Sustainability and conflict in small-scale fisheries

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Abstract

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Anna Sophia Kochalski

Small-scale fisheries account for one third of the global fisheries catch and employ the majority of fishers, yet they are under-represented in terms of the science focused on fisheries management and the application of this. The sustainability of small-scale fisheries is crucial to end the global fisheries crisis and ensure food security in coastal areas. This thesis aimed at contributing to the better integration of the ecological and social side of small-scale fisheries in order to move towards sustainability. Using a quantitative linguistic approach, the meanings of sustainability were explored across the fisheries science literature and a holistic and unambiguous definition of sustainability was proposed as "*the continuous existence of the socio-ecological fishery system, in such a way that it provides goods and services now and in the future, without depleting natural resources, and the sustainable processes that make both possible*". The thesis compared the meaning and breadth of the sustainability concept in fisheries science literature with the criteria used in fisheries sustainability standards. Twelve core criteria were identified. While a consensus on criteria contributes to transparency towards the consumer, it is also cause for concern because the sustainability standards largely ignored human and social aspects. To assess fisheries from the human or social perspective, this thesis adapted a formal conflict analysis approach from research on peace and war and applied it to an English small-scale fishery with co-management arrangements in place and a UK offshore fishery that is centrally managed. The analysis was based on the line of thinking that the understanding of and way towards sustainability is determined by a societal dialogue and that conflict indicates that this dialogue is facing difficulties. Conflict, which is omnipresent in fisheries but not used as an analytical tool, proved to be a multifaceted phenomenon and an informative indicator to study and assess social sustainability in fisheries, albeit it was not correlated to biological sustainability of fish stocks. The thesis finally integrates the review of the sustainability meanings, the comparison of eco-certification schemes, and the insights from the conflict analysis to determine and discuss their suitability for assessing sustainability of small-scale fisheries. It is finally concluded that sustainability of small-scale fisheries could be furthered by moving away from managing outcomes towards enabling cooperative relationships.

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Declaration

I hereby certify that this dissertation constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions or writings of another.

I declare that the dissertation describes original work that has not previously been presented for the award of any other degree of any institution.

Sophia Kochalski

1. Introduction

1.1. Humans and the environment

The world's population has grown from 1.5 billion people in the 1900s to 7.4 billion people in the present day (Population Reference Bureau 2016), thanks to technological and medical developments and access to natural resources. However, growth and development have taken their toll on the natural environment. Since the late 1980s, humans have used more resources each year than the Earth can produce in the equivalent period of time; for example it was estimated that in 2007, one and a half Earths would be required to sustain humankind over the long-term (Ewing et al. 2010). This imbalance is mainly due to an increased carbon footprint (Ewing et al. 2010) with the increased production of greenhouse gases leading to changes in the carbon cycle, global warming, Arctic sea ice loss, and rising sea-levels (Stocker et al. 2013). The extent of global environmental change caused by humans since the Industrial Revolution has led to suggestions that we have exceeded several planetary boundaries (Rockström et al. 2009; Steffen et al. 2015), and now live in a new geological era referred to as the Anthropocene (Crutzen 2002; Steffen et al. 2007).

Anthropogenic environmental change can be observed in all parts of the world, including the world's oceans, coastal and freshwater systems (Dudgeon et al. 2006; Lotze et al. 2006; Halpern et al. 2008). Usually, several pressures act at once in the natural environment and their interactions can have synergistic and cascading effects (Brook et al. 2008; Halpern et al. 2008). There is clear evidence that we are losing biodiversity of aquatic species at a rate that has increased dramatically since industrialisation (Harnik et al. 2012; Ceballos et al. 2015) and we are also seeing redistribution of species across the world (Chen et al. 2011). The most important anthropogenic drivers of biodiversity loss, species distribution change and resource depletion in the marine environment today are climate change (Hughes et al. 2003; Halpern et al. 2008; Hoegh-Guldberg & Bruno 2010; Stocker et al. 2013) and fishing (Halpern et al. 2008).

In this thesis the concept of fisheries sustainability is explored, with a focus on the implications for small-scale fisheries, where there are some particular challenges (see Section 1.6). In this introductory chapter, I review the background on fisheries exploitation and its impacts (Section 1.2), consider the benefits associated with fishing and the implications of this on sustainability (Section 1.3), describe the different forms of fisheries management and challenges associated with these (Sections 1.4), the social aspects of sustainability (Section 1.5), before focusing on the particular issues associated with small-scale fisheries (Section 1.6). Finally I set out the objectives of the thesis and provide a guide to the chapters that follow.

1.2. Fisheries exploitation, overfishing and wider impacts

Fisheries resources were once thought to be inexhaustible, yet the finite nature of fisheries resources has now become clear and has resulted in a global fisheries crisis (McGoodwin 1995; Buckworth 1998; Pauly et al. 2002; Worm 2016). The oceans have a limited capacity to produce new biomass over the timescales on which we require it and so the number of fish that the oceans can sustain at our current rate of harvest is limited (Pauly & Christensen 1995). The Food and Agriculture Organization of the United Nations (FAO) collects data and produces an authoritative biannual report on the state of world fisheries and aquaculture. The FAO suggest that the maximum production capacity of the oceans was reached in the mid-1990s when global marine catches peaked at 86 million tonnes per year (FAO 2016). Since then, global marine catches have decreased slightly and were close to 82 million tonnes in 2014, the most recent year of assessment (FAO 2016, Fig. 1.1).

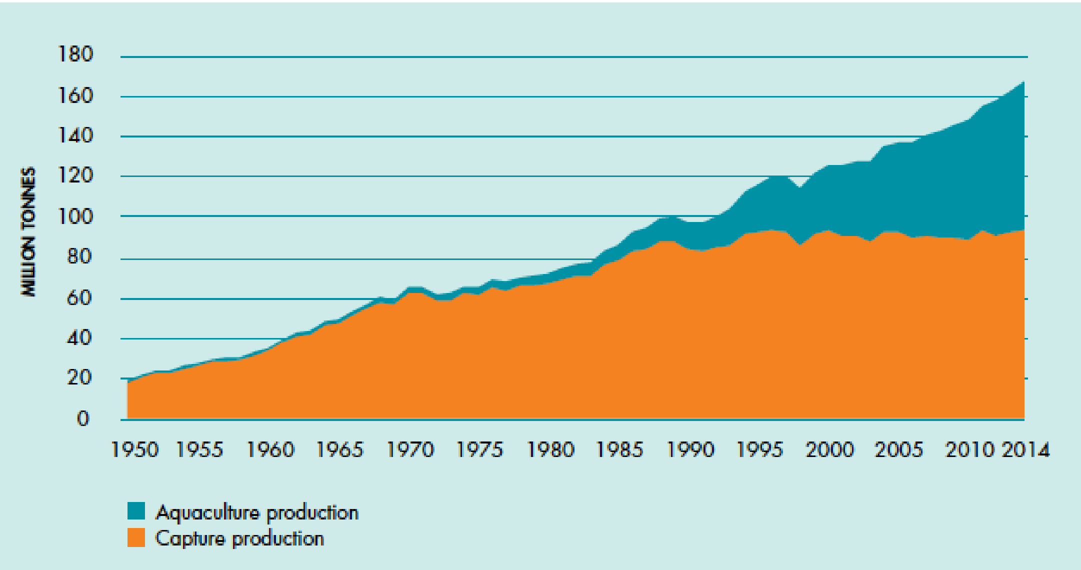

Figure 1.1: Capture fishery and aquaculture production (million tonnes) between 1950 and 2014 (taken from FAO 2016).

According to estimates that include unreported catches and discards (the part of catch that is thrown back into the sea), global marine catches peaked at 130 million tonnes in the mid-1990s and have since declined (Pauly & Zeller 2016a). The FAO (FAO 2016) and the *Sea around Us* project (Pauly & Zeller 2016a) estimate that global catches have likely reached their maximum level (Garcia & Grainger 2005). Growth in the seafood sector is now dominated by the aquaculture industry (Godfray et al. 2010; Allison 2011, FAO 2016). However, aquaculture production is associated with its own sustainability challenges in terms of limiting resources that include space, disease, freshwater scarcity and the sustainability of the fish caught in the wild and used as feed (Naylor et al. 2000).

Not only are global fish catches limited, but so are the individual fish stocks. Already within the first half of the 20th century, modern fishing technology had advanced to such a degree that overfishing and the depletion of fish resources became a reality (Russell 1931; Hjort et al. 1933; Graham 1939). At that time, the concept of maximum sustainable yield developed (Baranov 1926; Russell 1931; Schaefer 1954) being defined as the catch that can be obtained annually while maintaining the natural resource at productive levels. In 1975 the proportion of fish stocks with abundances *below* 'sustainable levels' was 10% and by 1989 this had risen to 26% (FAO 2016). Overfishing, without doubt, contributed to the collapse of a number of iconic stocks in the second half of the 20th century e.g. North Atlantic cod, North Sea herring, Atlantic bluefin tuna, and blue whales (Hannesson 2015). In the 1990s, the proportion of overfished stocks continued to rise, albeit at a slower rate. The percentage of overfished stocks peaked in 2008 (32.5%), and has since decreased slightly and in 2011 was estimated at 28.8% (FAO 2016).

The apparent recovery of some fish stocks (Cardinale et al. 2013), and the relatively stable global catch levels since the 1990s, have been used to refute the overfished status (Hannesson 2015) and the rhetoric of a global fisheries crisis has been criticized as being exaggerated and destructive (Hilborn 2004; 2007a; Beddington et al. 2007; Cinner et al. 2013). However, statistics on global catch levels do not take into account that the overfished stocks include highly productive fish stocks (Watson et al. 2003) and that the catch losses have been compensated by fisheries moving into new previously unfished areas (Pauly et al. 2005; Pauly 2009). Such underdeveloped fishing grounds include the deep sea (Clark et al. 2016), the Arctic (Christensen et al. 2014) and other high seas fisheries (Coelho et al. 2015), which were economically unattractive when more accessible stocks still provided good catches. Also, fisheries do not only remove fish, but also select for specific traits so that populations may undergo long-term or evolutionary changes such as selection for earlier sexual maturation (Kuparinen & Merilä 2007; Hard et al. 2008; Heino et al. 2015). Finally, fishing has also indirect effects by affecting the ecosystems that support these fish stocks (Jennings & Kaiser 1998).

The impacts of fishing on ecosystems have formed a major part of the rhetoric surrounding the global fisheries crisis (Pauly et al. 2002; Pikitch et al. 2004). Fishing affects marine habitats, and thereby, also the diversity, composition, biomass and productivity of the species that depend on these habitats (Jennings & Kaiser 1998; Fulton et al. 2005; Clark et al. 2016). During fishing operations, non-target species are caught as bycatch or discarded (Alverson 1994; Catchpole et al. 2005; Kelleher 2005; Davies et al. 2009; Bellido et al. 2011) which can have negative effects on populations of the bycatch species (Lewison et al. 2004) and is generally seen as a wasteful practice (Kelleher 2009; Diamond & Beukers-Stewart 2011). Fishing also has a direct impact on marine food webs. In the context of the fisheries crisis, the focus has been on long-lasting changes in the basic structure of food webs, the so-called regime shifts (Lees et al. 2006; Daskalov et al. 2007; Spencer et al. 2011), with the removal of top-predators subsequently causing cascading effects (Myers et al. 2007; Ferretti et al. 2010), and by reducing the average trophic level of food webs (Pauly et al. 1998; Branch 2010; Christensen et al. 2014). Long-lasting changes and degradation of marine ecosystems are not the only reason for concern; a decrease in the provision of resources and benefits to humans is also occurring and this can threaten human well-being (Palumbi et al. 2009).

1.3. Benefits derived from fisheries

People derive a variety of benefits from the oceans (Costanza & Folke 1997; Holmlund & Hammer 1999; Peterson & Lubchenco 2003; Barbier et al. 2011; Costanza et al. 2014). While some benefits are derived without human intervention (e.g. climate and water regulation), many require a human intermediary to transform natural processes into benefits for human use. Fisheries can be viewed as one such intermediary that uses fish and the oceans to provide a range of benefits. The main benefits provided by fisheries are the provision of food and livelihoods; they also offer the possibility for recreation and cultural experiences, e.g. as tourist attractions (Tokyo fish market, fishing villages) and as a source of local identity (Holmlund & Hammer 1999; Acott & Urquhart 2012; Hattam et al. 2015).

Of the combined production from capture fisheries and aquaculture, 87.5% is directly used for human consumption (FAO 2016). This means that the global consumption of fish is on average 20 kg per capita (FAO 2016). While developed countries are consuming more fish, and the consumption in developing countries is also rising (FAO 2016), indicating the importance of fish for global food security now and in the future (Godfray et al. 2010; Béné et al. 2016). Food security is defined as "a condition when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 2003). Fish as a food product is rich in proteins and fatty acids and has a particularly important role in securing sufficient nutritious food (Bell et al. 2009; Béné et al. 2016).

After food, employment is the most widely recognized benefit derived from fisheries. Globally, more than 50 million people are directly employed within the fishing industry (Teh & Sumaila 2013). Ain total, the livelihoods of 210 million depend directly and indirectly on the fishing industry (Teh & Sumaila 2013). Recreational fisheries create another million jobs (Teh & Sumaila 2013). Consequently, fisheries contribute significantly to national economies (Dyck & Sumaila 2010), and the global economic impact of fisheries output has been estimated at $301.2 USD billion (Sumaila et al. 2016). In countries where the contribution of fisheries to the overall economy is comparably small, it can still be an important economic activity in rural areas and areas with a historic dependency on the sea (e.g. Brookfield et al. 2005; Natale et al. 2013).

Fisheries also provide a wide range of cultural ecosystem services (Acott & Urquhart 2012), and these are defined as the non-material benefits (e.g. aesthetic, spiritual and psychological) derived from ecosystems (Millennium Ecosystem Assessment 2005). For fisheries, these include recreation, tourism, cultural identity, heritage values, sense of place, spiritual services, inspiration, aesthetic appreciation and educational opportunities (Close et al. 2002; Minnegal et al. 2003; Urquhart & Acott 2014). While there are many case studies describing them, cultural ecosystem services are difficult to measure (Winthrop 2014) so that often only recreation and tourism can be included when discussing the "value" of fisheries (e.g. Hattam et al. 2015). International trade in seafood, part-time employment and diverse livelihood strategies, and the difficulties in estimating cultural services make it difficult to completely assess those delivered by a fishery, but the combination of food supply, employment and cultural ecosystem services ensures that the continuation of fisheries is a management priority across the globe.

1.4. Fisheries management and its challenges

Fisheries provide valuable benefits for humans (Section 1.3) whilst also having serious impacts on natural resources and ecosystems (Section 1.2). Global recognition of the need to both continue to exploit marine resources, whilst conserving species diversity is captured in the United Nation's sustainable development goal 14 (SDG 14), which sets out to "Conserve and sustainably use the oceans, seas and marine resources for sustainable development"(United Nations General Assembly 2015). Achieving this balance is often seen as the core task of fisheries management (Rice & Garcia 2011).

Based on the concept of sustainable harvest evolved in 18th century from forest management (Carlowitz 1713; Wiersum 1995; Grober 2012), fisheries management initially aimed at achieving the maximum sustainable yield (MSY; Schaefer 1954). MSY is the yield that can be obtained annually while maintaining the natural resource at the most productive levels and this was the most influential concept in fisheries management throughout the 20th century (Pitcher & Pauly 1998; Charles 2001). However, it has also been a controversial objective for fisheries management because aiming at the highest possible yield makes it easy to overfish and because MSY perpetuates a single species approach that ignores ecosystem complexity (Gulland 1977; Larkin 1977; Cunningham 1981; Ludwig et al. 1993; Botsford et al. 1997; Roberts 1997). Due to these inherent flaws and a lack of political will to reduce overcapacity in the fishing industry (Ludwig et al. 1993) and implement and enforce sustainable catch levels (Daw & Gray 2005; Carbonetti et al. 2014), the MSY concept failed to successfully limit overexploitation. Nevertheless, the MSY persisted in fisheries management (Mesnil 2012), and was later used as an upper limit for fisheries catches rather than as a target (Mace 2001; Punt & Smith 2001). Recognizing the short-comings of MSY, natural and social fisheries science supporting management has sought complementary or superior concepts.

From an economic perspective, MSY evolved into the maximum economic yield (MEY), the catch that persistently maximized the differences between the total revenue and the total costs of the fishery as a whole (Gordon 1954). MEY has often been perceived positively for ecological reasons, because it tends to recommend retaining higher biomass levels in the stock than the MSY (Clark 1990; Grafton et al. 2007). But MEY is not always a "win-win" situation (Grafton et al. 2007) and the trade-offs between ecology and economics are apparent. MEY would recommend the immediate depletion of the stock in the case of profit-maximizing companies exploiting a common-pool resource (Clark 1973), thus conflicting with the essential component of sustained yield that is the future of the fisheries resources. Fisheries economists have tried to solve this issue through a rights-based approach, meaning that a fisher or part of the fishing sector buy long-term fishing rights so that they have an incentive not to overexploit resources (Grafton 1996). However, these approaches do not provide incentives to protect the ecosystem and associated species (Gibbs 2010) and often result in the concentration of property rights in the hands of few actors (Yandle & Dewees 2008), so that there have been worries about both the ecological and social consequences of property rights in fisheries (Eythórsson 2000; Yandle & Dewees 2008; Sumaila 2010).

From an ecological perspective, the most influential approach for fisheries management in recent decades has been ecosystem-based fisheries management (EBFM) which views fisheries as part of the ecosystem and thus takes a more holistic approach to fisheries management (Link et al. 2002; Pikitch et al. 2004; Francis et al. 2007). In its extended version, the Ecosystem Approach to Fisheries (EAF) also recognizes the interdependencies between humans and the ecosystem (Ward 2002). EBFM is widely accepted at the policy level (Murawski 2007; Smith et al. 2007), but its full implementation suffers from continuing uncertainty surrounding ecological processes and a lack of information (Link et al. 2002; Christie et al. 2007; Pitcher et al. 2009; Collie et al. 2016; Skern-Mauritzen et al. 2015). Therefore, EBFM is often applied as a more holistic approach to fisheries management that combines the management of individual fish stocks with the prevention of bycatch and the protection of habitats (e.g. through preventing the destruction of seafloor habitats by trawling; Hilborn 2011). Fisheries management has addressed the complexity of fisheries and ecosystem interactions by developing more and more complex models (Caddy 1999; Garcia & Charles 2007; Fulton 2010), however, the models can become so complex that they reduce in utility (Plagányi et al. 2014) and it has been suggested that fisheries are confronted by problems that are so complex that a technical solution cannot be found (Jentoft & Chuenpagdee 2009).

The most prominent of the problems that eludes technical solutions is the "Tragedy of the commons". Hardin (1968) described how the accessibility of common resources leads inevitably to their overexploitation because there is no incentive to preserve the resource for the future when others can easily capitalize on the immediate sacrifice. For a long time, strict state authority or private rights (discussed above) were thought to be the best solutions to the Tragedy of the Commons. However, it has been pointed out that while management and markets often fail at circumventing the Tragedy of the Commons, there are natural resource systems that are managed by the resources users themselves and achieve sustainability on their own (Ostrom 1990). This observation has promoted self-governance and co-management in fisheries (Townsend & Shotton 2008; Gutiérrez et al. 2011; Rodwell et al. 2014) and has stimulated research trying to identify the factors that lead to sustainable outcomes from self-governance and co-management (Gutiérrez et al. 2011; Cinner et al. 2016). This line of work is closely linked to the appreciation of local knowledge, adaptive management and resilience thinking (Berkes 2003).

While not an exhaustive list, maximizing yield, rights-based approaches, ecosystem-based fisheries management, and community-based co-management are presently the most prominent approaches for fisheries management (Caddy 1999; Garcia & Charles 2008; Selig et al. 2016). All four approaches employ a suite of restrictions on the inputs (e.g. limited access to fishing grounds, limited fishing time, or gear restrictions) and outputs (e.g. catch quotas) of fisheries and use different technical measures (e.g. spatial and temporal closures, size limits) (Selig et al. 2016). Most importantly, the approaches are not always mutually exclusive but can be combined (e.g. Mace 2001; Beddington et al. 2007).

So overall, fisheries management has a wide range of tools and much has been learnt over the last few decades, but there is a pervasive view that fisheries management has failed (Villasante 2010; Anticamara et al. 2011), given that more than 80 years after being recognized as a problem (Russell 1931) overfishing is far from being solved (Boonstra & Oesterblom 2014). The reasons why fisheries management has not always succeeded in securing sustainability are manifold. Fisheries are inherently difficult to manage because most of the resources are mobile, often crossing natural boundaries, are invisible to the human eye, embedded in complex ecosystem interactions, are exposed to several natural and anthropogenic pressures including environmental changes, and are inherently stochastic in nature, so that it is difficult to predict MSY or yield-based management. However, managed fisheries do tend to be generally more sustainable than those that have not been subject to management (Hilborn & Ovando 2014) and many success stories exist (Hilborn 2007a; 2016; Dankel et al. 2008; Cardinale et al. 2013; Cinner et al. 2013). Alternatively, fisheries management can be considered as a succession of periods of success and periods of failure (Smith 1977). Indeed the criteria for successful fisheries management may depend on whom you ask, so that the failure for one person can represent success for another (Hilborn 2007b). When even the formulation of a problem is subjective and difficult and its treatment presents constant challenges, these are referred to as "wicked problems" (Rittel & Weber 1973; Jentoft & Chuenpagdee 2009). Wicked problems are "complex, persistent or reoccurring and hard to fix because they are linked to broader social, economic and policy issues" (Khan & Neis 2010).

1.5. The social dimensions of fisheries

The observation that "people matter in fisheries" is far from new (e.g. Roedel 1975; Smith 1977), yet the value of people and their choices/needs and influences on fisheries sustainability are not well understood, even with the aspirations set out in ecosystem-based fisheries management. The interactions between the human systems and natural systems have historically been described primarily in economic terms (Vaccaro et al. 2010). Accordingly, fisheries economics (dealing with the human system) and the study of fisheries governance (dealing with the management system) were the first social science disciplines to be incorporated in fisheries science (Wilen 2000; Kooiman et al. 2005; Symes 2006; Pomeroy 2016). Up until the mid-2000s, the contributions of other social science disciplines to fisheries science and management were marginal (Orbach 1989; Jentoft 1997; Kaplan & McCay 2004; Pauly 2006; Bundy et al. 2008; Jacquet 2009; Urquhart et al. 2011; Cinner et al. 2013; Pomeroy 2016). This changed because of the continuing fisheries crisis and the subsequent need for new solutions (Kooiman et al. 2005) and because of international agreements and conventions that expressed a societal demand for a more holistic approach to resource exploitation (Garcia & Charles 2007).

Fisheries are conceptualized as systems that consist of related and interacting subsystems (Garcia & Charles 2007). One possible division of the fishery system into subsystems is that fisheries consist of a natural system, a management system, and a human system (Charles 2001). These subsystems are connected to each other through an adaptive management cycle (Fulton et al. 2011), with resource dynamics in the natural system monitored and assessed by the management system. Based on these assessments, the management system makes decisions that it transfers to and implements within the human system. The human system performs fishing activities and has subsequent impacts on the natural system (Fulton et al. 2011). Within this conceptualization, natural sciences are concerned with the resource dynamics (the natural system) and its assessment (part of the management system), and the social sciences are concerned with the management decisions (another part of the management system) and the fishing activities (the human system).

There are three main strands of additional social sciences that can be considered essential for resolving the fisheries crisis and improving its sustainability. (1) Understanding human behaviour and social drivers because they have major impacts on fish stocks and ecosystems. (2) Including societal goals such as food provision and employment within fisheries management because these are the goals commonly traded off against the ecological goals. (3) Analysing the social qualities of the processes of fisheries and fisheries management, e.g. fairness and justice. It has been suggested that resource managers cannot manage the fish directly, only the people exploiting the fish (Jentoft 1997; Hilborn 2007c), so that without understanding the human dimensions of fisheries, the management is bound to fail (Kooiman et al. 2005). A holistic approach to fisheries management is perhaps needed most in those fisheries where the fishery is a key part of economic and social structures (small-scale fisheries).

1.6. Small-scale fisheries

The use of the terms coastal, inshore, small-scale and artisanal fishery varies between countries dependent on fishing grounds, national administration, fleet structure and technological development (Carvalho et al. 2011; Freire & Garcia-Allut 2000; Stobutzki et al. 2006). There has been much international focus on small-scale fisheries related to their critical role in supporting coastal communities in economically less developed countries (Béné 2006). The FAO has now developed an explicit policy vision for small-scale fisheries that recognises their key role in supporting coastal communities' social and economic structures, but recognises the challenges they face in terms of ensuring effective sustainable management and competition with industrialised fisheries in increasingly international markets (FAO - http://www.fao.org/fishery/ssf/en).

In most developed countries small-scale fisheries exist alongside 'industrialised' commercial fisheries. These fisheries are often seasonal (or at least switch target species seasonally), and tend to fish from small vessels, with those involved tending to be self-employed, or working in small businesses (Guyader et al. 2013). These fisheries typically have a greater proportion of fishers working part-time, and are partly reliant upon other forms of income and often operate in rural locations (Walmsley & Pawson 2007) where fuel, equipment and transport costs are higher compared with those for fleets operating out of major ports. Governments often impose less stringent data reporting requirements on these fisheries – easing the regulatory burden on the fishers, but reducing the availability of data on which to base management.

Technological advances and the falling costs of engines, satellite navigation systems, 'fish finders' etc., have seen the fishing power of the small-scale fisheries across the world increase (Symes & Phillipson 1997), but this is perhaps most significant in developed countries. For example in the UK, significant reductions in the number of large and medium-sized vessels have been offset by an increase in small fishing vessels (Fig. 1.2) relying on greater fishing power than previous small fishing vessels so that the fleet power has not decreased as much as the number of fishing vessels (MMO 2013). So these fisheries are responsible for a significant proportion of the catch (UK estimates suggest that over half the vessels operate in the inshore sector), and their social and political importance may be higher while their economic impact is constrained by access to markets, lack of security of supply, and high costs.

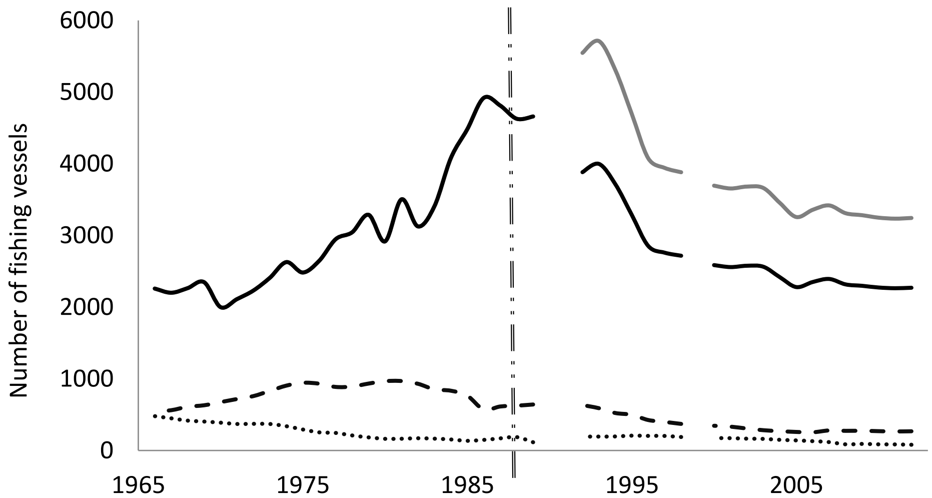

Figure 1.2: Number of fishing vessels of a size of <12 m (solid line), 12-24m (dashed line), and >24m (dotted line) for England and Wales combined from 1966 to 2013 based on the Marine Management Organisation's (MMO) annual fishery statistics. Missing values in 1990, 1991 and 1999. Solid grey line after 1992 is the number of all fishing vessels registered, the parallel solid black line after 1992 is the number of fishing vessels being active assuming an activity level of 70% (SAIF 2010) in order to continue the time series consistently with the data from 1966 to 1990.

Small-scale fisheries are also important from an ecological point of view because they mostly take place in coastal areas that provide a range of habitats for plant and animal life and are known for their biodiversity (Costello et al. 1996; Gray 1997). This means that small-scale fisheries are often potentially in conflict with (biodiversity) conservation management, but are also vulnerable to pressures on the ecosystem from development and reduced water quality (Andrew et al. 2007). Around 120 fish species alone can be found in English inshore waters (Henderson 1989) that also serve as nursery grounds for fish occurring offshore, such as herring, cod, whiting, plaice and sole (Ellis et al. 2012) and as feeding and resting area for seabirds (Tucker & Heath 1994). The limited absolute area of coastal habitats (compared to the high seas habitats) means that inshore areas are a focal point of nature conservation. Approximately 23% of English inshore waters are protected under the European Birds and Habitats Directives (DEFRA 2012); together with the intertidal Sites of Special Scientific Interest, national designated Marine Conservation Zones and Ramsar sites of international importance, these form an extensive network of Marine Protected Areas (HM Government 2011). While fisheries are permitted in the majority of these areas, the nature and intensity of use is increasingly constrained by biodiversity management.

The sustainability of fisheries and integrated ecosystem approaches to fisheries management are required by national (e.g. Marine and Coastal Access Act 2009; Marine Strategy Regulations 2010) and international laws and regulations (e.g. FAO Code of Conduct for Responsible Fisheries 1995; 5th Conference of the Convention on Biological Diversity 2000; the Reykjavik Declaration 2001; World Summit on Sustainable Development 2002). These frameworks do not distinguish small-scale fisheries from other types of fishery. However, the lack of data has prompted recognition by the FAO that small-scale fisheries are a distinct management challenge (FAO 2015).

Focusing on small-scale fisheries, Pomeroy (2016) reviewed the history of social fishery science by decade: in the 1970s, social fisheries science focused on the understanding of fishing households and communities. In the 1980s, socioeconomic approaches dominated and governance studies predominated in the 1990s. The 2000s saw a broadening of topics and approaches including the ecosystem approach to fisheries, the sustainable livelihood approach, well-being, social-ecological systems, complex adaptive systems, management for resilience and others (Pomeroy 2016). These approaches continued to be studied in the 2010s together with newly emerging market-based approaches and management approaches that integrated different ocean uses (Pomeroy 2016). Pomeroy (2016) concluded the review by pointing out that the different approaches are still “often not utilized together in an integrated manner”.

So the focus to date has been on the social science of small-scale fisheries that are often critical to the social, historical and economics of small coastal communities. This gives the issue a political importance that exceeds their direct economic value. However, the ability to manage these fisheries is constrained by the lack of understanding of the fishery system. The transient nature (seasonal migrating stocks) and/or temporal variability (boom or bust) of the resource, and the lack of biological models of population dynamics and the data to make such models, all constrain the application of traditional approaches to fisheries management in these systems.

1.7. Research objectives and structure of the thesis

This Chapter has explained the context and background to fisheries sustainability, the nature of small-scale fisheries, and the development and limits of fisheries management. It identifies the need to further understand and develop tools for assessing the sustainability of small-scale fisheries and elaborates on the research needs. The overall objective of this dissertation was to contribute to the development of approaches to holistically assess the sustainability of small-scale fisheries. In this thesis, I will explore the concept of sustainability and ways of determining and supporting sustainable fisheries in the following way:

Chapter 2 uses a quantitative linguistic approach to analyse the different meanings that the sustainability concept may take within different fisheries science contexts, and to explore whether there are meanings that stay the same across different contexts (Fig. 1.3). Sustainability is a complex and seemingly abstract concept, and to achieve sustainability it is important to first understand what is meant by the term. Existing definitions of fisheries sustainability leave the concept open to interpretation. Chapter 2 suggests a sustainability definition that is not meant to replace other definitions, but to help improve our understanding of sustainability by compiling, comparing and analysing the different meanings that are already in use. Given the necessities of small-scale fisheries, it was of particular interest if there has been a change over time in the understanding of sustainability away from ecological sustainability and towards socio-economic or a holistic understanding of sustainability.

