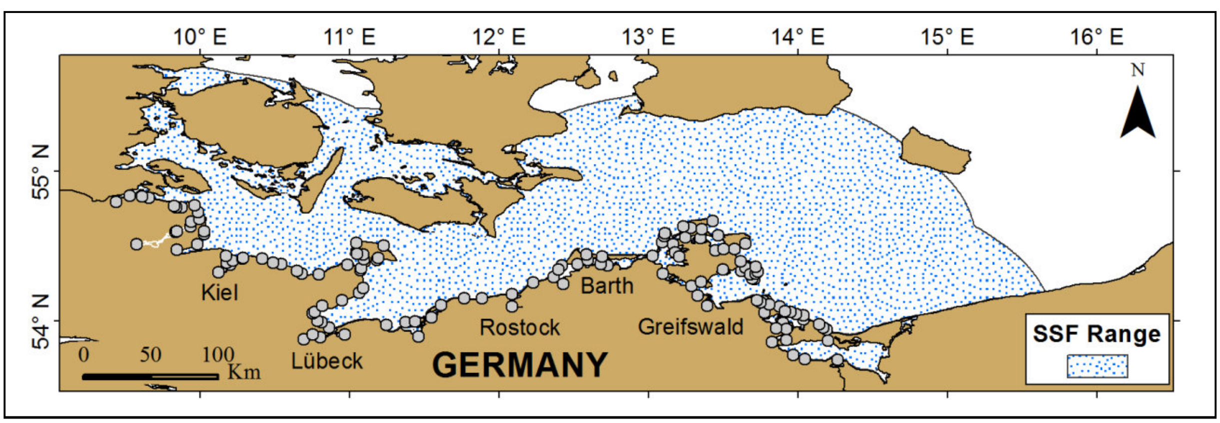

Figure 3-6: Mean range of operation of German Baltic SSF. n.b. Assuming a mean travel distance of 100 km from fishing grounds to landing harbors.

In summary, we have made use and effectively combined an extensive amount of fishery primary data and demonstrated the need to address spatial considerations (i.e. range of operation) when assessing the state of the sector. We believe that the findings of the present study will aid the assessment and evaluation of the German Baltic SSF in particular, but can also serve as an aid when assessing the state of small-scale fisheries in other regions. Although the analysis of the SSF sector was restricted to the German Baltic coast, the present methodology can be adapted and transferred to other regions and potentially extend to cover the entire Baltic region.

Acknowledgements

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4. Using indicators based on primary fisheries' data for assessing the adaptation potential of Small-Scale Fisheries to management changes in the German Baltic

The chapter has been submitted for publication as an Original Research Article. Papaioannou E.A., Vafeidis, A.T., Quaas, M.F., Schmidt, J.O. and Strehlow, H.V. 2014a.

4.1. Abstract

During the period 2000-2009, shifts in the levels of fish stocks and changes in the management regime of fisheries in the Baltic Sea affected the German Baltic Small-Scale Fishery (SSF). Using a spatial database developed specifically for the SSF sector, we assess the sector's key parameters (vessels and technical characteristics, landings, target species) for the period 2000-2009 and link exhibited trends with past changes in fisheries resource abundance and management. Our results show that the SSFs fundamental characteristics determined the response to management changes. Key characteristics were fleet heterogeneity, relative high target species' diversity and restricted operational range, coupled with a broad geographic distribution of harbors. The evaluation showed that the SSF was affected by changes in the allocation of TACs for herring and cod, technical measures for fishing gear, especially with relation to the Large Scale Fishery (LSF), while targeting a diversity of different species was essential for the sector to adapt to changes in resource abundance and management. We argue that such an approach can provide new insights on the impacts of future management changes or incidents of environmental variability on the SSF sector and is crucial in establishing those characteristics which differentiate it from the LSF, in order to effectively integrate SSFs within policy.

4.2. Introduction

Small-Scale Fisheries (SSF) are characterized by a high diversity of fishing gears, a variety of motorized and non-motorized vessels, a large number of target fish species and a dependence on the coastal waters located near the respective fishing communities (Berkes et al., 2001; Pomeroy, 2011).

SSFs are lately at the forefront of the policy agenda of international, regional and local institutions (European Commission, 2009a; IOC/UNESCO et al., 2011; FAO, 2011; 2012a; 2012b; European Parliament, 2013a). However, constraints still exist to the SSF sector's integration within governance and management (FAO, 2013e) thus further limiting its prospects for sustainable development.

The lack of data on the number of coastal fishing boats, amount of gear deployed and/or the frequency of fishing activities, has been considered a central challenge in the process of assessing the impact of SSFs on coastal ecosystems (Stewart et al., 2010). The need for better data for the SSF sector is now recognized by major institutions globally (IOC/UNESCO et al., 2011; FAO, 2013e) and is considered among the most important issues for improved fisheries management (Horta and Defeo, 2012). A rising number of studies assess the impacts of management changes on SSFs (e.g. da Silva, 2004; Forcada et al., 2010; Gonzalvo et al., 2010; Strehlow, 2010; Castello et al., 2013), however, there is a lack of studies linking such changes with their impacts on SSFs key structural and operational characteristics (e.g. catch, fleet composition, target species etc.).

The aim of the present study is to quantitatively assess the structural (vessel numbers, gears, etc.) and operational (landings, operational distance, target species, etc.) changes in the German Baltic SSF in the period 2000-2009 and link them with environmental and management changes that took place in the wider Baltic Sea region during the same period.

In our analysis we employ the institutional definition of the EU for the SSF valid during 2000-09, namely '*fishing involving vessels less than 12 m length overall (LoA) not using towed gear'* (European Council 1999; 2006a) and focus on the segment[7] of the German Baltic SSF smaller than 10 m LoA (hereafter referred to as 'SSF'), because (i) the particular segment accounts for the majority of vessels of the SSF (>90 %) and (ii) the primary data used for the analysis did not enable reviewing the > 10 m LoA segment.

We look at (i) changes in fish resource abundance (e.g. western Baltic cod stock decline), (ii) major changes in the management of fish resources and fishery activities and (iii) infrastructure development. We hypothesize that the combined impacts of environmental and management changes affected the catch (landings) and fleet structure (vessels, gears) of the German Baltic SSF. The present analysis utilizes a spatial database tailored to the German Baltic SSF sector developed in an earlier study (Papaioannou et al., 2012). This database combines primary fisheries' data (logbooks,

[7] In the present study '(fleet) segment' is used to denote a sub-division of the SSF sector that encompasses vessels of similar technical characteristics (engine power, length) that make use of the same type of fishing gear. The term '(species) segment' is also used to describe a particular group of vessels that targets the same fish species (e.g. 'herring segment').

fleet register) and enables the characterization and quantification of key structural (vessel numbers, gears) and operational (landings, target species) characteristics of the German Baltic SSF.

4.2.1. The German Baltic SSF and past changes in fish resource abundance and management

The activity of German Baltic SSFs is governed by the framework of the European Common Fishery Policy (CFP). Baltic Sea fisheries are managed and governed by a multitude of relevant measures and regulations; measures include the allocation of TACs and quotas for commercially-important species (cod, herring, etc.); regulations limiting the use of gears and defining their technical characteristics; multi-annual plans for the management of certain fish stocks; spatial and seasonal fishery closures, etc. Baltic Sea fisheries are also integrated within the framework of inter-regional organizations such as the Baltic Sea RAC (Regional Advisory Council), ICES and HELCOM.

In the German Baltic Sea commercial fishing is managed by the federal states of Schleswig-Holstein (SH) in the west and Mecklenburg-Western Pomerania (MV) in the east (SH: State Agency for Agriculture, Environment and Rural Areas, LLUR; MV: State Office for Agriculture, Food Safety and Fisheries, LALLF MV). In Germany, a federal authority allocates annual fishing quotas to fisheries co-operatives, which subsequently distribute their quotas among their members.

Between 2000-09 major alterations in the management regime of fish resources and fishing activities took place in the wider Baltic Sea region. These alterations were driven by the severe fluctuations in the region's fish resources, particularly the decline of the western Baltic cod stock, and introduced in turn changes in the level of exploitation of fish resources.

Although recently progress has been made regarding the determination and assessment of the German Baltic SSF (Döring, 2003; FAL; 2007; Strehlow, 2007; 2010; Zeller et al., 2011b; European Parliament, 2011; STECF, 2011; Papaioannou et al., 2012) little insights exist on the impacts past changes had on the region's SSF in quantitative terms.

We examine the impacts of alterations in the region's fish resource abundance and management regime on the German Baltic SSF mainly focusing on:

(1) The 2005 change in the management regime of fish resources in the Baltic following the accession of new EU member states, the dissolution of the International Baltic Sea Fishery Commission (IBSFC) and the post-2005 fisheries' management regime (Council of the European Union, 2004; Aps et al., 2007).

(2) The introduction of the European Council (EC) Regulations No. 2187/2005 ('technical measures') in 2005 and No. 1098/2007 ('multi-annual plan for cod') in 2007; and

(3) Changes in the allocation of TACs and fishing opportunities for certain fish species of relevance, in particular for herring and cod, and especially following the 2005 change in management (henceforth 'management division') and the subsequent allocation of quota for ICES Subdivisions (SDs) 22-24 (figure 3-1).

A brief description of the Regulations (technical measures; cod multi-annual plan) along with the major provisions of relevance to the SSF is presented in table 4-1. Relevant provisions have been implemented within German Federal Law [Quota allocation: German Republic, Gazette No. 245; No. 241; Nr. 2; Bundesanzeiger, 2006; 2007; 2009].

In addition, the analysis considers the impacts on the SSF from infrastructure development, in particular the 'EUROBALTIC' fish processing factory (newly established in 2003), located at the port of Sassnitz-Neu Mukran, at the island of Rügen (see figure 3-1), its main processed fish species being herring.

4.3. Materials and methods

For assessing and quantifying the impacts of selected changes on the structure and operation of the German Baltic SSF, we review trends on the sector's key variables between 2000-2009. We employed a spatial database tailored to the specifications of the German Baltic SSF (Papaioannou et al., 2012) spanning the period from 2000 to 2009 (2001-2009 for landings' information). The database contains annual fleet register [EU Community Fleet Register (CFR), 2010] and logbook data (German Federal Office for Agriculture and Food, BLE, 2010) and includes relevant information on key variables (number and technical characteristics of vessels, target species, weight of landings, etc.).

The categorization of the German Baltic SSF is based on the methodology set forward in Papaiaoannou et al. (2012). The German Baltic SSF sector was determined and characterized based on a series of technical/structural and operational criteria. With reference to the technical characteristics (fleet-related information), vessels of the sector should be <12 m LoA, have a carrying capacity of <20 GT, an engine power <100 kW and at least one static gear. For a single fishing operation (landing incident) to be perceived as small-scale, its catch should not exceed 20 t and originate from fishing grounds located at a distance >100 km. Subsequently the SSF sector was determined and quantified and all relevant information integrated within the spatial database. A detailed description of the database and the methodology used to compile it is provided in Papaioannou et al. (2012).

Table 4-1: Selected management framework alterations, major provisions and hypothesized impacts on the German Baltic SSF (Adapted after Papaioannou et al., 2014a)

Management changes and major provisions of relevance to the SSFs	Hypothesized impacts on the German Baltic SSFs
2005 Baltic management division (Council of the European Union, 2004)	
Allocation of TACs / German quotas for commercially-important species (cod, herring) for ICES SDs 22-24	Anticipated impacts on the landings of the German Baltic SSF; change in landings (↑) between 2004-2005.
EC Regulation No. 2187/2005 ('technical measures') 2005	
Introduced among others: i. limits dimensions and immersion time of passive gear. ii. a prohibition of eel fishing with the use of active gear. iii. a total ban of the use of driftnets from 1/1/2008. iv. a seasonal closure to the fishery of salmon and trout in subdivisions 22-31 [1/6 to 15/9 no fishing of sea trout and salmon], promotion in the use of FPO. v. The Odra Bank spatial closure to active gear	We hypothesize that the regulation has impacted the structure, composition and dynamics of the SSF both directly, through the technical measures for passive gear, and indirectly, through limiting the use of active gear. This study further investigates the SSF sector's response to the Odra Bank closure. The location of the closure is within a broader area of high importance to the SSF with respect to the weight and price of landings. Trends in the dynamics of the SSF and the larger, active sector of the fishery in the vicinity of the closure (ICES Rect. 37G4) are assessed and SSF is compared to the large scale fleet to review the impacts of the closure.
EC Regulation No. 1098/2007 ('multi-annual plan for cod') 2007	
The plan established methods for reducing fishing effort and limiting TAC variations for cod which included among others: a cod closed season in ICES SDs 22-24 from 1-30/4; technical specifications in gear characteristics (min mesh size for gillnets/ trammel nets) [applicable to vessels > 8 LoA]; a maximum number of days when fishing is allowed, outside the set period when fishing is prohibited.	The regulation is envisaged to have impacted the development of the SSF both with respect to the reductions in cod quota but also through the provisions relating to the use of gear and the maximum number of days when fishing is allowed. Here we investigate how the sector developed following the regulation, especially in fishing areas and landing harbors that have been shown to be important for the particular target species, as for instance the Lübeck Bay fishing area (ICES Rect. 37G1).
EC Regulation No. 52/2006 (Quota 2006); No. 1941/2006 (Quota 2007); No. 1404/2007 (Quota 2008); No. 1322/2008 (Quota 2009)	
2005-2009: Changes in the allocation of TACs/German quotas, in particular for herring and cod for ICES SDs 22-24	Anticipated change in overall landings of the German Baltic SSF and landings of cod, herring segments (↓) between 2005-2009

4.3.1. Variables and assumptions considered

We selected the following variables for the purpose of the analysis: (i) the size of the fleet, (ii) the technical characteristics of vessels, (iii) the distribution of fishing ports, (iv) major target species, (v) the range of operation of the sector, (vi) landings and their distribution per fishing area, (vii) the weight of landings per harbor (Papaioannou et al., 2012). These variables have been used in previous studies (Daw, 2008; Tzanatos et al., 2008; Dunn et al., 2010; Forcada et al., 2010; Gonzalvo et al., 2010; Katsanevakis et al., 2010; Stewart et al., 2010) to characterize and assess SSFs. Number of vessels, types of gear used, and fishing strategies were considered to constitute estimates of the sector's degree of heterogeneity (Tzanatos et al., 2008). Total number of different species present in the catch (landings) constitutes an estimate of the sector's diversity, and the distance between fishing areas and landing harbors an estimate of the sector's range of operation (Daw, 2008). Primary data availability was also an important factor for the selection of variables (e.g. data on the sector's catch were available in the form of weight of landings).