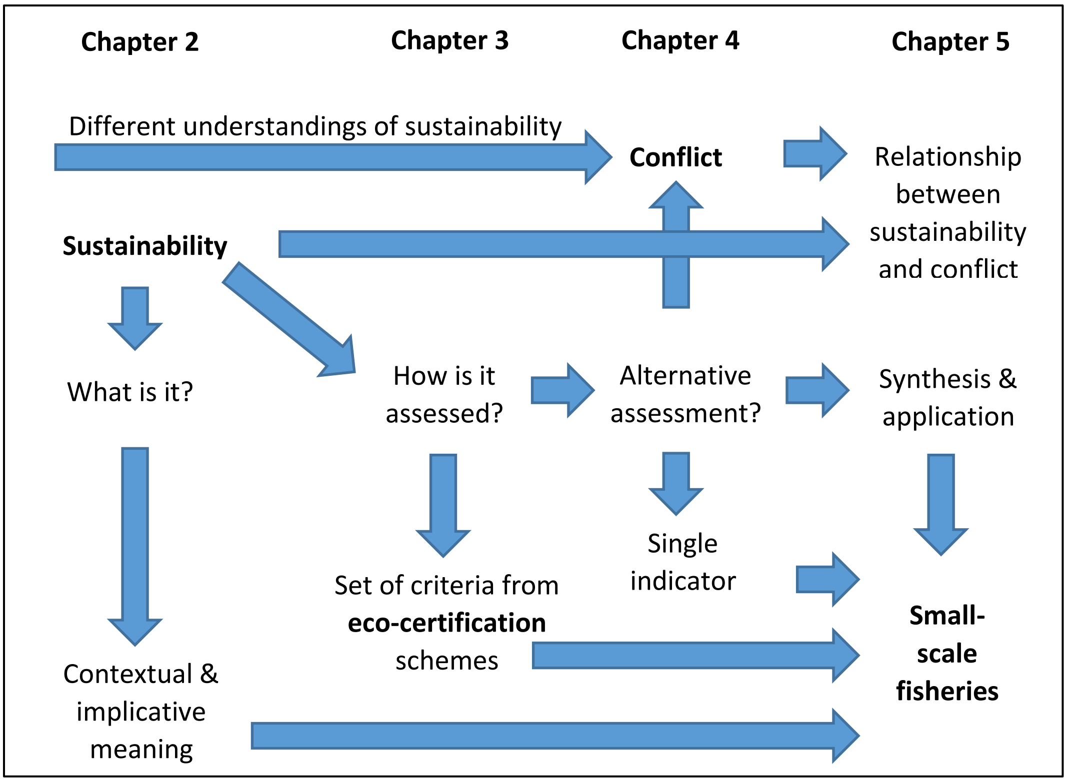

Figure 1.3: Overview of key concepts (in bold) and structure of the thesis.

After sustainability, **Chapter 3** addresses with eco-certification a second key concept in fisheries science (Fig. 1.3). It investigates how fisheries sustainability is assessed currently from the perspective of eco-certification and other sustainability assessment standards. Thereby, it specifies the definition of fisheries sustainability derived in Chapter 1. It compares the market-based fisheries sustainability standards using their individual sustainability criteria, and it identifies which are most commonly used, forming a core definition within the standards. Based on a review of published case studies from sustainable fisheries, new criteria are proposed that complement those predominantly used in the fisheries sustainability standards to identify how such sustainability stands could be better applied to small-scale fisheries.

Based on the finding that existing sustainability criteria (Chapter 3) are not sufficient to fully operationalize the sustainability definition developed in Chapter 2, **Chapter 4** deviates from the common approach of using a set of indicators and criteria to assess sustainability and explores the use of a single but comprehensive indicator, conflict (Fig. 1.3). Conflict is a common phenomenon in fisheries, but it is rarely used as a theoretical tool. In Chapter 4, the usefulness of conflict as sustainability indicator is explored as well as the relationship between this social phenomenon and ecological sustainability. Conflict analysis could be an add-on to stock assessments and highlights the importance of people, dialogue and cooperation, and thus might be suitable to support small-scale fisheries management.

In **Chapter 5**, the meaning and application of the results for determining and supporting the achievement of fisheries sustainability are discussed, with particular reference to the challenges faced by small-scale fisheries and the relationship between sustainability and conflict

This thesis has analysed extensive literature and assessment frameworks to develop approaches that can be applied to provide robust sustainability assessments for the ecological, social and economic dimensions of small-scale fisheries. These tools could be incorporated into market based schemes tailored towards inshore and small-scale fisheries and hence provide incentives that help to drive improvements in fisheries sustainability.

2. Improving our understanding of the meaning of ‘sustainability’

Abstract

Sustainability is a central notion in the management of natural resources but its usefulness as a management principle has been challenged because of the ambiguity of the ‘sustainability’ concept. This study analysed the multiple meanings of ‘sustainability’ in 4500 scientific publications on topics related to fisheries sustainability, published between 1990 and 2015. Citation network analysis revealed 19 research areas that shared an ecological understanding of sustainability. Approximately half the publications further focused on fisheries yield and limiting the pressures on ecosystems, while the other half complemented the ecological understanding of sustainability with a socio-economic component. Linguistic analysis revealed there to be a number of implicative meanings associated with the fisheries science literature, sustainability as: continuity through time, the delivery of benefits, and the processes that achieve sustainable outcomes. Reasons for the ambiguous use of ‘fisheries sustainability’ are discussed and ‘fisheries sustainability’ is defined based on the results of the empirical text analysis as “*the continuous existence of the socio-ecological fishery system, in such a way that it provides goods and services now and in the future, without depleting natural resources, and the sustainable processes that make both possible*”. Furthermore, it is suggested that the elements of the sustainability concept as applied to fisheries science, can be captured in a four-layer conceptual model, whereby dialogue is the outermost layer, and is required in order to set the societal limits or objectives for sustainability. The new sustainability definition and the suggested broader 4-level model could contribute to the operationalization of sustainability goals, improve the communication between stakeholders, and inform sustainable consumer choices.

2.1. Introduction

Sustainability has long been the key concept within all the fields of natural resource management that have to balance the needs of nature and society (Brklaccich et al. 1991; Wiersum 1995; Mace 2001). The UN report ‘Our Common Future’, also known as the Brundtland Report, examined the interconnectedness of the natural environment and societal development (Brundtland 1987) and paved the way for the global recognition of the need for sustainability (Mebratu 1998). Since then, sustainability has become an integral part of the work of governments (United Nations General Assembly 2015) and corporations (Epstein 2008), and a major area of interest for science (Kates 2011).

One of the core areas for sustainability science are fisheries (Kajikawa et al. 2007), where sustainability considerations have always formed an integral part of science and management (Mace 2001). The emergence of eco-certification schemes as a relatively new way of safeguarding sustainability (Ward & Phillips 2009; Chapter 3) and the FAO´s guidelines for securing sustainable small-scale fisheries (FAO 2015; Chapter 1) have led to a renewed interest in the concept of sustainability. A good understanding of 'sustainability' is essential for both eco-certification and small-scale fisheries: without a clear definition of 'sustainability', the fishing industry and the communities dependent on it may be losing out on potential benefits (Shelton & Sinclair 2008), and eco-certification may be granted to fisheries that are not commonly accepted as being sustainable thus undermining the trust in sustainable seafood schemes (Eden et al. 2008; Ben Yousef & Abderrazak 2009; Brécard et al. 2012).

As of now, there is no universally accepted definition of fisheries sustainability (Hilborn et al. 2015). The term appears in national legislation and international agreements (e.g. FAO 1995), but the interpretation of 'sustainability' varies between treaties and has changed over time (Rice 2013). The concept has evolved (Mace 2001) and its definition depends on the underlying philosophical assumptions of the individual applying it (Baghramian 2001).). The goals pursued to achieve sustainability can be as different and potentially irreconcilable as economic efficiency and the provision of employment, or export-oriented production and local food supply (Staples et al. 2004). This variability has led to the conclusion that sustainability is dependent on the individual and cultural context (Garcia & Staples 2000; Hilborn 2005; Shelton & Sinclair 2008; Hilborn et al. 2015) and, essentially, means "different things to different people" (White 2013).

However, the context-dependency of the sustainability concept has been challenged (Shearman 1990). Across several agricultural contexts (Brown et al. 1987), the different perspectives on sustainability were found to always boil down to the meaning of sustainability as "a continuity through time" (Shearman 1990). This definition of sustainability is not very useful because it does not cover what we expect to "continue through time" and how this might be achieved (Hilborn 2005), but it shows a way of defining sustainability in a way that its meaning does not vary from one context to the next. Shearman (1990) called this the *implicative meaning* where a concept changes our understanding of another concept (Shearman 1990). The implicative meaning considers what is understood by a particular combination of terms, e.g. what is meant by a "sustainable fishery" in comparison with just a "fishery" or an "unsustainable fishery". For example, 'sustainable' can change the meaning of 'economic development' from measureable economic growth to a multifaceted improvement in the living standards of the poor ('sustainable economic development') (Barbier 1987).

For the following analysis, the implicative meaning is understood as the (perhaps hidden) meaning(s) of a term which modifies the meaning of the terms with which it is paired in a consistent manner, whatever the context is. The contextual meaning is the meaning of a term that only unfolds in a specific context e.g. the wider perspective, theory or socio-cultural context in which the term is embedded.

Given the complexity of sustainability challenges, this study does not suggest that 'sustainability' has only a single meaning. Instead, it was the aim of this study to improve our understanding of fisheries sustainability by studying both the contextual and the implicative meaning in the fisheries science literature. So far, fisheries sustainability has only been analysed in historic (Mace 2001) or conceptual reviews (Charles 2001; Stojanovic & Farmer 2013; Hilborn et al. 2015). To ensure that all contexts in which sustainability is applied in fisheries science are included, and to minimise potential bias through the reviewer's own individual and cultural perspective on fisheries sustainability issues, a novel approach from empirical linguistics analysis, previously used to study the academic landscape of sustainability science (e.g. Kajikawa et al. 2007), was employed.

2.2. Methods

2.2.1. Identification of research areas (by citations)

Scientific publications were used to assess the contextual meaning of fisheries sustainability because they reflected a broad range of perspectives on sustainability. The publications were sampled from the core collection of Web of Science (as at 13.02.2016) using the search terms "sustainab*" or "unsustainab*" and "fisheries" or "fishery" or "fishing" in the publication title, abstract or keywords for a period of 26 years (1990 to 2015). The search only went back to 1990 in order to focus on the more contemporary meaning of sustainability in fisheries science. The search yielded 6305 publications which were exported with CitNetExplorer v. 1.0.0 (Van Eck & Waltman 2014) and converted into a citation network with the R package igraph (version 1.0.0) (Csardi 2015).

A citation network displays publications and the references between the publications as a network in which each publication is treated as a node and each reference as a link between two nodes (Kajikawa et al. 2007). 1731 publications that were not citing or being cited by the other publications and that, therefore, were not connected to the main network were deleted. Inspection of the titles and abstracts of the unconnected and thus deleted publications confirmed that they were not dealing with fisheries sustainability. The remaining 4574 publications were checked individually for their relevance. Duplicated publications (*N*=8), book reviews (*N*=2), publications dealing with terrestrial hunting (*N*=7), forestry (*N*=6), farming (*N*=7) and other topics not relevant for fisheries (*N*=8) were deleted from the network. These publications were picked up by the original search e.g. because they adopted an approach from fisheries to another domain. Publications that had a distant relationship to fisheries e.g. agriculture having an impact on water quality, were kept and included in the further analysis. After the removals, publications that were not connected to the main network anymore were deleted as well (*N*=3). Also deleted were two small self-citation networks (*N*=33). Self-citation networks were located at the edge of the network and only connected to the network through one citation. They were not being cited by others papers in the network, consisted of many papers published in a few years, and were authored by one scientist with the same group of secondary authors. The final network consisted of 4500 publications. The trend over time in their year of publication was compared to the trend over time for publications retrieved from the Web of Science Core collection when searching only for “fisheries” or “fishery” in publication title, abstract and keywords.

The citation network was clustered to identify research areas within the fisheries science sustainability literature (Kajikawa et al. 2007). Clustering was performed using a modularity optimization algorithm for finding community structure (Blondel et al. 2008) and maximum modularity as the evaluation criterion for the quality of the clustering solution (Clauset et al. 2004). The modularity optimization algorithm is an agglomerative approach to hierarchical clustering where in an iterative process; nodes are assigned to the cluster with which they contribute most to the overall modularity of the network (Blondel et al. 2008). Modularity compares the ratio between the connections inside the clusters and the connections between the clusters with the number of connections that would be expected for a randomized network (Clauset et al. 2004). With the nodes being merged to larger clusters, modularity increases until the optimum clustering solution is reached. In real-world applications, good optimal clustering solutions typically render a maximum modularity *Q* between 0.3 and 0.7 (Newman 2004). The clusters were labelled according to the topics of the twenty publications with the most citations in each cluster. To confirm that the clusters corresponded to fisheries research area, the content of the most cited publications was analysed as well as the development of the clusters over time in terms of number of publications per year by using linear regression to assess the trend in publications over time.

2.2.2. Extraction of key terms

Of the 4500 publications in the citation network, 4410 publications (98%) contained an abstract that could then be used for the extraction of key terms. Before extracting the key terms, special characters were removed from the abstracts, upper cases were turned into lower cases, British spelling was aligned with American spelling, the use of hyphens was standardized, and plural forms of nouns were converted into their singular forms.

Key terms could be single words (e.g. “overfishing”) as well as compound terms (e.g. “fisheries management”). The abstracts contained ca. 21000 different words of which 36% occurred only once. Only terms that passed a minimum frequency threshold were included in the analysis. As a minimum frequency threshold, the rule was used that any key term compound of two words (e.g. “fisheries management”) must have occurred in at least 1% of the 4410 abstracts (i.e. F_2=44).

Two words forming a compound term are less likely to both appear randomly in the same abstract than a single word but more likely to appear together than three words. Therefore, the minimum frequency threshold had to be greater for terms consisting of single words and lower for terms consisting of three words. To calculate the minimum frequency threshold for single words, the question was: if paired with the most frequent single word, what has to be the frequency of an unknown single word to just pass the minimum frequency threshold of F=44 for compound terms?

The calculation was:

Terms composed of (1) 1 word: $F_1 = F_2 / F_{max} * N_{abs}$

(2) 2 words: $F_2 = 0.01\% * N_{abs}$

(3) 3 words: $F_3 = F_2 * F_{max} / N_{abs}$

where F is the minimum frequency threshold for terms composed of one, two or three words, F_{max} is the frequency of the most common noun, and N_{abs} is the number of abstracts. The most frequent noun in this study was "fishery" (F_{max}=2815). Consequently, the minimum frequency threshold were F_1=70 for single word terms and F_3=28 for terms consisting of three words.

Single word terms were extracted using the word cruncher function of Atlas.ti (Muhr 2004). Not counting numbers and single letters, 1303 words passed the minimum frequency threshold. Words were eliminated if they were not a noun (N=724) to ensure equivalence between single word and multi-word terms. Names of countries, places and species (N=40) were eliminated to be able to discover overarching sustainability themes that transcend geographical and species boundaries.

Multi-word terms were identified using the term management system TerMine (www.nactem.ac.uk/termine). TerMine relies on a combination of linguistic and statistical methods to extract technical multi-word terms (Frantzi et al. 2000). 228 of the multi-word terms extracted by TerMine had a frequency above the minimum frequency thresholds. After eliminating nonsensical word combinations and names of countries, places and species, 196 multi-word terms remained. Visual inspection showed that TerMine had not been able to extract multi-word terms that contain very short words, therefore the two terms "sustainable use" and "resource use" were added to the list.

The combined candidate list of single and multi-word terms consisted of 737 terms. Some of the single word and two word terms occurred within other longer terms (Frantzi et al. 2000). If the short word did not pass the minimum frequency threshold anymore when subtracting it from the times when it occurred as part of a longer term, the short term was deleted from the list. E.g. "security" appeared in 149 abstracts, but 123 times as part of the term "food security", therefore "security" was deleted from the term list. Thirty nested terms were deleted, leaving 709 key terms for the analysis of the contextual meaning.

2.2.3. Contextual meaning of fisheries sustainability

The frequency of the 709 key terms (identified under Section 2.2.) was analysed over all abstracts as well as their frequencies within the research areas (identified under 2.1). A Shapiro-Wilk test of normality was used to identify the terms that occurred equally often across the research areas and which ones were specific to one or few research areas. To further differentiate between "general" terms that occur across all groups and "specific" terms that play only an important role in one or two areas of research, the key term frequencies per research areas were standardized by the overall frequency of a key term in an additional step.

Searching for overarching sustainability themes, research areas were grouped using the correlation in rank of the key terms used in the research areas. Spearman's rank correlation was used because all clusters had a right-skewed distribution and smaller clusters, with less than 200 publications, did not contain some of the key words. Due to shared common terms, all research areas used to some degree similar terms. Therefore, the distribution of the correlation coefficient (Spearman's *rho*) was taken into account: two research areas having a correlation coefficient below the first quartile were considered to be weakly correlated, correlation coefficients between the first and the third quartile corresponded to a medium-strong correlation, and a correlation coefficient above the third quartile signalled a strong correlation.

2.2.4. Implicative meaning of sustainability

The basic idea of the implicative meaning is that pairing "sustainable"/"sustainability" with other terms changes our understanding of the meaning of those terms (Shearman 1990). When the implicative meaning was first proposed as a way of analysing an abstract concept, Shearman (1990) proposed that "sustainability" was consistently used to mean "a continuity though time" as in "the continued satisfaction of basic human needs" and in "the continued productivity and functioning of ecosystems" (Brown et al. 1987). Shearman thus deemed "to continue" or "to sustain" to be the implicative meaning of sustainability (Shearman 1990). Based on reviews of fisheries sustainability (Charles 2001; Hilborn et al. 2015), it was expected that (1) Shearman's (1990) definition of the implicative meaning of sustainability would hold true for fisheries where the '*what*' we expect to "continue through time" would be what we might call 'sustainable fisheries outcomes'; and that (2) sustainability had a second implicative meaning in the fisheries context that refers to the '*how*' this might be achieved ('processes to achieve sustainable fisheries').

To operationalize the determination of the implicative meaning, the following example was considered: in the formulation "to sustain/ to continue a sustainable fishery" the verb is redundant if the implicative meaning of sustainability was "a continuity though time". So if a verb is used with a key term, but not with word combinations that include "sustainable" or "sustainability", the meaning of the verb is implied in the "sustainable"/ "sustainability" part of the word combination. Based on this consideration, a comparison was made of the verbs used with word combinations of "sustainable"/"sustainability" and key terms, with the verbs used with the same key terms without the "sustainable"/"sustainability" modifier (e.g. compare the verbs used with "sustainable fishery" and with "fishery"). This approach provided also the flexibility to examine if "sustainability" had other implicative meanings that had not been explicitly stated before.

The basis for the analysis of the implicative meaning was a set of word combinations with "sustainable" or "sustainability". Due to grammatical structure rules, only the following word combinations with "sustainable" or "sustainability" were possible and searched for:

1. sustainability + key term (e.g. sustainability concept)
2. key term + sustainability (e.g. community sustainability)
3. sustainable + key term (e.g. sustainable fisheries management)
4. adverb + adjective + sustainability (e.g. maximum sustainable yield)
5. adjective + sustainability (e.g. environmental sustainability)

Using the 709 key terms identified under Section 2.2, all terms that were paired with "sustainable"/"sustainability" across the 4410 abstracts were extracted. As previously only nouns had been extracted as key terms, combinations of "sustainability" with adjectives were missing, and word combinations with adjectives that passed a frequency criterion were added. Trials showed that this minimum frequency was between ten and twenty occurrences of a word combination, dependent on how often it was used with verbs. The word combinations that made the cut and their verbs were used to derive the implicative meaning. Furthermore, the occurrence and frequency of the word combinations in the research areas identified in Section 2.1 were assessed.

2.3. Results

2.3.1. Identification of research areas (by citations)

The field of fisheries sustainability science contained 4500 publications according to the literature search in the Web of Science Core Collection. The 4500 publications were connected to each other by 17807 citations. The clustering solution yielding the highest modularity (Q = 0.555) divided the citation network into 23 clusters (Fig. 2.1). On average 64% (SD = 6.5%) of the citations were within the same cluster thus confirming that the field of fisheries sustainability science contains several discrete but interconnected research areas. Inspection of the twenty most highly cited publications in each cluster confirmed that the 23 clusters corresponded to clearly identifiable research themes.

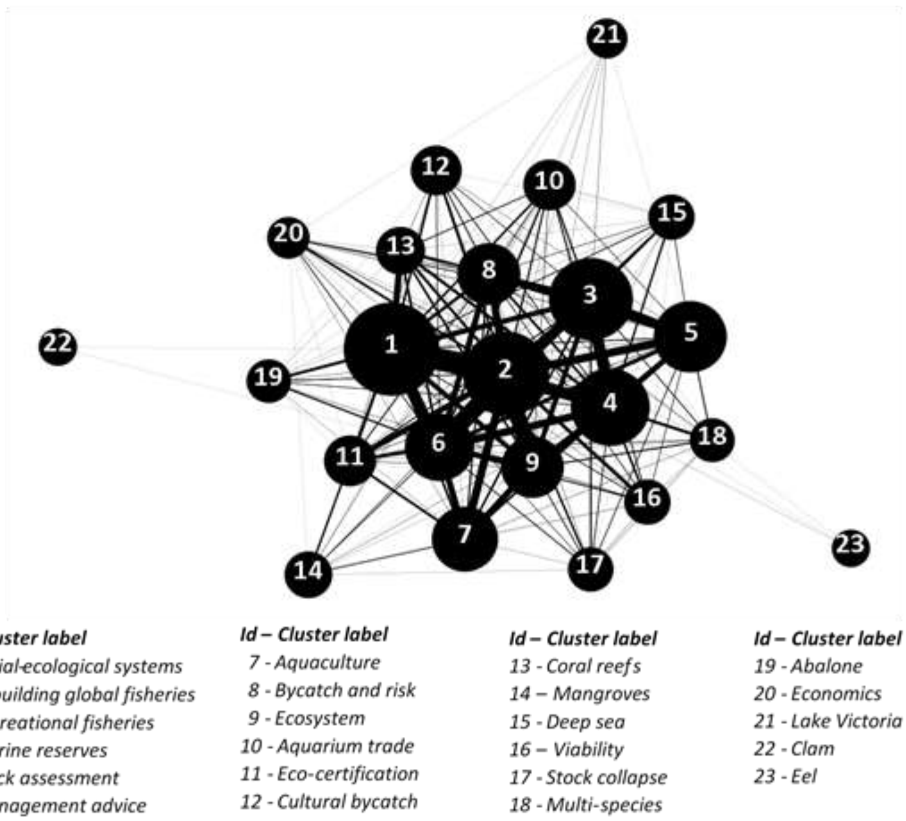

Figure 2.1: A citation network where papers are located within nodes and links between the nodes represent citations. Size of nodes relates to the number of publications within each cluster and thickness of the connecting lines to numbers of citations

The largest cluster treated fish as a common pool resource and fisheries as socio-ecological systems ("*Socio-ecological systems cluster*") (Fig. 2.1). Other large clusters were concerned with the rebuilding of global fisheries, recreational fisheries and evolutionary time-scales ("*Recreational fisheries cluster")*, marine reserves, fish stock assessment, methods and management advice ("*Management advice cluster*"), life cycle assessment and aquaculture production ("*Aquaculture cluster*"), and food web interactions and ecosystem-based management ("*Ecosystem cluster*").

Two clusters were dedicated to the issue of bycatch with one focusing on the risk that the populations of non-target species and particularly sharks are exposed to due to fishing and the implications for management ("*Bycatch and risk cluster*") whereas the other was more concerned with cetaceans and bycatch in traditional and small-scale fisheries ("*Cultural bycatch cluster*"). Other smaller clusters dealt with corals, crabs, seahorses and aquarium trade ("*Aquarium cluster*"), the eco-certification of sustainable seafood products ("*Eco-certification cluster*"), coral reef fisheries ("*Coral reef cluster*"), and mangrove forests ("*Mangrove cluster*") as well as the effect of trawling on the deep sea ("*Deep sea cluster*"), the viability of fish stocks, particularly ground fish stocks, using ecosystem-based fisheries management and bio-economic models ("*Viability cluster*"), the impacts of climate and fishing and the collapse of cod stocks as well as the situation of fish stocks in the North Sea and the Baltic Sea (*Stock collapse cluster*), predator-prey interactions and the maximum yield for multiple species ("*Multi-species cluster*"), Abalone stocks, fishing in South Africa and poaching ("*Abalone cluster*"), maximum economic yield and bio-economic models ("*Economics cluster*") and the fish community in the Lake Victoria ("*Lake Victoria cluster"*). Two very small clusters (N < 10) dealt specifically with clam and eel fisheries (Fig. 2.1).

Over all clusters, the 4500 articles were not published uniformly, but their number increased exponentially from 1990 to 2015. Over the same period of time, publications containing only "fishery" or "fisheries" in their titles, abstracts or keywords, but not necessarily "sustainable" or "sustainability", also increased by the power of 10. In comparison with the total number of publications on fisheries in general, the share of the ones dealing with sustainability increased linearly through time from 2% in the early 1990s to 12 – 14 % in the 2010s (F (1, 24) = 446, $p < 0.001$; Fig. 2.2) with an R^2 of 0.947.

The year of publication can indicate the emergence of, or increased interest in, new research areas, as well as the lack of the interest. When looking at the 23 clusters individually, the eco-certification cluster exhibited the greatest increase over time, followed by the clusters on rebuilding global fisheries and social-ecological systems. Other research areas with an above average increase of publications were the clusters on recreational fisheries, marine reserves, aquaculture, and on bycatch and risk. The abalone, Lake Victoria, clam, and eel clusters were the only clusters without a significantly increasing number of publications and as they all dealt with specific target species or areas and contained very few publications I felt that they were unlikely to represent meaningful research areas in terms of setting the broad context of sustainability in fisheries overall and they were excluded from the further analysis.

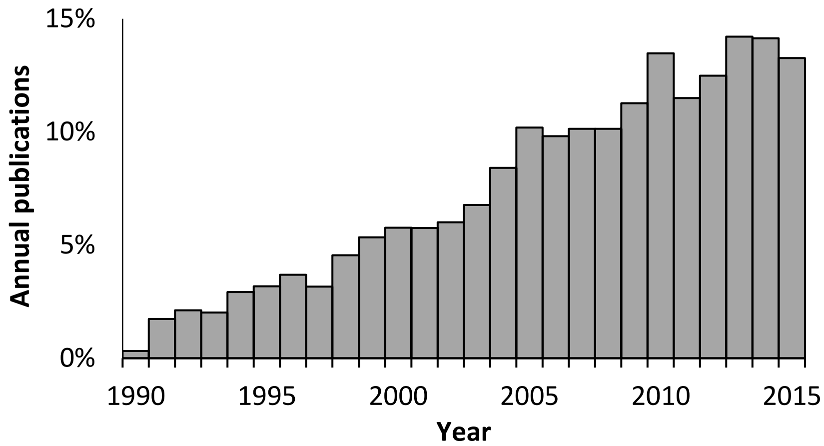

Figure 2.2: Publications in the Web of Science Core Collection which contain sustainab* or unsustainab* and "fishery" or "fisheries" in their title, abstract or keywords as a share of all publications which contain "fishery" or "fisheries" in their title, abstract or keywords.

2.3.2. Extraction of key terms

Of the 709 key terms identified, a median number of 35 key terms occurred in each abstract. Looking across all 4410 abstracts, the terms that occurred most often were "fishery" (64 % of abstracts), "management" (39 %), and "species" (37 %) (Table 2.1). "Sustainability" was one of the ten most frequently occurring key terms and could be found in nearly a third of the abstracts. The most frequently used multi-word terms were "fishery management" (19 %), "maximum sustainable yield" and "fish stock" (9 %). The key terms fell roughly into three groups of words: terms that specifically referred to fish, fisheries and management, like the ones just quoted; terms that were related to methods and science (e.g. "result" and "study", 33 % of abstracts); and rather general terms from the English language (e.g. "year", "area" and "change", 22 %; Table 2.1). Of the 100 most commonly used key terms (Table 2.1), the vast majority dealt with biological sustainability, i.e. fish stocks, their exploitation, and methods to estimate both. Terms related to management measures, the ecosystem, or humans were also present, but less frequent (Table 2.1).

Table 2.1: Occurrence of the most common key terms across the abstracts of 4410 publications dealing with fisheries sustainability. Plural forms were turned into singular for the analysis.

Rank	Key term	Occurrence	Rank	Key term	Occurrence
1	Fishery	2815	51	Assessment	544
2	Management	1742	52	Water	538
3	Species	1618	53	Biomass	534
4	Result	1462	54	Framework	534
5	Fishing	1439	55	Strategy	532
6	Study	1438	56	Abundance	524
7	Level	1331	57	Region	519
8	Fish*	1247	58	Support	517
9	Sustainability	1227	59	Increasing	513
10	Population	1202	60	Factor	512
11	Data	1104	61	Key*	507
12	Resource	1086	62	Dynamic*	493
13	Model	1067	63	Mean	486
14	Stock	1065	64	Case	482
15	Analysis	1064	65	Benefit	479
16	Catch	1039	66	Range	474
17	Year	988	67	Issue	472
18	Area	986	68	Harvest	466
19	Change	969	69	Understanding	465
20	Impact	939	70	Rate	462
21	System*	932	71	Decline	461
22	Approach	924	72	Fisher*	461
23	Ecosystem	916	73	Human	458
24	Use	903	74	Country	453
25	Effect	888	75	Condition	447
26	Paper	886	76	Period	446
27	Development	856	77	Structure	441
28	Fishery management	843	78	World	435
29	Conservation	833	79	Problem*	433
30	Potential	814	80	Group	428
31	Time	777	81	Yield*	427
32	Need	745	82	Objective	422
33	Policy	739	83	Pattern	422
34	Increase	706	84	Knowledge	419
35	Value*	705	85	Order	418
36	Size*	698	86	Ocean	417
37	Information	669	87	Challenge	412
38	Effort*	654	88	Role	412
39	Process	651	89	Growth*	405
40	State*	641	90	Response	400
41	Number	608	91	Age*	398
42	Future	606	92	Maximum sustainable yield*	397
43	Research	601	93	Activity	396
44	Production*	589	94	Implementation	396
45	Community*	586	95	Importance	394
46	Individual	585	96	Relationship	394
47	Estimate	572	97	Regulation	392
48	Habitat	569	98	Set	391
49	Exploitation*	556	99	Environment	390
50	Method	552	100	Fish stock	390

* Key terms not normally distributed across the 19 research areas according to Shapiro-Wilk normality test.

2.3.3. Contextual meaning of fisheries sustainability

2.3.3.1. Common key terms in the research areas

Of the 709 key terms, 39 % occurred equally often across the 19 research areas according to the Shapiro-Wilk test of normality ($p > 0.05$). However, of the 100 most commonly used terms (Table 2.1), 82 % were equally distributed across the research areas, indicating that the biological understanding of sustainability identified in 2.3.2 was shared across the different research areas. The commonly used key terms that were not equally distributed across the research areas included terms related to fish stocks ("fish", "age", "size"), their exploitation ("effort", "exploitation", "yield"), methods to estimate both ("estimate", "dynamic", "maximum sustainable yield") as well as general terms ("state", "key", "problem") and terms related to the human dimension of fisheries ("fisher", "community") (Table 2.1). For example, maximum sustainable yield occurred in most research areas in 1 – 11 % of the abstracts, but in 34 – 40 % of the abstracts of the multi-species, stock assessment and economics clusters; the term "community" was used in 0 – 25 % of the abstracts per research area, but in 36 % of the abstracts of the social-ecological systems clusters. So while the biological understanding of sustainability was shared across the research areas, there were research areas that further "specialized" in biological sustainability as well as research areas that complemented the biological aspect with other attributes.

2.3.3.2. Specific key terms in the research areas

To further identify key terms that were specific to the individual research areas, the key terms were standardized for their overall frequency (Table 2.2). The most frequent specific key terms in the research areas included terms that were related to their themes (e.g. "coral reef fishery", "reef fish", "coral reef" and "reef" in the Coral reef cluster), but also terms that referred to different methods and models or described different impacts and solutions (Table 2.2). For example, the social-ecological systems cluster viewed fisheries as common pool resources and was primarily concerned with the type of management and institutions that would reduce poverty and maintain livelihoods (Table 2.2). As another example, the mangroves cluster was concerned with the restoration of mangrove forests and how the mangroves could continue to deliver ecosystem services while being under pressure from farming and nutrient input. The marine reserves cluster aimed at conserving biodiversity as well as providing yield for fisheries. This could be achieved by spatial management and by studying the dispersal of fish. By focussing on the terms that were not common across all research areas, it became clear from the key words that each research area had a specific take on fisheries sustainability.

Table 2.2: Clusters in a citation network of 4500 publications dealing with fisheries sustainability (Web of Science, 1990-2015). *Size* is the number of publications per cluster. *Key terms specific to the research area* are the key terms in the abstracts of the publications forming a cluster after having standardized the key terms' frequencies; the ten most frequently used key terms in each cluster after standardization are displayed.

ID	Cluster label	Size	Key terms specific to the research area
1	*Social-ecological systems*	571	Social-ecological system, co-management, common pool resource, poverty, resource user, household, livelihood, institution, small-scale fisheries, natural resource management
2	*Rebuilding global fisheries*	479	Individual transferable quota, world fisheries, reform, global fisheries, fisheries policy, fishing industry, exclusive economic zone, incentive, quota, rebuilding
3	*Recreational fisheries*	459	Angler, recreational fisheries, recreational fishing, release, population structure, life his trait, minimum size, marine fish, selection, age structure
4	*Marine reserves*	409	Dispersal, marine reserve, reserve, marine protected area, spatial management, marine conservation, marine biodiversity, network, fishery yield, park
5	*Stock assessment*	351	Surplus production model, stock recruitment, error, biological reference point, spawning biomass, fishing mortality rate, stock size, harvest control rule, harvest rate, effort data
6	*Management advice*	310	Fishery system, evaluation, attribute, scientific advice, sea-surface temperature, dimension, management process, preference, methodology, fishing community
7	*Aquaculture*	285	Life cycle assessment, aquaculture production, oil, farming, environmental impact, protein, aquaculture, energy, chain, product
8	*Bycatch and risk*	254	Shark, life history parameter, management strategy evaluation, ecosystem-based fisheries management, bycatch, trawl, longline, life history characteristics, trawl fishery, management objective
9	*Ecosystem*	250	Primary production, food web, pelagic fish, fisheries science, ecosystem-based approach, time series, marine mammal, century, coastal ecosystem, fishery production
10	*Aquarium trade*	145	Minimum size, trade, mass, export, commercial catch, juvenile, release, month, organism, phase
11	*Eco-certification*	143	Marine Stewardship Council, certification, consumer, seafood, chain, standard, actor, product, market, scheme
12	*Cultural bycatch*	133	Marine mammal, removal, bycatch, longline, breeding, fishing vessel, exclusive economic zone, fishing gear, marine biodiversity, human activity
13	*Coral reefs*	114	Coral reef fishery, reef fish, coral reef, reef, fish community, fishing method, trap, composition, human population, family
14	*Mangroves*	101	Mangrove, forest, farming, water quality, coastal zone, nutrient, service, ecosystem services, restoration, household
15	*Deep sea*	88	Deep water, bottom, life history characteristics, depth, spatial management, shelf, trawling, assemblage, record, natural mortality rate
16	*Viability*	87	Viability, constraint, dynamic model, bio-economic model, capital, ecosystem-based fisheries management, profit, theory, definition, concept
17	*Stock collapse*	80	Sea surface temperature, environmental condition, climate, fluctuation, possibility, precautionary approach, pelagic fish, predation, ecosystem-based approach, competition
18	*Multi-species*	74	Extinction, prey, equilibrium, stability, existence, predator, harvesting, surplus production model, presence, fishery stock
19	*Abalone*	69	Commercial catch, compliance, reform, subsistence, total catch, invertebrate, access, management decision, survey data, export
20	*Economics*	50	Maximum economic yield, bio-economic model, profit, effort data, economic benefit, revenue, management strategy evaluation, fishing fleet, cost, return
21	*Lake Victoria*	33	Predation, fish community, population growth, export, prey, management option, protein, mass, introduction, basin
22	*Clam*	8	Authority, sampling, event, fluctuation, farming, culture, comparison, site, step, carrying capacity
23	*Eel*	7	Spawner, phase, management option, management policy, experiment, viability, effectiveness, availability, output, variety

2.3.3.3. Clustering research areas by use of terms

The clustering of the research areas by citations had shown that the largest clusters were closely connected by their citations (Fig. 2.1). However, when grouping the research areas by their use of the 709 key terms, the research areas were separated into two groups (Fig. 2.3). The first group contained nine research areas. Of the larger clusters, it contained the recreational fisheries, marine reserves and stock assessment clusters (Fig. 2.3). The second group contained nine research areas, including the social-ecological systems cluster, the rebuilding global fisheries cluster and the management advice cluster (Fig. 2.3). While some of the research areas shared predominantly similar terms with the other research areas in the same group (recreational fisheries, stock assessment, coral reefs and deep clusters in the first group; social-ecological systems, aquaculture, eco-certification, mangroves and viability clusters in the second group), there were three clusters that almost equally shared terms with the research areas of both groups: the ecosystem, cultural bycatch and economics clusters (Fig. 2.3).

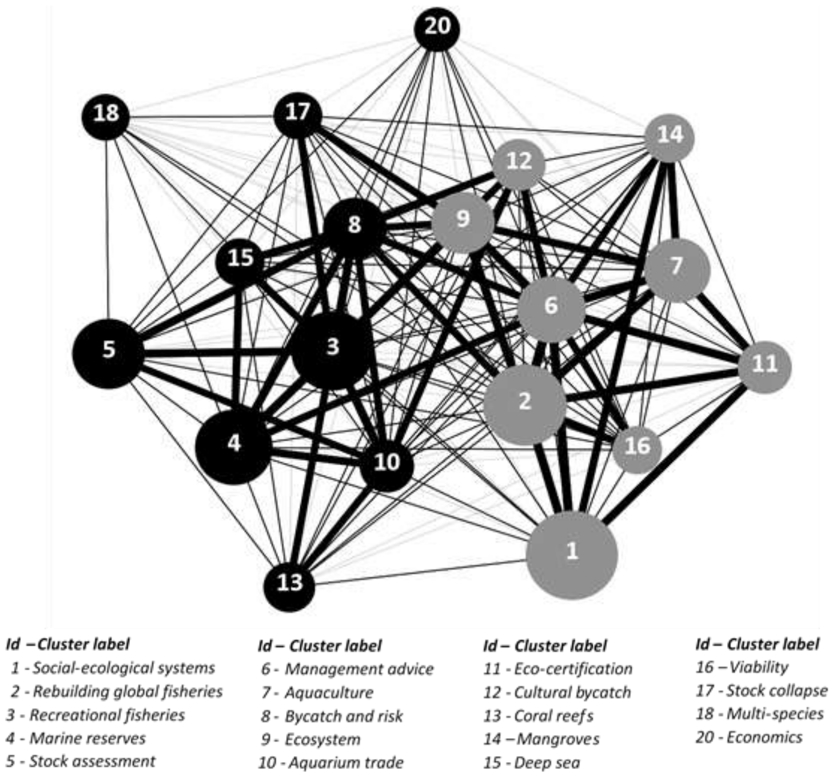

Figure 2.3: A network where papers are located within nodes and links between the nodes represent the correlation between two research clusters (black and grey nodes) based on the use of key words (thick black lines: strong correlation (Spearman's *rho* > 0.6175; thin black lines: medium correlation (*rho* = 0.4870 – 0.6175); thin grey lines: weak correlation (*rho* < 0.4870)). Size of nodes relates to the number of publications within each cluster. Four clusters that were considered to be independent research areas were not included in the analysis (*Id* 19, 21, 22 & 23).

The two groups of research areas (Fig. 2.3) shared the use of some common terms such as “fishery”, “management” and “fishing” (Fig. 2.4). The first group used more often many of the terms relating to fish stocks and their exploitation, such as “species”, “catch” and “recruitment”. The second group used significantly more often key terms such as “development”, “policy” and “community” (Fig. 2.4). The two groups were labelled accordingly the “predominantly fish” and the “including humans” group, where the “including humans” group included both social and political themes.

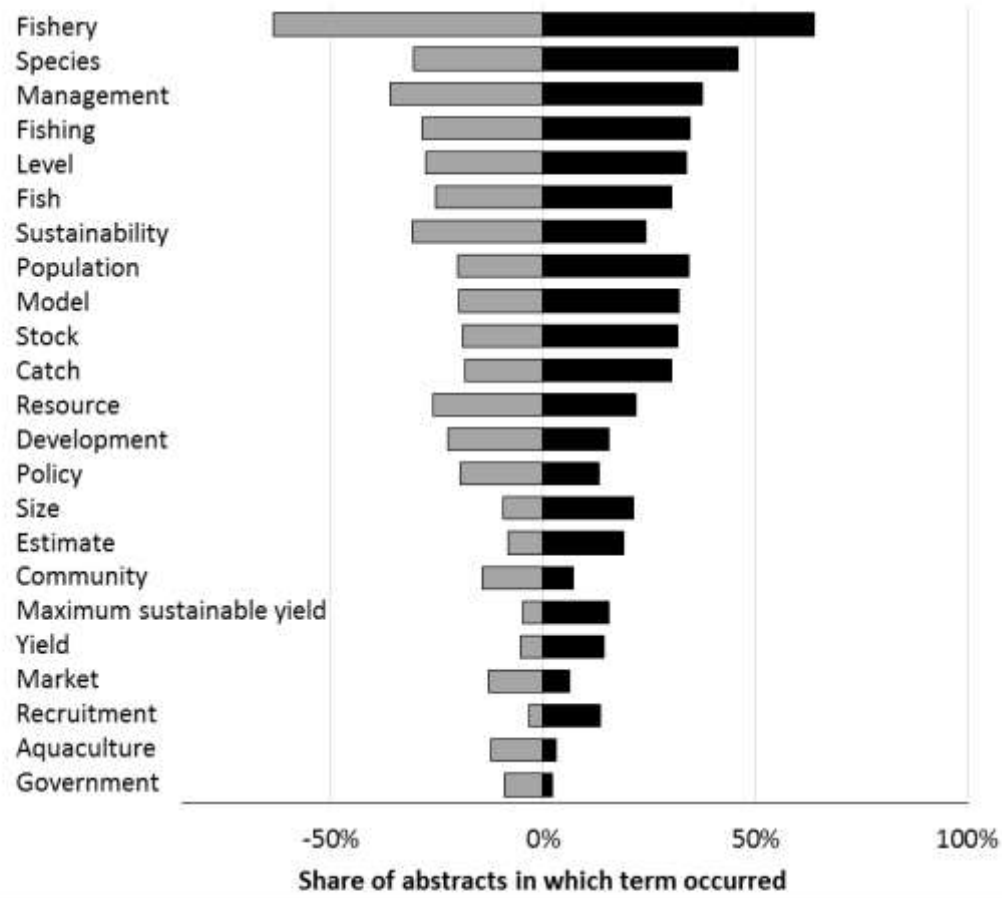

Figure 2.4: Examples of key terms and the frequency of their use (% of abstracts) in the two groups of fisheries research areas (Fig. 2.3). Grey bars: research areas including humans; black bars: research areas predominantly concerned with fish.

2.3.4. Implicative meaning of fisheries sustainability

2.3.4.1. Word combinations

Word combinations with “sustainable”/”sustainability” were explored for the implicative meaning of fisheries sustainability. In accordance with their grammatical structure, four groups of word combinations were identified (Table 2.3): (1) Combinations of “sustainability” with “objective”, “assessment” and other analytical terms that indicated the examination and discussion of sustainability as an abstract concept. (2) Nouns such as "fishery", "resource" and "population" paired with "sustainability" representing different components of the fishery system. (3) "Sustainable" combined with nouns such as "fishery" and "management" further specifying the pillars of sustainability, e.g. "sustainable livelihood" and "sustainable development" specifying "social sustainability" for the level of the individual fishermen and the societal level. "Maximum sustainable yield" as the only frequently occurring combination of adverb + "sustainable" + noun was included in the "sustainable" + noun category for the further analysis. (4) Adjectives paired with sustainability and corresponding to the pillars of sustainability as well as to the temporal ("long-term sustainability", "future sustainability") and spatial scale (e.g. "local sustainability", but terms were below frequency threshold).

2.3.4.2. Analysis of the implicative meaning

The word combinations with "sustainable"/"sustainability" occurred often with the verbs "to achieve", "to ensure", "to promote" and "to maintain", both when they stood alone and when they were paired with "sustainable"/"sustainability". So sustainability is a goal to be achieved and promoted, yet this "meaning" is not already implied in the term itself. For other verbs, it was noted that they were commonly paired with different key terms when the key terms stood alone, but practically never with the key terms as word combinations. A representative selection of these verbs is given in Fig. 2.5. Other verbs which were used with key terms but not with "sustainable"/"sustainability" word combinations were "to affect" (which was used with the same terms as "to exploit") and "to increase" and "to reduce" which were either used with the same terms as "to improve" when something should be increased and it was feared that it would be reduced; or they were used with the same terms as "to limit, constrain, control, regulate" when a pressure should be reduced and it was feared it further increased.

According to their use with the verbs identified, the key terms fell into five groups (Fig. 2.5):

- "Ecosystem", "population", "resource" and "stock" occurred together with "to sustain" and "to exploit". These were the ecological components of the fishery system, which needed to be sustained over time despite being heavily or fully exploited.

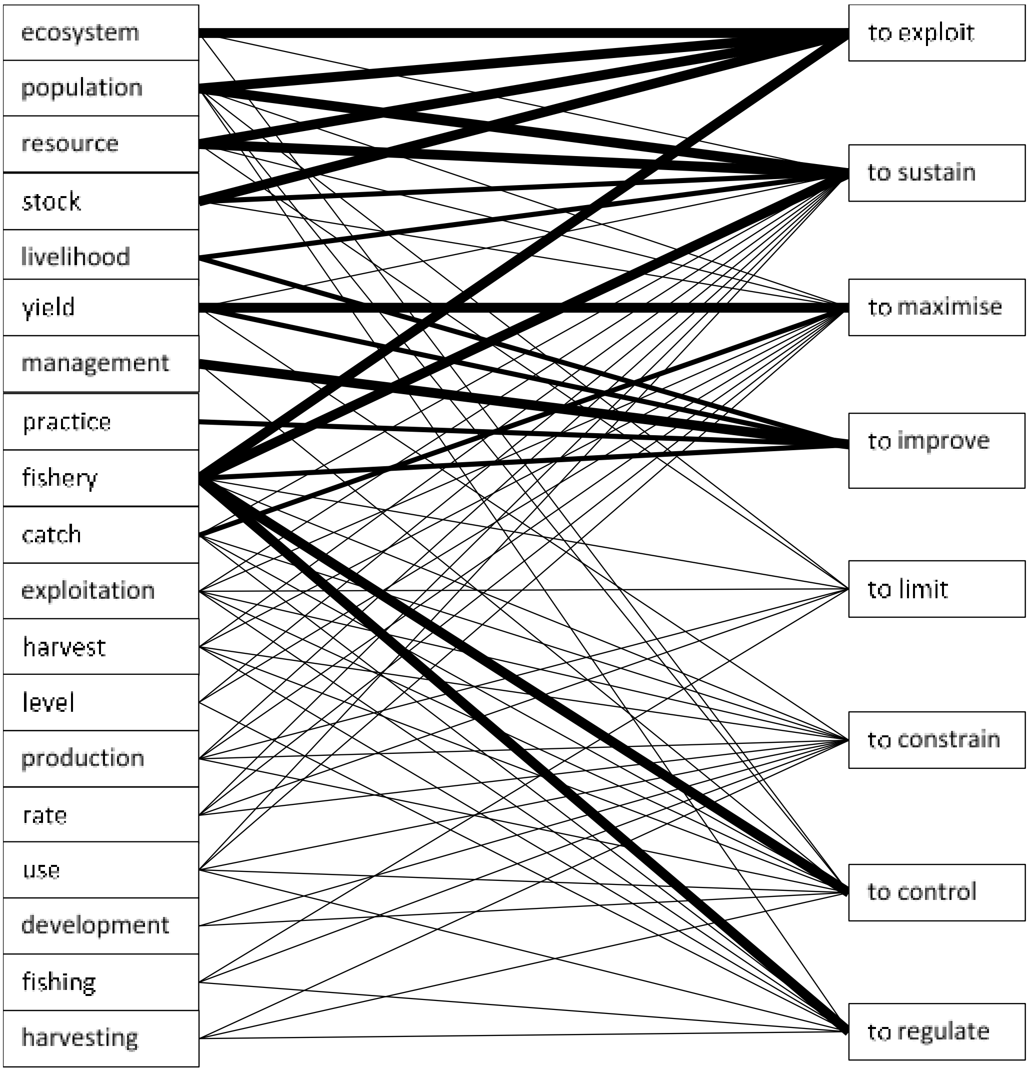

Figure 2.5: Co-occurrence of key terms (left side) and verbs (right side). Thin line: 1-5 times; intermediate line: 6-10 times; thick line: >10 times. Multi-word terms, e.g. "fisheries management" are not displayed because they had the same linkages as the single word terms (in this case "management").

- "Catch", "exploitation", "harvest", "level", "production", "rate" and "use" were used together with "to sustain", "to maximize" and several of the verbs "to limit, constrain, control, regulate". The key terms of this group were supposed to continuously deliver benefits, while they were also exerting pressure on the ecosystem, populations, resources and stocks and thus needed limitations and regulations.
- "Livelihood" and "yield" were used together with "to sustain" and "to improve", but not with "to exploit", "to maximize" or "to limit, constrain, control, regulate". They were outcomes delivered by a sustainable fishery.
- "Development", "fishing" and "harvesting" were not used with "to sustain", instead they were used with "to limit, constrain, control, regulate". As the word group of

catch, exploitation and harvest, these terms reflected pressure on the ecological components and thus needed limitations and regulations.

- "Management", "fishery management", "resource management" and "practice" were not used with "to sustain" but with "to improve". They referred to the processes that made the viability of the ecological components and the delivery of the outcomes possible.

The categorization of the terms in accordance with their verb use was relatively straight forward. For example, none of the terms were used with "to exploit" *and* with "to maximize". A special case was "fishery" which was used with "to sustain", "to exploit", "to improve" and "to limit, constrain, control, regulate". According to these uses, fisheries themselves need to be sustained, but the term is also used to refer to pressures exerted on the ecological components and to processes, that maintain their viability and deliver outcomes. Another special case was "population" which was on the one hand used for fish populations as part of the ecosystem that should be sustained, and on the other hand appeared in the context of a growing world population putting natural resource systems under pressure.

The four groups of terms suggested three implicative meanings of fisheries sustainability: continuity through time (ecosystem, population, resource and stock), delivery of outcomes (livelihood and yield), and processes that make both possible (management, fishery management, resource management and practice). "Catch", "exploitation", "harvest", "level", "production", "rate" and "use" while being somewhat technical terms, contained each as single terms all three implicative meanings: continuous delivery of outcomes (continuity through time and delivery of outcomes) and limiting their pressure on the ecological part of the fishery system (processes that make both possible).

2.3.4.3. Word combinations in research areas

When comparing the two groups of fisheries research areas (section 3.3.3), most of the word combinations with "sustainable"/"sustainability" occurred in the same percentage of research areas compiled in the two groups and, on average, in the same amount of abstracts (Table 2.3). In the "including humans" group, "sustainability indicator" and "sustainable population" and "sustainable livelihood" occurred in more research areas than in the "predominantly fish" group. Also, "sustainable fishery", "sustainable development" and "sustainable livelihood" occurred in more abstracts (Table 2.3). On the side of the "predominantly fish" group, "population sustainability" and "sustainable catch" were used in more research areas (occurrence) and "sustainable yield", "maximum sustainable yield", "sustainable exploitation", "sustainable catch" and "sustainable ecosystem" in more abstracts (frequency; Table 2.3). Another clear difference was the reference to the pillars of sustainability: in the "including human" group, ecological, environmental, economic and social sustainability all occurred in twice as many research groups as in the "predominantly fish" group.

Table 2.3: Word combinations of key terms with "sustainable"/"sustainability" in two groups of research areas. *Occ.* is the percentage of research areas in which the word combinations occur. *F* is the minimum, median and maximum number of abstracts in which the word combinations occur averaged across the research areas in each group.

Group	Term		Including humans group				Predominantly fish group			
		Freq	Occ	F.min	F.med	F.max	Occ	F.min	F.med	F.max
1	sustainability objective	18	0,4	1	2	5	0,4	1	2	5
1	sustainability assessment	15	0,3	1	2	3	0,3	1	4	5
1	sustainability indicator	14	0,7	0	1	3	0,2	1	1	2
1	sustainability goal	12	0,3	1	1	1	0,2	1	2	3
1	sustainability criterion	11	0,4	0	1	2	0,4	1	1	2
2	fishery sustainability	74	0,8	1	5	8	0,9	1	3	5
2	resource sustainability	29	0,6	1	2	4	0,7	1	1	9
2	population sustainability	15	0,1	3	3	3	0,5	1	2	2
2	ecosystem sustainability	11	0,3	0	1	2	0,3	1	1	2
3	maximum sustainable yield	397	1,0	2	7	24	1,0	5	17	92
3	sustainable fishery	274	1,0	5	12	43	1,0	3	12	24
3	sustainable management	210	1,0	4	10	24	0,8	7	14	26
3	sustainable use	166	1,0	3	6	14	0,9	4	8	13
3	sustainable development	160	1,0	3	10	16	1,0	1	7	11
3	sustainable exploitation	119	0,9	2	5	9	0,9	3	8	17
3	sustainable yield	107	0,9	2	3	5	1,0	3	8	19
3	sustainable level	89	0,8	1	2	16	0,9	2	6	11
3	sustainable fishery management	75	0,8	2	5	8	0,8	2	4	8
3	sustainable harvest	67	0,8	1	2	5	0,8	3	5	6
3	sustainable fishing	64	0,9	2	3	9	0,8	2	3	9
3	sustainable catch	33	0,3	1	2	4	0,8	1	2	7
3	sustainable livelihood	29	0,4	0	2	9	0,2	1	2	2
3	sustainable population	14	0,6	0	1	2	0,3	1	1	2
3	sustainable ecosystem	12	0,3	1	1	2	0,3	1	2	16
3	sustainable production	11	0,3	1	1	3	0,4	1	1	2
4	long-term sustainability	99	0,9	2	4	7	0,8	5	5	12
4	economic sustainability	33	1,0	1	2	13	0,4	2	2	3
4	environmental sustainability	32	0,8	2	2	5	0,4	1	1	3
4	ecological sustainability	31	0,8	1	2	3	0,5	1	3	5
4	social sustainability	23	0,6	1	2	4	0,3	1	2	3
4	future sustainability	22	0,7	0	1	3	0,7	1	2	5

2.4. Discussion

This chapter reviewed the meaning of sustainability in the fisheries science literature (4500 papers) to find out whether sustainability had different or a consistent meaning across the different research areas and to improve our understanding of fisheries sustainability. Using citation network analysis, I was able to identify the different research areas that comprise the field of fisheries sustainability science. According to the use of key terms in the different research areas (the "contextual meaning"), there was a shared ecological understanding of sustainability and fisheries management. Around half of the publications focused on fisheries yield and limiting the pressures on ecosystems, while the other half complemented the ecological understanding of sustainability with a socio-economic and political component, confirming that people matter in fisheries (Chapter 1). The analysis of word combinations with "sustainable" or "sustainability" (the "implicative meaning") suggested that there were at least three discernible perspectives on sustainability: sustainability as continuity through time, the delivery of benefits, and processes to achieve sustainable outcomes. These three perspectives largely coincided with the initial expectations, but continuity through time and delivery of benefits were initially expected to form only one perspective. The differentiation into the three perspectives could be used to help derive a useful new definition of sustainability.

Fisheries sustainability science

Based on an extensive collection of the fisheries sustainability literature, this study found that sustainability is a topic that has increased in prominence over the last decades. This is in accordance with the results from other studies (e.g. Kajikawa et al. 2007; Bettencourt & Kaur 2011). Sustainability challenges and solutions have been changing over time in fisheries, with some research areas showing a recent expansion, i.e. the ones dealing with fisheries eco-certification, rebuilding global fisheries, and fisheries as social-ecological systems. When considering these research areas within the larger sustainability narratives (Miller 2013; Luederitz et al. 2016), fisheries eco-certification and the rebuilding of global fisheries align with the concept of "green economies". This narrative focuses on environmental degradation, resource scarcity and the economic consequences of both (Luederitz et al. 2016). As social-ecological systems, fisheries form part of a narrative centred on producing knowledge concerning the complex dynamics between nature and society (Miller 2013). Similarly, the other research areas identified in this study can be related to general sustainability narratives.

However, there was no independent fisheries research area dealing with sustainability that employed narratives and approaches from political ecology (Perreault et al. 2015). This means that some of the research approaches, which could be particularly valuable for small-scale fisheries, are not well represented in the mainstream literature on fisheries sustainability. For example, the "social change approach", which is about the researcher participating in the knowledge production and where change towards sustainability is obtained from understanding and addressing ultimate drivers such as power, culture and values (Miller 2013), could be a valuable tool to understand and empower small-scale fisheries. As of now, approaches from political ecology are integrated in the social-ecological systems cluster (e.g. Fabinyi et al. 2014), which has been growing quickly over the last years and might subdivide itself into several distinct research areas in the near future. Overall, it appears that fisheries sustainability science has been growing in depth and breadth, but that there remains further potential for identifying new pathways for achieving sustainable fisheries (e.g. Miller et al. 2014).

The breadth of fisheries sustainability science as identified in this study encompassed 19 research areas (Fig. 2.1). In the context of each research area, sustainability challenges were addressed differently (Table 2.2). There was variety in what should be sustained (ranging from deep sea resources to small scale fishers' livelihood) and how (ranging from stock assessment methods to bio-economic models and spatial management). The diversity can be explained by the disciplinary backgrounds (e.g. cluster "*Economics*"), the different study subjects (e.g. "*Mangroves*"), the challenges addressed (e.g. "*Bycatch*") and the approaches taken (e.g. "*Marine reserves*") in each research area. To meet complex sustainability challenges, there lies great potential in collaborating across research areas and applying findings or adopting methods from other research areas (Bettencourt & Kaur 2011; Sala et al. 2013). The citation network analysis showed that the different research areas were connected and relied upon each other's outputs (Fig. 2.1). This suggests that fisheries science is becoming a multidisciplinary and interdisciplinary field (Kajikawa 2008; Phillipson & Symes 2013) in order to meet sustainability challenges.

The analysis of the contextual meaning showed that each research area had a specific perspective on sustainability, but also that an ecological understanding of sustainability dominated. Of the 19 research areas, there were two small ones which focused on economic sustainability (Clusters "*Viability*" and "*Economics*; Table 2.2) and a large one that included economic approaches ("*Rebuilding global fisheries*"). One large research area focused on social issues ("*Social-ecological systems*") and included a variety of issues such as food security, good governance and procedural and distributive justice. Three medium-sized research areas ("*Cultural bycatch*", "*Coral reefs*" and "*Mangroves*") also included social considerations. The majority of publications were dedicated to primarily ecological research and the greater number of ecological research areas together indicated a differentiation of ecologically oriented research relative to its economic and social counterparts (Table 2.2). This confirmed the observation that the human or social perspective tends to be underrepresented in fisheries research (Cochrane 2000; Symes & Phillipson 2009; Fulton et al. 2011; Chapter 1), although some of the socio-economic research areas also showed the largest increase in the number of publications indicating a switch towards a more holistic approach to understanding fisheries sustainability (Phillipson & Symes 2013).

The ecological focus is also a feature of other areas of sustainability science (Kates 2011) and can be explained by fisheries science starting in the biological sciences with a focus on stock assessments and yield (Mace 2001). Many sustainability issues foremost require a good understanding of ecological processes (e.g. depletion of natural resources and environmental change; United Nations General Assembly 2015). However, it is also clear that human behaviour plays a key role in addressing resource depletion and environmental degradation (Hardin 1968; Fulton et al. 2011) and so the social aspects of sustainability need to be part of the solution (e.g. poverty and hunger; United Nations General Assembly 2015). The results of the analyses of fisheries sustainability research areas suggest that the different components, processes and interactions of fisheries are not equally well understood. A larger contribution from a greater diversity of disciplines could thus be beneficial for achieving sustainability in the long-term.

A quantitative approach to understanding fisheries sustainability

In this study, citation network analysis and approaches from linguistics were used to analyse definitions of sustainability. In comparison to qualitative reviews of sustainability (e.g. Brklacich et al. 1991; Bolis et al. 2014), these two quantitative approaches allowed the inclusion of a large number of publications and the completion of a comparably objective and transparent analysis (Colicchia & Strozzi 2012). However, these approaches also have some potential drawbacks. Firstly there is the assumption that there is a relationship between form and content, so that the frequency with which a word is used, expresses its importance, or that it is meaningful if two terms often occur together. This linguistics approach (after De Saussure 1916) differentiates between the position or formation of words which are dictated by the grammatical rules of a language (the so-called "syntagmatic" dimension), and the choice of a word which could be substituted in the text by another word in the same position and with the same form (e.g. choosing the word "girl" over the term "woman"; the "paradigmatic" dimension). If words are chosen over other words, the frequency of a specific word also becomes meaningful. The second potential source for bias was the selection of adequate key terms, i.e. which part of speech (nouns, verbs, etc.) to include, how to deal with multi-word terms, and the determination of minimum frequency thresholds for terms. While the approach taken is certainly not the only possible method, the frequency of key terms in each abstract (median 35) indicated a good overall choice of key terms, and inspection of the abstracts confirmed that the key terms reflected the themes of the research areas (Table 2.2). Thirdly, the processes for selecting publications for the text corpus was somewhat limited. The citation network approach and individual checking of the publications made it possible to eliminate all false positives, i.e. the publications which used the search terms but which were not relevant for the aims of the study. However, the literature search was limited to the Web of Science Core collections, and did not include publications in languages other than English or formats other than peer-reviewed publications. The search terms were only analysed in the abstract, title and key terms of each publication and so it is possible that some relevant publications were not included. However, the large number of publications and themes included in the analysis suggests that a large proportion of the mainstream scientific literature on fisheries sustainability was covered.

Defining sustainability

Sustainability started to be recognised as an important topic in the 1980s (Bettencourt & Kaur 2011; Kates 2011) and was already considered an ill-defined concept at this point in time (e.g. Brown et al. 1987; Brklacich et al. 1991). This perception has not changed 25 years later (e.g. Bolis et al. 2014; Hilborn et al. 2015). The analysis of the contextual meaning in this study showed that "sustainability" had different meanings in different contexts, confirming that it is an ambiguous concept. The analysis of the implicative meaning, however, identified several meanings that were consistent across different contexts; the concept was only vague with regard to its level or direction as it was left open for interpretation if a sustainable fishery meant that something should be increased, maintained or protected from collapse.

The perception that “sustainability” is difficult to define is probably due to one term bearing several (implicative) meanings, and different sustainability meanings existing in each research area. Something similar was found for agriculture where several perspectives on sustainable agriculture were identified, but two or three of these perspectives were found mixed together in each scientific study dealing with agriculture sustainability (Brklacich et al. 1991). Linguistic studies show that new terms attach themselves to existing terms (Arora et al. 2014) and network theory suggests that new nodes in a network are most likely to attach themselves to the existing well connected nodes (preferential attachment model; Price 1976). Taking these aspects together, the sustainability concept is likely to gain more meanings when other new challenges, approaches and terms emerge. Therefore, a useful definition has to be broad enough to capture the complexity of fisheries (Jentoft & Chuenpagdee 2009) and future challenges (Rice & Garcia 2011).

Based on the contextual and implicative meanings of ‘sustainability’ identified in this study, a useful definition needs to include at least both what is sustained and how it is sustained. It is therefore suggested in the present study to define sustainability in the fisheries context as “*the continuous existence of the socio-ecological fishery system, in such a way that it provides goods and services now and in the future, without depleting natural resources, and the sustainable processes that make both possible*”.

Sustainability and societal choices

The proposed sustainability definition is future oriented, and includes constraints set by nature, emphasizes human actions, and aspires to direct action. Above all, the definition comprises different goals, so that conflict between individual goals, which has been another objection to the sustainability and sustainable development concepts (Robinson 2004; Redclift 2005), are no longer a restriction of use. However, the different elements of the sustainability definition are not contradictory until their “direction” is considered, e.g. should a component of the fishery system or an outcome be maintained, increased or maximized, or is it sufficient if it simply continues to exist? In this study, the undecided issue of direction could be seen by the diversity of verbs used with the sustainability terms: from affect, sustain, decrease and increase to enhance, ensure and maximize. Only when answering the question of direction, the fundamental question of “how do we want to live?” enters the sustainability debate. This is then no longer a question of the definition, but a question of dialogue, politics, equity, power and societal discourse.

Studies on sustainability typically reflect the importance of the right temporal and spatial scale of sustainability (Kates et al. 2001; Burger et al. 2012; Sala et al. 2013; Clements & Cumming 2017). The direction is not explicitly covered, or even treated as bias: "Although sustainability means a state that can be maintained at a certain level and does not have a directional bias, sustainable development has the connotation of sustainable economic growth, not its saturation" (Kajikawa 2008). To me, the direction is not a bias; it is the moment when sustainability becomes a societal choice.

Previously, this societal choice has also been included in sustainability definitions: "Sustainability […] is not even a process of moving toward some predetermined view of what that would entail. Instead sustainability is itself the emergent property of a conversation about what kind of world we collectively want to live in now and in the future" (Robinson 2004). It appears that sustainability definitions in the realm of natural resource management have differed in their coverage (Fig. 2.6). First and at the centre, there is the lexical (OED Online 2016) or ecological definition (Callicott & Mumford 1997) of sustainability as continuity through time. Next, there are the goods and services derived from the resources (Charles 2001; Baumgärtner & Quaas 2010). This is followed by the processes or the individual human and institutional actions that make both possible (Hilborn et al. 2015), and finally, the dialogue surrounding sustainability (Robinson 2004) (Fig. 2.6).