The analysis is governed by certain assumptions regarding the trends exhibited by the SSF sector's selected variables. These assumptions were formulated based on prior knowledge of the region's SSF. Following the results of the analysis, we re-evaluated these assumptions to conclude on whether changes in fish resource abundance and management had the hypothesized impacts on the SSF.

Weight of landings: We assessed trends in the sector's landings and assumed that declining landings signified reduced fishing opportunities for the SSF.

Vessels' numbers: Declining numbers of vessels were considered to be a way by which the SSF adapts to reduced fishing opportunities.

Richness of target species [i.e. total number of species present in the landings deriving from a particular fishing area (ICES Rect.[8])]: Trends in target species' numbers, or likewise the number of fishing strategies, reflect an adaptation of the SSF to changes in fluctuations of resource or fishing opportunities. Increased diversification may be a means to reduce the risk for the SSF.

Range of operation: In general, a restricted range of operation is one of the defining characteristics of SSFs (Daw, 2008). As such, in order to assess changes in the sector's spatial dynamics we analyzed shifts in the sector's range of operation.

[8] Species with an average monthly landings' weight of less than 30 t, accounting for an insignificant fraction of the total weight of landings, were excluded from the analysis. We verified that this exclusion did not affect the investigation of trends in total weight of landings, whereas all species were included in the analysis of trends in total numbers of species.

4.3.2. Methodological framework of analysis

The analysis involved the assessment of key parameters in 2001, 2005 and 2009 (sum per year) for landings information and 2000, 2005 and 2009 for fleet information; the average change per year for the entire time-series; and the relative change between years during 2005-2008, in order to associate trends with the alterations in management. We focused our analysis on SSFs vessels using gillnets, since gillnets comprised the dominant gear of the SSF (97% of total SSFs vessels for 2009).

All parameters were examined in relation to the landing harbor (i.e. the harbor where the catch has been landed) and the fishing area (i.e. the area where the catch has been caught). Information relating to the location of fishing area was available per ICES Rectangle[9], whereas catch information was available as 'weight of landings per landing harbor' (hereafter referred to as 'landings').

Our analysis examined the landings of the entire German Baltic SSF (non-species specific) and focuses particularly on trends exhibited by the segments of the SSF targeting cod and herring. These species constitute the major target species for the SSF (in 2009 herring and cod accounted for 57% and 12% of the total weight of landings of the sector respectively, see also figure S4-5), generate a significant share of revenues (in 2009 herring and cod revenues amounted to 1,202,980 € and 607,337 € respectively from the total revenues of 3,959,000 €), and are explicitly addressed by management changes (cod multi-annual plan; TACs etc.). We compared landings of cod and herring with their respective quota allocated to the German Baltic fishery in ICES SDs 22-24 (offset of analysis: 2005. Prior to 2005 no extrapolation of German quota for ICES SDs 22-24 is possible to enable link with trends in landings). Unrealistic records (single landing incidents >22 GT (Gross Tonnage) were excluded. This threshold was set according to López Benítez (2010) and corresponded to the average tonnage of European fishing vessels of 12 m LoA[10]. With reference to the assessment of fleet-related data, vessels' decommissioning has also been taken into account, by quantifying and accounting for annual entry-exit of vessels.

We use two measures of change in the range of operation (i) the change in the number of landing harbors and the number of respective fishing areas (ICES Rect.) between years; and (ii) the change in distance between fishing areas (ICES Rect.) and respective landing harbors. To determine trends in the range of operation of the SSF we focused our analysis on the major fishing areas for cod and herring, namely the bay of Lübeck (ICES Rect. 37G1) and the Greifswald Bay (37G3) respectively.

[9] The ICES Statistical Rectangle was the reference unit of analysis since most countries in the Baltic Region must report fishery-related information per ICES Rectangle.

[10] For 2009, this procedure resulted in the exclusion of a total of 15 records from the respective landings information, or a weight of 741 t from a total of 37,768 records of a total weight of 5,590 t.

The study also investigated the impacts from the establishment of the Odra spatial closure (ICES Rect. 37G4) to active gear introduced by the 'technical measures' Regulation (figure 3-1; table 4-1). Our hypothesis was that the closure resulted in declines in the landings from the larger-scale, active fishery, while improving fishing opportunities of the SSF in the closure's vicinity (anticipated increase in weight of landings). Thus, in the vicinity of the closure, the landings' distribution of the SSF was compared with the distribution of the large-scale fishery (LSF) (>10 m LoA)[11].

4.4. Results and discussion

Changes in resource abundance and implemented alterations in the region's management regime are connected to changes in the key structural (vessel numbers, gears) and operational (landings, species richness) characteristics of the German Baltic SSF (table 4-2). Results on the trends of key variables of the German Baltic SSF sector between 2000-2009 are presented below.

Table 4-2: Overview of selected changes on the structure and operation of the German Baltic SSF

Year	Change	Landings (t) SSF	Landings (t) cod	Landings (t) herring	Vessels Nº	Species Richness	Range cod	Range herring
2004 -05	East-West delineation	↑↑↑ (20%)	-	-	↓	↑↑↑	-	-
2005 -06	Quota reduction; Technical Measures	↑	-	-	↓	↑	↓	↔
2006 -07	Quota reduction	↑	↓	↔	↓	↓	↓	↑
2007 -08	Quota reduction; Cod multi-annual plan	↓	↓↓	↑	↔	↓	↓	↑↑
2008 -09	Quota reduction; (HER: 39%) decline in herring stock	↓↓↓ (28%)	↓↓	↓↓	↓	↔	↓	↓↓↓

↑: Increase ↓: Decline ↔: Non-significant change in respective variable

[11] Logbook data for the LSF were available from BLE (2010). Gear codification after FAO, 1980; EU CFR, 2010. Only vessels with active fishing gears were included i.e. ottertrawls (OTB), bottom pairtrawls (PTB) and midwater pairtrawls (PTM). Vessels with passive gears, such as gillnets (GNS), pots (FPO), poundnets (FPN) and barriers, fences and weirs (FWR) were exempted.

4.4.1. Weight of landings

Between 2001-2009 there has been an increasing trend in the weight of landings of the German Baltic SSF. However, trends exhibited inter-annual variations, in particular after the introduction of major management changes in 2005 (management division), 2008 (multi-annual management plan) and 2009 (quota cut), in conjunction with other reasons. In 2005, the offset year of the management division, the overall weight of landings for the SSF amounted to 6,530 t, exhibiting an increase of approximately 20% compared to 2004 (5,450 t) (see also figure S4-1). This increase indicates that the 2005 management division benefited the catch of the SSF and is in line with previous assessments that also noted an increase in landings and fishing effort for certain segments of the German Baltic SSF (STECF, 2011).

German Baltic SSF landings post-2005 followed closely the German quotas allocation for cod and herring in ICES SDs 22-24 (figure 4-1). In 2009 there was a decline in the total weight of landings (t) for the entire area (~28%) compared to 2008, following the declines in western Baltic cod stock and spring spawning herring stock and the subsequent quota reductions. The close relationship in the trends of quota and landings from the sector suggests a high level of compliance. Moreover, results highlight the small contribution of the SSF to the total catch utilized by the German Baltic Fishery, which are similar to the results from past assessments that also noted the small amount of resource utilized by the SSF (STECF, 2011).

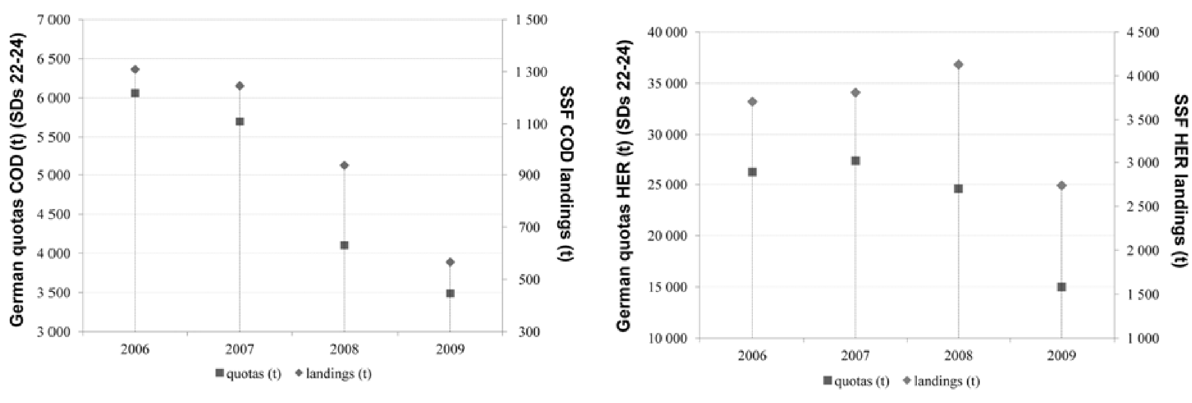

Figure 4-1: Relationship among quotas for Germany (t) (ICES SDs 22-24) and annual total weight landings (t) (as of 31.12 of each year) from SSF (<10 m LoA) for a. cod, b. herring (European Council 2006b; 2006c; 2007b; 2008)

The patterns of landings during the period and the magnitude of change along the area are shown in figure 4-2. The main factor determining the distribution of SSF landings along harbors seems to be their proximity to productive fishing areas. Between 2001-2009, fishing areas exhibiting the largest declines in the weight of landings were also related with declines in their corresponding harbors' landings, especially for those harbors located the furthest away.

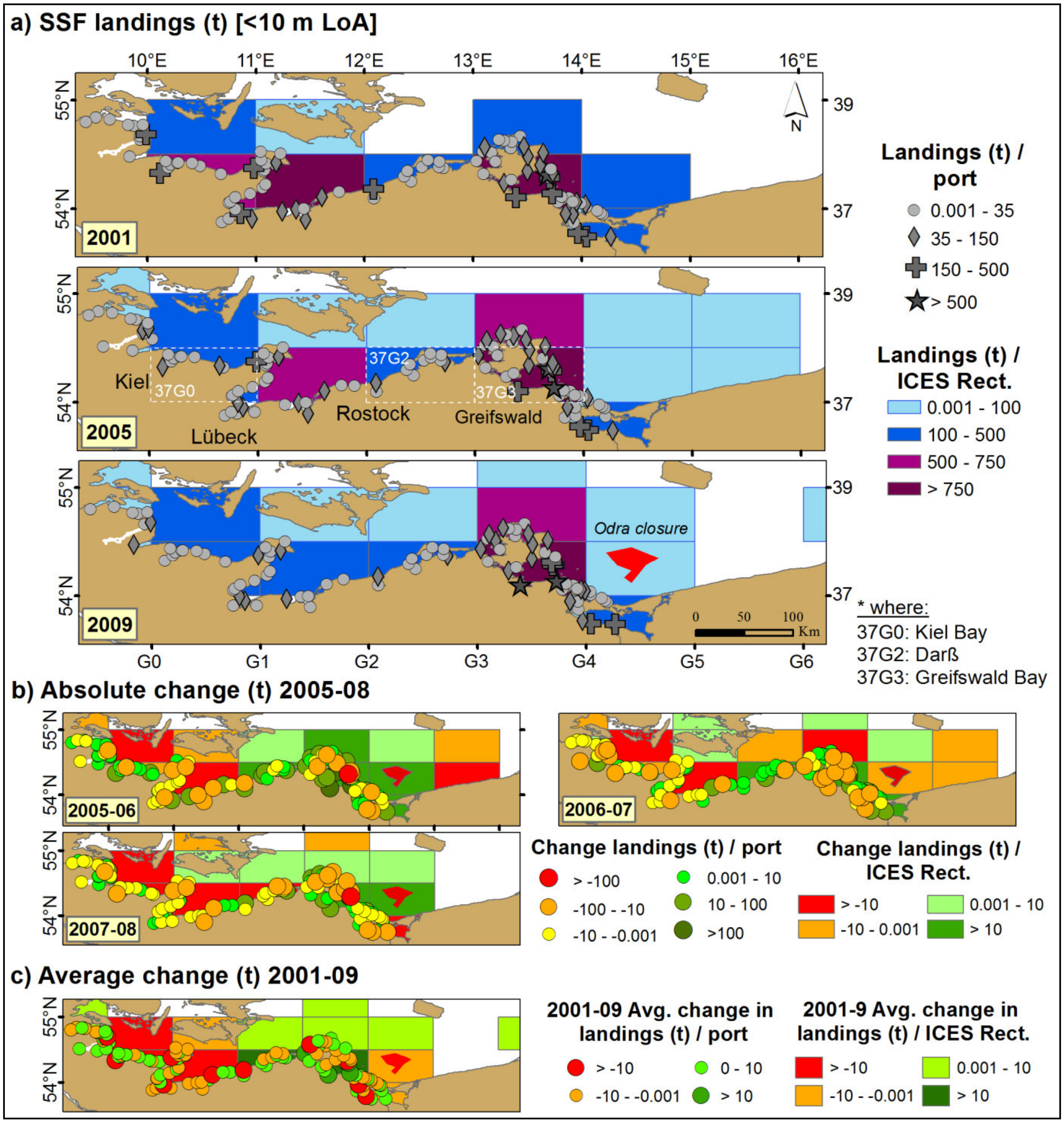

Figure 4-2: Trends in SSF landings (t) per fishing area and port. (a) 2001, 2005, 2009 total SSF landings (t) per fishing area (ICES Rect.) and port (unsorted per species, season). (b) Absolute change in weight of landings (t) between the years 2005 and 2008. (c) Average changes in weight of landings (t) between 2001 and 2009.

Between 2001 and 2009, there was an overall increase in the weight of landings (t) originating from fishing areas located in the east (ICES SD 24), while there was a decrease in landings from the west (ICES SD 22, cf. figure. 4-2a). Major fishing areas exhibiting negative trends were the Bay of Kiel (ICES Rect. 37G0) and Lübeck (37G1), while Greifswald Bay (37G3) and the vicinity of Darß' peninsula (37G2) showed increasing trends. Similar patterns also occurred between years (figure 4-2b), with annual declines, especially in the western part, in some instances >10 t/ICES Rect. Harbors located in the west showed progressive declines (in many instances >10 t per year) in the weight of landings from 2005 to 2008 (The mean weight of landings along the area's harbors between 2001 and 2009 is shown in table S4-1). In summary, between 2001-2009 there was a noticeable shift in the sector's weight of landings with the eastern part accounting for the majority of weight of landings and the western part exhibiting large declines. In the eastern part, increasing trends in landings were due to the fact that the local SSF targeted primarily herring. Meanwhile, declines in the west were due to the decline in cod and the lack of alternative target species (Strehlow, 2010). The observed phenomenon may corroborate our findings that stock dynamics act as strong driver of the fishery sector, i.e. the availability of fish in SD 24 have led to strong concentration effects of the fishery in the same area (ICES, 2013). Results highlight that despite the small contribution of the SSF sector to the total catch of the German Baltic Fishery, it provides an important livelihood option for rural coastal communities where alternative options may be limited.

4.4.1.1. Cod landings

From 2001 to 2009 the weight of cod landings from the SSF declined, primarily due to the dramatic decline of the western Baltic cod stock (ICES, 2009c) and the subsequent quota cuts from 2005 onwards (figure. 4-1). The overall decline in the landings of cod from the German Baltic SSF is in line with previous assessments that also noted a decline in landings for the <8 m LoA segment of the cod fishery between 2007, 2008 (STECF, 2011). This decline in cod landings was also evident in the distribution of landings along fishing areas and landing harbors (figure 4-3).

Following a TAC reduction in 2007, the weight of landings from the SSF declined in the majority of areas, with the exception of Greifswald Bay. Fishing areas and harbors located in the west showed large declines (in many instances >20 t) between years. Meanwhile our results indicate slight increases in cod landings in the eastern part of the study area; the weight of landings of the cod segment in the vicinity of Bornholm (ICES Rect. 38G4) increased, although marginally (2005-2008 average increase 2 t). This situation could be attributed to fishers' potential to access the Bornholm Sea (SD 25) and the eastern Baltic cod stock, which showed signs of recovery during 2003-07 due to increased reproductive success (Strehlow, 2010; ICES 2009b). Past accounts (Strehlow, 2010) mention that certain fishers based in the area had quota for the eastern Baltic cod stock.

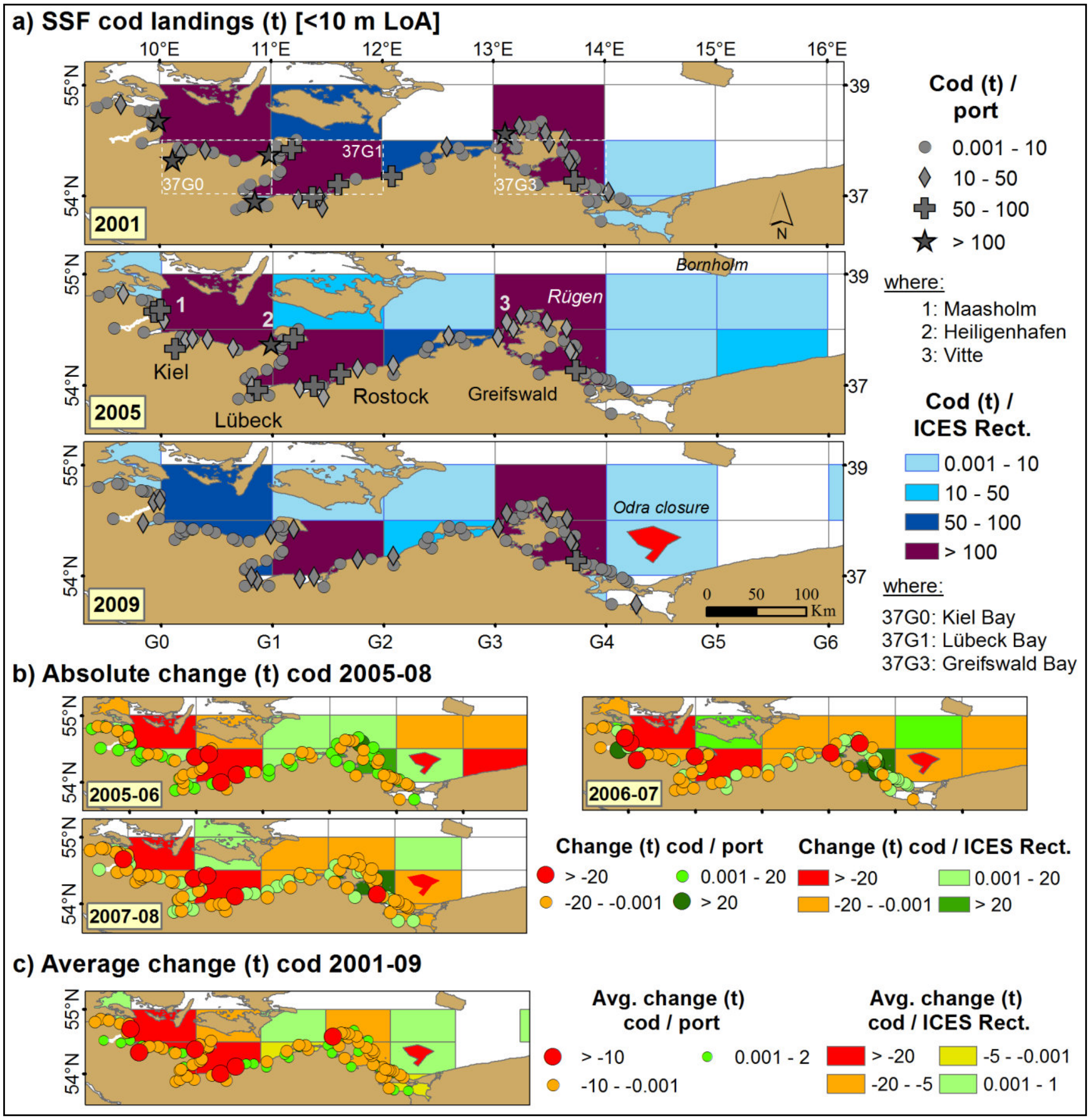

Figure 4-3: Trends in cod landings (t) per fishing area and port. (a) 2001, 2005, 2009 cod landings (t) per fishing area (ICES Rect.) and port. (b) Absolute change in cod landings (t) between the years 2005 and 2008. (c) Average changes in cod landings (t) between 2001 and 2009.

In 2009, the bays of Lübeck (37G1) and Greifswald (37G3) continued to be important cod fishing areas (>100 t weight of landings), despite large declines between the years. The harbors of

Heiligenhafen and Maasholm (both situated in the west and traditionally associated with cod) have shown large average declines in landings (>20 t), yet the harbor of Vitte in the east also showed average declines in the order of 5-15 t. The changing SSF fishing patterns resemble the latest findings of the different cod dynamics in SD 22 and SD 24 (with high abundance in SD 24 and poor status in SD 22 (ICES, 2013).

4.4.1.2. Herring landings

From 2001 to 2009 the weight of herring landings from the SSF sector increased. Similar to cod, trends in landings followed the trends in quotas (figure 4-1). However, in 2008, a quota decrease was not reflected in the segment's landings. Then, in 2009 herring landings from the sector decreased considerably, most likely due to the strong decline in herring biomass in 2006 (European Parliament, 2011), owing to the poor recruitment of the spring spawning stock during 2004-2008 (ICES 2009b; Strehlow, 2010) that also resulted in the severe quota cut in 2009.

Between 2001 and 2009 the fishing areas in the vicinity of Darß peninsula (37G2) and Greifswald Bay (37G3 and 38G3) showed increasing herring landings (>10 t) (figure 4-4). From 2005 to 2008 the harbors of Greifswald, Freest, Barhöft showed average increase in the weight of landings (>10 t per year), while the harbor of Gager, although remaining important in terms of weight of landings, exhibited progressive declines (avg. change per year >10 t). In 2006 we see an increase in the weight of landings in the fishing areas and in a large number of landing harbors located in the eastern part (figure 4-4b). After 2007, the relative increase in the weight of landings was smaller and there were declines in herring landings in several of the areas' harbors.

4.4.2. SSF fleet composition

Between 2000 and 2009 there is an absolute decline in the numbers of SSF vessels, which follows the overall decline of German Baltic fishing vessels. However, the share of the SSF in the total German fleet was stable, accounting for the vast majority of the fleet (>90% of total German Baltic vessel numbers, see also table S4-2 and figure S4-2). The decline in the number of SSF vessels in 2007 and subsequent increase in 2008 can also be partly attributed to EC Regulation 2187/2005 ('technical measures'), with the sector showing a lag in its response. The increase in the number of SSF vessels during 2008 could also be attributed to Regulation 1198/2006 (European Fisheries' Fund; European Council, 2006a) and the priority funding for SSF. Vessels using gillnets and no (or unknown) secondary gear showed the biggest declines in numbers (table S4-3).

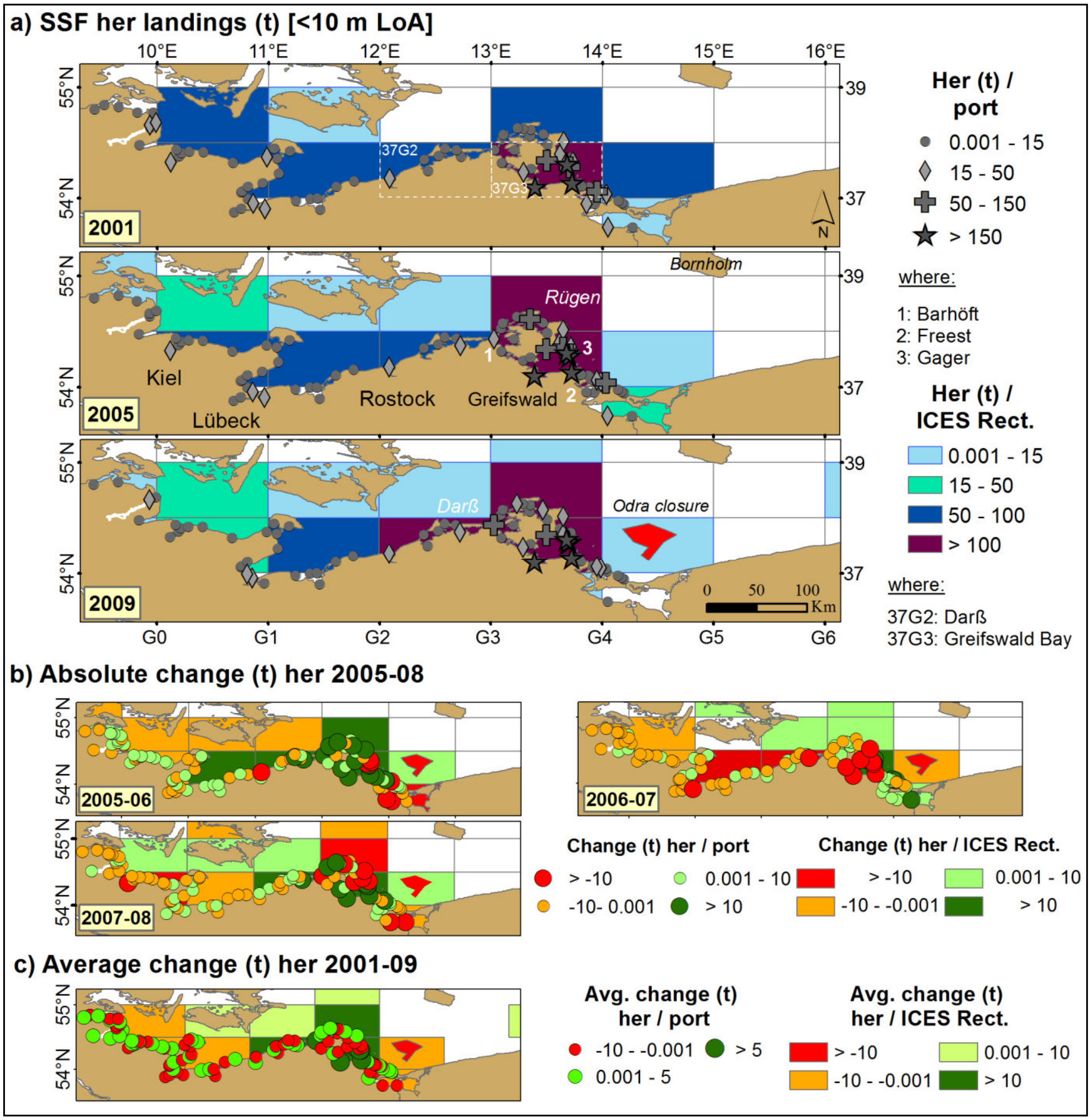

Figure 4-4: Trends in herring landings (t) per fishing area and port. (a) 2001, 2005, 2009 herring landings (t) per fishing area (ICES Rect.) and port. (b) Absolute change in herring landings (t) between the years 2005 and 2008. (c) Average change in herring landings (t) between 2001 and 2009.

The vast majority of SSFs vessels did not acquire more powerful engines, as shown by the stable numbers and technical characteristics (kW, GT) of static-geared larger scale vessels. As in the case with the SSF in general, the German Baltic SSF has a limited capital and technological capacity and thus is not as likely to shift to the use of more powerful engines. Also, the technical measures introduced by Regulation 2187/2005 ('technical measures') and the provisions of the multi-annual management plan, did not provide an incentive for SSFs to change to active gear or invest in higher technology. EC Regulation 2187/2005 introduced technical and operational measures for gillnets thus contributing to the decrease in the number of gillnets with no secondary gear. However, no definite conclusions can be reached regarding trends in the use of secondary gear, since there is evidence suggesting that fishers fill in relevant information arbitrary.

The decline in SSF vessels was also visible in the distribution of vessels along the ports of registration (figure 4-5). This decline was not uniform, with declines between years (> 5 vessels) occurring in Kappeln, Wismar and in ports located in the vicinities of Lübeck, as well as the islands of Poel and Rügen. The biggest declines in vessel numbers occurred in the western part, which may indicate that SSFs in this area were more susceptible to the negative impacts from resource declines than in the eastern part. This may be attributed to the fact that the SSF could not shift to alternative species besides cod, after the introduction of the technical measures regulation and the multi-annual management plan, since there were no fishing grounds for herring in the area (Strehlow, 2010). The decline could also signify a comparatively higher livelihood diversification potential in the western part, with exit from the fishery being a more viable option. Simultaneously, several ports exhibited a relative increase in the number of SSF vessels, in accordance with previous assessments (European Commission, 2009b)[12]. The previous findings indicate a long-term significance of the sector, especially for rural coastal fishing communities.