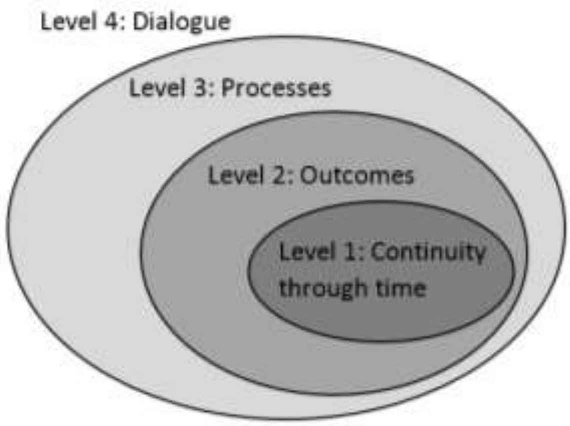

Figure 2.6: A conceptual model of fisheries sustainability. The innermost layer 'continuity through time' defines those elements of the fishery system that should be sustained (e.g. stocks, resources, ecosystems). The second layer considers the 'outcomes' that are derived from those sustained elements of the fishery system. The third layer, considers the 'processes' needed to ensure that the different elements of the fishery system are maintained and that sustainable outcomes are achieved. The final layer 'dialogue' relates to the societal choices surrounding sustainability, e.g. which elements should be sustained and at what levels, what are the desired outcomes, and which processes are prioritised for achieving both.

The analysis of the implicative meaning completed in this study suggests that the use of the term sustainability only includes the first three layers. Our interpretation of sustainability reveals the different levels of the sustainability definition. It is important to be aware which layer of sustainability definition is being used in order to avoid misunderstandings and conflict. Also, a sustainability definition operating in one of the outer layers has to include the inner layers, so that when sustainable outcomes are the focus (2nd layer), the continuity of the system (1st layer) also has to be taken into consideration. Sustainability as a process (3rd layer) only makes sense if the processes are about achieving and balancing the continuity of the system (1st level) and the desired outcomes (2nd layer). Finally, sustainability as a dialogue (4th layer) has to include what the topic of the dialogue is (layers 1-3).

Conclusions

Sustainability is one of the key concepts of fisheries science and management. There has been an increasing scholarly focus on sustainability corresponding to the ongoing sustainability challenges and an increased awareness of these issues, e.g. poverty, hunger, global inequalities, depletion of natural resources, environmental degradation and climate change. There is a need for science to better understand these themes and be a part of their resolution. Based on a quantitative linguistic analysis, this study analysed the understanding of fisheries sustainability in the scientific literature and proposed a new definition. Clarifying the different levels of sustainability and their relationships can help to improve the communication between stakeholders and contribute to the sustainable management of small-scale fisheries.

As outlined in Chapter 1, traditional approaches to fisheries management are often not applicable to small-scale fisheries, but these fisheries take place in ecologically important coastal and inland areas and can be of high importance for the local community. Striving for sustainability small-scale fisheries, both ecological and socio-economic sustainability goals needs to be considered. The proposed sustainability definition conceptually unites these contradictory issues and highlights the need for dialogue and cooperative management. In order to “fill” the conceptual model with specific sustainability criteria, Chapter 3 will analyse the criteria that are currently used in fisheries sustainability assessments.

3. Fisheries sustainability standards: the issue with the social issues

Abstract

Market incentives for sustainable fishing, through the designation of sustainably caught fish products, is a popular new approach to fisheries governance, both as reference for, and an alternative to, traditional fisheries management. These incentives are delivered through consumer-targeted sustainability recommendation lists and fisheries eco-certification schemes (together referred to as sustainability standards here). Over the last twenty years, both the number of fisheries, and the number of available sustainability standards have increased considerably. In this study a comparison was made of what the different standards assess, i.e. the assessment criteria used, their frequency of use across the different standards, and their importance within each standard, was compared for twenty popular standards. Results showed 35 different criteria were used across the assessed standards, within five themes: fish stocks, management, ecosystem, social aspects and scientific research. The standards shared twelve core criteria. Two thirds of the standards made comprehensive assessments, but others were narrower and assessed different aspects of sustainability. The six social sustainability criteria were used in just 40 % of the standards, thus sustainability was predominantly understood as an ecological concept. Nine new social criteria were proposed from a review of scientific studies assessing fisheries sustainability. It was deemed important to capture these more fully in order to make sustainability standards more applicable to small-scale fisheries.

3.1. Introduction

Seafood represents 16.7% of the animal protein consumed by the world population (FAO 2016). Globally, more than 50 million people are employed directly within the fishing industry, with a further 210 million employed indirectly, for example, in fisheries canning, processing and distribution (Teh & Sumaila 2013). Besides these positive aspects, the intensity and scale of fishing during the last century has significantly contributed to the current state in which many fish stocks are depleted with significant pressures also exerted more widely on marine ecosystems and marine life (Pitcher 2001; Jennings & Kaiser 1998, Chapter 1). Analyses of historical and archaeological data have shown that fishing has had a major impact on marine and coastal ecosystems for centuries (Jackson et al. 2001, Lees et al. 2006). The socio-economic importance of fisheries, their depleted state and the destructive impacts on marine ecosystems make achieving sustainable exploitation of the resource paramount.

A variety of measures have been proposed and/or introduced in order to ensure the sustainability of both the natural resource i.e. the fish stocks, and the socio-ecological system i.e. the fisheries. Since the 1950s, fisheries management relied on using maximum sustainable yield to protect the regenerative capacity of fish stocks (Larkin 1977). This approach was expanded in the 1980s and 1990s to include the interactions between species (i.e. predation and competition) (Kerr & Ryder 1989) and more recently, to ecosystem-based fisheries management (Link et al. 2002; Pikitch et al. 2004). The requirements for the normal functioning of an ecosystem, i.e. preserving habitats, predator and prey interactions and other ecosystem components and interactions, also eventually became incorporated into fisheries science and management as a basis for sustainable fisheries (Pikitch et al. 2004; Pitcher et al. 2009; Link & Browman 2014). Other approaches to achieving sustainability have included the creation of networks of marine protected areas (Lester et al. 2009), and efforts to preserve the resilience of marine socio-ecological systems (Berkes et al. 2008).

Although this list of approaches for achieving sustainability is incomplete (Jennings et al. 2009), the number of stocks that continue to be classified as overfished (FAO 2016) suggests mainstream fisheries management has not been effective. Alternative approaches that move away from top-down management include the strengthening of self-governance within fisheries and the co-management between state authorities, the fishing industry and other stakeholders (Carlsson & Berkes 2005; Chapter 1); and, economic approaches that use property rights and transferable fishing quotas to stimulate stewardship of the natural resource and thus avoid overfishing (Costello et al. 2008). One recent development that follows the logic of market-based approaches is eco-certification (Auld et al. 2008; Ward & Phillips 2009; Reinecke et al. 2012).

Market-based sustainability initiatives

The basic premise of eco-certification is that the farmers or fishers acquire a 'sustainable' ecolabel that can be displayed on the retail packaging in order to inform and attract consumers. These producers may benefit from a financial market advantage, so providing an incentive to engage in sustainable practices. These financial benefits would be derived from the premium price paid by consumers for sustainable products. Surveys using self-reported information from consumers have shown that well-informed consumers are willing to pay more for sustainable products (Thøgersen et al. 2010; Uchida et al. 2014). However, the actual sales data for certified products provide at best inconsistent evidence supporting the willingness to pay premiums (Roheim 2009a; Blackmore et al. 2015; Bellchambers et al. 2016a; Carlson & Palmer 2016). For fisheries, the consensus is that pressure from retailers, and the fear of losing access to markets, particularly the European, North American and Japanese market (Potts et al. 2016), have been the main incentives for participation in eco-certification schemes (Blackmore et al. 2015; Cairns et al. 2016; Carlson & Palmer 2016). However, fisheries that do not sell or export products to these markets have also sought certification suggesting there may also be other complex factors motivating them to seek eco-certification (Blackmore et al. 2015).

The eco-certification of agricultural products as an alternative means of safeguarding sustainability can be traced back to 1972 when the International Federation of Organic Agriculture Movement (IFOAM) brought together national groups that promoted organic farming (Potts et al. 2014). In 1993, the forestry industry followed with the establishment of the Forest Stewardship Council (FSC; Potts et al. 2014). The first fisheries eco-certification initiative, the Marine Stewardship Council (MSC) began in 1996/1997 as a cooperation between the World Wildlife Fund (WWF) and Unilever (at the time the largest supplier of frozen fish in the world); thus the concept of fisheries eco-certification has been around for 20 years. It took the MSC several years to become operational, including two years of stakeholder consultation with fisheries experts, scientists, environmental non-governmental organisations (eNGOs) and other interested groups, and its transformation into an independent non-profit organization (Cummins 2004; Gulbrandsen 2009). The first fishery was certified with the MSC label in 2001. On a global scale, fisheries (and aquaculture) eco-certification only became important towards the end of the 2000s when the number of certified fisheries reached a critical mass (Potts et al. 2016).

In addition to fisheries eco-certification schemes, sustainable seafood recommendation lists represent a second important type of market-based sustainability standard for fisheries. Recommendation lists are typically issued by eNGOs and were introduced for fisheries in the 1990s (Washington & Ababouch 2011). These lists target the consumers and recommend whether a product is an ethical option (Shelton 2009). Additionally, retailers have also used recommendation lists as a base for their seafood procurement policies (Roheim 2009b). The main difference between the two forms of sustainability standards is that recommendation lists unilaterally flag fisheries or fish species as either sustainable, or not. The fishing industry is not involved in this process. For eco-certification schemes, the standards are set by an organisation (NGO, government, or fishing industry organisation), but a fishery is only flagged as sustainable, or not, when it voluntarily seeks assessment of its fishing operations. In return, the fishery may receive sustainability certification and subsequent market benefits (Parkes et al. 2010; Brunsson et al. 2012). Certification of a fishery is typically not performed by the organisation setting the standard, but externally by an independent third party and the process is paid for by the fishing industry (FAO 2005; Gulbrandsen 2009). In contrast, recommendation lists are not requested or financed by fisheries, and they may advise in favour, as well as against, seafood products.

The effectiveness of sustainability standards

Eco-certification schemes and recommendation lists (together referred to as 'sustainability standards' going forward) use a range of criteria to assess fisheries sustainability (Gullbrandsen 2009; Ward & Phillips 2009). The standards typically use a graded assessment and in this way provide an incentive for fisheries that perform poorly to seek improvement for specific features (Parkes et al. 2010). In the case of eco-certification, the fishery may reapply and become certified if it meets the criteria. So, sustainability standards can both assess and enhance sustainability (Cairns et al. 2016).

The capacity of eco-certification schemes to enhance sustainability has been a matter of debate because participation is voluntary, and it is feared that only those fisheries which are already using sustainable practices participate (Gulbrandsen 2009; Butterworth 2016). Furthermore, broad-scale changes in the marine environment are difficult to monitor (Gulbrandsen 2009), for instance it can take years or decades to observe positive environmental impacts, and even if change is indicated, it is difficult to attribute these changes to fisheries certification over the multitude of relevant environmental and anthropogenic factors (Blackmore et al. 2015). However, a comparison of 45 MSC certified stocks with 179 uncertified stocks found that three quarters of those that were certified, as opposed to 44% of the uncertified, were above the biomass required for maximum sustainable yield (Gutiérrez et al. 2012). Overall the fisheries certified by the MSC were 3-5 times more likely to be fished sustainably than those that were not assessed (Gutiérrez et al. 2012). Gutiérrez et al. (2012) concluded that, independent of their ecological impact, eco-certification was able to identify sustainable fisheries correctly and thus communicate accurate information to consumers.

Environmental campaigns have historically been very successful in influencing fisheries, e.g. promoting dolphin-safe tuna (Baird & Quastel 2011), fighting discards (Borges 2015) and boycotting certain fish products (Roheim 2009a). Consumer surveys suggest that recommendation lists encourage consumers to be more careful when buying seafood and that they would avoid certain species and 'unsustainable' products (Kemmerly & Macfarlane 2009), but there are no data on the impacts of recommendation lists on fisheries or marine ecosystems.

In terms of distribution and uptake, fisheries sustainability standards have been very successful. The number of certified fisheries products and the reach of recommendation lists have both increased considerably. The eco-certification schemes with the largest market shares and global coverage are the MSC and Friends of the Sea (FoS) which are international schemes that had, as of 2015, together certified 12% of global seafood production (Potts et al. 2016). The other eco-certification schemes operate mostly at national levels (Leadbitter & Ward 2007; Gulbrandsen 2009; Parkes et al. 2010) or have very small (<1%) market shares (Potts et al. 2016). The recommendation lists have differing geographic foci, e.g. the Monterey Bay Aquarium and the Safina Center operate predominantly in the U.S., whilst the Marine Conservation Society is based in Europe (MCS) and Australia (AMCS). The WWF and Greenpeace, two large global eNGOs, also have recommendation lists for sustainable seafood. Nowadays consumers can download the recommendation lists on their mobile phones (Nghiem & Carrasco 2016), but they were issued previously as pocket guides and the numbers of copies issued, e.g. 20 million for the lists issued by the Monterey Bay Aquarium (Roheim 2009b), illustrate their widespread use.

The influence of sustainability assessments on society

Sustainability standards are not only widely distributed, whole regions and countries now use the MSC criteria to assess the sustainability of their fisheries sectors (Nimmo & Southall 2012; Adolf et al. 2016; Bellchambers et al. 2016b). When fisheries sustainability standards emerged they fulfilled a need for coherent tools to assess the sustainability of fisheries (FAO 2009), but their criteria have now been widely accepted and further institutionalized (Brunsson et al. 2012). Thus, the criteria of sustainability standards seem to have become synonymous with the concept of fisheries sustainability.

Sustainability standards are in essence an expression of societal consensus on how to deal with the natural resources of interest. However, the relationship is bidirectional: sustainability standards also influence what society accepts as ´sustainable´. For example, sustainability standards could change public perceptions to the point where only certified or recommended fisheries are considered sustainable, whilst the uncertified or not recommended are perceived to only employ unsustainable practices (Bellchambers et al. 2016b). This can be problematic for fisheries that are excluded from certification because of the costs, e.g. in the case of many small-scale fisheries or fisheries in developing countries (Constance & Bonnano 1999; Blackmore et al. 2015; Butterworth 2016; Potts et al. 2016), or because they share the fish resources with other fisheries that do not fish sustainably (Blackmore et al. 2015; Butterworth 2016). Public perception could also change so that sectors where sustainability standards are not common (e.g. freshwater fisheries), are not perceived as being threatened, and this could reduce future management investments in these areas (Cooke et al. 2011). Sustainability standards also shift the perspectives regarding who is responsible for solving sustainability problems away from governments and towards private companies (Constance and Bonnano 1999) and consumers (Stern 2000; Bamberg & Möser 2007; Steg & Vlek 2009). Overall, the implementation of fisheries sustainability standards could be understood as a large-scale societal experiment. If sustainability standards change the societal understanding of sustainability, it is important to understand how they actually assess sustainability.

With regard to the proposed definition of sustainability (in Chapter 2) as the *continuous existence of the socio-ecological fishery system in such a way that it provides goods and services now and in the future, without depleting natural resources, and the sustainable processes that make both possible*, the criteria used by sustainability standards can be viewed as a way of filling the definition with specific content. The initial aim of this study was to compare the different fisheries sustainability standards by comparing the criteria used in assessment by the various market based schemes, and considering similarities and differences based on use of these criteria. The proliferation of consumer-focussed sustainability assessments should raise questions regarding what is measured, and given that there are different schemes available, inter-scheme comparability should also be questioned. This is important because sustainability standards are starting to be used in operational management of fisheries. For example, inshore fisheries in the UK (Nimmo & Southall 2012), small-island states in the western and central Pacific (Adolf et al. 2016) and Western Australian fisheries (Bellchambers et al. 2016b) have all begun using the criteria from eco-certification schemes to formally assess their sustainability. Additionally, it has recently been suggested that the criteria used in eco-certification schemes and recommendation lists could be adapted for evaluating the performance of fisheries management (Hazen et al. 2016). The formal adoption of the criteria from the sustainability standards into government assessments of stock sustainability and fisheries management means it is critical that the mechanics of sustainability standards are understood. Given the different eco-certification institutions, it was expected that the criteria would vary greatly between the standards, depending on their primary focus of interest. In addition, a literature review was used to suggest additional criteria that could be used to increase the consideration of social issues in sustainability standards assessments, since there was a clear under-representation of these in the approaches examined, and it is known that these criteria can be of particular importance in reaching sustainable outcomes for small-scale fisheries (see Chapters 2 and 5).

3.2. Methods

3.2.1. Criteria used by fisheries sustainability standards

3.2.1.1. Data sources

Sustainability criteria were compiled for the 10 most popular sustainable recommendation lists, and 10 fisheries eco-certification schemes (from this point forward together referred to as 'sustainability standards') (Table 3.1). The sources used to compile a list of the most popular standards included the peer-reviewed (Leadbitter & Ward 2007; Roheim 2009b) and "grey" literature (Wessells et al. 2001; Parkes et al. 2010; Washington & Ababouch 2011).

Of the twenty sustainability standards used in the analysis, only one standard referred to a single specific fishery ("Clean Green Australian Southern Rock Lobster Product Standard"). All the other sustainability standards had been applied to several fisheries and fish species. All eco-certification schemes had been used to certify fisheries (as of spring 2015) with the exception of the "Nordic Voluntary Certification", the recommendation of a technical working group on eco-certification composed by European Nordic countries.

Table 3.1: The 20 fisheries eco-certification schemes and recommendation lists, collectively referred to as sustainability standards, their respective certifiers and URLs. Abbreviations are the acronyms for each standard used in the present study. All certifiers are independent non-profit organisations with the following overall objectives: *indicates an eNGO (environmental Non-Governmental Organizations), †developed by or has strong connections to the fishing industry, ‡linked to promotion of seafood products and/or retailers; §developed as government initiative; #organization which consider additional social objectives.

Sustainability standard	Abbrev.	Certifier	URL
Recommendation lists			
"Seafood guide"	AMCS	Australian Marine Conservation Society*	http://www.sustainableseafood.org.au/
"Seafood guide"	BOI	Safina Center (before Blue Ocean Institute)*	http://safinacenter.org/seafoods/
"Best Fish Guide"	BFG	Forest and Bird's New Zealand*	http://www.forestandbird.org.nz/best-fish-guide-13-14
"Seafood guide"	Choice	SeaChoice Canada*	http://www.seachoice.org/search/
"Oceans campaigns"	EJF	Environmental Justice Foundation*#	http://ejfoundation.org/campaign/Oceans
"Consumer guide"	GreenP	Greenpeace*	https://www.greenpeace.de/fischratgeber
"Good Fish Guide"	MCS	Marine Conservation Society*	http://www.fishonline.org/fishfinder?min=1&max=2&fish=&eat=1
"FishSource"	Source	Sustainable Fisheries Partnership†	http://www.fishsource.com/
"Seafood Watch Program"	Watch	Monterey Bay Aquarium	http://www.seafoodwatch.org/seafood-recommendations/consumer-guides
"WWF Seafood guides"	WWF	World Wide Fund for Nature*	http://www.wwf.de/
Eco-certification schemes			
"Certification Criteria Checklist for Wild Catch Fisheries"	FoS	Friend of the Sea*	http://www.friendofthesea.org
"Marine Stewardship Council Fisheries Standards"	MSC	Marine Stewardship Council*	https://www.msc.org/
"Icelandic Responsible Fisheries Certification Program"	IRF	Icelandic Responsible Fisheries*†	http://www.responsiblefisheries.is/certification/
"Global Standard for Responsible Supply"	IFFO	Marine Ingredients Organisation‡	http://www.iffo.net/
"Clean Green Australian Southern Rocklobster Product Standard"	Lobster	Southern Rocklobster Limited†	http://www.southernrocklobster.com/cleangreen/
"Marine Eco-Label Japan"	MEL	Japan´s Fisheries Association†	http://melj.jp/eng/index.cfm
"Sustainable Capture Fishery Standards"	NaturL	Naturland‡	http://www.naturland.de
"KRAV Standards"	KRAV	Swedish Association for Control of Organic Production*‡#	http://www.krav.se/krav-standards
"Nordic Voluntary Certification"	Nordic	Nordic Technical Working Group on Fisheries Eco-Labelling Criteria§	http://www.norden.org/en
"Sustainable Australian Seafood Assessment Program"	SASAC	*Australian* Conservation Foundation*	http://www.acfonline.org.au

3.2.1.2. Identifying and scoring the sustainability criteria

The criteria used within each of the 20 fisheries sustainability standards were identified from their published guidelines and supporting documentation. The guidelines of the standards were examined iteratively, and the criteria were coded and aggregated thematically, e.g. the criteria "the size of the fish population is above the sustainable population size (BMSY)" and "the size of the fish population is not classified by FAO as overexploited or depleted" were combined into one criterion called "size of the fish population". In the same way, the overarching themes were identified.

Each criterion was weighted based on its importance within each standard on a scale of 1 to 4 (Table 3.2). The scoring scale aimed to reflect the common divisions of the assessments into goals, criteria and indicators. "Goals" were super-ordinate statements, ideals or fundamental principles; criteria were more specific than goals, e.g. specifying a desirable state or condition (not to be confused with the sustainability criteria themselves); and, indicators were specific variables that could be measured and assessed (Ritchie et al. 2000). Some standards differentiated between "core criteria" and "points of adjustment" or between "essential requirements", "important requirements" and "recommendations". For the sustainability standards that ranked the criteria in this way these rankings are reflected in the score assigned in this study.

Table 3.2: Scoring system for evaluating the importance of sustainability goals, criteria and indicators in fisheries sustainability information and assessment standards.

Score	Explanation
NA	Not used as indicator, criterion or goal
1	Mentioned in supplementary text, sub-ordinate indicator or non-obligatory criterion
2	Indicator or sub-ordinate criterion
3	Criterion or sub-ordinate goal
4	Goal

The overarching sustainability goals were rated "4", the highest score, which was awarded to the main goals in each standard. Sub-ordinate goals, criteria and indicators were rated "2" or "3". Non-obligatory criteria and subordinate indicators were rated "1". Criteria that did not appear in a standard did not receive a score. This type of ordinal scoring is used widely when dealing with the interactions between social and natural phenomena, e.g. to score the performance of ecosystem indicators across pre-defined criteria (Rice & Rochet 2005), or to translate complex human activities into threat categories for ecosystem risk assessment (Halpern et al. 2008). The present study had the advantage that most of the sustainability standards already had an internal hierarchy, i.e. some form of ranking or weightings indicating the relative importance of the different criteria. For example, by giving criteria with a super-ordinate numbering a higher score, or by assigning the same score to two criteria that were at the same hierarchical level within the list/scheme. For sustainability standards without internal rankings that used very few criteria all were assigned the highest score. A summary table of the scores was produced in which each criterion constituted a row and each of the 20 sustainability standards constituted a column.

3.2.2. Comparison of sustainability standards and criteria

The relative frequency of the 35 criteria, i.e. the number of standards that a criterion occurred within, was calculated across the 20 standards, and the importance of the criteria was derived from the median of the awarded importance scores. This approach helped identify criteria that occurred in only a few standards but that played an important role in the assessments. Identifying and scoring the sustainability criteria allowed an assessment to be made over what aspects of fisheries sustainability each standard was assessing.

To determine whether the standards represented similar aspects of fisheries sustainability, the standards were clustered into groups based on the similarity in criteria and the importance given to these (importance scores). Hierarchical cluster analysis was used to identify similarities and differences beyond the single criteria, using the Bray-Curtis dissimilarity measure (Bray & Curtis 1957) and the unweighted pair group method with arithmetic mean for the agglomeration process (UPGMA; Sokal & Michener 1958). Analysis was performed with the vegan package of R version 3.2.2 (Oksanen et al. 2007).

3.2.3. Assessments including social criteria

A number of studies have suggested that at present social sustainability criteria are underrepresented in fisheries management and in sustainability assessments of fisheries (Cochrane 2000; Leadbitter & Ward 2007; Symes & Phillipson 2009; Hicks et al. 2016; also see Chapter 2). Social sustainability criteria are here understood as being variables that describe the conditions or trends that are primarily relevant for human well-being (e.g. Coulthard et al. 2011). They do not include management criteria that prioritise fish stocks or the ecosystem. We explored which criteria could be used to appropriately reflect the social sustainability of fisheries.

In order to derive a list of social criteria that could complement the criteria already used in the sustainability standards, fisheries sustainability assessments from the research literature, which were independent of the sustainability standards, were reviewed. Relevant studies were identified from Web of Science (as at October 2015) using the terms “fishery” AND “sustainability” AND (“framework” OR “assessment” OR “criteria” OR “indicator”). Of the 986 scientific publications retrieved, approximately 15% included a number of social sustainability criteria. From these results a random subsample of 51 publications were chosen and information on the sustainability criteria they employed was extracted. The criteria were again coded and aggregated thematically. However, the scientific studies did not consistently rank the sustainability criteria so that only their relative frequency and not their importance could be determined from the sources.

3.3. Results

3.3.1. Criteria used by the fisheries sustainability standards

The review of fisheries sustainability standards identified a total of 35 criteria that were used to assess the sustainability of fisheries and fishery products (Table 3.3). Nine of the 35 criteria considered aspects of the fish stock, eight the fisheries management regime, seven the ecosystem, six the social issues, and five addressed fisheries science and stock assessment (Table 3.3). The five themes were as follows:

- The criteria that dealt with the fish stocks referred to the size (SF1), life history (SF3), health (SF5) and ecological role (SF6) of the stocks, and also the pressure exerted by the fishery (SF2), overcapacity of the fishing industry (SF7) other users of the marine realm (SF8) and other fisheries (SF9). Another criterion was the recovery of overfished stocks (SF4).
- The criteria for sustainable fisheries management included: the existence of fisheries management (SM2) and regulatory measures (SM4); precautionary (SM3), effective (SM5), adequate (SM6) and efficient (SM8) management, and adherence to fisheries regulations (SM1). Another assessment criterion was the option for interested parties to participate in the management of the fishery (e.g. co-management; SM7).

Table 3.3: The 35 sustainability criteria, their frequency and importance within 20 sustainability standards; criteria are grouped by the five sustainability themes. "Importance" was scored on a scale from 1 (not important) to 4 (very important) and the median importance across the 20 sustainability standards is shown here. "Frequency" is the share of sustainability standards in which a criterion can be found. For each of the five themes, the overall frequency (the proportion of standards that used at least one criteria per theme) was used and their median importance is indicated (across the 20 standards). The 12 criteria with both a high frequency (>50%) and high importance (≥3) are indicated with an *.

Themes and criteria	Frequency	Importance
Fish stock		
SF1 - Status of the stock*	0.90	4
SF2 - Fishing pressure	0.80	2.5
SF3 - Life history*	0.60	3
SF4 - Recovery of overfished stocks	0.50	2
SF5 - Health and vulnerability of the fish stock	0.40	2.5
SF6 - Fish stock can fulfil its ecological role	0.30	2.5
SF7 - Overcapacity	0.30	1.5
SF8 - Non-fishery impacts	0.25	3
SF9 - Impacts of other fisheries	0.25	2
Overall frequency & median importance of the theme	0.95	2.5
Management		
SM1 - Compliance*	0.80	3
SM2 - Management framework in place*	0.70	4
SM3 - Precautionary principle*	0.70	3
SM4 - Management measures in place*	0.65	3
SM5 - Effectiveness	0.50	3.5
SM6 - Adequacy of management	0.40	3
SM7 - Participation and transparency	0.35	2
SM8 - Efficiency	0.15	3
Overall frequency & median importance of the theme	0.95	3.0
Ecosystem		
SE1 - Impact of the fishing method on the habitat quality*	0.95	3
SE2 - Bycatch*	0.95	3
SE3 - Bycatch of endangered, threatened & protected species*	0.65	4
SE4 - Ecosystem functioning and integrity*	0.65	4
SE5 - Discards*	0.60	3
SE6 - Ghost fishing	0.25	2
SE7 - Environmental sustainability (energy, waste, pollution)	0.20	4
Overall frequency & median importance of the theme	0.95	3.0
Social		
SS1 - Fair, safe and healthy working conditions	0.25	4
SS2 - Training opportunities	0.15	3
SS3 - Incentives and subsidies	0.15	2
SS4 - Appropriate dispute resolution framework	0.10	3
SS5 - Management protects cultural heritage	0.05	3
SS6 - Access and use rights	0.05	3
Overall frequency & median importance of the theme	0.40	3.0
Science		
SR1 - Collecting data and information (for stock assessment)*	0.70	3
SR2 - Use of reference points and stock assessment	0.55	2
SR3 - Impact of science	0.40	3
SR4 - Research	0.30	2.5
SR5 - Sound basic biological knowledge of the species	0.20	1
Overall frequency & median importance of the theme	0.85	2.5

- Criteria for the sustainability of the ecosystem included: its general health and integrity (SE4), fisheries specific issues such as the effects of fishing gear on the seabed (SE1), bycatch (SE2 and SE3), discards (SE5) and ghost fishing (SE6). Environmental sustainability in terms of energy consumption, pollution and non-fish waste production (SE7) was another criterion.
- Social criteria were linked with safe and healthy working conditions (SS1), but also to education and training opportunities (SS2), incentives and subsidies (SS3), conflict resolution (SS4), the protection of traditions and cultural heritage (SS5), and equitable access and use rights (SS6).
- Criteria attributed to the thematic category "science" referred both to applied fisheries science and stock assessment (SR1 and SR2) as well as to research on and understanding of fundamental biological and ecological processes (SR4 and SR5). The influence of science and research on fisheries activities, especially the restriction of fishing effort, was another criterion used to assess sustainability (SR3).

In 95% of the sustainability standards, at least one criterion from the "fish stock" theme was used. The same was true for the "management" and "ecosystem" theme (Table 3.3). The criteria referring to fisheries science were used in 85% of the sustainability standards (Table 3.3). However, social criteria (of which there were six) were only used in 40% of the sustainability standards. Only eight of the standards employed between one and three of the six social criteria, and 12 standards did not use any social criteria. The median importance of criteria in the social sustainability theme, across all twenty standards, was 3.0 and was as high or higher as the importance score for the other thematic areas (2.5 and 3) (Table 3.3).

3.3.2. Similarities between the fisheries sustainability standards

The cluster analysis showed that the twenty standards (Table 3.1) formed four clusters containing between two and nine sustainability standards (Fig. 3.1). Two of the clusters (Clusters 2 & 3) contained only eco-certification schemes, in the other two (Clusters 1 & 4) eco-certification schemes and recommendation lists were mixed (Fig. 3.1, Table 3.4). Two recommendation lists (Source & EJF) did not belong to any of the clusters and also did not have any criteria in common with each other (Table 3.4). The recommendation list of the Sustainable Fisheries Partnership (Source) was the only one of all the 20 standards that did not contain any criteria referring to ecosystem sustainability (Table 3.4). The recommendation list of the Environmental Justice Foundation (EJF) considered ecosystem criteria and fair and safe working conditions, but it did not include any criteria from the fish stock, management or science themes (Table 3.4).

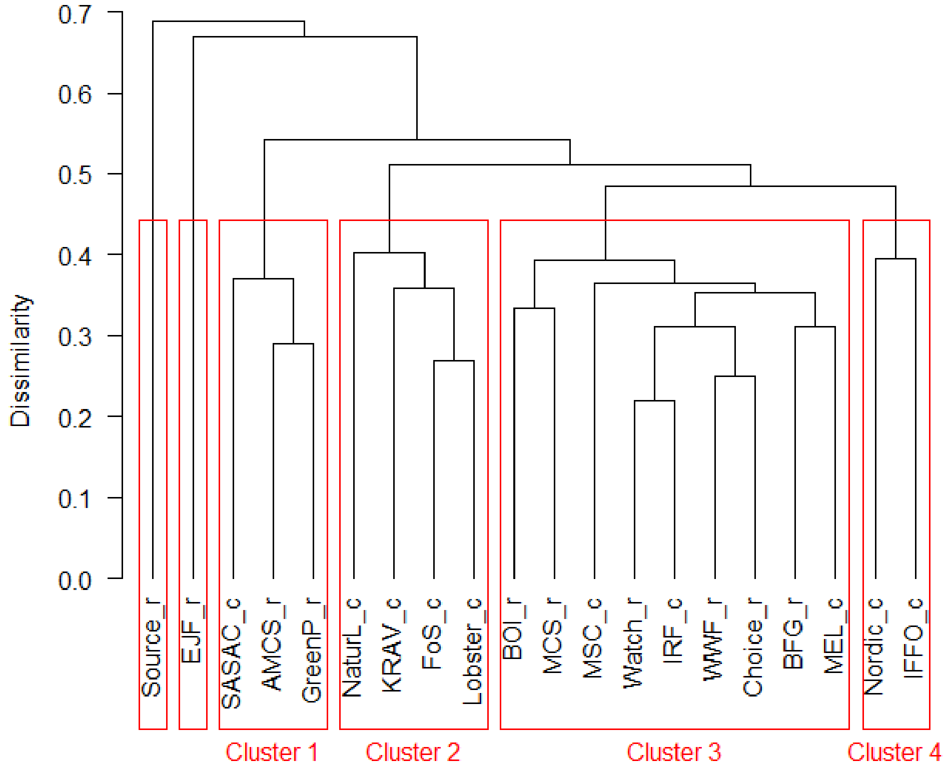

Figure 3.1: Hierarchical cluster analysis of the importance scores of the 35 sustainability criteria within 10 eco-certification schemes ("_c") and 10 sustainable seafood recommendation lists ("_r"). Clustering used Bray-Curtis dissimilarity distance and unweighted pair group method with arithmetic mean as agglomeration approach. Abbreviations explained in Table 3.1.