4.4.3. Target species

The species' composition of the landings showed that the SSF sector targeted a large number of different species (in certain instances >30 species/fishing area) (figures S4-3, S4-4, S4-5). The fact that many of the species' of secondary significance, with reference to their total weight in overall landings, comprised the vast majority of weight for single landing incidents, indicates that most of them were specifically targeted by the particular operations and were not incidental bycatch. From 2001 to 2009 there was an overall small decrease in the number of target species in the west, whereas the east showed a small increase over the same period (figure S4-4).

[12] European Commission (2009b) recorded a 7% overall increase during 2003-07 in small-scale passive gear vessels of the herring and pelagic German Baltic fishery (n.b. the 0-12 m SSF being part-time and also relying on income sources other than fishing especially during winter months), coupled with a reduction for segments targeting pelagic species due to policy of decommissioning and fleet size.

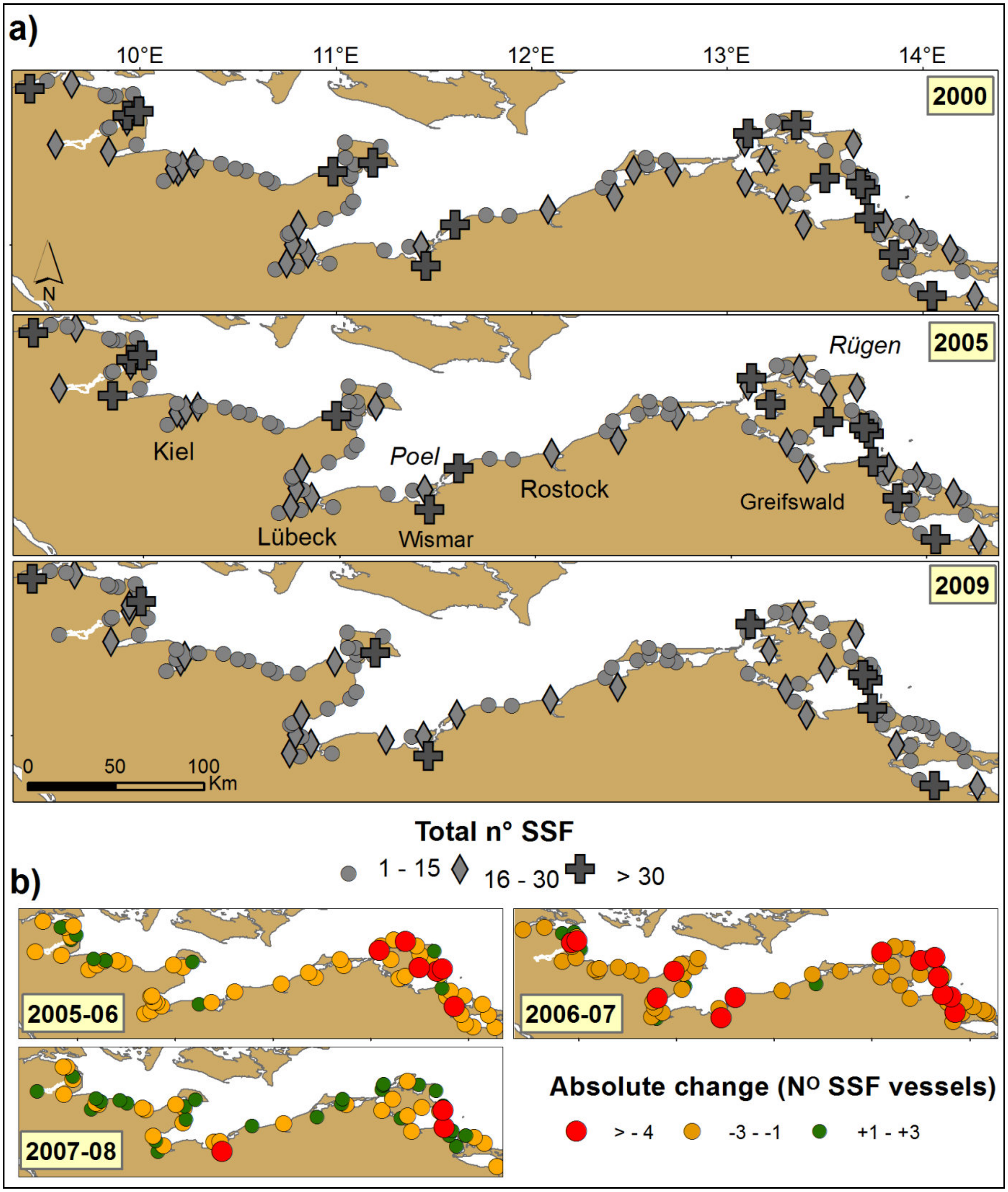

Figure 4-5: Trends in German Baltic SSF fleet per port of registration. (a) 2000, 2005, 2009 distribution of SSF vessels (total n°) (SSF<12 m LoA) along ports of registration. (b) Absolute change in n° of SSF vessels between the years 2005 and 2008. (c) Average change in n° of SSF vessels between 2001 and 2009 (Primary data source: EU CFR, 2010)

The increase in species richness in the east followed the increase in the sector's weight of landings. The decrease in the numbers of species targeted by the SSF in the western part of the area followed the decline in the vessel numbers and landings for the sector in the area. However, fishing areas located in the western part still had among the highest species richness in landings. The previous demonstrates the importance of species diversity for the SSF, with the declines in landings for the western area partly owing to the fact that the SSF could not shift to alternative species (Strehlow, 2010).

In 2009, the highest number of landed species occurred in the vicinity of Darß-Zingst peninsula (37G2); this area also showed high numbers of species in 2001 and an overall increase in total number of species between 2001 and 2009. It should be noted that the area lies within the Western Pomerania Lagoon Area National Park; the high species richness and overall increase in species numbers between 2001 and 2009 from the vicinity of the Darß peninsula could be attributed to the presence of the National Park. Within the Park, a ban of the large-scale, active fishery applies and fishing is restricted to static gear SSF vessels (gillnets, long-lines). It is envisaged that this situation led to the progressive increase in the contribution of the smaller, static fishery, which was also reflected in the trends in species numbers.

4.4.4. Range of operation

The increase in the range of the overall SSF cod segment (total number of ICES Rect., figure 4-3) is concurrent with a coupled increase in the spatial extent of operation and an overall decrease in fishing effort of the German Baltic LSF for cod (ICES, 2012; STECF, 2011). These changes could be attributed to the introduction of the 'technical measures' regulation and the multi-annual management plan. The previous may signify a shift between métiers with the decrease in the contribution of the active fishery and an increase in the contribution of the smaller, static fishery for cod. Previous assessments also recorded an increase in the landings of the smaller static fishery for cod between 2003 and 2008 (STECF, 2011). Furthermore, fishing opportunities for the larger scale, active fishery in SDs 22-24 were found to be affected by the establishment of the cod closure in SD 25 (Probst et al., 2011). The small increase in the landings of the cod segment in the Greifswald Bay may be due to the new regime for the active, larger scale fishery in SD 25.

Although the overall operational range of the SSF targeting cod increased (total number of ICES Rect.), in the main fishing area for cod (Bay of Lübeck), the range of the local segment decreased. Cod landings from the bay of Lübeck (37G1, see figure S4-6) were primarily distributed in the harbors located in the area's vicinity (figure 4-6a). The progressive declines in cod landings from the area can also be seen in the declines in the weight of landings for the respective landings harbors. Past studies of the German Baltic SSF (Strehlow, 2007) also mentioned fishers' preference to fish close to ports.

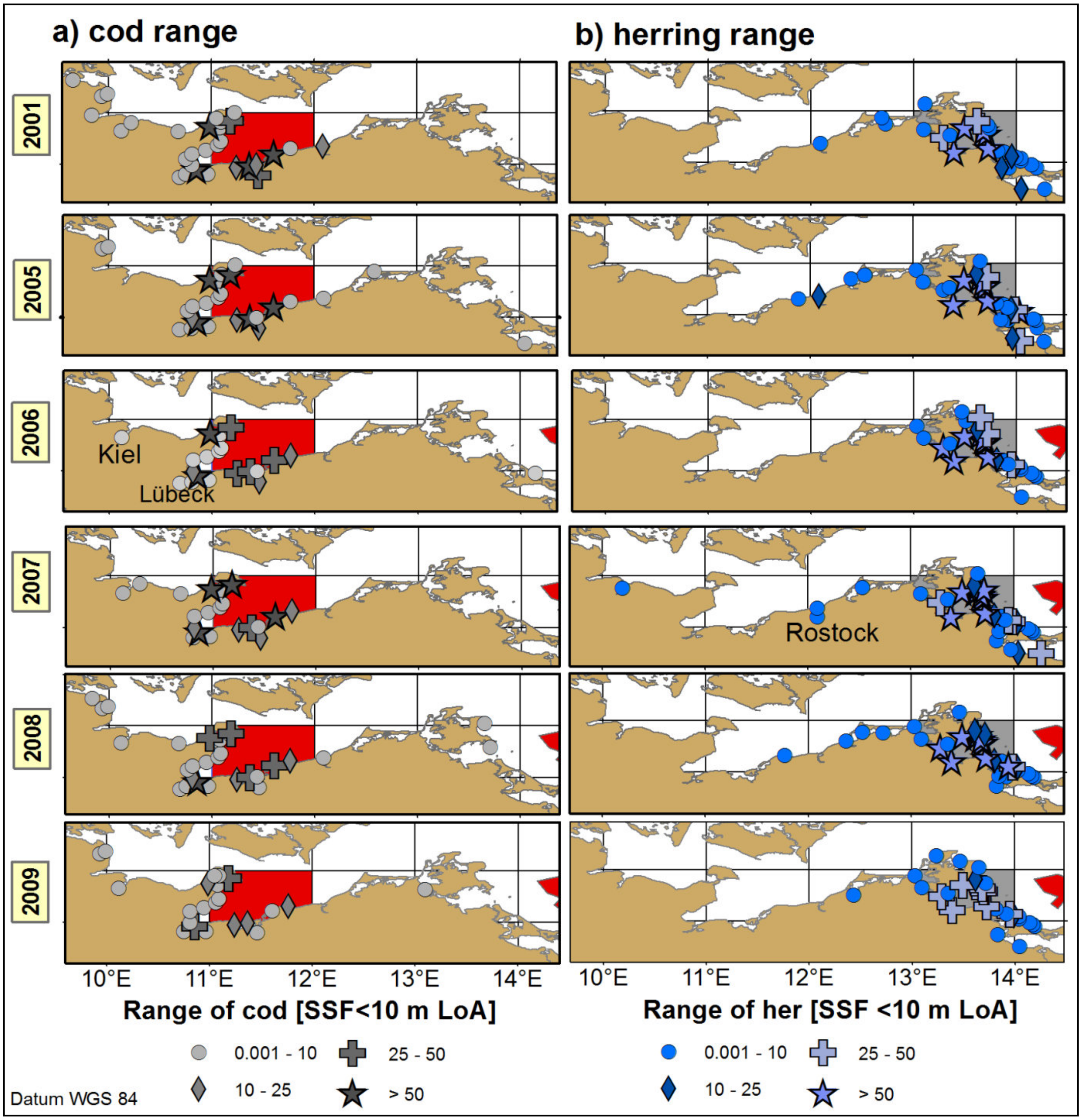

Figure 4-6: Range of the SSF and shifts in range between years. (a) Cod landings (t) per harbor from the Bay of Lübeck (37G1) between 2001 and 2009. (b) Herring landings (t) per harbor from Greifswald Bay (37G3) between 2001 and 2009.

For herring, the landings originating from the Greifswald Bay (37G3, see figure S4-7) were also mostly distributed in harbors in the immediate vicinity (figure 4-6b). No major landing incidents occurred in the harbors located the farthest away from the area, while these harbors also showed declines in the weight of landings from 2005 to 2009. In 2007, the range of the fishery expanded, as demonstrated by the increase in both the number of landing ports and the increase in the farthest distance traveled. In most cases, catches from the fishing area were distributed along a 50 km radius, in line with previous assessments for the herring segment of the SSF in the area (Delaney, 2007). The presence of numerous landing sites and the major herring fishing areas in the immediate vicinity (possibly also due to the presence of the herring processing facility in Neu Mukran), accounted for the restricted range of the SSF in the area. Since 2007 the increase in the range in the eastern part was less pronounced than previous years.

4.4.5. Changes due to spatial closure

As mentioned above, the 'technical measures' regulation (EC No. 2187/2005) also introduced the Odra closure to any kind of active gear. Landings of the SSF in the vicinity of the closure (37G4) were compared to the ones of the LSF, to assess the impacts from the establishment of the closure.

Our analysis showed that in the short-term the closure resulted in an increase in the SSF weight of landings, coupled with a progressive increase in the number of its landing harbors, while the LSF weight of landings decreased substantially (figure 4-7). It appears that, at least in the short-term period considered here, the SSF benefited from the Odra closure to active gear, in terms of weight of landings. This is another indication of the SSF being responsive to the implications of management changes on the LSF, which seem to have affected harbors located the furthest away from respective fishing areas.

4.4.6. Limitations of the study

There is no unique definition of SSFs (FAO and WorldFish Center, 2008). In the present study SSFs have been defined according to their technical characteristics (LoA, engine power) based on the current EU institutional context (European Council, 1999; 2006a); however difficulties in accurately determining the 10-12 m LoA segment of the SSF restricted the analysis of trends in landings to the <10 m LoA segment of the SSF. As mentioned before, the potential bias is expected to be insignificant since only few vessels fall into the 10-12 m LoA category. Also, defining the SSF based on its technical characteristics is not exhaustive of all aspects that pertain to the sector. Within the ongoing Reform of the Common Fisheries Policy (CFP) of the EU, there have been suggestions of extending the definition to vessels up to 15 m LoA (European Parliament, 2013a), and also integrating socio-economic considerations for defining the sector (García-Flórez et al., 2014).