Cluster 1 contained three standards which had a 34% dissimilarity score based on criteria used and importance of these (SASAC, AMCS, GreenP; Fig. 3.1). These standards mostly used the fish stock and ecosystem criteria to assess sustainability; the criteria for the sustainability of management and science were less important and less frequently used, and social criteria were not included (Table 3.4). This cluster was a mix of an eco-certification scheme and two recommendation lists, however all three standards were set by eNGOs. Contrastingly, cluster 2 contained only eco-certification schemes (NaturL, KRAV, FoS, Lobster; Fig. 3.1). Schemes in this cluster used criteria from all five themes including social criteria such as healthy and safe working conditions (SS1) and training opportunities (SS2) as well as environmental sustainability (SE7; Table 3.4). Dissimilarity between the schemes was scored at 37 %.

Table 3.4: Importance score (1 low; 4 high) of the 35 sustainability assessment criteria (rows) in the 20 fisheries sustainability standards (columns). Assessment criteria are ordered by themes (leftmost column) and fishery sustainability standards were ordered by their similarity according to a hierarchical clustering solution (Fig. 3.1). †Indicates eco-certification schemes.

Theme and criteria		Sustainability standards																			
				Cluster 1			Cluster 2				Cluster 3									Cluster 4	
		Source	EJF	SASAC†	AMCS	GreenP	NaturL†	KRAV†	FoS†	Lobster†	BOI	MCS	MSC†	Watch	IRF†	WWF	Choice	BFG	MEL†	Nordic†	IFFO†
Fish stock	*SF1 - Status of the stock*	4		4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	1	
	SF2 - Fishing pressure	4		3	4	4		3	3		1	1	2	4	1	2	1	3	2	1	
	SF3 - Life history			3	4	4					4	4	2	4	3	2	3	3		1	
	SF4 - Recovery of overfished stocks	4									3	1	4	2	2	2	1		2	2	
	SF5 - Health and vulnerability of the fish stock					3					2		3	4	3	2	2	1			
	SF6 - Fish stock can fulfil its ecological role				4								3	4		2	1	1			
	SF7 - Overcapacity										2	1				2	1			1	3
	SF8 - Non-fishery impacts						4							3	3	2	1				
	SF9 - Impacts of other fisheries												3		2	2			1		3
Management	*SM1 - Compliance*	4				2	3	4	4	3		3	3	4	4	2	2	2	2	4	4
	SM2 - Management framework in place						4		4	4	4	3	4	4	4	2	1	3	4	4	4
	SM3 - Precautionary approach	4			4	3		3	3			3	2	3	4		1	1	2	4	4
	SM4 - Management measures in place						3			3	4	3	3	4	3	2	1	1	1	4	4
	SM5 - Effectiveness			3					3		4	3	3	4	3	4	4		4		
	SM6-. Adequacy of management											1		4	3	2	3	3	2		3
	SM7 - Participation and transparency									3			3	2	3	2	1		2		
	SM8 - Efficiency	3											3				1				
Ecosystem	*SE1 - Impact of fishing method on habitat quality*		4	4	4	4	3	3	3	3	4	3	3	4	3	3	4	3	1	4	3
	SE2 - Bycatch		4	4	4	4	3	3	4	4	4	3	3	4	3	3	4	3	2	1	3
	SE3 – Bycatch, ETP species		4		4	4			3	4	3		3	4		2	4	4	2	1	
	SE4 - Ecosystem functioning and integrity			3		4		3	4		2		3	4	4	2	1	4	4	4	
	SE5 - Discards		2			4			3	3		2		4	3	3	4	1		4	2
	SE6 - Ghost fishing								3							2	4	2	2		
	SE7 - Environmental sustainability (energy, etc.)							4	4	4									3		
Social	*SS1 - Fair, safe and healthy working conditions*		4				4	4	4	4											
	SS2 - Training opportunities						3	3		4											
	SS3 - Incentives and subsidies											1	3			2					
	SS4 - Appropriate dispute resolution framework						3						3								
	SS5 - Management protects cultural heritage							3													
	SS6 - Access and use rights												3								
Science	*SR1 - Collecting data and information*						3	3	3	3	2	1	3	4	3	2	2	3	3		2
	SR2 - Use of reference points & stock assessment								3	3		1	3	2	4	2	1	1	2	4	
	SR3 - Impact of science	4				4								2	3	2	1			3	4
	SR4 - Research												3		4		1	2	2		3
	SR5 - Sound basic biological knowledge of species							3									1	1			1
Number of assessment criteria used		**7**	**7**	**7**	**8**	**12**	**11**	**13**	**16**	**14**	**14**	**17**	**24**	**22**	**22**	**25**	**27**	**20**	**20**	**16**	**14**

Cluster 3, the largest of the four clusters, was composed of six eNGOs' sustainable seafood recommendation lists (BOI, BFG, Choice, MSC, Watch, WWF) and three eco-certification schemes (MSC, IRF, MEL; Fig. 3.1, Table 3.1), which had a dissimilarity score of 36%. The sustainability standards in this cluster contained more criteria (14 – 27 criteria) than those in any of the other clusters (7 – 16 criteria; Table 3.4). Criteria in this group came from all thematic areas, but included less social criteria than the other themes (Table 3.4).

Cluster 4 included only two eco-certification schemes (IFFO, Nordic; Fig. 3.1), and the dissimilarity between them was 40%. The themes in this cluster were similar to those in cluster 3 (fish stocks, management, ecosystems, science). However, the criteria for management and science played a larger role compared to the fish stocks and the ecosystem (Table 3.4). The two schemes in this cluster were the only standards that did not count the status of fish stocks (SF1) as an important sustainability criterion (Table 3.4).

3.3.3. Core and conflicting criteria

Of the assessment criteria identified in the sustainability standards, some appeared within the majority of standards and had a high importance score whilst other criteria were mentioned in just a few standards and were of minor importance (Table 3.3). Consequently, there existed four possible combinations between the importance and frequency of use for the sustainability criteria (Table 3.5). A *high importance* score characterised criteria that were essential to the understanding of sustainability in the context of the sustainability standards, whereas low importance characterised the opposite. A *high frequency* indicated agreement between sustainability standards, whereas low frequencies indicated conflicting views. There were core sustainability criteria on which most schemes agreed and those that only had an important role in a few sustainability schemes (Tables 3.5).

Table 3.5: A general classification of sustainability criteria that reflect their usage (based on their frequency of occurrence and importance scoring; Table 3.6) in fisheries sustainability standards.

	Low importance	**High importance**
Low frequency	Least relevant for fisheries sustainability	Criteria for which the relevance for fisheries sustainability is debated
High frequency	Commonly accepted additional sustainability criteria	Core criteria for fisheries sustainability

Classifying the sustainability criteria from their relative frequency of occurrence and importance score (Table 3.6) showed that status of the stock (SF1) was the only criterion with very high frequency (>80 %) and a very high importance score (4.0). Eleven other criteria had a high frequency (>55 %) and a high importance score (>3.0) and together with SF1 (status of the stock) formed a core set of twelve fisheries sustainability criteria. The core criteria belonged to the fish stock status, ecosystem and fisheries management and science thematic areas (Table 3.6).

Table3.6: Classification of the 35 sustainability criteria based on both their frequency of occurrence across the 20 standards (5-25% low; 80-100% high) and their importance (1-1.5 low; 4 high) within the standards as determined in this study (Table 3.3). For criteria codes see Table 3.1.

Relative frequency of occurrence	Importance score: 1.0-1.5	2.0-2.5	3.0-3.5	4.0
5-25%	**SR5:** Sound basic biological knowledge of the species	**SF9:** Impacts of other fisheries **SE6:** Ghost fishing **SS3:** Incentives and subsidies	**SF8:** Non-fishery impacts **SM8:** Efficiency **SS2:** Training opportunity **SS4:** Dispute resolution **SS5:** Cultural heritage **SS6:** Access and use rights	**SE7:** Environmental sustainability (energy, waste, pollution) **SS1:** Working conditions
30-50%	**SF7:** Overcapacity	**SF4:** Recovery of overfished stock **SF5:** Health of fish stock **SF6:** Stock fulfils ecological role **SM7:** Participation and transparency **SR4:** Research	**SM5:** Effectiveness **SM6:** Adequate management **SR3:** Impact of science	
55-75%		**SR2:** Use of reference points and stock assessment	**SF3:** Life history **SM3:** Precautionary principle **SM4:** Management measures **SE5:** Discards **SR1:** Collecting data & information	**SM2:** Management framework in place **SE3:** Bycatch of ETP species **SE4:** Ecosystem functioning and integrity
80-100%		**SF2:** Fishing pressure	**SM1:** Compliance **SE1:** Impact of fishing methods on the habitat quality **SE2:** Bycatch	**SF1:** Status of the stock

SF: Assessment criteria referring to the sustainability of fish stocks; **SM:** Assessment criteria referring to sustainable fisheries management; **SE:** Assessment criteria referring to the sustainability of ecosystems; **SS:** Assessment criteria referring to social sustainability; **SR:** Assessment criteria referring to science and research for sustainability

Additional sustainability criteria that either had moderately high importance (2.0-2.5) or were used moderately frequently (30-50 %) contained mostly criteria from the thematic areas of fish stocks, management and science (Table 3.6). Social sustainability criteria were infrequently used (5-25 %) but had a high importance (3.0-4.0) (Table 3.6). Five of the social sustainability criteria (SS1, SS2, SS4, SS5 and SS6) together with environmental sustainability (SE7), non-fishery impacts on the fish stocks (SF8) and efficient management (SM8) formed a group of conflicting criteria for which the relevance for fisheries sustainability was debated between standards (low frequency but high importance; Table 3.6). There were no criteria with very low importance (1.0-1.5) that were used frequently (>50 %).

3.3.4. Identification of candidate social sustainability criteria

The published scientific studies assessing the sustainability of fisheries used a range of social sustainability criteria. Twenty eight criteria were extracted from the random literature sample (N = 51) and aggregated into two sustainability themes corresponding to sustainability at the level of the individual fishermen and the fishing communities (Table 3.7).

Table 3.7: Candidate list for social sustainability criteria relating to fishermen and the fishing communities, that were used in a sample of 51 published studies on fisheries sustainability assessments (this is a randomly selected 15% of the total number of studies identified in a Web of Science search). *criteria that refer to assets that are necessary in order to deal with change and shocks.

Social sustainability criteria	Frequency
Fishermen	
Basic rights (no discrimination)	49%
Income	49%
Employment diversity and fishing dependency	31%
Fair use and access rights	26%
Financial situation*	23%
Safety	23%
Knowledge*	20%
Infrastructure*	20%
Health*	17%
Social and economic well-being	17%
Natural assets (land, livestock…)*	9%
Fishing communities	
Employment	66%
Food supply	46%
Productivity	46%
Conflict	40%
Industry profitability	37%
Social cohesion and cooperation*	34%
Market structure and access*	31%
Contribution to economy	29%
Age structure of fisher population*	29%
Equity of income and benefits	29%
Subsidies	27%
Culture and Tradition	20%
Benefits for fishing communities and towns	14%
External drivers (natural and social)	9%
Gender equity	9%
Indigenous communities	6%
Values and stewardship	6%

For the individual fishermen, the respect for basic rights and income were the most frequently employed criteria (Table 3.7). For the fishing communities, the level of employment was the most commonly used sustainability criteria (66%), followed by food supply (46%) and the productivity of the fisheries (46%; Table 3.7). There was overlap between the criteria identified here and the sustainability standards for five of the six social sustainability criteria of the sustainability standards: the respect for basic rights including fair, safe and healthy working conditions (SS1), subsidies (SS3), no conflict or an appropriate dispute resolution framework (SS4), culture and tradition or the protection of cultural heritage (SS5), and fair use and access rights (SS6). Only training opportunities for resource user was a social criterion used by the sustainability standards, but not by the scientific assessments. The scientific assessments used more (frequency of criteria) and more different (number of criteria) criteria. Several of the criteria were related to different forms of assets that the fishermen or the fishing communities need to possess in order to deal with change and shocks (Table 3.7). In contrast to the sustainability standards, the scientific assessments did not use science specific criteria, i.e. no criteria to better understand fishing communities or to monitor trends in employment.

3.4. Discussion

This study reviewed the criteria used by 20 sustainability standards for evaluating fisheries sustainability and informing consumers about the sustainability of different products. We assessed what the sustainability standards actually measured and how their assessments compared. The costs of seeking assessment (Blackmore et al. 2015) have put market-based fisheries sustainability assessments under pressure to prove and quantify their effectiveness (Christian et al. 2013). The uptake of sustainability standards and their impacts have consequently been an active area of research interest (Gutiérrez et al. 2016).

The 20 standards employed a total of 35 criteria belonging to five overarching themes: sustainability of the fish stocks (9 criteria), fisheries management regimes (8 criteria), the ecosystem (7 criteria), social aspects of fisheries (6 criteria), and the use of science to assess fish stocks and inform management (5 criteria). All criteria covered themes that are relevant to sustainable fisheries management (Beddington et al. 2007; Chapter 2). The sustainability standards aligned with the current paradigm of fisheries management and science: to expand the sustainability concept from the fish stocks to the ecosystem (e.g. Pikitch et al. 2004). However, the criteria used in the standards did not address all of the issues identified by the research on fisheries sustainability. For instance, fisheries co-management, sustainable livelihoods, poverty reduction, individual transferable quotas and economic benefits can also be important within the context of fisheries sustainability (Chapter 2). Although some of the standards addressed social and economic components of the fishery system, they were covered poorly when compared with the ecological components (Tables 3.2 and 3.8). Thus, it seems justifiable to conclude that as of now, the concept of sustainability is understood in fisheries sustainability standards as a predominantly ecological concept.

Shared assessment criteria

In opposition to the initial expectation that sustainability criteria would vary greatly between different standards issues by different institutions, the results of this study showed that there were twelve criteria in common between the 20 standards that represent their unified definition of fisheries sustainability. The twelve core criteria included two referring to the fish stock, five referring to the ecosystem, and five referring to management and science, and none referred to the social sustainability (Table 3.8). The criterion that was used most frequently and that had the highest importance was the status of the stock (SF1; Table 3.3). However, all sustainability standards with the exception of one (WWF; Table 3.4) considered other criteria to be equally important as the status of the stock. A fishery that scores well on all 12 of the core criteria (Table 3.8) is probably ecologically sustainable. The overlap in criteria can be explained by the sustainability standards using some of the same sources to develop their criteria (Cummins 2004; Gulbrandsen 2009), e.g. the Food and Agriculture Organization’s (FAO) Code of Conduct for Responsible Fisheries (FAO 1995), the Guidelines for the Ecolabelling of Fish and Fishery Products (FAO 2005), and some which include stakeholder consultation with fisheries experts, scientists, and eNGOs. It has been suggested repeatedly that the introduction of shared criteria should be a minimum requirement for fisheries that pass sustainability standard schemes to help to avoid confusing the consumer(s) and thus maintain their support for sustainable products; although this concern has often been raised, no empirical evidence has been presented that shows a loss of consumer support (Wessells et al. 2001; Leadbitter & Ward 2007; Roheim 2009b; Schmitt 2011). It is also possible that familiarity with eco-labels increases consumers’ willingness to buy sustainable products. This could mean that the reverse would apply: a bad reputation for one standard could have negative spill-over effects on the others reducing consumer trust. To fulfil the information needs of the consumers and maintain trust in eco-labels in general (Roheim 2009b), it is desirable to ensure that all “sustainable” fishery products address certain core criteria as a minimum requirement.

To increase the consistency among standards, the Global Sustainable Seafood Initiative (GSSI) developed a tool to benchmark fisheries and aquaculture standards (GSSI 2015). As of March

2017, the relatively new benchmark tool had recognized three schemes: IRF, the Alaska Responsible Fisheries Management Certification Program, and with the MSC, also a globally operating sustainability standard. Several large retailers (e.g. Walmart U.S.) have committed to accepting seafood products certified by sustainability standards that are recognized by the GSSI. The benchmark tool considers: how a standard is managed, how the accreditation and certification process are handled, and how a standard assesses sustainability. The twelve core criteria identified in this study overlap mostly with the ecological criteria required by the benchmark tool (Table 3.8). In the management and science themes the GSSI requires a larger number of criteria (GSSI 2015) than identified in the standards assessed by the present study. The standards reviewed additionally considered the life history of the target species (SF3) and discards (SE5). So, overall it seems that in the future the GSSI should promote consistency between the criteria of the different standards in addition to the 12 presently shared criteria.

Table 3.8: The 12 core sustainability criteria used in the 20 fisheries sustainability standards reviewed here and the suggested additional new sustainability criteria (the first seven are from the literature review and the final two were added to cover a gap identified on management structures and research around social issues). *Indicates core criteria that are similar to those listed in the GSSI global benchmark tool for seafood certification schemes.

Core criteria	Suggested new social sustainability criteria
- **SF1:** Status of stock* - **SF3:** Life history - **SE1:** Impact on habitats* - **SE2:** Bycatch * - **SE3:** Bycatch of ETP sp.* - **SE4:** Ecosystem health* - **SE5:** Discards - **SM1:** Compliance* - **SM2:** Management framework* - **SM3:** Precautionary principle* - **SM4:** Management measures* - **SR1:** Collecting data & info.*	- Trends in the productivity of the fishery - Minimum income or food supply for fishers - Level of employment in the fishery - Food supply to the community - Respect for basic human rights - Equity in access and use - Assets of fishers and the fishing community - Existence of supportive management structures - Understanding the underlying processes of social sustainability

While the existence of a set of core criteria is encouraging, their longevity may be limited unless they are reviewed periodically. Many of the core criteria are based on international treaties and stakeholder consultation and so will need to be updated along with new international agreements and guidelines (e.g. FAO 2015). Adjustments will also be required for changing stakeholder preferences (Tompkins et al. 2008). Both issues pose a challenge for eco-certification because it is unclear if fisheries should lose their eco-label if the criteria are changed (Butterworth 2016). Some of the criteria identified in this study, e.g. fisheries bycatch, discards and compliance with rules, appear to be core criteria because they correspond to negative impacts from fishing that are currently perceived as serious issues.

Such criteria are based on the current realities rather than on a vision of sustainability (Bratt et al. 2011). With changes in fisheries management, they may become less relevant, while emerging challenges will have to be incorporated. Thus, over the long-term the sustainability standards need to be dynamic and their criteria should be viewed explicitly as the expression of societal challenges, priorities and capacities at a given point in time.

Diversity of assessment criteria

Although there were twelve core criteria (Table 3.8) adopted by over half of the standards reviewed (Table 3.4) there remained a further 23 criteria used in the 20 standards. The standards formed four groups that differed with regard to the inclusion of social and science themes and the prioritization, i.e. the number and importance of the criteria, of the fish stock, ecosystem and management themes. For other sectors the case is similar; there are many standards, and while they employ some common criteria they also use a variety of different criteria (Reinecke et al. 2012). Two dynamics are thought to be at work: they share the same overall goal and so some criteria converge, but because discrete characteristics are required to sustain their market shares they maintain differentiation (Roheim 2009b; Reinecke et al. 2012). However, different criteria and inconsistent weightings of criteria can lead to one fishery or fishery product being evaluated differently by the different standards (see examples in Roheim 2009b). This study found that some criteria were used in less than half the standards, but were considered very important within those standards (Table 3.6). These were identified as "conflicting criteria" (Table 3.5 and 3.6), meaning that there was now agreement on these criteria between the different standards. They included (1) the effectiveness (SM5), adequacy (SM6) and efficiency (SM8) of fisheries management, (2) social criteria (SS1, SS2, SS4, SS5, SS6), and (3) environmental criteria (SE7). In order to balance the potential benefits derived from having diverse sustainability standards with the drawbacks, an increased transparency of the conflicts (i.e. the pros and cons) could be included in the labelling on the packaging (Van Amstel et al. 2008), which could then improve consumer education and awareness (Kemmerly & Macfarlane 2009).

Using a limited number of core criteria for fisheries sustainability could become counterproductive to achieving sustainability. A fishery that does not fulfil all 12 core criteria is not automatically unsustainable; the complexity of fisheries sustainability means that a fishery could achieve comparable sustainability due to different factors. For example, fisheries where the stocks are assessed scientifically and which have a management regime in place have been found to be, on average, more sustainable than those that do not (Hilborn

& Ovando 2014). However, fisheries have also been found to be sustainable e.g. when the stocks have natural refuge areas (Cinner et al. 2016) or when there is strong leadership within the fishing industry and high social capital (Gutiérrez et al. 2011). In this sense, the 12 criteria are not a *necessary* condition but rather form a *sufficient* condition for a fishery that is sustainable ecologically. The 12 core criteria are sufficient for indicating the achievement of sustainable fishery outcomes but they are not necessary because there are other alternative ways of achieving sustainability that may not have been captured by the core criteria (Manktelow 2012). Streamlining the sustainability criteria too much could actually invalidate sustainable pathways that are working successfully for a small number of fisheries, and innovative solutions, for achieving sustainability, may be lost.

Diversity of different sustainability standards

The selection of themes and the comprehensiveness of the criteria did not vary systematically between the eco-certification standards and the recommendation lists (Table 3.1). This may be because all parties were involved in the creation and revision of the eco-certification schemes so that their sustainability demands widely align (Wessells et al. 2001). Eco-certification schemes were inspired by eNGOs guidance on sustainable seafood (Gulbrandsen 2009) and in turn sustainable seafood recommendation lists have imitated the assessment process of the eco-certification schemes (Roheim 2008). Recommendation lists were less likely to include social criteria than the eco-certification schemes, i.e. of the ten recommendation lists only the MCS and WWF included incentives and subsidies (SS3) as criteria, albeit not weighted as important, and the EJF included working conditions (SS1; Table 3.4). The omission of social criteria from those used in the recommendation lists is probably related to the environmental focus of the organizations that produce them (Table 3.1). The involvement of primarily socially-oriented NGOs in the production of fisheries sustainability standards could redress the balance and raise the prominence of the social components of fisheries.

The underlying criteria of the different standards show that they are assessing different aspects of sustainability. The most comprehensive assessments in order of the total number of criteria used were Choice, WWF, MSC, Watch and IRF, BFG, MEL, which all used ≥20 criteria. KRAV, NaturL, Lobster, MSC and FoS considered criteria from all five sustainability themes to be important and so gave a good overview of the different aspects of sustainability. MSC and FoS are the most widely-used standards (Potts et al. 2016). However, if we consider the complete fishery system comprised of both the ecological and social components (Ostrom 2009) the best balance was achieved by the Krav, NaturL and Lobster standards. BOI, Watch, IRF, Choice, BFG, MEL, Source, Nordic, GreenP and IFFO contained no social sustainability criteria, but used criteria from all of the other four themes. Some of the standards which included only one or two management criteria (SASAC, AMCS, GreenP) compensated by attributing high importance to criteria for the pressure on (SF2 and SF7) and the life history and health (SF3 and SF5) of the stocks, i.e. the pressures on and the resilience of the natural resource. EJF was exceptional in not including a single criterion that assessed the fish stock or the management process and so only reflected ecosystem (five criteria) and social (one criterion) sustainability. Another notable standard was Source which did not once refer to ecosystem sustainability.

Social sustainability criteria

The sustainability standards covered six criteria in the social sustainability theme (SS1-6, Table 3.1) and of these each occurred in between one and five of the 20 standards (Table 3.4). Thus, the socio-economic criteria were fewer and were used far less frequently compared to the other four themes (fish stocks, ecosystem, management, and science). This finding confirms the results from earlier studies that compared fisheries eco-certification schemes according to a set of a priori attributes (Wessells et al. 2001; Leadbitter & Ward 2007; Parkes et al. 2010). The MSC standard, which uses three social criteria (from 24) consciously focused on assessing the management system and the ecological sustainability of fisheries, because there was no consensus on how to assess social sustainability (Gulbrandsen 2009). There is also an underlying fear of neglecting ecological concerns when focusing on socio-economic criteria (Bush et al. 2013). In this way, fisheries sustainability standards differ from comparable approaches in aquaculture and forestry where at least the working conditions of employees (SS1) are commonly included in the sustainability standards (e.g. Forest Stewardship Council and Aquaculture Stewardship Council). It could be that because fisheries operate offshore it is more difficult to monitor e.g. working conditions (Bailey et al. 2016), despite fishing being a notoriously dangerous job (Windle et al. 2008).

The lack of social criteria could also be due to fisheries management focussing traditionally on the ecological aspects and attributing a lower priority to the social issues (Cochrane 2000; Symes & Phillipson 2009). However, a new paradigm was established in fisheries management and science in the 2000s so that now fisheries are often viewed as one connected social-ecological system (McClanahan et al. 2009; Ostrom 2009; Chapter 2). Thus, the importance of social factors for the ecological sustainability of the resources, has now gained prominence in fisheries science (e.g. Gutiérrez et al. 2012; Cinner et al. 2016). Fisheries sustainability standards, despite only emerging in the 2000s (Chapter 2) have not incorporated this changing perspective on fisheries, and thus, are not reflective of recent research that shows that to achieve sustainability action must be holistic (e.g. Gutiérrez et al. 2012; Cinner et al. 2016).

A number of studies have recently highlighted the additional less tangible benefits of eco-certification including: an improved reputation of some fisheries (Bellchambers et al. 2016a), self-esteem and pride of the fishermen (Carlson & Palmer 2016), and the empowerment of fishermen by making them aware of their rights (Carlson & Palmer 2016). Eco-certification also stimulated participatory management processes (Gulbrandsen 2009, but see also Carlson & Palmer 2016) and strengthened the partnerships between states and fishery stakeholders (Adolf et al. 2016; Butterworth 2016). Government authorities identified policy gaps (Cairns et al. 2016), employed new management strategies (Cairns et al. 2016; Carlson & Palmer 2016) and showed increased interest in investing in fisheries (Blackmore et al. 2015; Bellchambers et al. 2016a; Carlson & Palmer 2016). Monitoring and data collection activities were enhanced (Carlson & Palmer 2016) and the environmental awareness of both the industry and the government increased (Butterworth 2016; Cairns et al. 2016; Carlson & Palmer 2016). Not all of these intangible benefits occurred consistently across the certified fisheries (Carlson & Palmer 2016), but the examples show that fisheries eco-certification can have positive intangible side-effects. Meta-analyses of fisheries as social-ecological systems (Gutiérrez et al. 2012; Cinner et al. 2016) suggest that psychological, social and political factors such as self-esteem, empowerment and participation in the management process may play a key role in achieving ecological sustainability.

One argument against using social criteria in fisheries assessments is that they are very diverse in terms of their gears, participants, fleet and community structure, and the social sustainability challenges (Chuenpagdee et al. 2006; Teh et al. 2013). However, fisheries are also very diverse in terms of their target species, fishing areas and the management systems (Salas et al. 2007; Guyader et al. 2013), and it has been possible to develop flexible ecological criteria that apply to a wide range of fisheries. With the increasing number of sustainability standards, it has been observed that some standards fulfil additional conditions in order to further differentiate themselves (Bush et al. 2013). This is one way in which social criteria could become integrated into the existing sustainability standards. The present study reviewed a sample of published studies that assessed fisheries sustainability and identified

28 social criteria that related to the individual fisher (11 criteria) as well as the communities (16 criteria) on which they were based (Table 3.7). The most frequently used criteria in the fisheries research literature included (in order of frequency) were: the overall level of employment within the fishery, respect for basic human rights, a minimum income for the fishers, the food supplied to the community, the productivity of the fishery (in terms of catch), and equity in access and use (Table 3.8).

Assessments of small-scale fisheries

Although fisheries eco-certification can have societal impacts that extend far beyond the individual certified fishery, the selection of which criteria to use is essential because they can directly affect which fisheries pursue assessment. Often, it is the fisheries that already fulfil the criteria that seek assessment whereas the others, using less sustainable practices, do not (Gulbrandsen 2009; Butterworth 2016; Carlson & Palmer 2016). This self-selection has meant that eco-certification schemes have not been adopted equally across the world, fishery sectors, fishing gears or fish stocks (Potts et al. 2016). For instance, by 2015 less than 12% of MSC-certified fish products are from developing countries (Potts et al. 2016).

Small-scale fisheries account for 25-33% of the global catch (Chuenpagdee et al. 2006) and developing countries account for 60-80% (FAO 2016; Potts et al. 2016). Thus, their involvement in the fisheries sustainability movement is critical (Jacquet & Pauly 2008; Blackmore et al. 2015). In the developing world, eco-certification was initially seen as a form of eco-imperialism: the industrialized world's understanding of sustainability was being imposed on them (Constance & Bonnano 1999), and used as a trade barrier, to the disadvantage of developing countries (Butterworth 2016). However, solutions to the under-representation of small-scale fisheries and developing countries have been developed. For instance, the MSC has initiated a Fishery Improvements Projects (FIPs) to include these fisheries in the eco-certification process (Sampson et al. 2015). In 2008 the FoS was founded, which has a different set of criteria and lower certification costs than the MSC, and the FoS has achieved a market share equal to the MSC in less than 10 years (Blackmore et al. 2015; Potts et al. 2016). This case demonstrates the impact of the selection of sustainability criteria for assessing sustainability and the importance sustainability standards could have as a tool for achieving worldwide fisheries sustainability.

Holistic assessments of fisheries as social-ecological systems

In Chapter 2 it was proposed that fisheries sustainability can be defined as: the continuous existence of the socio-ecological fishery system in such a way that it provides goods and services now and in the future without depleting natural resources, and the sustainable processes that make both possible. This definition was a clarification of the understanding of the sustainability concept in the fisheries science literature. In order to be applicable to fisheries assessment, and e.g. to be useful in integrating small-scale fisheries in the process of eco-certification, this definition has to be filled with more specific criteria and indicators.

The 12 core criteria identified in this study can be used to fill the sustainability definition from an ecological point of view. But these criteria do not incorporate adequately the social components of fisheries (Table 3.8). Addition of the following social criteria (italicised) would satisfy the definition of sustainability for the social elements of the fishery system (Table 3.8): the continuous existence of the fishery (*the trends in the productivity of the fishery*); the delivery of benefits to the individual (i.e. *a minimum income or food supply*) and the community (i.e. *the level of employment or food supply*); the processes that make both possible (*the assets of the fishers and the community, supportive management; and the understanding of underlying processes*); and, should comply with societal standards (*respect for basic human rights; equity in access and use*).

Six of these criteria were identified frequently as important within the sample of fisheries research literature reviewed in this study (Section 3.4, Tables 3.7 and 3.8), the remaining three (Table 3.8) could be reflected by combinations of several, infrequently used, criteria within the 20 standards reviewed in the present study. For instance the *existence of supportive management structures* could be determined from the adequacy (SM6) and transparency and participation in management (SM7). There are several frameworks that have already operationalized these elements of fisheries, e.g. the sustainable livelihood framework for the issue of fishers' assets (Allison & Ellis 2001).

As discussed earlier, diverse assessment criteria can also be beneficial for fisheries sustainability, and the diversity of aspects that can be included in the sustainability concept is part of the reason for the many different contextual meanings of sustainability found in Chapter 2. The proposed sustainability definition in Chapter 2 operates on a meta-level and avoids the difficult decision which specific criteria indicate sustainability. However, the lack of specifics may also limit the applicability of the definition. Combining the twelve core criteria with the nine other proposed criteria would be one configuration of the sustainability definition that brings it into alignment with recent international agreements such as the FAO's Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries (FAO 2015) and could help to further both ecological and social sustainability through fisheries eco-certification.

Conclusions

Market based sustainability assessments have been one of the great turning points in the management of natural resources in recent years (Jacquet & Pauly 2007; Gulbrandsen 2009). The attractiveness of sustainability standards such as eco-certification is that they combine elements of exploitation, management, and environmental conservation to provide an overview of the sustainability of natural resources. In addition, they may help consumers make informed decisions and show their support for sustainable practices (Ward & Phillips 2009). Consumers of seafood products are becoming increasingly acquainted with sustainability standards and so their influence is growing.

The sustainability standards examined in the present study assessed different aspects of fisheries sustainability but shared a dozen criteria. A suite of consistent *necessary* common criteria can provide clarity for consumers and promote continued consumer support (Roheim 2009b) for sustainable products, but while consistency is beneficial for consumers a diversity of dynamic criteria is also desirable. This engenders innovation and allows for the accommodation of different types of fisheries that may be achieving sustainability through other pathways such as those for small-scale fisheries. Unlike sustainability standards for natural resources in aquaculture, agriculture and forestry within the fisheries standards the concept of sustainability was understood as a predominantly ecological concept. Although the concept of the wider ecosystem was incorporated in most standards consideration of social aspects of the fishery system were lacking. Thus, the standards have not incorporated the changing perspectives on fisheries that show the achievement of sustainability needs to be holistic including consideration of the wider ecosystem and social elements of the fishery system (e.g. Gutiérrez et al. 2012; Cinner et al. 2016). Within fisheries science, it has been shown that sustainable fisheries are those that are both ecologically and socially sustainable, and one in fact can depend on the other (Gutiérrez et al. 2012; Cinner et al. 2016).

Small-scale fisheries and those in developing countries account for 25-33% and 60-80% of the global catch, respectively (Chuenpagdee et al. 2006; FAO 2016; Potts et al. 2016) but their engagement in sustainability assessments is low compared with commercial fisheries. To further their inclusion and improve the overall ecological outcomes nine new criteria were identified in the present study to reflect the social sustainability of the fishery system. The inclusivity of social criteria within the sustainability standards is important because they are increasingly being adopted into fisheries management and regulatory assessments in some countries (Nimmo & Southall 2012; Adolf et al. 2016; Bellchambers et al. 2016b; Hazen et al. 2016). The new criteria will also help to align the standards more closely with relevant international agreements (FAO 1995; 2015) and the current paradigm of fisheries management (Chapter 2 and references therein).

In the context of this thesis, the analysis of the sustainability standards and the extraction of social criteria from scientific studies resulted into a set of ecological and social criteria that specify the layers of the sustainability definition developed Chapter 2: Continuity through time, sustainable outcomes and sustainable processes. But the established approach of assessing sustainability through a set of criteria did not allow the assessment of the outermost layer, the dialogue by which decisions about the other layers are taken. To fill this gap, Chapter 4 proposes a different approach of using conflict as sustainability indicator.

4. Fisheries sustainability: A conflict analysis approach

Abstract

Sustainability assessments that consider the ecological as well as the socio-economic dimension of sustainability face the challenges of incorporating the diverse and often incompatible goals of the different actors. Decisions about the sustainability of the entire fishery system are taken in a dialogue between these actors. I suggest that the degree of conflict (or cooperation) between actors can be used as an indicator of this dialogue, and, given that the dialogue has an impact on the continuity, outcomes and processes in the fishery, conflict (or cooperation) may also indicate other aspects of sustainability. A formal conflict analysis was used to assess if an English inshore fishery with co-management arrangements in place was managed more sustainably, when multiple aspects of sustainability were included and achieved more sustainable outcomes than the centrally managed UK component of the cod (*Gadus morhua*) fishery in the North Sea. The fisheries were conceptualized as social networks and the interactions between the actor groups were scored as being either positive or negative in nature. The net quality of the interactions between key actor groups represented the level of conflict. Contrary to our expectations, the same actor groups were involved in both fisheries. From the beginning, there was less conflict in the inshore fishery than in the cod fishery. In the cod fishery, patterns of interactions repeated themselves and the overall level of conflict decreased over time. The relationship between conflict and resource levels was assessed for the cod fishery where cooperation between the fishing industry and the management authorities only occurred once resource levels had reached their lowest point. I conclude that conflict analysis is a promising tool to study empirically human behaviour in marine management, but that only conflict and resource levels together give a complete picture of the sustainability of a socio-ecological system such as a fishery.

4.1. Introduction

Worldwide fisheries and aquaculture provide 3.1 billion people with ~20% of their animal protein, and directly employ over 50 million people (Teh & Sumaila 2013; FAO 2016); but, in addition they exert great pressure on fish stocks and the marine ecosystems exploited (Pauly & Zeller 2016a). Against the background of an increasing world population and limited natural resources, the United Nations' Sustainability Development Goals (SDG) contain both the call to end hunger, achieve food security and improve nutrition (SDG 2), and they recognise the need to conserve oceans, seas and marine resources and use them sustainably (SDG 14) (United Nations General Assembly 2015). To maximise human well-being whilst ensuring the conservation of natural resources is a challenge inherent to the concept of sustainability (Redclift 2005) and *the* core task of fisheries management (Rice & Garcia 2011).

In order to manage natural resources sustainably, we must understand what sustainability is and how it can be assessed (Garcia & Staples 2000; Chapter 2). Four approaches are commonly used to assess fisheries sustainability: (1) comparison of the current state of the fish stocks or the environment with previously healthy or natural states (Jackson et al. 2001); in this approach, the previous state or the natural conditions embody sustainability. (2) Measuring a range of sustainability reference points, criteria and indicators (Garcia & Staples 2000; Caddy 2011; Pitcher et al. 2013); where these metrics are used to reflect the condition of the fishery, to compare different fisheries, and to communicate the state of fisheries to the authorities and the public. (3) Aggregating multiple indicators into a single sustainability index that can be used for large-scale comparisons and to raise public awareness (Halpern et al. 2012); alternatively, a single variable can be used as sustainability indicator if it reflects the characteristics of the overall situation (e.g. Swartz et al. 2010). (4) The state of the resources are evaluated against the preferences of key stakeholders and decision-makers (Pascoe et al. 2014); and, these general trends in opinion can be used to guide management.

The four different assessment approaches all face the challenge of embracing differing sustainability goals such as long-term environmental protection and immediate societal benefits (Halpern et al. 2013). The negotiation about these different goals takes place in a dialogue between stakeholders or on the societal level (Chapter 2). When sustainability goals are incompatible, conflict arises (Charles 1992; Hilborn 2007b). For example, when sustainability goals are not met, fisheries scientists denounce a lack of biological sustainability; environmental organizations condemn the impacts on the ecosystem: and, fishing organizations complain about poor management and unequal access rights (Hilborn 2007b). The presence of conflict in fisheries management has been seen as an indicator of a major failure of the management process (Bennett et al. 2001; Arlinghaus 2005; Coffey 2005; Stepanova & Bruckmeier 2013). However, the existence of conflict between stakeholders might itself be employed as a powerful indicator of the sustainability of the fishery system. Conflict indicates that there are problems with the dialogue surrounding natural resources and sustainability.

As conceptualized in Chapter 2, the dialogue is about sustainable management processes, outcomes, and the continuity of the fishery and fishery resources. In Chapter 3, fisheries sustainability standards were analysed to propose specific criteria for these layers of sustainability. However, conflict may also be an indicator of a lack of sustainability in one or several of these layers. For example, conflict about access rights and the efficiency of management systems (Charles 1992) is a debate about the fisheries management process. Conflict may also arise because of unsustainable outcomes, e.g. when fishermen fear for their livelihoods. Finally, suppositions have been made about the relationships between natural resource levels, i.e. the continuity of fishery resources, and the emergence of conflict (Garcia & Charles 2008): they have not, to our knowledge, been the focus of empirical conflict research (Stepanova & Bruckmeier 2013). Without an objective means of assessing conflict such hypotheses regarding the interactions between conflict and complex natural resource systems cannot be tested.

In this study, 'conflict' is measured as the prevalence of negative interactions between stakeholders over positive interactions. The more negative interactions the greater the level of conflict. Analysis of such interactions between key actor groups has been used with success in other fields to research violence, war and peace (Schrodt 2012a). The approach allows for comparisons of conflict across time (Goldstein & Pevehouse 1997) and systems (Murdie & Peksen 2015), for the empirical testing of hypotheses about complex social phenomena (Zeitzoff 2016), and for the forecasting, and perhaps prevention, of conflict (Brandt et al. 2011).

Formal conflict analysis was adapted from that used in the political science and applied to a co-managed inshore mixed fishery in the UK. Even in industrialized countries, small-scale fisheries often lack the resources for effective top-down management and have to rely instead on cooperation between management authorities, fishermen and other stakeholders. To address the question whether conflict is a suitable indicator for dialogue and other layers of sustainability in small-scale fisheries, the inshore fishery was compared to a contrasting offshore fishery: the centrally managed UK cod fishery. It was assumed that the dialogue would be more cooperative and less conflictive in a co-managed fishery than a centrally managed fishery (Ostrom 1990; Cinner et al. 2012) because there is greater public participation in the management process (Coffey 2005) and greater opportunities for establishing strong relationships, mutual respect and understanding between the actors (Bennett et al. 2001; Arlinghaus 2005; Stepanova & Bruckmeier 2013). Therefore, a more constructive dialogue about fisheries sustainability issues was expected to be evidenced by: (i) more actors being actively engaged in the dialogue, (ii) a decrease of conflict over time as the actors repeatedly interact and get to know one another, and (iii) the development of patterns of interactions that facilitate cooperation. From a management and outcome perspective, sustainability would be evidenced by lower levels of conflict when (iv) actors are achieving their sustainability goals. From the perspective of continuity through time, conflict would be a suitable indicator for sustainability if it correlated with (v) healthy fish stocks.

It was not possible to perform separate conflict analyses for sustainable management processes and the desired outcomes, such as healthy fish stocks and the enhancement of livelihoods, because the two concepts were too closely intertwined in the two case study fisheries. With low stock levels and a good recovery management plan in place, the fisheries can be considered sustainable from a management process perspective although not (yet) from an outcome perspective. Likewise, the biomass of a fish stock may be high (*a sustainable outcome*), but if the fishery is not regulated *and* exploitation is high, it may not actually be a sustainable fishery because *the management process is unsustainable* (Hilborn et al. 2015).

It is recognised that inherent differences between the two management regimes and the two data sets, e.g. length of time series and temporal resolution of the data, are likely to affect the apparent variance. For example, the annual reporting of the cod fishery will show no seasonal variation, whereas the seasonal nature of different components of the mixed fishery combined with the greater frequency of meetings, could induce a seasonal signal leading to a higher variance over the time series. This difference in variability was not expected to undermine the basic premise. This point will be taken up again in the discussion.

4.2. Methods

4.2.1. Case studies

This study used data from two case studies: the inshore fishery in the territory of the English North Western Inshore Fisheries and Conservation Authority (NWIFCA), and the UK North Sea cod fishery (ICES division IV). In the NWIFCA, hand gatherers target cockles and mussels in the intertidal zone, there is beam trawling for shrimps, pots are used for brown crab and lobster, small vessels set gillnets (for cod, bass, grey mullet, sole and plaice) and the area is dredged for seed mussels (Nimmo & Southall 2012). In the North Sea, cod is caught by trawl, seine, and gillnet as a target species and is also caught in mixed demersal fisheries (ICES 2014). UK vessels comprise the largest fleet in the cod fishery accounting for on average 45% of the landed biomass from 2010 to 2014 (ICES 2014). These two fisheries were chosen to compare a centrally managed fishery with a fishery that has co-management arrangements in place, i.e. involves fishers and other stakeholder groups in the decision-making process (Table 4.1).

Table 4.1: Characteristics of the case study fisheries.

Characteristics	NW English inshore fishery	UK North Sea cod fishery
Fishery type	Inshore (6 nm zone)	Offshore
Attributes of resource users		
Resource dependency	Low - medium (mixed fishery)	Low - medium (mixed fishery)
Self-organization	Low	High
Attributes of the resource		
Biomass levels	Below historic levels (2011-2014)	Below the biomass that would provide the maximum sustainable yield (BMSY) (1998-2014)
Population dynamics	Highly unpredictable & not well-studied	Well-studied
Mobility of species	Sedentary	Mobile
Value of target species	Medium - high	Medium – high
Management type	Stakeholder integrated in decision-making process through positions on the committees of the regional fisheries authority. Stakeholders are selected for their expertise, not to represent the interests of a specific group	Centrally managed by the EU and Norway; Total allowable catches for EU fleets set by EU Council of fisheries Ministers. Stakeholders not formally included in decision-making
Occurrence of conflict	Conflicting views are obstacle for management (Rodwell et al. 2014)	Controversial policy changes (Gray et al. 2008)

[1] The cod fishery is part of a mixed fishery, but this study used only interactions relating to cod fishing and management.

4.2.2. The generation of conflict data

4.2.2.1. General approach

Conflict associated with the exploitation of natural resources can be analysed using ‘event data’: a type of information commonly used in quantitative analyses of international politics (Schrodt 2012a). Event data as a tool for the quantitative analysis of international politics dates back >30 years (Azar 1980) and the approach has seen a renaissance in the 2000s (Schrodt 2012a). An ‘event’ is defined as “an interaction, associated with a specific point in time, that can be described in a natural language sentence that has as its subject and object an element of a set of actors and as its verb an element of a set of actions, the contents of which are transitive verbs” (Gerner et al. 1994). ‘Transitive verbs’ are those that have a direct object so that the action always has a recipient (Table 4.2).

The codes that record the interactions or events are referred to as ‘event data’ (Gerner et al. 1994). The common structure of event data is <date> <source> <action> <target> (Table 4.2) where the “source” is the subject performing an “action” towards the “target” within a specific time interval (“date”). For each event a score is assigned depending on the type of interaction (Table 4.2). Positive and negative actions are summed over each time interval, e.g. a year (Table 4.2), and represent the level of cooperation within a fishery. This approach of measuring positive against negative actions is used in research on conflict, violence, war and peace where it has been shown that cooperation and conflict can be viewed as two opposite ends of one continuum (Rummel 1987; Institute for Economics and Peace 2014; Thomas 2015).

Table 4.2: Example for event coding using the ontology <data> <source> <action> <target> <weight> (Gerner et al. 1994) and the action codes and weights from the Conflict and Mediation Event Observations (CAMEO) database (Schrodt 2012b).

Hypothetical statements:	Coding scheme	Summed actions by actors for each year
“In December, the minister consulted several environmental organisations.”	<15.12.14> <[GOV]> <meet> <[ENV]> <+1>	Interactions in 2014: <GOV> ➔ <ENV> +1 <ENV> ➔ <GOV> NA
“Last Monday, the head of the environmental organisation criticized the government.”	<12.01.15> <[ENV]> <criticize> <[GOV]> <-2>	Interactions in 2015: <GOV> ➔ <ENV> +4 <ENV> ➔ <GOV> +2
“But today, the organisation offered to cooperate more closely with the government.”	<12.01.15> <[ENV]> <express intent to cooperate> <[GOV]> <+4>	
“The government accepted the offer to cooperate.”	<12.01.15> <[GOV]> <express intent to cooperate> <[ENV]> <+4>	

4.2.2.2. Data sources

Newspaper articles are the most commonly used sources for event data analysis (Schrodt 2012a). For the cod fishery, data were derived from the online database of the British Broadcasting Corporation (BBC) monitoring articles reporting on the North Sea cod fishery between 1998 and 2014. BBC monitoring covered the EU fisheries quota negotiations and the reactions from the different sectors indicated. The consistency of the reports on these annual events did not indicate that there was a shift in the media coverage e.g. towards social media. BBC monitoring has been used previously for event analysis when dealing with conflicts related to e.g. water scarcity (Bernauer et al. 2012). Due to the regular annual nature of the EU fisheries quota negotiations, events in the cod fishery were aggregated over each calendar year.

Data for conflict analysis of the inshore fishery were derived from the minutes of 14 meetings of the NWIFCA Technical, Science and Byelaw Subcommittee from June 2011 to October 2014. Each meeting was treated as a discrete data point. The first year of analysis was also the first year the NWIFCA was operational, however the NWIFCA continued the work of the North Western and Wales Sea Fisheries Committee (Phillipson & Symes 2010) and part of the NWICA committees' personnel had already been active in the Sea Fisheries Committee. The subcommittee is composed of NWIFCA staff, representatives from the local authorities, the UK's Marine Management Organisation (MMO), the Environment Agency and the conservation body Natural England, and individual fishermen and marine scientists (appointed by the MMO based on their expertise).

4.2.2.3. Coding of actors and actions

As highlighted in the definition of an 'event', actors and actions are the decisive elements of event data. All actors and events were coded by one experienced person to ensure that the dataset was coherent over time. To reduce subjective bias in the coding of interactions, the coding followed established guidelines from the Conflict and Mediation Event Observations database (CAMEO) (Schrodt 2012a; 2012b). The actors were coded by their role using the CAMEO ontology with name and nationality preserved in the coding if needed (Supplementary Tables A1-A2).

Actors were aggregated into groups based on their role e.g. GOV (all government actors). Of the 298 action codes from the CAMEO coding ontology, 103 actions were deemed applicable to fisheries and 47 of these actions were ultimately used in the coding (Table 4.3). Two additional action codes, not part of the CAMEO scheme, were instigated which were: *appeal to others to engage in cooperation* and *accept aid* (Table 4.3).

Table 4.3: Action coding scheme used to assess fisheries interactions and their assigned weightings for the analyses of cooperation and conflict. The scheme used is derived from the Conflict and Mediation Event Observations (CAMEO) database. $F_{inshore}$ and F_{cod} are the relative frequencies of the codes as used in this study for the conflict analyses of an English inshore and the UK cod fishery in the North Sea, respectively. Codes are presented in order from positive to negative interactions and are broadly grouped as: very positive (+5 to +8), positive (+3 to +4), neutral (-0.4 to +1), negative (-4 to -2), and very negative (-7.5 to -5). The 47 individual codes are presented as 23 aggregations on the basis of their weight (the raw codes are available in supplementary Tables A1-A2).

Code	Weight	$F_{inshore}$	F_{cod}
Sign formal agreement	+8.0		0.3%
Apologize, negotiate, express intent to yield or for political reform, provide aid	+7.0	2.7%	1.2%
Engage in cooperation	+6.0	1.7%	1.2%
Express intent to provide aid	+5.2	1.4%	2.3%
Accede to requests or demand for political reform, ease political dissent or administrative sanctions, yield	+5.0	6.1%	2.8%
Accept aid, appeal to others to cooperate, meet, negotiate, or settle dispute, express intent to cooperate, meet, or negotiate	+4.0	8.4%	3.6%
Rally support on behalf of	+3.8	5.4%	5.0%
Defend verbally	+3.5	2.7%	1.0%
Appeal for aid or cooperation, express accord, praise, make empathetic comment	+3.4	16.6%	12.8%
Make an appeal or request	+3.0	2.0%	1.0%
Consult and meet	+1.0	4.7%	6.8%
Make optimistic comment	+0.4	2.4%	5.4%
Acknowledge or claim responsibility, consider policy option	±0	1.4%	0.3%
Decline comment	-0.1		0.3%
Appeal for political reform	-0.3	7.1%	5.5%
Make pessimistic comment	-0.4	6.1%	4.4%
Investigate, disapprove, criticize, accuse, rally opposition against, complain officially or bring lawsuit against	-2.0	13.9%	26.8%
Reject cooperation or request for aid or political reform, reject accusation, deny responsibility, refuse to yield	-4.0	9.5%	7.2%
Reject mediation or proposal to meet, discuss or negotiate, defy norms, impose sanctions, demand cooperation, meeting, negotiation, aid, or political reform	-5.0	4.6%	5.6%
Threaten (non-force), threaten with political dissent or sanctions	-5.8	2.3%	4.4%
Halt negotiations, engage in political dissent, demonstrate, strike or boycott	-6.5		1.7%
Withdraw, give ultimatum	-7.0	0.7%	0.2%
Obstruct passage, block	-7.5		0.3%

4.2.2.4. Reliability of coding

For consistency the full data set was coded by a single worker. To determine the reliability of the coding 10% of the raw data from each of the cod fishery and the inshore fishery were taken as random subsamples and coded by an additional two independent coders (Lombard et al. 2002). With no previous coding experience, the independent coders identified: 73% of the same events, 80% of the same actor groups in these events and 39% of the same event weightings as the original coder. A comparison of the coding revealed that both the independent coders coded more actions than the original coder. These underlying issues were resolved by refining the coding manual.

One of the independent coders then coded another 10% subsample of the cod fishery (30 of the 304 newspaper articles) using the refined coding manual and this increased reliability substantially (84% of the same events, 92% of the same actor groups, and 62% of the same weightings were assigned). As a measure of overall reliability, the degree of conflict between two actor groups in one year differed between the two coders by on average 3.2 (±2.5) points when the differences in events, actor groups and event weightings were all included.

4.2.3. Analysis of conflict

4.2.3.1. General approach

Five criteria for the dialogue surrounding and the sustainability of fisheries were addressed in the conflict analysis as follows: from the dialogue perspective on sustainability, (i) the fisheries were conceptualised as social networks and the level of involvement of different actor groups was assessed and compared based on their number, frequency and intensity of interactions with other actor groups (Section 2.3.2). (ii) To assess the trends in conflict over time, the level of conflict was measured as the summed interactions between the different actor groups and the fishery as a whole (Section 2.3.3). (iii) A dynamic behaviour model was used to identify repeated patterns of interactions between actor groups (Section 2.3.4). Positive patterns were expected to promote cooperation e.g. where one actor group's behaviour triggers a positive reaction from, or buffers, the negative reactions of the others.

For exploring the suitability of conflict as an indicator for sustainable management processes and sustainable outcomes, (iv) the mean score of interactions from one actor group towards the others were used to determine whether, as postulated, conflict decreased as sustainability was achieved (Section 2.3.5). To determine whether the continuity of the fish stock through time drove conflict, (v) the relationships between conflict and fish stocks (as landings and estimated spawning stock biomass) were investigated (Section 2.3.6).

4.2.3.2. Structure of social network

The fisheries were conceptualized as social networks with the actor groups being the nodes and the positive and negative interactions being the links between the nodes (Wasserman & Faust 1994). In social network analysis, the importance of actors is operationalized by the position that the actors hold in the network: for example, actors that interact with many other actors have a central position in the network and are, therefore, considered important (e.g. Barnes-Mauthe et al. 2015). In each of the two fisheries networks, key actors were defined as those that interacted on average with at least two other actor groups per time step. The number of other actor groups with which they interacted over time is also called their 'degree' (Wasserman & Faust 1994). Both the 'out-degree' the number of actors a group directs its interactions towards and the inverse, 'in-degree' centrality, were determined. Actors with high out-degree centrality drive the dynamics of conflict and cooperation, whereas actors with high in-degree centrality are perceived to be important by the others.

Actor groups were also considered to be key actors if they interacted frequently or intensely with the other actor groups. 'Frequency' refers to the number of time intervals (low (<33% of the time intervals), moderate (33-67%) or high (>67%)) within which interactions occurred and the 'intensity' (the number) of actions in each interval. The relationship between the intensity and frequency of interactions was exponential. Therefore, the intensity of interactions was log-transformed to a linear function and the linear function was divided into its lowest (weak intensity), middle (moderate intensity) and highest third (strong intensity).

The number of actor groups and their level of involvement was compared between the two fisheries by assessing the size, density and centralization of both networks (Wasserman & Faust 1994). The size of the network corresponds to the average number of actor groups involved in the fisheries management process during each time interval. The density of the network is the number of links in the network during each time interval. The centralization is the centrality of the most central actor in comparison to the centrality of all other actors (Freeman 1977). The centrality of the actor groups was calculated as total degree, out-degree and in-degree, therefore, it was also possible to calculate the centralization of the network as total, outward and inward centralization. Size, density and centralization were all normalized with their maximum possible score so that they all had a range of (0, 1). Differences between the two fisheries with regard to these three network indices were assessed with the Mann-Whitney U rank sum test.

4.2.3.3. Trends in level of conflict

The overall level of conflict was measured for the entire fishery as the sum of all interactions and tested for significance using Kendall's tau (Kendall 1949). For the relationships between specific actor groups, the behaviour of each actor group towards each other actor group was also expressed as sum of actions and tested for significant trends over time (Kendall's tau). An increase through time indicated a reduction in conflict and a decrease indicated the development of conflict. The overall level of conflict and the interactions between specific actor groups were tied together by testing if the interactions between two actor groups were significantly correlated to the overall level of conflict (Kendall's tau).

4.2.3.4. Patterns of conflict behaviour

Patterns of interactions are understood as a repeated way of reacting to the behaviour of another actor. The influence of the behaviour of one actor on the behaviour of another is expected to be non-linear (Vallacher et al. 2013). Interactions were expected to follow either a cooperative-competitive or an accommodating-contentious pattern (Fig. 4.1; Vallacher et al. 2013).

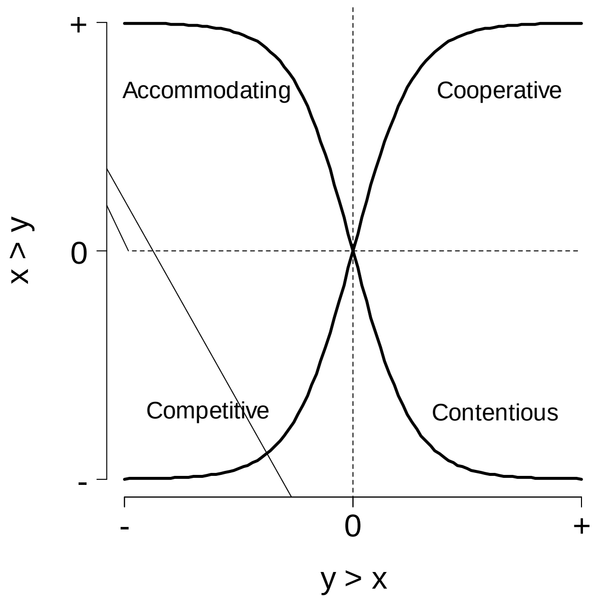

Figure 4.1: Two response functions *fx*(*y*) of the behaviour of actor group *x* towards actor group *y* dependent on the behaviour of actor group *y* towards actor *x*. Actor groups can behave accommodatingly, cooperatively, contentiously or competitively. Attitude to the other actor group (*bx*) is neutral if response function passes through zero, displacement from zero would indicate a generally positive or negative attitude towards actor group *x*.

The interdependence of the behaviours of an actor "x" interacting with another actor "y" was modelled using a dynamic behaviour model (Vallacher et al. 2013), as follows:

$$s(x) = b_x + s(x)_k - m*s(x)_{k-1} + f_{xk}(y)$$

where, b_x was the general attitude of x towards y and was measured as the mean sum of actions from x towards y when there were no or few actions from y towards x; $s(x)_k$ was the behaviour s of actor x at time step k; m was the autocorrelation factor representing how much the actor's current behaviour $s(x)_k$ depends on its own previous behaviour $s(x)_{k-1}$ and was tested for significance ($p<0.05$) using the Durbin-Watson Test (Fox 2015); and $f_{xk}(y)$ was the influence of the behaviour of actor y (or actor z in a three actor exchange network) on the behaviour of actor x at time step k (Vallacher et al. 2013). The interactions were corrected for the general attitude b and for the autocorrelation factor m before coding actor x's actions binomially as positive or negative. The probability of actor x responding positively or negatively to the actions of actor y were examined using generalized linear models (GLM) assuming a logit link function. The behavioural relationships between the two or three actors were tested for significance ($p<0.05$) with likelihood ratio tests.

4.2.3.5. Conflict and management for sustainable outcomes

The focus for this criterion was on the interaction between individual actor groups because it was assumed that actors who do not achieve their sustainability goals and did not agree with management processes would direct their negative actions toward the other actor(s) who they think are capable of achieving the desired sustainability outcomes. The interactions between actor groups were measured as the mean actions from one actor group to the other during the entire period of observation. To highlight the intensity of interactions, time intervals during which two actors groups did not interact were counted as missing values rather than as neutral interactions. Positive values indicated that an actor group felt that its sustainability goals were achieved or supported the goals of another actor group. Negative values indicated conflict because an actor group perceived the other actor group as responsible for the non-achievement of its sustainability goals.

4.2.3.6. Conflict and natural resource availability

Temporal dynamics of the conflict were related to the changing state of the fisheries resources over time. Estimates of fishery landings and spawning stock biomass were only available for the cod fishery (ICES 2014). Emphasis was put on the interactions between the government authorities and the fishing industry which was expected to be conflictive when stocks were low and the executive was imposing protective administrative measures. The relationships were explored using rank correlation (Kendall's Tau).

4.3. Results

4.3.1. Structure of social network

The conflict analyses identified seven actor groups in each case study fishery with six of the actor groups occurring in both fisheries, and these were: (1) the government or administration forming the executive, (2) the fishing industry, (3) environmental representatives or environmental non-governmental organizations (eNGOs), (4) scientists, (5) civil society actors, and (6) members of other fisheries (Supplementary Tables A1-A2). In the cod fishery, the executive group consisted of the Scottish and UK governments and EU institutions because the UK's devolved government and EU's supra-national decision-making made it impossible to separate most of their actions from each other. In the cod fishery, the final group of actors (7) were the political opposition parties. In the inshore fishery, the final actor groups (7) were governmental agencies superior to the IFCAs such as the UK's Marine Management Organisation (Table 4.4).

Table 4.43: The seven actor groups in the conflict analyses of the North Sea cod fishery (1998-2014) and the inshore fishery in the Northwest of England (14 meetings of the administration body from 2011 to 2014). Importance of the groups is expressed as: the mean (± SD) number of other actor groups with which each actor group interacted over time (the degree of interaction), the mean (± SD) number of actor groups an actor group addressed over time (out-degree interactions), and the mean (± SD) number of actor groups that addressed the actor group over time (in-degree interactions).

Actor groups	Degree of interaction	Out-degree interactions	In-degree interactions
North Sea Cod Fishery			
Executive	4.8 (±1.4)	3.6 (±1.3)	4.6 (±1.5)
Fishing industry	3.7 (±1.3)	2.9 (±1.1)	3.3 (±1.4)
Scientists	2.3 (±1.9)	1.4 (±1.3)	1.8 (±1.8)
eNGOs	2.1 (±0.9)	2.0 (±0.7)	0.9 (±1.2)
Polit. opposition	1.5 (±1.7)	1.5 (±1.7)	0.6 (±1.1)
Civilian actors	1.1 (±1.1)	0.8 (±1.0)	0.7 (±0.9)
Other fisheries	0.8 (±0.7)	0.5 (±0.6)	0.6 (±0.6)
Northwest England Inshore fishery			
Executive	5.2 (±1.3)	5.1 (±1.4)	4.4 (±1.4)
Fishing industry	3.6 (±1.5)	2.9 (±1.0)	2.8 (±1.4)
Environmental	2.6 (±1.5)	2.1 (±1.5)	1.6 (±1.0)
Scientists	1.7 (±1.1)	1.6 (±1.1)	1.1 (±0.8)
Civilian actors	1.4 (±1.0)	0.6 (±0.9)	1.4 (±1.0)
Superior admin.	1.3 (±1.0)	0.5 (±0.7)	1.1 (±1.0)
Other fisheries	0.9 (±1.3)	0.4 (±0.9)	0.7 (±0.9)

Number, intensity and frequency of interactions indicated that civil society actors and members of other fisheries were of marginal importance in both fisheries. All of the five other actor groups were key actors. The executive, the fishing industry and, to a lesser degree, environmental representatives, acted as central drivers of conflict and cooperation (out-degree) in both fisheries, and they were also important to other actors (in-degree) (Table 4.4). Their interactions were also among the most frequent and intense interactions in both fisheries (Supplementary Table A3). Scientists, political opposition parties and superior governmental agencies also interacted on average with at least two other actor groups per time interval (scientists in the cod fishery; Table 4.4) or had a frequent or intense key relationship with the executive (opposition parties in the cod fishery; scientists and superior governmental agencies in the inshore fishery; Supplementary Table A3).

The mean size, density and overall centralization did not differ significantly between the two fisheries (Table 4.5). Three quarters of the actor groups in the cod fishery were involved in the fisheries management process during each year (Table 4.5). In the inshore fishery, 84% of the actor groups were involved during a typical committee meeting. In both fisheries, around a quarter of the possible number of interactions between the actor groups took place during each time interval (Table 4.5). The mean centralization of the networks was 0.479 in the cod fishery and 0.552 in the inshore fishery (Table 4.5). The two fisheries networks only differed significantly with regard to the centralization based on the outward actions, with the social network of the inshore fishery being more centralized ($C = 0.621 \pm 0.153$) than in the cod fishery ($C = 0.382 \pm 0.148$) ($p<0.001$, Mann-Whitney U rank sum test).

Table 4.5: Mean (±SD) characteristics of the social networks (size, density and centralization) for the North Sea cod fishery (1998-2014) and the inshore fishery in the Northwest of England (14 meetings of the administration body from 2011 to 2014). Characteristics compared with the Mann-Whitney U rank sum test (p<0.001); significance indicated by *.**

Metric	Inshore fishery	Cod fishery
Size[a]	0.837 (±0.185)	0.748 (±0.156)
Density[b]	0.273 (±0.102)	0.245 (±0.102)
Centralization[c]		
Overall degree	0.552 (±0.148)	0.479 (±0.121)
In-degree	0.587 (±0-173)	0.526 (±0.177)
Out-degree	0.621 (±0.153)***	0.382 (±0.148)***

[a] Number of active actor groups divided by total number of actor groups and averaged over all time steps.
[b] Number of links between actor groups divided by total number of possible links and averaged over all time steps.
[c] Centrality of all actor groups divided by centrality of the most central actor and averaged over all time steps.