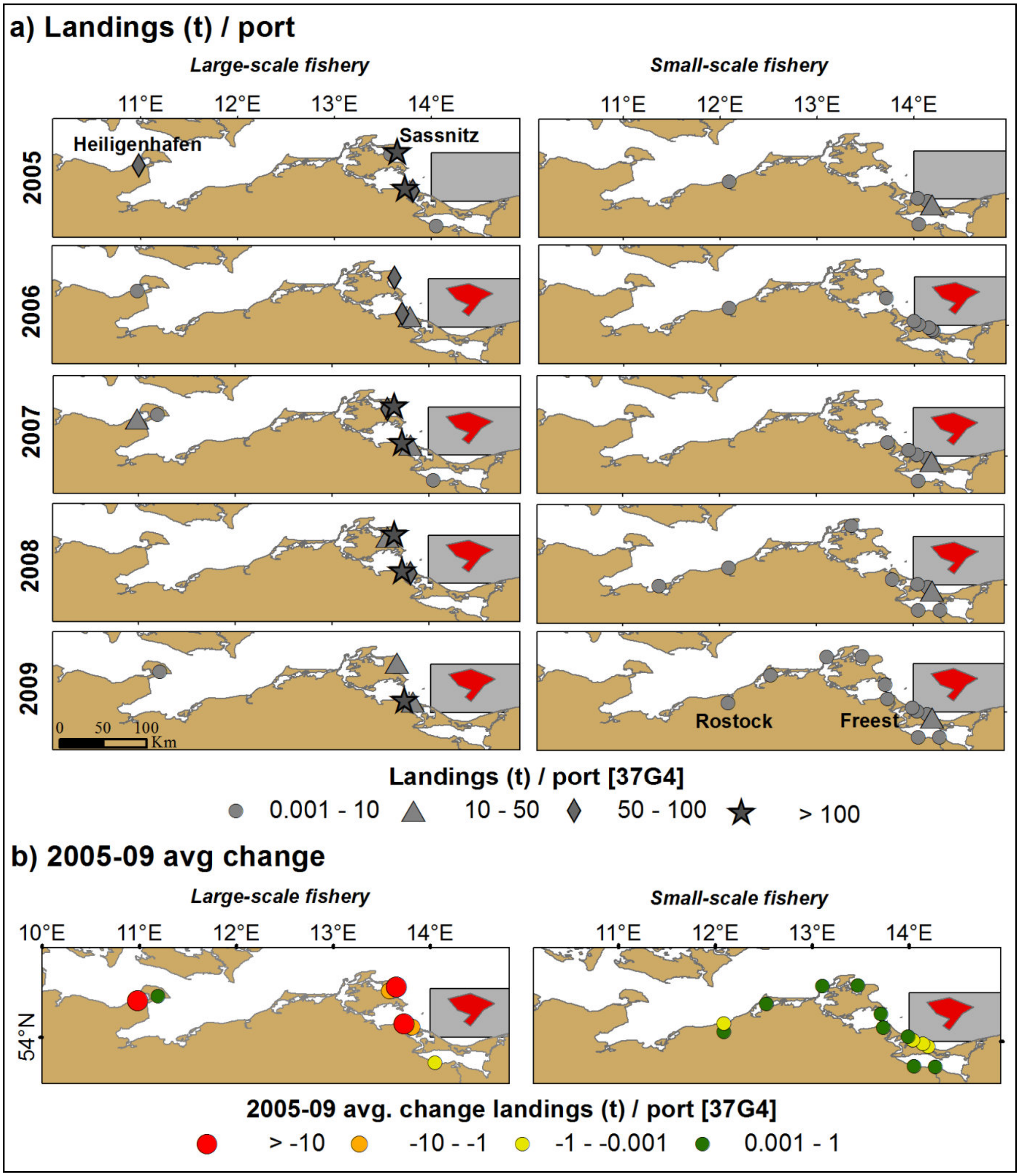

Figure 4-7: Trends in landings (t) for the SSF and the larger-scale active fishery (LSF) from the fishing area in the vicinity of the Odra closure [ICES Rect. 37G4].

The reviewed management alterations were primarily aimed at tackling the resource decline observed between 2000 and 2009. Thereby our evaluation builds on assumptions that may introduce bias, since it is generally difficult to quantitatively study social-ecological interdependencies (Bodin and Tengö, 2012).

Past studies have extensively discussed the limitations and drawbacks using primary data of the SSF sector for analysis (Forcada et al., 2010; FAO and Word Fish Center, 2008; Zeller et al., 2011b, Papaioannou et al., 2012; O' Donnell et al., 2012). The absence and fragmentation of primary data is recognized as a key limitation in quantifying biomass removal by gear type of the SSF sector (IOC/UNESCO et al., 2011). A major reason for the absence of adequate data for the sector stems from the difficulty in data collection and reporting (FAO and WorldFish Center, 2008), due to the numerous and diverse fishing practices and dispersed nature of the activity, with formal scientific methods requiring funds and being time-consuming (O' Donnell et al., 2012). To that end, data lacking from the present analysis are primarily associated with the fact that there is no possibility of referring catch and landings information to specific fishing operations and dates; such data could be obtained via sources such as sale slips, surveys, etc.

In the present study, estimates of the amount of catch (landings) are approximate, yet the analysis presents an assessment of annual trends. The previous however are corrected by the extensive data cleaning operations that were performed, such as the omission of unrealistic values that do not correspond to catches from SSF vessels (e.g. distance >100 km between fishing area and landing harbor; single landing incidents >22 GT; for more information see Papaioannou et al., 2012). We note that the number of unrealistic landing records (i.e. >22 t) during the time period progressively decreased, which may suggest a more effective monitoring from fisheries' authorities. Regarding the sector's range of operation, our evaluation of fishing patterns can only be seen as a first step, since the available spatial unit (ICES Rectangle) has a coarse spatial resolution. In the future, essential fish habitat modeling, Vessel Monitoring System (VMS) data and/or on-board survey results could improve the spatial analysis by providing more detailed spatial information on the exact location of fishing grounds and vessel/fishing operation.

In the present analysis, fleet-related data, namely the number of registered vessels, were specified as 'active at date' and do not correspond to the entire vessel history. Trends in the numbers of SSF vessels do not account for vessels shifting specifications e.g. acquiring more powerful engines. Moreover, fishers may make multiple selections of primary and secondary gear depending on the individual fishing trip, leading to an overestimation of fishing vessels and misinterpretation of fishing gears used. Thereby the information on type of gear is not always reliable, thus not allowing for precise estimates of total landings and effort spent by gear.

4.5. Conclusions

The German Baltic SSF covers a broad geographical area, evident in the large number of harbors; meanwhile, secondary harbors in rural areas show a high contribution with respect to total number of registered vessels and total weight of landings (decentralization). However the range of operation of the sector is still restricted, despite an increase in the total number of fishing areas between 2000 and 2009, with the catch being primarily distributed in the immediate vicinity of the fishing area.

The German Baltic SSF sector is heterogeneous in terms of fishing strategies (gears) and target species. This heterogeneity, coupled with a broad geographic range (decentralization) of harbors and limited range of operation, clearly differentiate the German Baltic SSF from the German LSF sector providing indices for assessing its development potential and sensitivity to changes. The effects of changing management regimes on the SSF and the LSF seem to be very different. The German Baltic SSF has adapted quite well to the Odra closure to active gear, benefiting from its pool of diverse fishing methods that include static gears. The SSF further benefited from the closure, because it effectively excluded the LSF. Parts of the German Baltic SSF apparently did not adapt to the multi-annual management plan for cod stocks in the Baltic Sea, in particular those affecting the eastern Baltic cod. The results also demonstrate the importance of reviewing the spatial framework of fisheries data in order to determine the sector's activity (and likely responses) in the coastal zone, which is fundamental for its effective integration within policy.

Such an approach can provide further insights in assessing the impacts of future management changes and events of environmental variability on the German Baltic SSF, particularly in the cases of:

- A ban of certain fishing practices (e.g. potential ban of gillnet fisheries to prevent incidental bycatch), within the context of implementing NATURA 2000 network sites management plans. The present methodology can provide input on the areas, vessels and harbors that could be affected.
- Spatio-temporal closures during spawning season that may be introduced for the western Baltic cod within the context of the multi-annual management plan evaluation.
- Dynamic fleet management with spatial and temporal closures for the small- and large-scale fishing fleets.

Although the SSF sector can have negative ecological impacts, those impacts might be significantly reduced if the sector is better determined, assessed, and defined in space. The management of the SSF should always take into account those characteristics that differentiate the sector from the larger scale one.

It is also important to stress the need of performing qualitative analysis for the definition and assessment of the SSF, to complement and add on our analysis of fisheries' primary data by means of spatial databases. We anticipate that results from future surveys will also enable streamlining different methodologies for assessing the SSF in the Baltic region.

Acknowledgments

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5. Conclusions

5.1. Key Findings

Characterization and definition of SSFs: The thesis highlighted that solely 'length of vessel' was not sufficient for characterizing and defining SSFs in general and the German Baltic SSF in particular. Other technical characteristics were equally important, such as carrying capacity (tonnage), employed gear and engine power, while other considerations, such as location of home port and proximity to fishing grounds were also fundamental for characterising the German Baltic SSF.

Structure of the German Baltic SSF: During 2000-09, the German Baltic SSF was heterogeneous with reference to type of fishing gear (>10 gear combinations, 'fishing practices', present annually) and was composed primarily of static-geared vessels with diverse technical characteristics (length, tonnage, engine power). The sector accounted for the majority of German Baltic fishing vessels and although it exhibited declining numbers during 2000-09, its share in the total German fleet was relatively stable (2008: 74% of total fleet; 92% of total Baltic German fleet).

Geographic distribution/Range of operation: The sector covered a broad geographic area, with a high number of fishing harbors (n=133) located along the entire extent of the German Baltic coastline. Meanwhile, the sector exhibited a restricted range of operation (<50 km), with the catch (landings) being distributed primarily in the vicinity of productive fishing grounds. Fishing strategies such as barriers, fences and weirs were confined within fishing areas with appropriate habitat characteristics (depth, etc.).

Weight of landings/profitability of the German Baltic SSF: In 2008, herring landings from the SSF sector amounted to <10,000 t while the herring quota for the entire German fishery (ICES SDs 22-24) was 24,579 t. This situation highlights that SSFs access to resource, in terms of allocated fishing opportunities (quotas) is an important issue to consider within the framework of fisheries' management and governance. Major fishing grounds for the SSF sector were the Bay of Lübeck and the Greifswald Bay, important habitats for cod and herring respectively. Results indicate high weight of landings in secondary harbors, while several harbors showed a higher price of landings compared to the average obtained on aggregate by Baltic fisheries. The eastern part of the area (SD 24, MV) showed higher numbers of vessels and landings (weight, price) compared to the western part (SD 22, SH), with the western part also exhibiting larger declines in numbers between 2000-09. Although the sector's contribution to the total catch of the German Baltic fishery was small, in certain locations it was relatively high, suggesting that the SSF sector could provide a livelihood option for coastal communities where alternative options are limited. This situation highlights the need for a location- and context- specific analysis when assessing the SSF sector.

Diversity/Target species: The sector targeted numerous species, both marine and freshwater (>30 per annum). The most important species with reference to weight and price of landings were herring and cod. Declines in the abundance of the western Baltic cod stock, cuts in quotas and the introduction of the multi-annual plan for the management of cod (2007) resulted in large declines in landings and the number of vessels for the SSF in the western part of the area (SD 22). The local SSF could not shift to alternative species, highlighting that diversity of target species is important for the sector's ability to cope with changes in resource abundance and management.

Importance of spatial dimension: The thesis highlights the need of reviewing fisheries' data and management measures spatially. Results show the difference in the sector's characteristics and development among the eastern (SD 24) and western (SD 22) part of the German Baltic region and the high profitability of the sector in certain locations.

Adaptation to changes in resource abundance and management: During 2000-09 resource abundance and management changes had a marked impact on the sector's fishing opportunities. Landings for the sector followed the allocation of quotas for cod and herring (ICES SDs 22-24). An important driver in the sector's development was the interaction with the larger-scale, active fishery. Management measures limiting the activity of the larger-scale fishery (gear restrictions, technical measures, spatial closures), benefited the fishing opportunities and landings of the SSF, suggesting spatial interdependencies (Horta and Defeo, 2012) among the two fleets. However, as is the general case, the SSF sector was limited by its small diversification potential to alternative technology, target species and livelihood options. The lack of capital and inability to adapt input to the fishery, in conjunction with the sector's restricted operational range and limited access to fishing grounds and marketing centres compromised its development.

Data issues and limitations: The development and application of the database was limited by the inherent limitations in primary data, especially for a data-poor sector such as the SSF. The database's spatial and temporal resolutions were selected on the basis of the best available information. Results present primarily trends in the state, distribution and development of the SSF and not precise estimates. The spatial integration of relevant data and the temporal framework of analysis corrected to a large degree of underlying limitations in the data.

5.2. Summary of results

Changes in the abundance of natural resources and the management and governance framework of their exploitation and protection may adversely impact resource users and associated socio-economic activities. Small-Scale Fisheries are an important socio-economic activity of the marine coastal area (FAO, 2012b). For designing the management framework of the sector, it is important to quantitatively assess the impacts on SSFs from changes in management and know which fishing activities and locations are most affected.

The major aims of the thesis were to (i) define and characterise the German Baltic SSF and (ii) assess its response to changes that took place in the Baltic Sea region’s resource abundance and management during 2000-09. The response of the SSF to these changes was assessed with reference to its fundamental structural and operational characteristics [vessels, catch (landings), target species, range of operation, etc.]. A major objective of the research was the development of a database tailored to the specifications of the German Baltic SSF. The database was employed to evaluate the impacts of management changes on the structure and operation of the sector, by linking trends in key variables with selected changes. The study provides the first known record on the development and use of a spatial database specifically tailored to the German Baltic SSF.

The bibliographic review (Chapter 2, Papaioannou et al., 2014b) was essential for determining how fundamental characteristics of SSFs in general, affect their catch, ecology, profit, the natural environment and social dynamics of coastal communities. The selected characteristics constituted the basis for the characterisation of the German Baltic SSF (Chapter 3, Papaioannou et al., 2012). Subsequently, and for the purpose of the analysis, trends in the sector’s structural and operational characteristics were linked with changes in resource abundance and management in the wider Baltic Sea region during 2000-09 (Chapter 4, Papaioannou et al., 2014a).