4.3.2. Trends in level of conflict

There was a small but significant decrease in the overall level of conflict in the cod fishery from 1998-2014 (r=0.397, p=0.027, Kendall's tau; Fig. 4.2) but no significant trend in conflict in the inshore fishery over 14 committee meetings (r=-0.077, p=0.747, Kendall's tau; Fig. 4.2). The only interaction between two actor groups that showed a significant (positive) trend over time were the actions from the political opposition towards the executive in the cod fishery (r=0.643, p=0.031, Kendall's tau) thus corresponding to the overall decrease of conflict in the cod fishery (Table 4.6). The other interactions that were correlated significantly with, and thus driving the course of conflict, did not show a significant trend over time (Table 4.6).

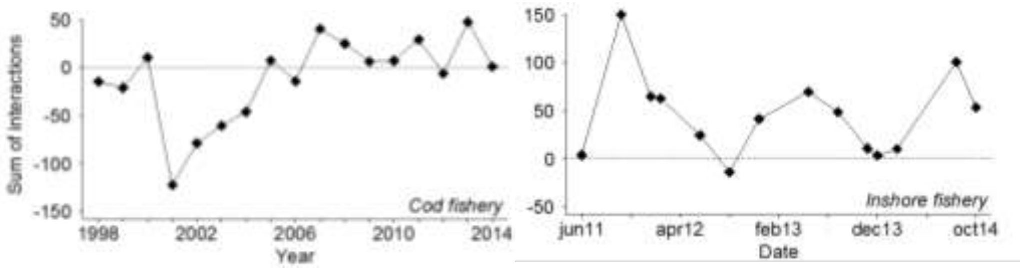

Figure 4.2: Sum of interactions between all actor groups. Positive values indicate cooperative and negative values conflictive interactions. Horizontal line at zero indicates neutral interactions.

In the cod fishery, the course of conflict was driven by the actions of the fishing industry towards the executive (r=0.779, p<0.001, Kendall's tau; Fig. 4.3). In a year with high conflict during which the cod fishing industry acted negatively towards the executive, conflict also dominated the interactions within the executive and the interactions from the opposition towards the executive (Table 4.6; Fig. 4.3). All these relationships became more positive over time, but only the trend in the actions from the opposition towards the government was statistically significant (Table 4.6). There was an intense period of conflict, between 2001 and 2004 (Fig. 4.2) over quotas, effort regulation, decommissioning, and compensation payments. The conflict reduced in 2005 and just two years later cooperation between the cod fishing industry and the executive reached a maximum (Fig. 4.3). After 2007 the actor groups acted positively or near neutrally towards each other until the end of the observation period (Fig. 4.2 and 4.3).

The overall level of conflict and cooperation in the inshore fishery correlated with the actions of the executive towards itself and towards the other key actor groups (Table 4.6). The reasons for conflict in the inshore fishery were diverse, but most common were disagreements over the right to exploit and the allocation of fishery resources. The sum of interactions was positive during all time-intervals except for September 2012 (Fig. 4.2) when the administration did not respond to (positively coded) appeals from the industry because they were outside of the administration's responsibility. In the inshore fishery, like the cod fishery, the administration behaved more positively towards the fishing industry than vice versa ($p<0.001$, Mann-Whitney U rank sum test; Fig. 4.3).

Table 4.6: Correlations between the frequency of key interactions (Kendall's tau), trends over time and correlation with the overall level of conflict (Kendall's tau; * = p <0.05, ** = p <0.01 and *** = p <0.001). Initiators of action are shown in rows, recipients are shown in columns. Key interactions are shown that occurred either at a high frequency <u>or</u> with a high intensity in the cod fishery and at a high frequency <u>and</u> with a high intensity in the cod fishery. Two key interactions from the inshore fishery are not displayed (Executive>Scientists; Fishing industry>Fishing industry) these occurred at high frequency, but with only moderate intensity; these were not significantly correlated with any of the other interactions, did not show a significant trend over time and were not correlated with overall level of conflict. See Supplementary Table A3 for data on frequency and intensity of interactions. Abbreviations: ind. = industry, Sup. gov. = superior government.

		Correlations					
Cod fishery		GOV > GOV	FIS > GOV	GOV > FIS	ENV > GOV	ENV > FIS	OPP > GOV
FIS > GOV		0.427*					
GOV > FIS		0.042	0.088				
ENV > GOV		0.159	0.221	-0.574***			
ENV > FIS		-0.411	-0.400	-0.585**	0.062		
OPP > GOV		0.214	0.714*	-0.571	0.857**	0.067	
Trend over time		0.243	0.353	0.235	0.015	-0.400	0.643*
Correlation with overall conflict		0.527**	0.779***	0.221	0.088	-0.431	0.643*
Inshore fishery	ADM > ADM	FIS > ADM	ADM > FIS	ENV > ADM	ADM > ENV	SCI > ADM	ADM > SUP
FIS > ADM	0.060						
ADM > FIS	0.205	-0.051					
ENV > ADM	0.067	0.289	-0.272				
ADM > ENV	0.477*	0.440	0.015	0			
SCI > ADM	0.494*	0.183	0	0.222	0.296		
ADM > SUP	0.450	0.197	0.225	-0.028	0.514	0.390	
Trend over time	-0.077	-0.231	0.253	0.273	-0.290	-0.184	-0.360
Correlation with overall conflict	0.487*	0.333	0.495*	0.091	0.473*	0.403	0.584*

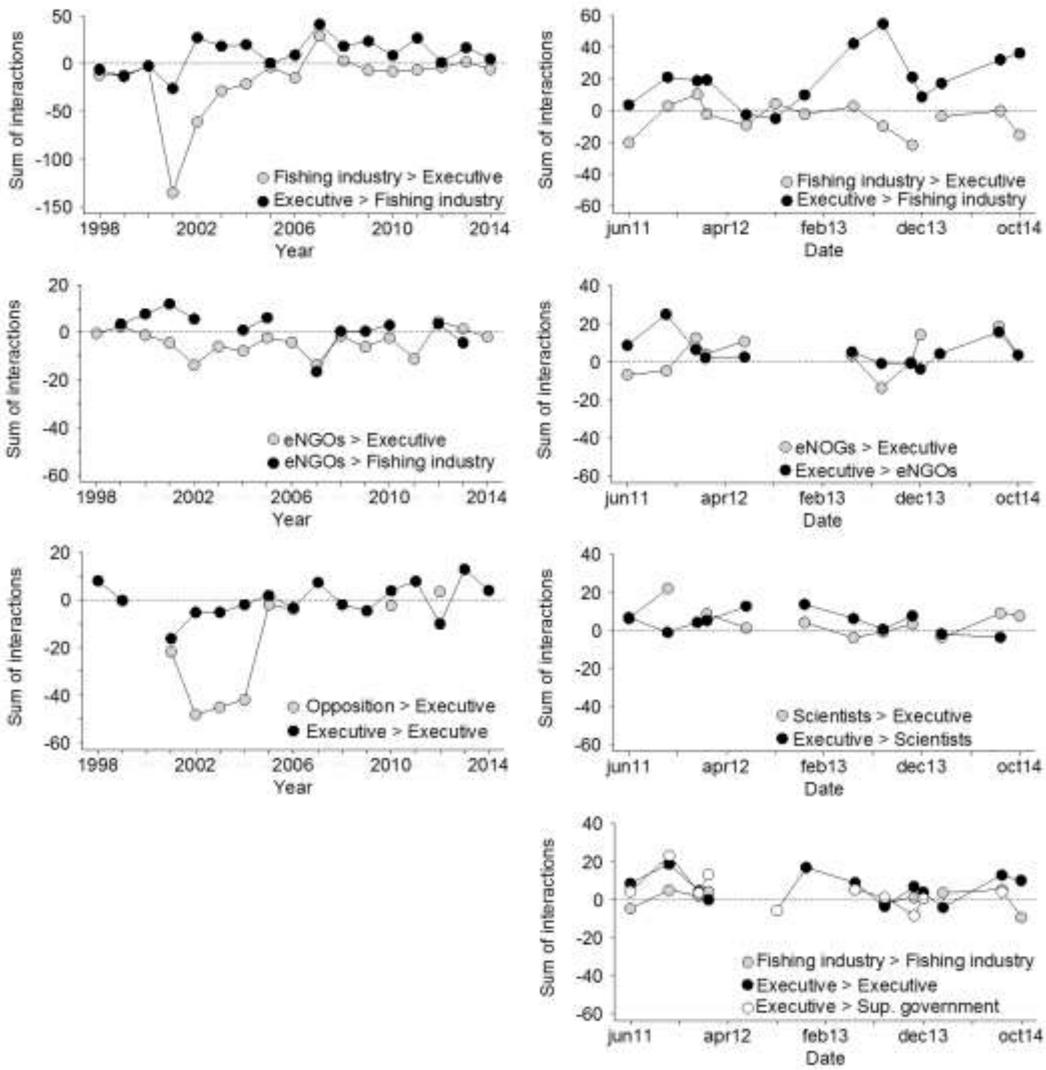

Figure 4.3: Conflict between key actor groups in the in the UK North Sea cod fishery (left) and in the North West English inshore fishery (right). Positive values indicate cooperative and negative values conflictive interactions. Horizontal line at zero indicates neutral interactions.

4.3.3. Patterns of conflict behaviour

The dynamic behaviour model showed that the executive and environmental groups in the cod fishery did not drive the conflict but reacted to the behaviour of other actor groups. The behaviour of the executive in the cod fishery was a reaction to the actions of the fishing industry (Fig. 4.4): in years with exceptionally positive (2007 and 2011; Fig. 4.4) or exceptionally negative (2001; Fig. 4.4) actions from the fishing industry towards the executive, the executive also acted exceptionally positively or exceptionally negatively (Fig. 4.4). While the impact of the general attitude *b* of the executive (*b*=2.081) and the fishing industry (*b*=-1.645) towards each other was close to neutral, both the executive (autocorrelation metric *m*=0.668) and the fishing industry (*m*=0.642) were influenced by their own behaviour at the previous time step. After correcting the data for the auto-correlation and general attitudes, the relationship was not statistically significant (χ^2= 194.2, d.f. = 2, p=0.057, GLM; Fig. 4.5).

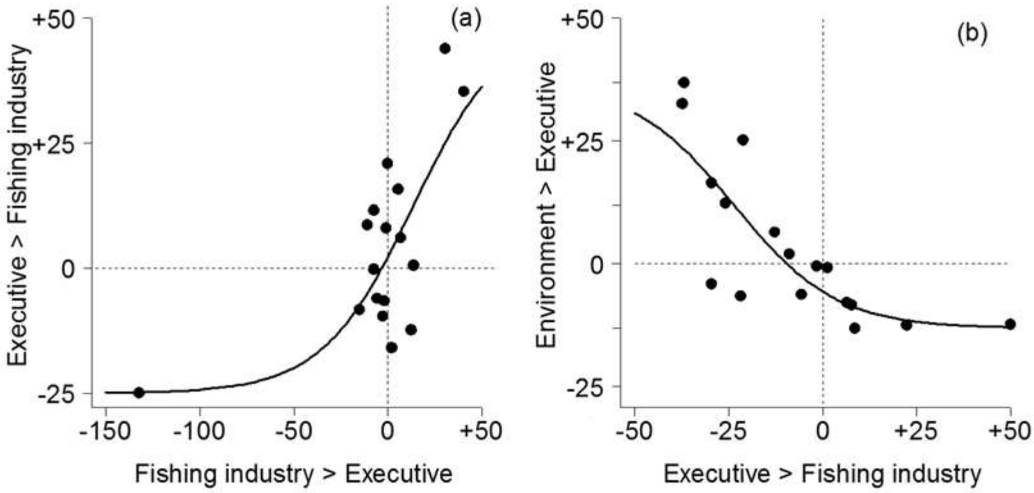

Figure 4.4: Dynamic behavioural model of the interactions in the cod fishery between the executive, the fishing industry, and environmental groups from 1998 to 2014. (a) Positive (sum of actions > 0) and negative (sum of actions < 0) behaviour of the executive towards the fishing industry as reaction to the behaviour of the fishing industry towards the executive. (b) Positive (sum of actions > 0) and negative (sum of actions < 0) behaviour of environmental representatives towards the executive as reaction to the behaviour of the executive towards the fishing industry.

The environmental actor group reacted as a "corrective measure" to the behaviour of the executive towards the fishing industry. After correcting for auto-correlation (*m*=0.817) and their general attitude towards the executive (*b*=-0.801), the actions of the environmental group towards the executive in the cod fishery were negatively correlated with the behaviour of the executive towards the fishing industry (Fig. 4.4). In years where the executive supported the fishing industry, the environmental representatives reacted with negative behaviour, in years when the relationship between the executive and the fishing industry was conflictive, the environmental actor group reacted positively towards the executive (χ^2= 49.3, d.f. = 2, p=0.006, GLM; Fig. 4.5).

The response function for the behaviour of the executive and the environmental actor group followed the two interaction types outlined in Fig. 4.1. The relationship between the executive and the fishing industry was cooperative or competitive. In the inshore fishery, no such reciprocal behaviour was found.

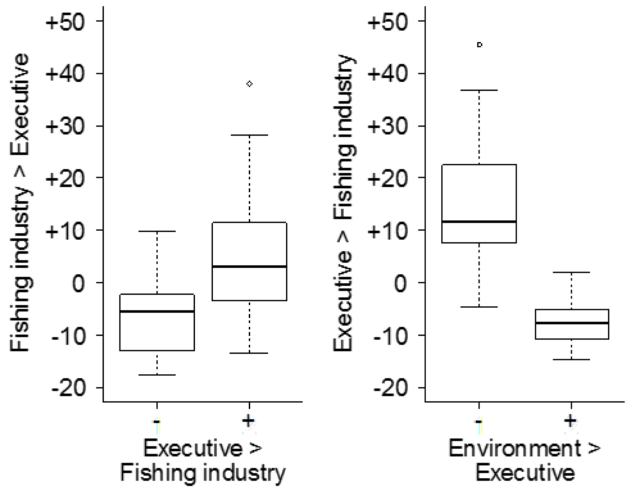

Figure 4.5: Significance of the dynamic behavioural model of the interactions in the cod fishery between the executive and the fishing industry (left; χ2= 194.2, d.f.=2, p=0.057, GLM), and the executive, the fishing industry and environmental groups (right; χ2= 49.3, d.f.=2, p=0.006, GLM) from 1998 to 2014; dependent interactions are being coded as binomial.

4.3.4. Conflict and management for sustainable outcomes

In eight of the fourteen years conflict dominated over cooperation in the cod fishery (Fig. 4.2). In the inshore fishery, the reverse was true: cooperation dominated over conflict during thirteen of the fourteen meetings (Fig. 4.2). In both fisheries, the executive was involved in most of the intense and frequently occurring interactions (Fig. 4.6). In the cod fishery, the interactions from all actor groups towards the executive were on average negative, whereas in the inshore fishery only the interactions from the fishing industry and the hierarchically superior governmental agencies towards the executive were negative (Fig. 4.6). Fisheries outside the jurisdiction of the IFCA and the scientist, environmental and civilian actor groups acted positively towards the executive. The executive was therefore able to address to some extent to claims in the inshore fishery, but to a much lesser degree in the cod fishery.

The actions of the fishing industry and the political opposition towards the executive in the cod fishery correlated significantly with each other indicating that these actor groups had complementary goals (Table 4.6). When the fishing industry acted negatively towards the executive, the political opposition party also acted negatively towards the executive and at the same time positively towards the fishing industry (Fig. 4.3). The NGOs acted negatively towards the executive and the fishing industry whenever the executive acted positively towards the fishing industry (Fig. 4.3). When the environmental groups behaved negatively towards the executive, the political opposition parties also behaved negatively towards the executive, but positively towards the fishing industry (Table 4.6). The actions from both the fishing industry and the environmental groups towards the executive were negative in most years (Fig. 4.3), the conflict analysis indicated that their sustainability goals were not achieved over the period of observation. In contrast, the actions from the political opposition towards the executive became significantly more positive over time (Table 4.6). In the inshore fishery environmental groups acted mostly positively towards the fishing industry (Fig. 4.3). As for the scientific actor group, scientists in the cod fishery mostly denounced low stock levels and therefore acted negatively towards the executive as well as towards the fishing industry (Fig. 4.6). In contrast, in the inshore fishery the scientist actor group acted on average positively both towards the executive and the fishing industry (Fig. 4.6).

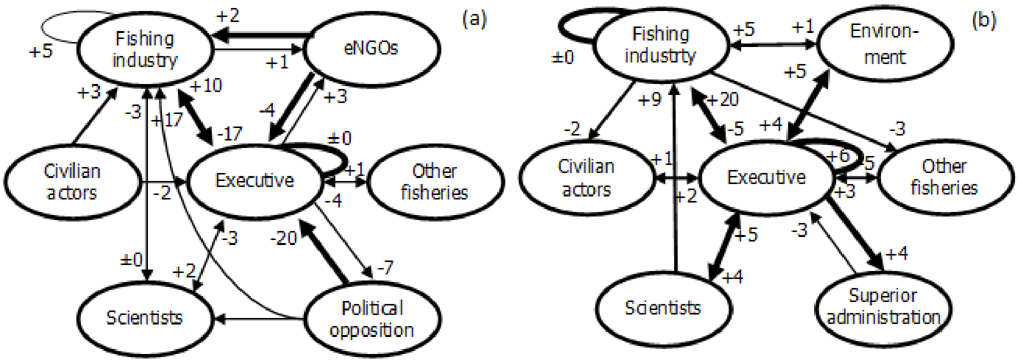

Figure 4.6: Social networks of (a) the inshore fisheries of Northwest England (14 committee meetings between 2011 and 2014) and, (b) the UK North Sea cod fishery between 1998 and 2014. Values on arrows are the mean interactions between each pair of actors during the entire period of observation; positive values indicate cooperation and negative values indicate conflict. Interactions are not displayed if they were of low frequency or of low intensity.

4.3.5. Conflict during low stock levels in the cod fishery

Cod stock biomass and landings data were not correlated with the overall levels of conflict and cooperation in the fishery. UK landings of cod decreased from 1998 to 2007 and in 2007 reached a minimum at 19,744 t (Fig. 4.7). After 2007, cod landings remained low (Fig. 4.7) due to quota restrictions and fluctuated around 26,549 ± 2,976 t from 2008 to 2013. The cod spawning stock biomass (SSB) was below the biomass limit reference level (B_{lim}) of 70,000 t over the entire period covered by the analysis (ICES 2014; Fig. 4.7). SSB decreased at the beginning of the time series and reached its all-time low in 2006, and after this it increased steadily and reached a value close to B_{lim} in 2014.

The year with the lowest landings, 2007, was also the year of highest cooperation between the fishing industry and the executive (Fig. 4.7) and occurred just one year after the all-time SSB low. At similar SSB, there was consistently more conflict from 1998 to 2006 compared with 2007 to 2014 (Fig. 4.7). There was no significant correlation between the SSB and the overall level of conflict (Kendall's tau, r=0.074, p=0.715).

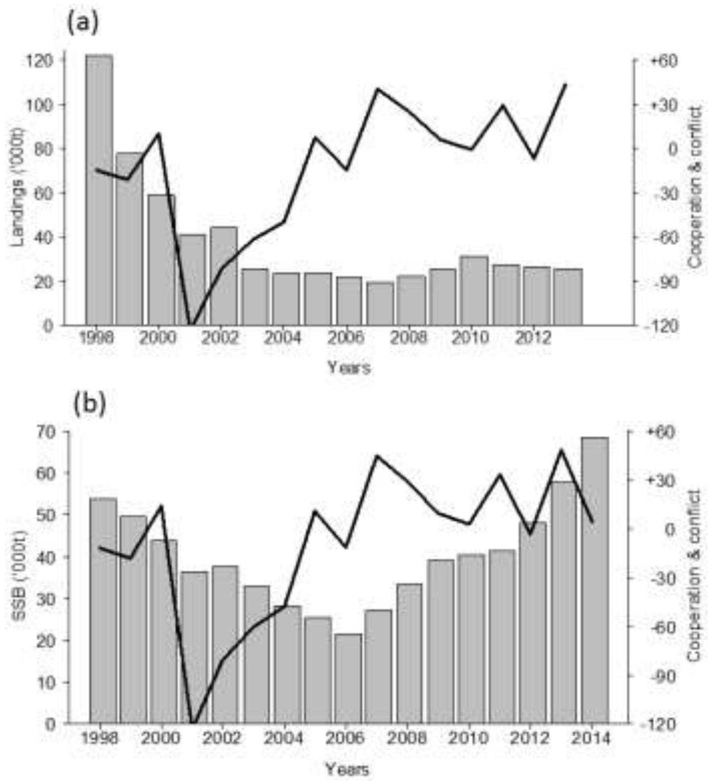

Figure 4.7: North Sea cod (a) landings ('000t) and (b) spawning stock biomass ('000t) (SSB) in the UK fishery from 1998 to 2013 and 1998 to 2014, respectively (data from ICES 2014). Landings were restricted by EU quotas which were on average 11% higher than the official landings. SSB was below the SSB_{lim} of 70,000 t throughout the entire period (ICES 2014). Solid black line indicates overall level of cooperation and conflict in the fishery as determined in this study (positive values indicate cooperation and negative values conflict).

4.4. Discussion

This study developed a methodology for the empirical analysis of conflict as a means of assessing fisheries sustainability. The conflict analysis approach employed in this study is an established method in the social sciences for studying the causes and dynamics of conflict, being used, for example, to further the understanding of the dynamics of war and peace (Schrodt 2012a). However, to our knowledge the conflict analysis has not been used to empirically analyse conflict over the exploitation of natural resources (Stepanova &

Bruckmeier 2013). Within conflict research, natural resources have been recognised as a stressor that may enhance or buffer violent social conflict (Koubi et al. 2014). Marín and Berkes (2010) used an approach similar to conflict analysis to assess the management of a Chilean coastal fishery. The links in this social network were the actor's own perceptions of their relationships with the other actor groups which were rated positively or negatively (Marín & Berkes 2010). However, the conflict analysis based on actual event data, as used in the present study, is more objective because it focuses on behaviour and not just perceptions.

Participation in the management process

The two traditional key players in fisheries management, the executive and the fishing industry (Mikalsen & Jentoft 2001), emerged as the key actors in the two case study fisheries. Environmental representatives, scientists, political opposition parties and superior governmental agencies were also frequently and intensely involved in the conflicts surrounding fisheries management (Fig. 4.6). The active participation of the different actors in the dialogue about fisheries management has been used as an indicator for sustainability (Pitcher et al. 2013) because a greater diversity of actors are more likely to have the expertise needed to successfully manage complex systems such as fisheries (Coffey 2005; Berkes 2009; Jentoft & Chuenpagdee 2009). However, the inclusion of new stakeholders can also lead to the traditional stakeholders becoming less prominent (De Vivero et al. 2008), and because the new stakeholder groups may lack expertise the decision-making can become less efficient (Mikalsen & Jentoft 2001). In the case studies, conflict analysis was an effective means of identifying all of the relevant actor groups and their actions, and thus can complement the social network analysis that have been used, within the context of 'stakeholder analysis' (Reed et al. 2009), to objectively identify and select stakeholders for participatory governance activities and investigate the relationships between them (Duggan et al. 2013).

The participation of all actor groups was measured by the network density, the total number of interactions divided by the number of possible interactions, and the centralization which is high if one or a few actor groups hold an influential position in the network (Bodin and Crona 2009). A greater social network density provides more opportunities for exchanges of information, advice and social support (Bodin & Crona 2008; Holt et al. 2012), and so can help to achieve sustainability. However, there is an optimum density because over time dense networks can become more homogenous, with little stimulation from outside the network, decreasing the network's creativity and capacity for problem-solving (Burt 2004). Similarly, non-centralized networks are more successful at overcoming complex problems (Bodin & Crona 2009), and because fisheries are inherently complex (Jentoft & Chuenpagdee 2009) non-centralized networks should be better suited to fisheries governance. In this study, the network densities for the two fisheries were of the same magnitude (Sandström & Rova 2010) or lower (Holt et al. 2012) than those found in studies of other governance systems for natural resources which relied on self-reported relationships between the actor groups. Whereas, social network centralization was similar or higher than for comparable studies (Sandström & Rova 2010; Holt et al. 2012). The low network densities and high centralization of both case study fisheries show that neither network exhibited the properties that are thought to be supportive of sustainable fisheries. However, the optimum network properties for successful resource governance have not been determined because few studies looked at the relationships between actor groups (Marín & Berkes 2010; Sandström & Rova 2010; Holt et al. 2012). Most studies that consider the role of network properties have focused instead on the relationships within an actor group (e.g. Barnes-Mauthe et al. 2015). Given the complexity of natural resource management more studies are needed that consider multiple actor groups, in this way understanding of the dialogue necessary for sustainable fisheries can be improved (Marín & Berkes 2010).

Building social capital

The analysis of conflict dynamics showed that conflict decreased in the cod fishery after a phase of intense conflict, whereas there was no significant trend in the generally more cooperative inshore fishery. The absence of a clear trend in conflict over time in the inshore fishery could be because the period of observation was shorter (14 data points over 3.5 years) than for the cod fishery (17 data points over 17 years). A decrease in conflict and an increase in cooperation such as that seen in the cod fishery is indicative of the building of social capital (Rummel 1987). "Social capital" comprises the trust, social networks and conventions (formal or informal) that together facilitate cooperation increasing the collective benefits for the actors (Putnam 1995). Thus, social capital can help fishermen secure their livelihoods (Allison & Ellis 2001) as well as being a prerequisite for collective action, i.e. working towards a common goal such as the preservation of shared resources (Krishna 2002). For these reasons, social capital plays a key role in sustainable fisheries management (Grafton 2005; Bodin & Crona 2008; Gutiérrez et al. 2011), and is an accepted indicator of the social sustainability of fisheries (Pitcher et al. 2013; Pascoe et al. 2014). In this study, I view social capital as part of the societal dialogue surrounding sustainability issues. The quantification of social capital within fisheries management has been largely unsuccessful to date because social capital is invisible (Ostrom & Ahn 2003), multi-dimensional (Putnam 1995) and can only be assessed at the group and not at the individual level (Grafton 2005). The analysis of long-term data sets of conflict and cooperation could represent a novel way to assess this key concept within fisheries.

Behavioural patterns

In the cod fishery conflict did not just randomly occur but could be modelled by the relationships and patterns of the interactions between the key actors. In a triad of interactions, the government reacted reciprocally towards the extreme positive and extreme negative behaviour from the fishing industry, and the environmental actor group usually reacted in opposition to this interaction (Figs 5 and 6). The inherent complexity of fisheries systems and their management (Jentoft & Chuenpagdee 2009) meant that the responses to the behaviour of the other actor groups were non-linear (Vallacher et al. 2013). Non-linear relationships imply strong feedbacks and hence the potential for destructive relations to escalate (Gartner & Regan 1996). In the cod fishery, the non-linear relationships between the three key actors led to an escalation of conflict between 2001 and 2004. Predicting and de-escalating such “fish wars” (Pomeroy et al. 2007; Harrison & Loring 2014) is thus complicated by non-linear relationships. This highlights the need for empirical studies and theoretical modelling of conflict within fisheries.

Sustainable processes and outcomes

In addition to conflict as an indicator for the dialogue surrounding sustainability issues, this study also aimed at exploring the relationship between conflict and sustainability itself, where sustainability is understood as processes, outcomes and continuity through time (Chapter 2). The level of conflict was low in the inshore fishery throughout the period studied, but there were periods of intense conflict in the cod fishery (Fig. 4.2). Conflict between actor groups could be an indicator for sustainable processes and outcomes on the basis that the actors create conflict when they disagree with the management process or when their various sustainability goals are not fulfilled (Hilborn 2007b). This assertion was supported by the results from the case studies where conflict was mostly directed towards the government who had power over the access and use regulations and thus strongly influenced the outcomes for other actor groups. Following this logic, actor groups that tended to behave negatively towards the government such as the fishing industry (Fig. 4.5) did not achieve their goals. During the shorter period of observation in the inshore fishery, the government was usually capable of accommodating the demands of the actor groups whereas in the cod fishery, the executive only succeeded in doing so in the latter half of the (longer) observation period.

However, it is possible that the failure to achieve sustainability goals is not the only driver of conflict or cooperation. For example, in the cod fishery the political opposition parties supported both the behaviour of the fishing industry and the environmental groups towards the executive. The more neutral behaviour of the opposition parties after 2007 probably reflects the election of the Scottish National Party into government in 2007 rather than the achievement of sustainability goals. Empirical conflict analysis could be further refined by including extrinsic political drivers such as changes in governance (this study) and the governance system (Boyes & Elliott 2016), and socioeconomic drivers such as a lack of food security, high crime levels and conflict at the village level (Pomeroy et al. 2007) that increase the likelihood of conflict or cooperation. It appears that conflict can be indicative for the achievement of sustainable processes and outcomes, but to draw this conclusion, the reasons for any conflict need to be understood. A possible approach to doing so could be mixed method research (Creswell & Clark 2007) where the quantitative assessment of the level of conflict could be integrated with the qualitative assessment of the reasons for conflict.

Conflict and stock levels

Limited availability of natural resources was expected to be reflected in the dialogue about sustainability issues and thus would be expected to directly link to conflict levels. It would be predicted that conflict would be highest when stocks were lower because access issues are at the heart of many fisheries conflicts (Charles 1992), and resource scarcity can increase competition instigating further conflict (Koubi et al. 2014). Stock levels in the cod fishery were below the SSB reference limit (B_{lim}) of 70,000 t over the entire period of observation from 1998 to 2014 (ICES 2014). Stock decreased consistently, year on year (except 2002), from 54,000 t in 1998 to 22,000 t in 2006. As expected, conflict was high in the early 2000s when stock levels were low. However, conflict should have been high over the entire period of observation given the low levels of SSB. Contrary to my expectations, conflict and SSB were not significantly correlated. In 2007 when landings reached their all-time low and just one year after the all-time low of the SSB (ICES 2014), cooperation between the government and the fishing industry peaked (Fig. 4.7).

I conclude that conflict is not a suitable indicator for the biological sustainability of fishery resources. Based on the reported comments of the actors and the landings data, the resource users were not dependent on the cod (Table 4.1) and could instead exploit alternative target species such as haddock and other whitefish. These additional resources provided another income stream, and hence the fishermen were able to remain critical of the regulators and government without being ´forced´ into entering meaningful dialogues and ultimately cooperative management. So low resource levels do not simply increase conflict, as actors involved in the exploitation of renewable resources are more inclined to cooperate when they are forced to take a long-term view, e.g. after the collapse of the resource (Garcia & Charles 2008).

The efficacy of co-management practices

The two case study fisheries were chosen for the conflict analysis because they represented two different approaches to management: quotas for the UK cod fishery are set centrally by the EU (Boyes & Elliott 2016) whereas the inshore fisheries in England have established collaborative management programmes (Rodwell et al. 2014). One of the recurring arguments in favour of fisheries co-management is its capacity for bringing different actors together to combine their knowledge (Coffey 2005; Berkes 2009). Co-management in fisheries is often associated with improved management practices and sustainable outcomes (Ostrom 1990; Grafton 2005; Cinner et al. 2012). It was therefore expected that the conflict analysis would show the co-managed fishery to have a more cooperative dialogue and to be more sustainable in terms of management processes and the achievement of sustainability outcomes.

The co-managed fishery considered in this study showed lower levels of conflict overall (sustainability management processes and outcomes) but did not demonstrate a higher degree of actor interactions compared with the centrally managed fishery (dialogue). The conflict analysis showed that in fact similar actor groups were involved in both the case study fisheries, and these actors interacted to a similar degree (Table 4.5). One possible explanation for this unexpected result is that another contextual factor, e.g. the degree of organization, counterbalanced the different governance arrangements. For instance, in the cod fishery, neither the resource users nor the environmentalists were involved in the decision-making process through formalized co-management, but they are organized into interest groups that could lobby the decision-makers. In many European countries lobby groups step in when stakeholders are not formally included in fisheries management (Mikalsen & Jentoft 2008). In the case study fisheries, co-management arrangements and the existence of lobby groups seemed to lead to the same level of interaction between actor groups (Table 4.5). Sustainability assessment schemes that aim to include social factors should therefore consider the level of participation of individual actor groups through other means, e.g. lobby groups that represent the interests of an actor group, and not simply the existence of formalised co-management practices. In the absence of co-management mechanisms, sustainable fisheries management could encourage and support the self-organization of actor groups to represent their interests towards the management authorities.

The co-management of natural resources is a powerful tool for the building of social capital (Grafton 2005). Co-management allows actor groups to collaborate whereby repeated successful interactions create trust and thus social capital increases (Berkes 2009). In the co-managed inshore fishery there was no evidence of the construction of social capital and no strong patterns of interactions that could be conducive for or prohibitive of cooperation. The shorter duration of the data analysed for the inshore fishery could have produced seasonal trends masking the longer-term patterns of behaviour. But the absence of increased cooperation in the co-managed fishery could also be due to several features of the co-management process in the inshore fishery. Members of the technical committee are appointed for four years, so that a continual resetting of the personal relationships between the actors because of the ´democratic´ process may have inhibited the development of the necessary trust and social capital (Harvey & Novicevic 2004). Also, the fishery cannot be considered fully co-managed because the selection process for the IFCA committee members is regulated by the government (Pieraccini & Cardwell 2016). Analysis of the social network showed that the executive actor group had high outward centralization confirming that this was the case: i.e. the IFCAs are a hybrid model that leans towards the centralized state. Conducting conflict analyses on a selection of fully co-managed fishery systems, e.g. in Norway, the Netherlands and Denmark (De Vivero et al. 2008), would improve understanding of how conflict and cooperation develop differently in centrally and co-managed fisheries.