Among the sector’s fundamental characteristics (Chapter 2) were found to be operational distance; heterogeneity with respect to fishing gears; diversity of target species and; livelihood diversification potential of fishers and communities. The operational distance of the sector was shown to be largely determined by proximity to fisher's point of origin/home port, with an indication that non-monetary considerations such as safety at sea influence fishers' decision of where to fish. Market forces (Cinner and McClanahan, 2006) and interactions and conflicts with the larger-scale fishery (Horta and Defeo, 2012) also influenced the range of SSFs. Heterogeneity of fishing practices and diversity of target species were important for SSFs, as targeting more than one species provided SSFs with versatility, especially during spatial and seasonal closures (Chuenpagdee and Juntarashote, 2011); however on an individual basis fishers are limited by their small capital and may resort to the use of low value métiers. Livelihood diversification was shown to be an important strategy for coping with resource variations and management changes. Livelihood diversification should be carefully considered within fisheries' management and governance schemes and should be pro-active rather than reactive.

SSFs are determined by the local combinations of natural and socio-economic conditions, thus it is important to address the sector on a context-specific basis. The sector's profitability is limited by assets and technology available to the fishers (Daw, 2010; Madau et al., 2009) and how the input to the fishery is used by fishers (Madau et al., 2009). Socio-economic and environmental sustainability are intertwined, and the diversification to more environmentally-friendly fishing practices requires investments in fishing inputs. As in the case with fishing activities in general, a fundamental requirement for the further development of the sector is dealing with overfishing. Furthermore, in the case of SSFs the sustainable exploitation of fish resources and the conservation of diversity are crucial in ensuring the subsistence nature of the activity. Fishers need to be presented with incentives for converting to the use of more sustainable practices; appropriate tools in the process could be microcredit, interest free microloans, etc. Labelling and certification can facilitate the sector's further development and sustainability. Also, the involvement of SSFs within fisheries' management and governance is an important means of ensuring the effective implementation of management measures and the integration of the activity within the coastal realm. For promoting the socio-economic sustainability of the sector, ensuring access to resource and marketing centres is crucial. There is evidence that subsidies directed to SSFs didn't have the desired effects of raising the standard of living and had distorting effects to the wellness of local fishers' communities (Mondaca-Schachermayer et al., 2011). To that end, linking fisheries management to the overall improvement of the economic and social reality of fishers will facilitate the sustainable development of the SSF.

A major limitation in the characterisation and assessment of SSFs is data scarcity and fragmentation. One of the main objectives of the research was the development of a database tailored specifically to the German Baltic SSF sector, which would effectively combine a series of disparate primary fisheries' data sources and information (Chapter 3), while setting forward a consistent methodology for characterising the sector. The database was integrated within GIS to further enable the investigation of spatial patterns. The database enabled the detailed assessment of fundamental variables of the German Baltic SSF. Results from employing the database for the year 2008 provided an overview on key attributes of the sector, such as the size of the fleet; technical characteristics of the vessels; fishing harbors' location; target species; distribution of landings per fishing area (ICES Rect.) and landing harbor.

Results from the thesis indicate that the length of vessel (LoA) was not sufficient for determining the German Baltic SSF. Other technical characteristics were also important, in particular the employed gear, the engine power and the vessel's tonnage (GT). Other important considerations for determining the SSF were location of home harbors and proximity to fishing grounds. Results indicate that, as in the general case with SSFs, the German Baltic SSF covered a broad geographic area with landings taking place along numerous harbors. During 2000-09 the German Baltic SSF accounted for the overwhelming majority of the German fishing fleet (year 2008: 74%) and was primarily composed of static-geared vessels. Although several fishing strategies (i.e. combinations of primary and secondary gears) were present (>10 annually), the main fishing gears were gillnets, with other fishing strategies being confined in areas with specific habitat characteristics (depth, etc.). The sector exhibited a comparatively high diversity of target species (number of species present in the catch) (2008: >30), with catch (landings) comprising primarily of herring and cod. With reference to weight of landings, major fishing grounds in the area were the Greifswald Bay and the Bay of Lübeck, associated with spawning grounds of herring and cod respectively. The majority of landings took place in the harbors located at the eastern part of the area (MV) (2008: ~90% of total weight). Regarding the price of landings of the SSF, these were higher from the ones obtained on aggregate for the overall Baltic fishery (STECF, 2010). High prices were recorded in harbors located towards the edges of the study area, dictating the sector's income-generating potential especially for rural areas away from main industrial centres.

The database was employed to evaluate the adaptation potential of the German Baltic SSF to major changes that took place between 2000-09 in the region's resource abundance and fisheries management (Chapter 4). Management changes that were addressed include: (i) The 2005 change in the management regime of fish resources in the Baltic; (ii) EC Regulation No. 2187/2005 (technical measures) and EC Regulation No. 1098/2007 (multi-annual plan for cod); and (iii) changes in the allocation of TACs and quotas for relevant species (ICES SDs 22-24).

Results highlight the sector's small contribution to the total catch removals for the overall German Baltic fishery. However, at a local scale, especially for fishing grounds and harbors located at the eastern part of the study area (SD 24, MV), the SSF exhibited high landings and vessels' numbers, thus suggesting that it could potentially constitute an important livelihood option for coastal communities where alternative options are limited.

The analysis showed that resource fluctuation and management alterations affected the structure (vessels, gears) and operation (landings, range of operation, target species) of the German Baltic SSF. The 2005 management division benefited the catch of the German Baltic SSF; after 2005, landings of the SSF sector followed closely the allocation of TACs for herring and cod (ICES SDs 22-24). During 2001-09 there was a marked decline in the landings of cod, primarily due to the decline in the abundance of the western Baltic cod stock and the cuts in allocated quotas. Inter-annual trends in the landings of herring were driven by the strong decline in herring biomass in 2006 and the quotas cuts, especially in 2009. Results of the relationship among the sector's landings and allocated quotas suggest a high level of compliance of the German Baltic SSF with management measures. Access to resource (with reference to allocated fishing opportunities, namely quotas) and infrastructure development were important for the sector's state and development, with the trends in the landings of herring in the eastern part of the area also possibly relating to the development of the Neu Mukran processing plant.

Although between 2000-09 the total number of SSF vessels declined, their share in the total German Baltic fishing fleet was stable (>90%), highlighting the SSF sector's importance for the broader region. It appears that the introduction of the technical measures regulation and the provisions of the multi-annual plan did not provide an incentive for SSFs to modernise (e.g. active gear, new technology), as suggested by trends in technical characteristics of vessels, although no definite conclusions can be reached.

SSFs located in the western part of the area (SD 22, SH), exhibited different trends in key variables, with reference to selected resource abundance and management changes, than their counterparts in the eastern part (SD 24, MV). Between 2001-09 the eastern part accounted for the majority of weight of landings and number of vessels, whereas the western part exhibited large declines in these variables. This situation may suggest that the SSF in the western part is more susceptible to the negative impacts from resource declines than the one in the eastern part. In the eastern part, increasing trends in landings were due to the fact that the local SSF targeted primarily herring, whereas declines in the western part were due to the decline in cod and the lack of alternative target species. The trends in SSF fishing patterns resemble the results from recent assessments that also noted higher abundances of cod in the eastern area (SD 24) and poor status in the western area (SD 22) (ICES, 2013). The increase in the overall operational distance for the cod segment of the SSF was concurrent with a decrease in the operational distance at the Bay of Lübeck. The cod segment of the SSF in the eastern part showed slight increases in landings; fishers in the eastern area had access to quota for the eastern Baltic stock, which exhibited signs of recovery during the specified period, denoting that access to resource (in terms of quotas and geographical proximity) are important aspects for the SSFs to cope with changes in resource abundance. It appears that certain segments of the SSF sector apparently did not adapt to the multi-annual management plan for cod stocks in the Baltic Sea, in particular those affecting the eastern Baltic cod.

Results highlight the close interactions of the SSF with the larger-scale fishery. The German Baltic SSF was responsive to management changes limiting the activity of the larger-scale, active fishery. The technical measures for the use of gear, the seasonal and spatial closures and the exclusion of the larger scale fishery from certain areas (Odra closure; Western Pomerania Lagoon National Park; ICES SD 25 and cod closure), resulted in turn in changes in the landings of the SSF. However, exhibited trends in the SSF sector's landings differed considerably between years, while the larger scale fishery managed to adapt to the changes (larger investment capital, ability to fish further, expand range and displace activity elsewhere), eventually returning to a similar situation to the one prior to the introduction of the measures.

Data used for developing the database are governed by certain limitations (chapters 3 and 4) however they are the best available data for characterizing and assessing the SSF sector. The spatial integration of respective information partly accommodated for limitations in data quality. Additionally, the investigation of exhibited trends, both in a temporal and spatial context, provided insight on the dynamics and development of the sector both in space and time.

5.3. Relevance of the thesis

SSFs are lately on the daily agenda of major institutions globally (FAO and WorldFish Centre, 2008; UNEP, 2011; IOC/UNESCO et al., 2011; FAO, 2012b; European Parliament, 2013a; European Parliament and Council, 2013). The quantification and characterisation of the SSF sector and the assessment of its state and development are major objectives towards achieving fisheries sustainability and empowering fish-depended coastal communities. The thesis contributes towards this direction, by presenting a concrete methodological approach in characterising, determining and quantifying the SSF sector, also based on the institutional framework (EU) of fisheries policy and governance. The adopted methodological approach and the spatial database developed within the context of the present thesis partly correct for the inherent limitations in the use of primary fisheries data, especially for a data-poor sector such as the SSF.

The analysis could provide insights in the implementation of the reformed CFP, with regard to SSFs, especially in the event of extending the definition of SSFs and also incorporating new criteria for characterising the SSF sector. The thesis could also contribute towards promoting SSFs environmental sustainability and the Ecosystem Approach to Fisheries (EAF), especially for matters pertaining to the sector's target species diversity, deployed gear, and implications relating with spatial planning and spatial and/or seasonal closures to fishing. In contrast to previous studies, the thesis assesses the entire German Baltic SSF sector and not specific segments of the fishery. The methodology disentangles to a large extent the SSF and larger-scale fishery, thus partly correcting for the inherent limitations in the use of primary fisheries data. The presented methodology can be adapted to other regions and adjusted accordingly to their SSF sectors, provided necessary primary data are made available.

The scope of the research ties in to ongoing and future projects that involve qualitative analyses and the conduct of interview and questionnaire surveys to investigate, among others, the socio-economic value of the SSF sector and its adaptive capacity to the ongoing reform of the CFP (e.g. EIGEN and SOCIOEC projects). Input from the research has been used for the design of questionnaire survey for the part of the projects pertaining to the evaluation of the German Baltic SSF. Insight from the projects will enable ground proofing the results provided in the present thesis and also contribute to streamlining different methodologies for assessing the SSF in the region. As mentioned earlier, the research could provide insight to other ongoing and planned projects in the Baltic Region, for instance the management plans for the NATURA 2000 Network Sites (Pedersen et al., 2009; Sell et al., 2011), whereas results and the methodological approach could be beneficial for the work of certain Working Groups in the region, such as the ICES WG for Spatial Planning and the HELCOM, and/or for regional analyses such as the STECF or EU Baltic Assessment Groups.

5.4. Future work – possibilities for further research

Input from ongoing and future projects will complement the research and will provide a more extensive evaluation of the socio-economic significance of the German Baltic SSF sector. Results from the projects will also enable additional considerations such as the evaluation of outside options available to fishers and a thorough analysis of livelihood diversification potential for SSFs. This situation could also assist in the planning of local management initiatives with reference to the investigation of the economic profitability and marketing centres.

A future step could involve the acquisition of new logbook data to extend the database past the year 2009. Fisheries' experts have already suggested that the situation after 2010 may differ from the trends presented within the thesis (Ralf Döring, vTi, pers. comm.). The database could also be extended in the past, with a methodology similar to the one described in past studies (Zeller, 2011a; 2011b) although the resolution of the spatial database used in the present work is more refined and careful attention should be paid when comparing and adapting relevant methodologies.

Refining the spatial resolution of the database could improve the quality of the analysis, especially when bearing in mind that the sector's spatial dynamics determine to a great degree its profitability and adaptation potential to changes in resource abundance and management. Field-based surveys, on board surveys and information from alternative sources could enable the acquisition of better information on the location of fishing grounds. For instance the methodology set forward by Sonntag et al. (2012) or the use of VMS data, in the event of the SSF definition being extended to vessels of 15 m LoA, could provide substantial insight for a faction of the SSF. The methodology could also potentially integrate environmental considerations and the database could be further enriched with abiotic (salinity, temperature, substrate) and ecological data (sea grass, trophic conditions) suitable for performing Essential Fish Habitat Modelling (EFH).

Despite the inherent limitations in the use of primary data and the subsequent limitation in the development and use of the database, results from the thesis provide useful insights into the state and development of the German Baltic SSF. The study comprises one of the first (and hopefully many to follow) initiatives for the quantification of the German Baltic SSF and the evaluation of its response to changes in resource abundance and management. The possibilities of enhancing and further developing the applied database, to also include socio-economic considerations are plenty. Including only a few may already increase the value of the database as a tool for devising strategies to successfully deal with changes in resource abundance and shocks, and outside options.

6. References

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7. Appendix - Supplementary Material

Table S2-1: Literature sources that were accessed and information used to assess corresponding variables

	Operational Range	Heterogeneity	Selectivity	Diversity	Livelihood diversification	Environmental Sustainability	Socio-economic Sustainability
Alfaro-Shigueto et al., 2011			x			x	
Allison and Ellis, 2001		x			x		
Brewer et al., 2012				x			x
Bundy and Pauly, 2001			x				
Cabrera and Defeo, 2001	x	x					
Caddy and Carocci, 1999	x						
Chuenpagdee and Juntarashote, 2011		x			x		x
Cinner and McClanahan, 2006	x	x	x	x			x
Cinner et al., 2009					x		
Davies et al., 2009					x		
Daw, 2008	x						
Defeo and Castilla, 2005; 2012				x			x
Döring, 2003			x				
DuBois and Zografos, 2012		x			x		
Dunn et al., 2010	x						

Table S2-1 cont.	**Operational Range**	**Heterogeneity**	**Selectivity**	**Diversity**	**Livelihood diversification**	**Environmental Sustainability**	**Socio-economic Sustainability**
Forcada et al., 2010	x						
Gasalla, 2011						x	
Gascoigne and Willsteed, 2009		x				x	x
Gupta, 2010				x			x
Hicks and McClanahan, 2012		x		x		x	
Horta and Defeo, 2012	x						x
Madau et al., 2009							x
Isaacs, 2011; 2012					x		x
Jacquet and Pauly, 2008						x	
Kraan, 2011					x		
Macbeth et al. 2005			x			x	
Mathews, 2001						x	
Molyneux, 2011						x	
Mondaca-Schachermayer et al., 2011						x	x
Muallil et al., 2011					x		x
Niesten and Gjertsen, 2010						x	
Noack et al., 2012					x		x
Pomeroy et al., 2009					x		

Table S2-1 cont.	**Operational Range**	**Heterogeneity**	**Selectivity**	**Diversity**	**Livelihood diversification**	**Environmental Sustainability**	**Socio-economic Sustainability**
Rueda and Defeo, 2003	x						
Salas et al., 2004	x	x					
Seilert & Suchat Sangchan, 2001		x					
Sowman and Cardoso, 2010	x						x
Stewart et al., 2010	x						
Strehlow, 2010					x		x
Teh et al., 2012	x						
Trimble and Johnson, 2013					x		x
Tzanatos et al., 2006		x					
Ünal and Franquesa, 2010							x
Vitale et al., 2011				x			

Sources that were used for assessing features of the SSF and information contained therein. (x): corresponding feature that source enabled reviewing, not exhaustive of all aspects that were dealt with by each publication. [§] Literature that was assessed for the purpose of the review and has not been included in the present table include: Bavinck, 2005; Béné, 2003; Béné et al., 2007; 2010; Charles, 2011a; 2011b; 2011c; Chuenpagdee et al., 2006; Chuenpagdee and Pauly, 2008; Chuenpagdee and Jentoft, 2011; Cinner and Bodin, 2010; Cinner et al., 2012; Costello et al., 2012; European Council, 2006a; European Parliament, 2013a; European Parliament and Council, 2013; Evans and Andrew, 2009; FAO and WordFish Center, 2008; FAO 2012a; 2012b; 2013e; García-Flórez et al., 2014; Garcia et al., 2003; 2012; Gutiérrez et al., 2011; Hall et al., 2010; 2013; Harper et al., 2013; IOC/UNESCO et al., 2011; Jentoft et al., 2011; Jentoft and Midré, 2011; Kébé, 2008; Macfadyen et al. 2011; Maxwell et al. 2012; McClanahan and Cinner, 2008; McClanahan et al., 2009; Misund et al., 2008; Ortega et al., 2012; Panayotou, 1982; Papaioannou et al., 2012; Quaas and Requate, 2013; Rochet et al., 2011; Sathyapalan et al., 2011; UNEP, 2011; Veitch et al., 2012; Ward et al., 2004; Wielgus et al., 2010; Worm et al., 2006; Zeller et al., 2007; 2011.

Table S3-1: Fishing harbors dataset (Extract)

Port Name	Port Code	X Point	Y Point	ICES Area	Geo Area	ICES Name	Country Code	New code	Notes
ALTWARP	631	14.27	53.73	24	MV	36G4	GM	GM631	…
GOTHMUND	218	10.75	53.90	22	SH	36G0	GM	GM218	Partly inland <12 nm
KAMMINKE	630	14.20	53.86	24	MV	36G4	GM	GM630	…
MOENKEBUDE	632	13.96	53.77	24	MV	36G3	GM	GM632	…
TIMMENDORF	215	11.37	53.99	22	MV	36G1	GM	GM215	…
USEDOM	633	13.92	53.87	24	MV	36G3	GM	GM633	…

Note: Extract of fishing harbors' dataset developed within the context of the analysis after combining available primary sources. The harbor dataset was edited (e.g. fields re-naming, new code field, new fields 'ICES Area' and 'Name' etc) to allow the integration of additional data, such as the CFR and logbook information, through a series of queries. The fishing harbor data were then integrated within a GIS database. Field 'Port code' according to the CFR codification system; X, Y points coordinates of location as point position; Fields 'ICES Area' and 'ICES Name', include information on the respective SDs (Area) and statistical Rectangle where the port is located; Field 'GEO Area' denotes the German Federal State where the port is located (MV- Mecklenburg-Western Pomerania, SH- Schleswig-Holstein); Field 'Country Code', Country where the port belongs (GM- Germany); Field 'New Code' combines the Country and CFR Code information; Field 'Notes' includes information on special features of ports (e.g. inland port etc).

Table S3-2: Fleet Register dataset example (Extract)

Country Code	Vessel Name	Port Code	Port Name	Gear Main Code	Gear Sec Code	Loa	Ton Gt	Power Main	…
DEU	…	313	ACCUMERSIEL	TBB	OTB	14.97	23	221	
DEU	…	313	ACCUMERSIEL	TBB	OTB	17.55	31	175	
…									
DEU	…	618	AHLBECK	GNS	LLS	6	1	4	
…									
DEU	…	618	AHLBECK	GNS	LLS	6.7	2	44	
…									
DEU	…	631	ALTWARP	GNS	NK	8.65	3	9	

Note: CFR extract for Germany (last accessed: 2/2010); information includes port code/name, main/secondary gear code (e.g. GNS: Gillnets, see table S3-4 for full list), length overall (Loa), gross tonnage (GT) and engine power (kW). N.B.: Single ports have numerous vessels (one-to-many relationship). Field entries 'Vessel name' have been erased for privacy policy considerations. …: indicate that additional fields/entries are present but were omitted.

Table S3-3: Logbook dataset example (Extract)

Year	Month	Landing harbor	Landing date	Fish Sp.	Length class	Gear	ICES Rect.	Landings (kg)	Price (€)
2008	1	BURGSTAAKEN	1/7/08 16:00	COD	> 10 m	OTB	37G1	450	1 009
2008	1	BURGSTAAKEN	1/7/08 16:00	DAB	> 10 m	OTB	37G1	132	123
…									
2008	1	GROSSENBRODE	1/1/08 18:00	BLL	> 10 m	GNS	37G1	1	3
2008	1	GROSSENBRODE	1/1/08 18:00	COD	> 10 m	GNS	37G1	897	2 975
…									
2008	1	KAPPELN	1/14/08 10:00	COD	> 10 m	PTB	38G0	146	288

Note: Logbook dataset extract for Germany (Year 2008) (Source: BLE); information includes year, month, date and time when landing incidents occurred, landed species code (e.g. HER: Herring), length class of the vessel (either generic '<10 m', or explicit length, e.g. 5.5 m), ICES Rectangle landings originated from (e.g. 37G3), weight (Kg) of landings and price (€) of landings. N.B.: Single ports have numerous vessels (one-to-many relationship) and many simultaneous landing operations occur at the same time/date. …: indicate that additional fields/entries are present but were omitted for better visualization.

Table S3-4: Fishing strategies and technical specifications of segments of German Baltic SSF sector

Gear Primary	Gear Secondary	Thresholds in technical characteristics
GNS	LLS	<12 LoA, <20 GT N.B. 13 vessels with kW>100
GNS	FPO	<12 LoA, <10 GT
GNS	NK	<12 LoA
GNS	NO	<12 LoA, <20 GT
GNS	GNS	<12 LoA, <10 GT, <100 kW
FPO	GNS	<12 LoA, <10 GT, <100 Kw
FPO	NO	<12 LoA, <10 GT, <50 kW
FPO	LLS	
LLS	GNS	
LLS	FPO	<12 LoA, <10 GT, <10 kW

Codes for Fishing gear
(After: ISSCFG FAO, 1980; EU CFR Gear Codification):
FPO: Pots and Traps;
GNS: Set gillnets (anchored);
LLS: Set long-lines;
NO: No gear;
NK: Gear Not Known

Table S3-5: Fishing strategies (Logbook data) of German Baltic SSF sector

<10 m LoA	**>10 m LoA**	
SSF Gear Strategies	**SSF Gear Strategies**	**Non-SSF Gear Strategies**
Generic gear type: 'Static nets'	FPN: Poundnets	DRB: Boat dredges
	FPO: Pots and traps	OTB: Otter Trawls
	FWR: Barriers, fences and weirs	OTM: Otter Trawls
	GND: Driftnets	PTB: Pair Trawls
	GNS: Gillnets	PTM: Pair Trawls
	LHP: Hand-lines and pole-lines (hand operated)	SDN: Danish seines
	LL: Long-lines (not specified)	SSC: Scottish seines
	LLS: Drifting long-lines	TBB: Beam Trawls

Table S3-6: Composition of German Baltic fishing fleet

	Total No.	**% contribution**	**Small-scale vessels**	**Medium/ large vessels**
Static	1 396	76	1 335	61
Active	342	19	0	342
Mixed	87	5	14	73
TOTAL	**1 825**	**100**	**1 349**	**476**

N.B. Results of total German Baltic SSF similar to respective numbers by European Parliament, 2011

Table S3-7: Fishing strategies/Segments of SSF sector

Gear strategy	No. of vessels	Technical Specifications		
		Avg LoA	Avg GT	Avg kW
GNS_LLS	679	6.4	2.5	22.5
GNS_FPO	461	5.9	1.6	15.6
GNS_NK	85	6.8	2.2	15.3
GNS_NO	67	6.1	2.0	12.7
GNS_GNS	18	7.0	3.4	21.6
FPO_GNS	11	5.8	1.0	18.0
FPO_NO	9	4.7	1.0	2.8
LLS_FPO	3	5.9	1.3	12.3
LLS_GNS†	1	9.0	12	135
FPO_LLS†	1	5.2	1.0	19
GNS_OTB	9	10	10	86.7
GNS_PTB	3	10.0	10.0	109
OTB_GNS	2	10.3	8.5	79

† Corresponds to single vessel

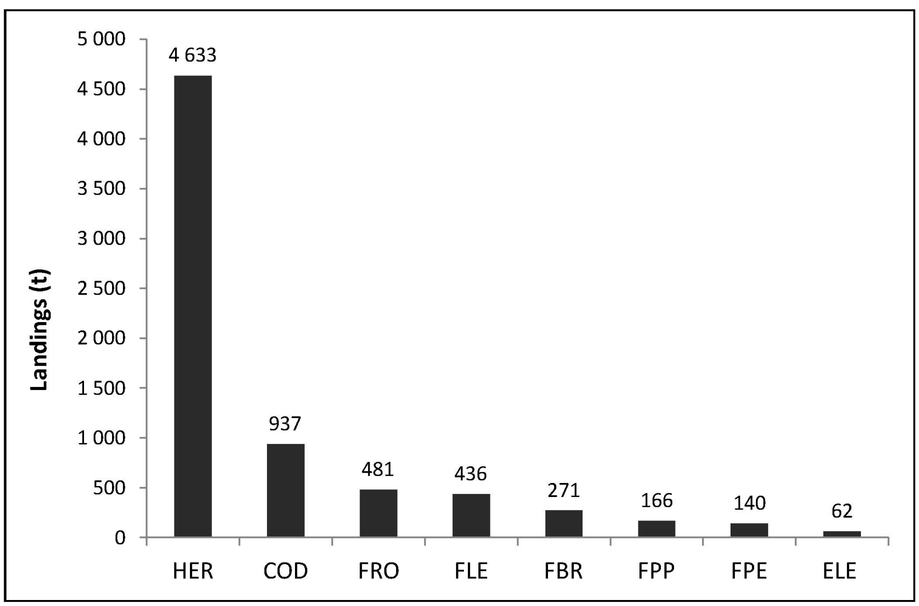

Figure S3-1: Total weight of landings (t) of SSF <10 m LoA of major species (2008)

Where: HER- Herring, COD – Cod, FRO-Roach, FLE-European flounder, FBR-Common bream, FPP-Pike-perch, FPE-European perch, ELE – European eel. N.B. Logbook's aggregated group 'Others', does not include information on comprising species and landings of the group correspond to less than 0.5% of total; group was omitted from the analysis.

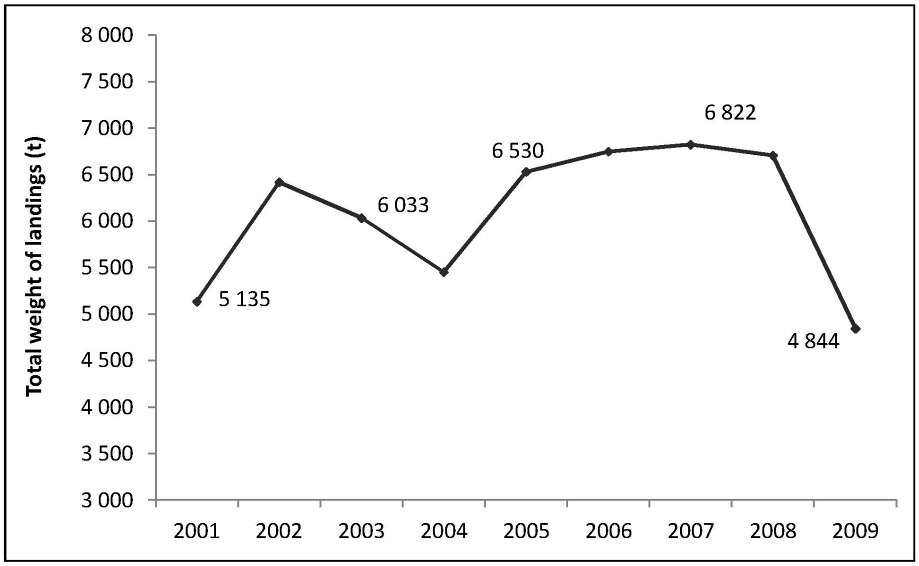

Figure S4-1: Overall trends in landings (t) during 2001-2009 (SSF <10 m LoA)

Where: Total weight of landings (t) sum of year

Table S4-1: Trends in landings (mean weight, t) along German harbors 2001-09

2001	2002	2003	2004	2005	2006	2007	2008	2009
38	48	45	41	49	51	51	50.5	36

n.b. Values correspond to total annual mean weight along all landing harbors (n= 133)

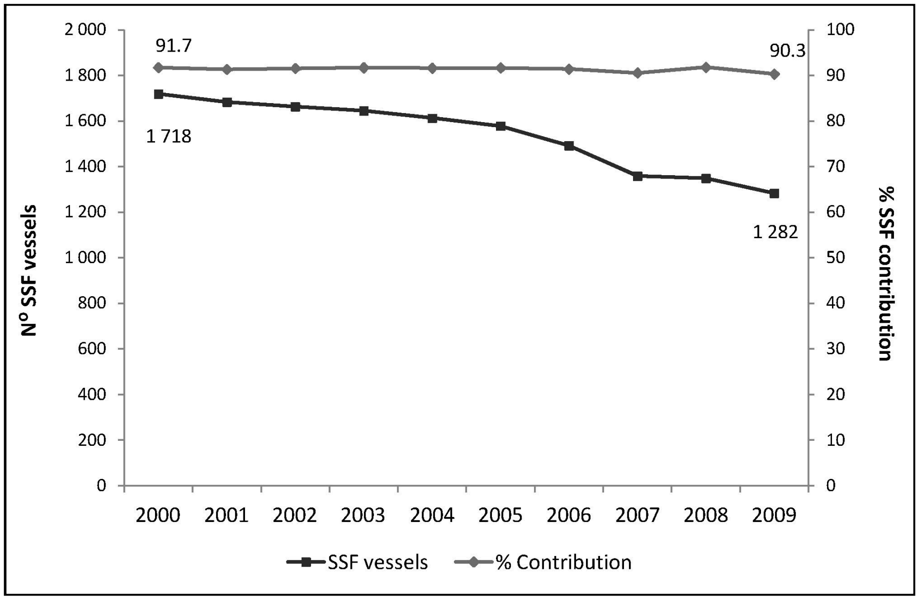

Figure S4-2: Trends in total number of German Baltic SSF vessels and % contribution of SSF to total number of fishing vessels along German Baltic ports of registration

Table S4-2: Trends in total number of German Baltic SSF vessels and % contribution of SSF to total number of fishing vessels

Year	Total No. Vessels	SSF Vessels Static	SSF Vessels Mixed	SSF Vessels TOTAL	SSF % of Total
2000	1 873	1 704	14	**1 718**	92
2001	1 843	1 669	14	**1 683**	91.4
2002	1 817	1 651	12	**1 663**	91.5
2003	1 793	1 633	11	**1 644**	91.7
2004	1 760	1 601	11	**1 612**	91.6
2005	1 722	1 569	9	**1 578**	91.6
2006	1 633	1 485	7	**1 492**	91.4
2007	1 500	1 351	8	**1 358**	90.5
2008	1 469	1 335	14	**1 349**	91.8
2009	1 420	1 269	13	**1 282**	90.3

Note: SSF vessels' specifications as defined in Papaioannou et al., 2012; Total number of vessels is German Baltic registered vessels. Primary data source: CFR, 2010 (CFR Datasets 'Active at date', 31/12 of each individual year) (Accessed: 1/6/2012)

Table S4-3: Number of fishing vessels per SSF fishing strategy category 2000-09

Year	GNS_ LLS	GNS_ NO	GNS_ NK	GNS_ GNS	GNS_ FPO	FPO_ GNS	FPO_ NO	FPO_ LLS	LLS_ GNS	LLS_ FPO	LLS_ NK	GNS_ PTB	GNS_ OTB	OTB_ GNS	SSF
2000	712	234	221	47	485	0	0	1	2	0	2	0	11	3	**1 718**
2001	750	198	199	39	477	1	0	1	2	0	2	0	11	3	**1 683**
2002	786	172	168	36	485	1	0	1	0	0	2	0	9	3	**1 663**
2003	802	161	159	30	474	2	0	2	0	1	2	0	9	2	**1 644**
2004	813	146	144	28	464	2	0	1	0	1	2	0	9	2	**1 612**
2005	805	136	138	25	456	3	0	1	0	3	1	1	9	0	**1 578**
2006	760	108	116	22	466	7	0	1	0	4	0	1	6	1	**1 492**
2007	688	77	97	19	451	7	6	1	0	4	0	1	7	1	**1 358**
2008	679	67	85	18	461	11	9	1	1	3	0	3	9	2	**1 349**
2009	649	52	54	14	472	13	11	2	1	1	0	1	9	3	**1 282**

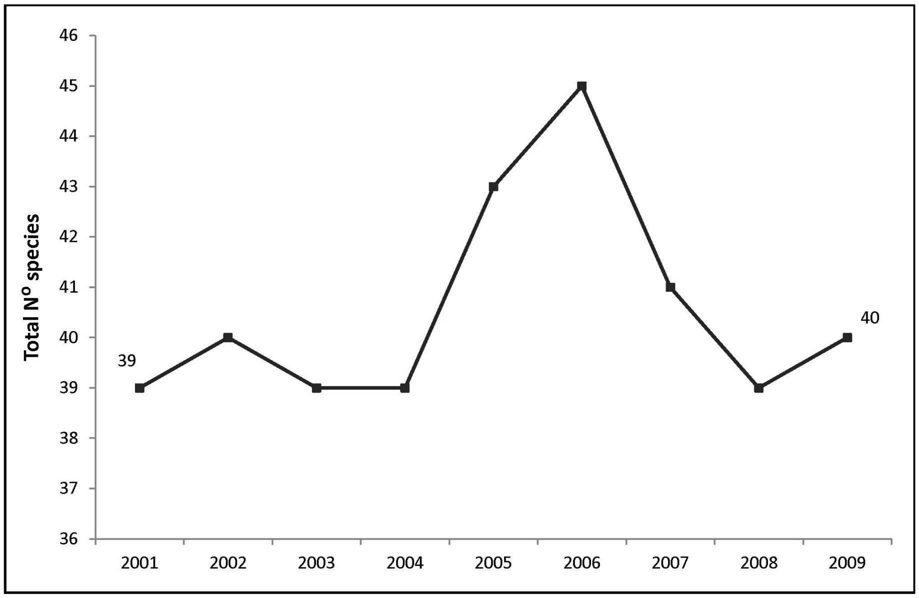

Figure S4-3: Trends in total number of species in landings (SSF<10 m LoA) 2001-09

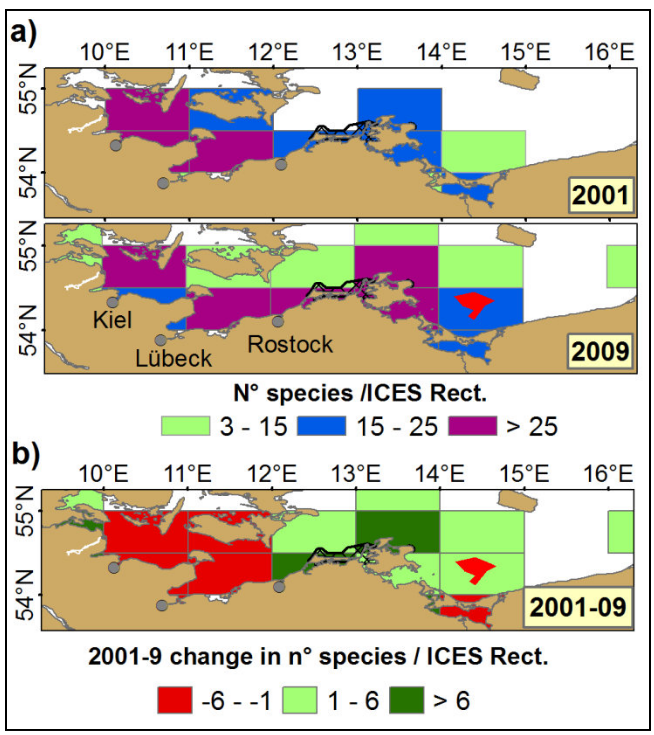

Figure S4-4: Trends in numbers of species in landings per fishing area

S4-4a. 2001, 2009 n° species in landings per fishing area (ICES Rect.). S4-4b. Overall change in n° species in landings per fishing area between 2001 and 2009 n.b. overall and not average change

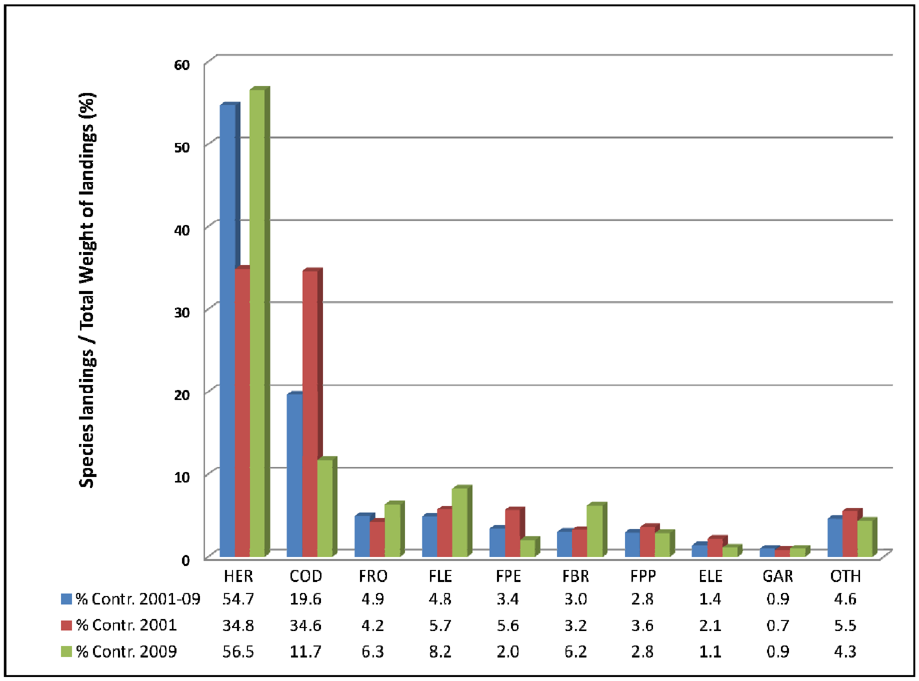

Figure S4-5: Contribution of 10 most dominant species from SSF<10 m LoA segment

Note: Contribution is % contribution of weight of each species to total weight of landings averaged for the 2001-09 period. Species codification according to BLE, 2010. Where: HER: Herring (Clupea harengus); COD: cod (Gadus morhua); FRO: Roach (Rutilus rutilus); FLE: European Flounder (Platichthys flesus); FPE: European Perch (Perca fluviatilis); FBR: Freshwater breams (Abramis spp.); FPP: Zander (Pike-perch) (Stizostedion lucioperca); ELE: European eel (Anguilla anguilla); GAR: Garfish (Belone belone); OTH: Includes weight of species with an average contribution less than 1% of total average weight (2001-09).

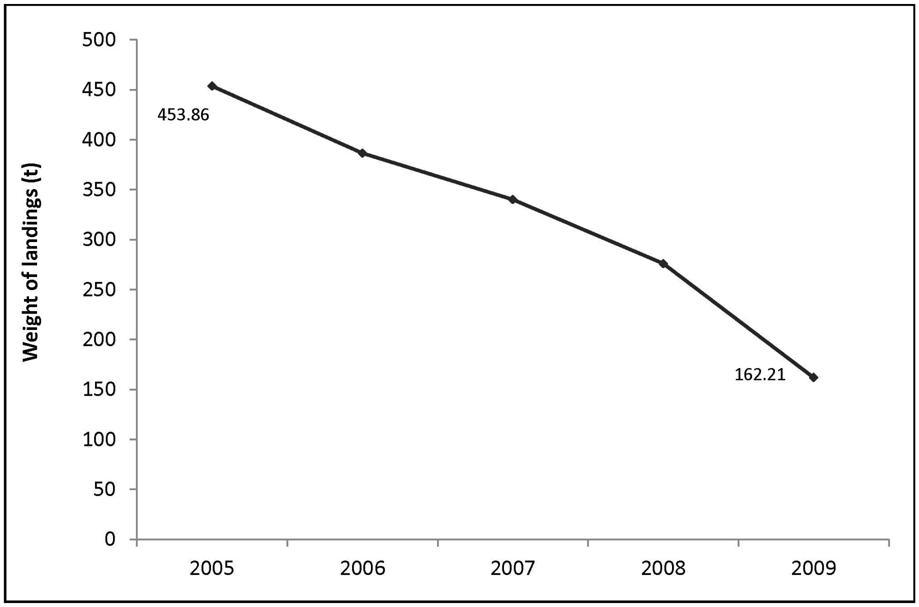

Figure S4-6: Temporal trends in the landings of cod [ICES Rect. 37G1, SSF<10 m LoA]

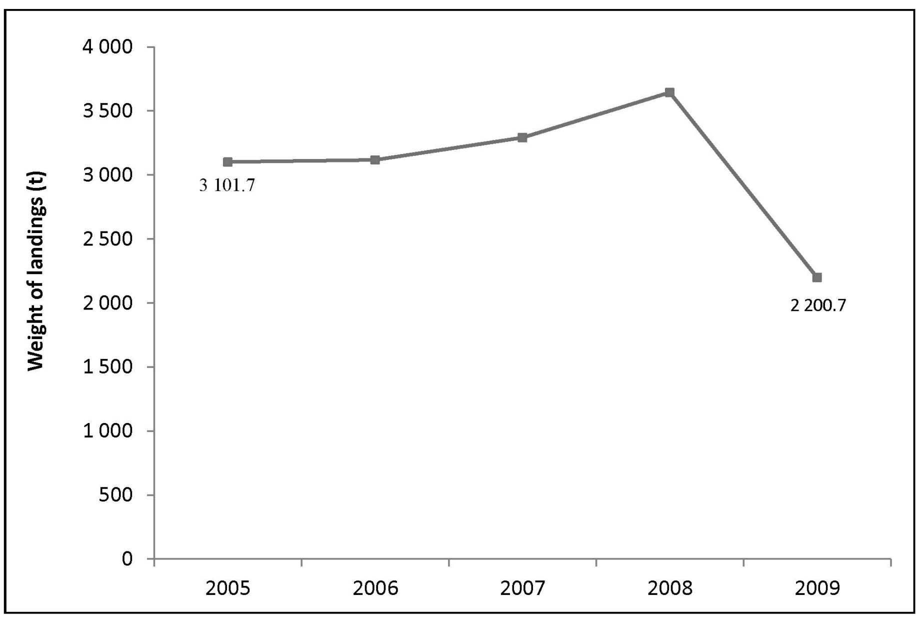

Figure S4-7: Temporal trends in the landings of herring [ICES Rect. 37G3, SSF<10 m LoA]