The potential for conflict analysis to act as an indicator of sustainability

Fisheries sustainability has rarely been holistically assessed because of the trade-offs between different sustainability goals and the subjectivity of these goals. The results of this study suggest that conflict works well as an indicator of the functioning of the dialogue surrounding sustainability issues. Conflict as sustainability indicator for the societal dialogue (this study) could thus be paired with other criteria for assessing the sustainability of processes, outcomes and resources (Chapter 3) in order to evaluate fisheries sustainability holistically (Chapter 2). As a tool for analysing the dialogue surrounding sustainability, conflict is currently limited as an indicator by a lack of knowledge of: which social network structures and patterns of interactions are conducive to sustainability.

The type and direction of interactions coincided with the description of the actors' respective sustainability goals (Hilborn 2007b; Gray et al. 2008), so that conflict could also be a useful indicator for the sustainability of management processes and outcomes. However, conflict is a complex social and psychological phenomenon (Turner 2004), and empirical conflict analysis is based on counts of positive and negative interactions which is a simplification of human behaviour. For using conflict as an indicator for sustainable management processes and outcomes, the reasons for conflict need to be better understood.

Scarce resources are one reason for conflict, but this study did not support that conflict is a suitable indicator for biological sustainability and the continuity of fisheries resources. The analysis in the present study was constrained by the stock levels of some of the main target species over the entire period in both fisheries being low, relative to the historic records and sustainability thresholds (ICES 2014). Thus, to verify that there is no direct relationships between stock levels and conflict an equivalent analysis on a fishery that experiences periods of both very high and very low resource levels is desirable (Ricard et al. 2012). Social and ecological components of the fishery system are connected and interact in complex ways. In the case study fisheries the actor groups exhibited established patterns of behaviour and relationships that formed trajectories over time that could be used to explain long-term changes in social interactions. By combining long-term time series of biological stock and social conflict data, conflict analysis actually holds the possibility for integrating ecological and social dynamics, a recent endeavour in natural resource governance (Bodin et al. 2016), and studying social and ecological networks as one single, dynamic system.

Conclusions

With a growing world population, limited natural resources and significant environmental changes occurring conflict surrounding natural resource exploitation is likely to become more frequent. In this study, a quantitative approach to conflict analysis was used as indicator for the societal dialogue surrounding fisheries sustainability. When the reasons for conflict are understood, conflict can indicate the achievement of sustainable management processes and sustainability goals. While conflict was not indicative of sustainable resource levels, it can be a useful addition to the fisheries scientist' toolbox that can be used to understand the events and processes underlying sustainable resource management. By quantifying conflictive and cooperative behaviour, conflict analysis allows for comparisons over time and between systems and thus can be an addition to in-depth qualitative analyses of fisheries conflict (e.g. Bennett et al. 2001; Gustavsson et al. 2014; Harrison & Loring 2014).

Conflict analysis integrates the behaviour of many different actors over time and can build upon the existing approaches for social network analysis. It could provide a better understanding of the relationships between actors and help to identify conflicting interests. Moreover, when the dialogue surrounding sustainability issues is integrated into the assessment of sustainability, a clear agenda for fisheries management emerges that includes: an orientation to task achievement, effective communication, communicating agreement with the values of the other actors, general friendliness, respecting each other's needs, and showing a willingness to enhance each other's knowledge, skills and resources. To ultimately achieve sustainable fisheries, the focus of fisheries management needs to shift away from the outcomes and towards forming cooperative relationships.

5. General Discussion

Small-scale fisheries (SSF) make up 40% of the global fishing fleet and are particularly important for food safety and livelihoods in rural areas, yet they are threatened by local, regional and global pressures. Ensuring the sustainability of SSF can make a major contribution to achieving global fisheries sustainability and is critical for maintaining vulnerable coastal resources, alleviating poverty and preserving a traditional way of life. Measurements of the sustainability of SSF and its attainment face difficulties that are shared by many of these fisheries: they target multiple species and use multiple gears, there is often a lack of formal data on the SSF stocks and ecosystems, the management institutions are often weak, the fisheries have low capital investment and are labour intensive, there are many part-time, seasonal and migrant fishers, and the fishers have limited market and/or bargaining power. Given these characteristics, what does sustainability mean in a SSF context, how could sustainability assessments be adapted to better meet the specific needs of SSF, and what should the management of sustainable SSF look like?

This thesis examined several of these issues beginning with the understanding of sustainability in fisheries science (Chapter 2), reviewing market sustainability assessment standards (Chapter 3), and exploring the role of conflict and cooperation as indicators for sustainability (Chapter 4). In Chapter 2, the sustainability definitions implied within the fisheries science publications were conceptualized as four layers (Fig. 5.1).

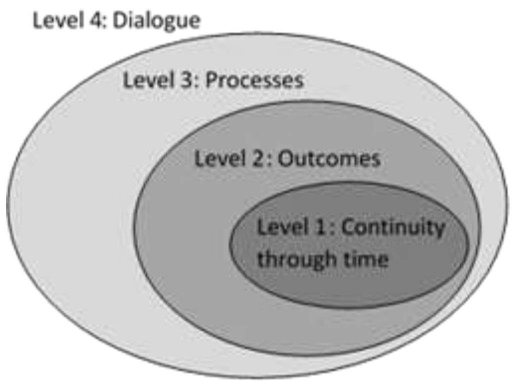

Figure 5.1: A conceptual model of fisheries sustainability (from Chapter 2). The innermost layer 'continuity through time' defines those elements of the fishery system that should be sustained (e.g. stocks, resources, ecosystems). The second layer considers the 'outcomes' that are derived from those sustained elements of the fishery system. The third layer, considers the 'processes' needed to ensure that the different elements of the fishery system are maintained and that sustainable outcomes are achieved. The final layer 'dialogue' relates to the societal choices surrounding sustainability, e.g. which elements should be sustained and at what levels, what are the desired outcomes, and which processes are prioritised for achieving both.

In this final chapter, I consider what we now understand about sustainability, and in particular, the need for improvements in understanding, assessing and managing small-scale fisheries. I start by reflecting on what has been learnt about the four layers of the conceptual model of fisheries sustainability shown above, in particular in terms of the applicability to SSF (Sections 5.1-5.4). Following this, a broader consideration of what is needed to move towards sustainability of SSF is presented (Sections 5.5-5.6).

5.1. The 'continuity through time' of small-scale fisheries

The analyses of the implicative meanings of sustainability identified continuity through time as one of the four layers of fisheries sustainability (Chapter 2; Fig. 5.1). Continuity through time regards what is going to be sustained, for how long and at what level. In fisheries science (Chapter 2), and sustainability standards (Chapter 3), it was found that the ecological components of the fishery system were still the main focus in terms of what should be sustained e.g. the species, stocks, resources, and the ecosystem. Two fisheries research areas (*Social-ecological systems* and *Viability clusters*; Chapter 2) also included consideration of the continuity of social and economic aspects of the fishery. Addressing continuity in socio-economic terms puts fishers and fishing communities at the centre of fisheries management, a perspective that is now thought to be crucial for achieving sustainable SSF (Berkes 2003; Andrew & Evans 2011; Kolding et al. 2014).

For the ecological components, continuity through time is often taken to mean "forever" (Brown et al. 1987). Based on the rather philosophical perspective that not even the universe is forever, it has been proposed that as an alternative, the time scale for sustainability should correspond to the natural expected life span of the system or the component to be sustained (Costanza & Patten 1995). There is a strong underlying understanding of sustainability that suggests natural resources cannot be exhausted in exchange for different types of capital because of the diverse and interlinked fundamental services that nature provides (Garmendia et al. 2010). For the socio-economic components of a fishery, continuity through time cannot mean "forever" in the face of modernization and constant societal change. I suggest that continuity through time, from a socio-economic perspective, means sustaining a fishery as long as it provides fundamental services and benefits that cannot be replaced by other activities. These aspects are picked up in the holistic definition of sustainable fisheries proposed in Chapter 2, as "*the continuous existence of the socio-ecological fishery system, in* *such a way that it provides goods and services now and in the future, without depleting natural resources, and the sustainable processes that make both possible.*"

In theory, there are two main ways of interpreting continuity through time: it may either be protecting something from disappearing, or maintaining it at productive levels (Rice & Legacè 2007). Ensuring the continuity through time of ecological components is already important because of nature's intrinsic value (Callicott 1985; Vilkka 1997). However, it should at least be considered what their (dis-)continuity means from the human perspective. From a fisheries perspective, the continuity through time of ecological components is associated with the production of an outcome (Table 2.2, Chapter 2). Maintenance at productive levels matches the historical understanding of sustainability within both the contexts of forestry (Carlowitz 1713; Wiersum 1995; Grober 2012) and fisheries (Russell 1931; Hjort et al. 1933; Graham 1939), and thus is relevant to all natural renewable resource systems including SSF. Fish stocks and ecosystems should be productive both to support the fishing industry and to support each other *(Fish stock can fulfil its ecological role* and *Ecosystem functioning and integrity*, Chapter 2). The fishery as a whole supports the individual fisher, e.g. by collectively maintaining ports and ensuring market access, and larger society, e.g. by reviving rural areas. So fisheries productivity can also be considered from a socio-economic perspective, and continuity through time requires that fisheries continue to be productive in all of these ways.

The assessment of 'continuity through time'

According to the review of fisheries sustainability literature completed in this thesis (Chapter 2), there were three research clusters dedicated to assessing the continuity through time of the ecological components of the fishery system: stock assessments, multi-species assessments and ecosystem productivity. Furthermore, *the status of the stock* was the single most important criterion in the fisheries sustainability standards (Chapter 3); and, *the collection of data and information for stock assessment* and the *use of reference points and stock assessment* were the most frequently used criteria in the science theme of the sustainability standards (Section 3.3.3). The continuity through time of the social components of sustainability was commonly assessed in fisheries science using income and employment as criteria (Section 3.3.4), but these criteria were not frequently used in the sustainability standards (Table 3.4, Chapter 3). Other criteria can be equally important to reflect the social part of the socioeconomic fishery system, e.g. women significantly contribute to the perseverance of SSF, but their role remains often invisible (Chuenpagdee et al. 2006; Zhao et al. 2013). Criteria such as this were very little reflected in either the existing science, or the sustainability standards assessed.

For any of the criteria used to assess continuity through time, even those better documented (e.g. ecological and management oriented criteria), there is often a lack of data for SSF (Cochrane et al. 2011; Nimmo and Southall 2012). This limits the potential for conventional population or ecosystem modelling (Salas et al. 2007), and can also hinder the potential to complete eco-certification (Chapter 3). To address this issue, methods for data-poor fisheries have to be developed (Pilling et al. 2009). Initiating the fisheries eco-certification approach (Chapter 3) might help support this pursuit by raising the profile of SSF and improving access to government funds available for their ecological assessment (Blackmore et al. 2015; Bellchambers et al. 2016a). However, financial support might decrease as more fisheries become certified (Blackmore et al. 2015).

A further challenge to the assessment of both the ecological and socio-economic continuity is that SSF often target short lived coral reef fish (Teh et al. 2013) or coastal invertebrates with highly variable population dynamics (Castilla & Defeo 2001; Basurto et al. 2013), and operate in coastal areas that are particularly vulnerable because many different human activities occur there (Guyader et al. 2013). As an adaptive strategy, SSF often rely on multiple stocks (Salas et al. 2007; Nimmo and Southall 2012; Guyader et al. 2013) and engage in fishing as a seasonal or part-time employment (Walmsley & Pawson 2007; Teh & Sumaila 2013). Consequently, data from a single stock and income and employment only from fishing provides limited information on the sustainability of the SSF social-ecological system.

This thesis showed that in research areas where it is difficult to obtain ecological data, i.e. recreational fisheries, bycatch, and deep sea fisheries (Chapter 2), a risk-based approach has been taken. Such an approach estimates to what degree an ecosystem component is exposed to a pressure, how much the pressure impacts the component, and how its inherent characteristics enable it to absorb, overcome or adapt to the pressure (Knights et al. 2013). The advantage of risk-based approaches is that the parameters are easier (and thus cheaper) to estimate than for data-hungry models. For socio-economic data, a similar approach is encapsulated in the sustainable livelihoods approach which considers the human, natural, financial, social and physical capital of fisheries (Allison & Ellis 2001; Allison, & Horemans 2006). In accordance with this approach, the scientific literature (Section 3.4) proposes social criteria that consider the capacity of fishermen and fishing communities to adapt to changes and withstand extreme events. However, while the idea has spread in the scientific literature, the most popular sustainability standards (Chapter 3) only incorporated a risk approach for ecological components (*Life history* and *Health and vulnerability of the fish stock*, Chapter 3; MSC 2010) and hardly any criteria reflective of the social adaptive capacity of fisheries (Table 3.4, Chapter 3). Possible reasons for this omission are that fisheries sustainability standards were designed to focus on ecological aspects, and that they aim at providing economic benefits to the fisheries through sustainable consumer choices so that giving a positive evaluation only to fisheries that are already doing well social-economically would be a circular connection.

An alternative approach to exploring continuity in time, through the analysis of conflict, was explored in Chapter 4. In one of the fisheries, decreasing stock levels were accompanied by a period of extensive conflict which abated when the government agreed to compensate the fishing industry for their economic losses. This was not a SSF, but the case study exhibited the characteristics of a multi-species fishery, and could be viewed through the lens of the sustainable livelihood approach where the fishers were able to achieve financial compensation for a loss of natural capital thanks to their political or social capital. It follows that conflict analysis is not a reliable indicator of the continuity through time of fish resources, but fishers employ conflictive behaviour when they fear that their livelihoods are being threatened. Conflict in fisheries can occur for different reasons (Deutsch 1977; Charles 1992; Harrison & Loring 2014; Øian et al. 2017) and fishers may use other strategies than conflict when their livelihoods are being threatened (neglect the problem, remain loyal to the management authority, or exit the fishery, Hirschman 1970), but if the reasons for conflict are taken into consideration, I conclude that conflict analysis is an adequate indicator of the continuity through time for the social side of a fishery.

5.2. The ‘sustainable outcomes’ of small-scale fisheries

The second layer of fisheries sustainability is the delivery of outcomes (Fig. 5.1) obtained by humans from natural resources. According to the linguistics analysis used in this thesis, “yield” was one of the most widely used terms in fisheries science, suggesting that it is still the main outcome associated with sustainable fisheries (Chapter 2). Other outcomes included: livelihood, poverty reduction, benefits at the household level, profit, revenue and economic benefits (Chapter 2), but Chapter 3 also identified cultural heritage, sense of place, identity, income, employment, food supply, social and economic well-being, and benefits for fishing communities, as important outcomes of some sustainable fisheries systems. These other outcomes contribute to the material, relational and subjective well-being of fishermen (Britton & Coulthard 2013; Weeratunge et al. 2014); where well-being is understood as "a state of being with others, where human needs are met, where one can act meaningfully to pursue one's goals and where one enjoys a satisfactory quality of life" (Britton & Coulthard 2013).

In comparison to material benefits such as yield, livelihood and food, it is clear that understanding and assessment of non-material benefits (e.g. cultural heritage) tend to be under-represented (Chapter 2) and these were also not prominently represented in fisheries sustainability standards (Chapter 3). Yet it is known that these non-material outcomes can be significant for SSF. For example, English fishermen were found to consider fishing a way of life rather than a job (SAIF 2010). Management measures restricting this way of life were as much disliked as competition from other resource users, both leading to conflict within the fisheries (SAIF 2010).

Outcomes accrue for both the individual fishermen (e.g. income, way of life) and the fishing community (e.g. employment rate, cultural heritage). They are certainly essential outcomes from a SSF perspective (Béné 2006), but another important aspect to consider is the inherent stochasticity and thus low predictability in the factors that can influence such outcomes. Aquatic systems are characterised by natural variability, short- and long-term fluctuations and occasional extreme events meaning that stock levels and ecosystem dynamics can be highly variable. Consequently, in addition to the quantity of outcomes delivered, their stability and security are also important for SSF.

The assessment of 'sustainable outcomes'

In conventional fisheries management, the outcomes are measured in terms of yield which is the base for sustainable livelihoods and food security. However, SSF can deliver other outcomes as well, such as a sense of place, identity and cultural heritage (Acott & Urquhart 2012) and can have educational benefits (Carlson & Palmer 2016) and strengthen social relationships (Adolf et al. 2016; Butterworth 2016). Simply assessing fisheries yield would exclude the many valuable non-material benefits, which are more difficult to assess and quantify (Milcu et al. 2013; Hattam et al. 2015).

In this thesis an alternative approach was tested for assessing sustainability as 'sustainable outcomes' (Chapter 4). The premise was that if all users were content with the state of the fishery it could not be considered unsustainable. The "state of the fishery" could either refer to the achievement of desired outcomes or the perception of the management processes that are supposed to achieve these outcomes. In a free and open society, stakeholders engage in discussions and when their sustainability goals are not obtained there would be conflict up to the point of escalating into "fish wars" (Pomeroy et al. 2007). The general behavioural interaction patterns in the fisheries confirmed that conflict emerged when people's goals seemed unfulfilled and the management processes were not in place to change the current situation or compensate for one's losses. Conflict emerged also for other reasons, so that a deep understanding of the causes of conflict would be necessary in order to use conflict as an indicator for sustainable outcomes and management processes.

5.3. The 'sustainable processes' in small-scale fisheries

The third layer of sustainability (Fig. 5.1) is the processes that achieve continuity through time and the sustainable fisheries outcomes. Two different types of processes were identified through the linguistics analysis (Chapter 2). (1) Processes such as fishing that deliver outcomes but can have negative impacts and thus must be limited; and, (2) fisheries management or the fishing practices that need improving. The two types are interlinked because fisheries management mostly targets the fishing industry, not the fish stocks or the ecosystem themselves (Fulton et al. 2011). Typically the fish stocks and the ecosystem are monitored by the management authorities, these regulate the fishery, and the fishing activities exert pressure on the stocks and the ecosystem in accordance with the management regulations (Fulton et al. 2011). The fish stocks and the ecosystem change state in accordance with the pressure, this change of state is then detected through monitoring. So, the linguistic analysis found the processes had a similar structure as that used in the Pressure-State-Response framework, a popular model to represent the interplay between environmental protection measures and environmental impacts that has been developed and is being used by the Organisation for Economic Cooperation and Development (OECD 2001) and European Environment Agency (EEA 1999).

Problems arise if the fishing activity does not comply with the management decisions. Non-compliance is one of the major drawbacks of conventional fisheries management and one of the factors contributing to the global fisheries crisis (Keane et al. 2008; Agnew et al. 2009; Pauly & Zeller 2016b). Accordingly, compliance was the most widely used criteria for sustainable management in the 20 market-based standards (Chapter 3). In SSF, there is often a lack of formal knowledge about the stocks and the ecosystem (Salas et al. 2007; Cochrane et al. 2011; Nimmo and Southall 2012) and a lack of monitoring, control and surveillance of the fishing activities (Castilla & Defoe 2001; Salas et al. 2007) due to a lack of management resources because of the small size of the fisheries. So the management circle just described is interrupted for SSF at two places, delivering a reasonable explanation why conventional top-down fisheries management does not work well for SSF. As an alternative, SSF fisheries management often relies on local knowledge and the power of self-policing and social norms (Berkes 2003; McClanahan et al. 2009). Exchange of knowledge and building of social capital is therefore of the highest importance for sustainable processes in SSF.

The assessment of 'sustainable processes'

In theory, there exist two mind-sets to approach the assessment of sustainable processes in fisheries: either fisheries share many characteristics so that a certain management measure will achieve sustainability anywhere it is used; or fisheries are so diverse in terms of their characteristics and challenges that approaches to steer processes have to be developed individually for each fishery. Most will find themselves somewhere between these extremes. For example, the recommendations for fisheries management range from learning from successful fisheries (Hilborn 2007a; Cinner et al. 2016) to being aware of panaceas and quick fixes (Degnbol et al. 2006; Ostrom 2009).

The fisheries science literature reviewed in this study used specific management approaches in each research area (Chapter 2). The research areas themselves might give a good indication of which management measures can be applied across many fisheries and which types of fisheries require a specific treatment: small-scale and recreational fisheries, the aquaculture and aquarium trade sectors, coral reefs, mangroves and the deep sea appear all to be in need of specific sustainable processes. In contrast, individual transferable quotas, marine reserves, stock assessment and eco-certification schemes can be applied across a broad range of fisheries (list not exhaustive, see also Table 2.2, Chapter 2). So the analysis showed that management processes have to be tailored to SSF and eco-certification is one of the approaches that can be used for this purpose.

The sustainability standards (Chapter 3) also contained two types of criteria for sustainable processes, and according to the analysis of fisheries research areas (Chapter 2), both types of criteria can be applied to a wide range of fisheries including SSF. Firstly, the sustainability standards used process criteria relating to the themes of fish stocks, ecosystem, social aspects and science, e.g. in a sustainable fishery the *fishing pressure* and the *impact of the fishing method on the habitat quality* must be restricted (Table 3.3, Chapter 3). Secondly, the sustainability standards used between them eight management criteria (Chapter 3), which functioned as a type of meta-criteria. Put differently: whatever the management measure was, it was important that some *management measures were in place* and that these were *appropriate for the fishery* and *were adhered to* (Table 3.3, Chapter 3). The first group of criteria represents the core content of the sustainability standards, while the second group of criteria allows the standards to be adapted to a wide range of fisheries. This type of flexibility is necessary because different processes can lead to the same (sustainable) outcomes or continuity (Boonstra & Oesterblom 2014). From a SSF perspective, I see the issue that many SSF will lack the necessary data for the first group of criteria and the management capacity for the second group of criteria. As highlighted earlier (Section 5.3), monitoring of stocks and compliance are two areas where achieving sustainable SSF faces bigger challenges than large-scale fisheries. Alternatives could be local knowledge instead of stock monitoring and peer pressure instead of control and surveillance of fishers. When people disagree about the suitability of management measures, conflict arises and may indicate unsustainable processes. As with the sustainability of outcomes, understanding the reasons for conflict is crucial when conflict is employed as indicator for the sustainability or processes.

5.4. 'Sustainability as dialogue'

The thesis showed that sustainability as a concept is socially constructed, and the concept is approached differently in different areas of fisheries science (Chapter 2), by different sustainability standards (Chapter 3) and by different stakeholders and other actor groups (Chapter 4). From a historic perspective, the understanding of sustainability has changed over time and it is anticipated that it will change again, or be updated, in the future. This is because at present, sustainability is understood as the solution to fisheries challenges and it is the expression of contemporary societal values (Chapters 2 and 3). Fisheries challenges and societal values do not translate directly into policy; rather the changes to policy are the result of dialogue, negotiations and societal choices. This dialogue is not part of the sustainability definition itself, but it functions as a fourth layer embracing the other three layers (Fig. 5.1) because it is the dialogue that determines which elements are sustained and at what levels, what are the desired outcomes, and which processes are prioritised.

The basic prerequisite for a dialogue is that all relevant stakeholders are involved (Reed et al. 2009). Transparency, consultation of stakeholders, participation and co-management become key when sustainability is viewed as embedded in a dialogue. With sustainability encompassing (per the definition proposed in this thesis) the ecological and socio-economic continuity, outcomes and processes, the consideration of the dialogue and the promotion of participation in management become relevant in many more areas than the review of fisheries science literature suggests (Chapter 2). There has been a recent turn towards participation and co-management in many types of fisheries (Berkes 2009; Rodwell et al. 2014; Clark et al. 2015). However, many case studies have shown that stakeholder participation and co-management are no guarantor for sustainability, which has motivated a search for success factors, internal and external to the fisheries that explain the success or failure of co-management (Gutiérrez et al. 2011; Cinner & Huchery 2014; Cinner et al. 2016). Based on the analyses in this thesis, I suggest that it is necessary to take the characteristics of the dialogue itself more into consideration, in order to move towards sustainable small-scale fisheries.

The assessment of a 'sustainable dialogue'

For assessing the sustainability of the societal dialogue, this thesis proposed conflict as an indicator (Chapter 4). More specifically, the dialogue was assessed through social network structures based on conflictive/ cooperative interactions, the trends in cooperation and conflict over time and established behavioural patterns. It is crucial to keep in mind that the other sustainability layers are dependent on the societal dialogue. For example, the understanding of stock dynamics in the absence of good monitoring data can greatly benefit from local knowledge, but this knowledge has to be viewed as legitimate and the social network has to be structured in a way that different types of actors can feed their knowledge into the management process.

SSF are often marginalized from decision making and are underrepresented (Pauly 1997; Béné & Friend 2001; Berkes 2003; Salas et al. 2007; Nayak et al. 2014). McConney and Charles (2008) summarize "It is clear that power dynamics play a large role in governance and may be especially important in SSF due to inequity among actors. It is necessary to take power into account and to appreciate how embedded it is in culture and society." Therefore, incorporating the dialogue about sustainability into the assessment of sustainability and sustainable management should be imperative for SSF.

In Chapter 4, conflict analysis showed that the dialogue in an inshore fishery in the UK exhibited similar patterns to the dialogue in a centrally managed offshore fishery. Conflict analysis should also be applicable to the range of research areas identified in Chapter 2 which represent specific types of fisheries (recreational fisheries, the aquaculture and aquarium trade sectors, coral reefs, mangroves and the deep sea) and a comparison with SSF would be helpful to further understand how power, values, relationships and knowledge shape the societal dialogue about fisheries and to address the specific management requirements of small-scale and other fisheries.

5.5. Towards sustainability in small-scale fisheries

The current fisheries crisis (Chapter 1) is largely due to the pressures from fishing operating on much faster time-scales or at a much higher intensity than the natural productivity of the fish stocks (Costanza & Patten 1995; Fresco & Kroonenberg 1992). As in the cod fishery whose stock fell below productive sustainable levels (Chapter 4), fishing pressure then has to be adjusted to match the reproductive capacity of the stock and an adequate recovery time is needed. A 'command-and control' approach such as this represents the conventional approach that has been historically used for fisheries management (Selig et al. 2016). Alternative approaches that are thought to be more suitable for SSF include adaptive management, the incorporation of local knowledge, co-management, learning, resilience thinking, understanding fisheries as linked social-ecological systems, governance, and enhancing capacities (Berkes 2003). Over the last decade, these new approaches have been developed extensively in the literature, however they have not been extensively put into practice because they represent a paradigm change (Kuhn 1974) that does not coincide with the perspectives held in fisheries, management and other institutions (e.g. belief in expert knowledge, controllability of the environment, goal orientation).

To move towards sustainable fisheries, this thesis makes the following suggestions:

Firstly, a definition of fisheries sustainability is proposed as "*the continuous existence of the socio-ecological fishery system, in such a way that it provides goods and services now and in the future, without depleting natural resources, and the sustainable processes that make both possible*" and sustainability is conceptualized as three layers of continuity, outcomes and processes embedded in the layer of dialogue about sustainability (Fig. 5.1). As we have learned from the history of MSY (Chapter 1), the goals of fisheries matter. Sustainability is widely accepted as a core concept in fisheries, but poorly conceptualized. The definition and conceptual model can help to operationalize sustainability goals, improve the communication between stakeholders, and better inform sustainable consumer choices, thus providing part of the base for meaningful societal dialogue about sustainability.

Secondly, eco-certification has been a major force of change in fisheries in the last decade. This thesis found that the criteria employed by all the popular fisheries sustainability standards were not well suited to enhance sustainability of SSF in a holistic way. As in other occasions, SSF were marginalized from the decision-making and did not have a seat at the table when the dialogue about fisheries eco-certification took place. It is not likely that the criteria will be adapted in the near future, but other societal actors, including managers and scientists, can support the sustainability of SSF by not uncritically perpetuating the criteria upheld by the sustainability standards and by developing and exploring alternative models of sustainability including the definition developed in this thesis.

Thirdly, it is suggested that fisheries conflict provide both a lens to analyse and to move towards sustainability. Conflict is omnipresent in fisheries, yet its role and meaning have hardly been understood so far. In this thesis, conflict is shown to be a complex concept. Conflict was found to emerge for different reasons such as fishers being threatened in their livelihood because of declining resources, actor groups not achieving their sustainability goals or disagreeing on fundamental issues and protecting their self-interest, and established relationships between actors. This is fundamentally different from the current view on conflict in fisheries, which is not dealing with the *why?* but with the *about what?*. By tackling the reasons for conflict one by one, disputes that were caused by personal relationships, misinterpretation of information, or similar issues, could be solved and substantial conflicts that indicate sustainability issues could be better understood.

This thesis has shown that there is a need to develop a more coherent definition of sustainability to underpin the management of SSF. Furthermore, the data challenges for SSF mean the classic approaches of using stock assessments to quantify ecological sustainability (as done for commercial fisheries) are not appropriate. Thus, new approaches for assessing and achieving sustainability are needed that could be applied in data poor situations and that put the appropriate weightings on the social components of sustainability. Ultimately, such approaches could help SSF develop, and obtain market advantage through mechanisms such as eco-certification. SSF will face more challenges in the future, and the fish and the people depending on them need appropriate support structures that ensure their own and the society’s long-term well-being.

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Appendix

Table A1: Coding and aggregation of actors for the conflict analyses of the inshore fishery in the district of the North Western Inshore Fisheries and Conservation Authority, England.

Groups	Individual actors	Justification for aggregation
[ADM] fisheries administration	**[NWI]** North Western Inshore Fisheries and Conservation Authority **[TSB]** Technical subcommittee **[FSC]** Financial subcommittee	Fisheries administration per definition
	[CEO] NWIFCA chief executive **[SCO** NWIFCA science officers **[CON]** NWIFCA enforcement officers	Staff of fisheries administration
	[CHA] Subcommittee chair	Mediator role
	[COU] Local authorities, councils	
[SUP] superior administration	**[MMO]** Marine Management Organisation **[EEC]** European Union **[HSE]** Health and Safety Executive	
[FIS] fishing industry	**[FUL]** Full-time fishers **[LOC]** Local fishers **[SMA]** Small-scale fishery **[HAN]** Hand gatherers **[DRE]** Dredge fishery **[PAR]** Part-time fishers **[MIG]** Migratory fishers **[LAR]**Large-scale fishery **[RAZ]** Razor clam fishery **[AQU]** Relaying and aquaculture	Diversity of fishery sector impedes further division
[OTH] other fisheries	**[ANG]** Anglers **[FOR]** Foreign dredge vessels **[VES]** >10m vessels with high kW **[BUY]** Fish buyers	Not under the influence of [ADM] or interests different to [FIS]
[ENV] environmental representatives	**[ENVORG]** Committee appointees from the Environment Agency and Natural England, other environmental organisations **[ENVCON]** Individual conservation representatives, conservation sector	Similarity of direction of impact
[SCI] scientists	**[ISC]** Individual scientists **[UNI]** Universities **[CEF]** Centre for Environment, Fisheries and Aquaculture Science	Similarity of direction of impact
[CVL] civil society actors	**[EST]** Private land owners **[IND]** Private companies, Energy, gas and wind companies, National grid **[FOR]** North West Coastal Forum; Regional Flood and Coastal Committee	Similarity of direction of impact

Table A2: The actor aggregates, the different actor types, and reasoning for the construction of each aggregate used for the conflict analyses of the UK inshore fishery and the North Sea cod (*Gadus morhua*) fishery. List of actors derived from the Conflict and Mediation Event Observations (CAMEO) database (Schrodt 2012b).

Actor aggregates	Actor groups	Reasons
[GOV] Government	**[EECGOV]** European Union, Commission, Fisheries Commissioner, Council, Fisheries Ministers, Parliament, Members of Parliament, civil servants **[GBRGOV]** UK Government, Fisheries Minister, Prime Minister, House of Commons, Members of Parliament government agencies, departments **[SCOGOV]** Scottish Government, First Minister, Fisheries Minister, government spokespersons, Deputy Fisheries Minister, Parliament, Members of Parliament, councils	Intertwining of institutions and governments
[OPP] Opposition	**[GBROPP]** UK opposition parties **[SCOOPP]** Scottish opposition parties	Intertwining of parties
[FIS] Fishing industry	**[GBRFIS]** British fishers, fishing industry, industry leaders, National Federation of Fishermen's Organisation, Cod Crusaders, Supporters **[SCOFIS]** Scottish fishers, fishing industry, industry leaders, Scottish Fishermen's Federation, Scottish Whitefish Producer Association **[GBRFISMED]** Editor of Fishing News **[GBRNDPSEA**] Seafish Industry Authority **[FISDEV]** NE Fisheries Development Partnership	Intertwining of fishing industry organisations and between Scottish and UK level
[OTH] Other fisheries	**[GBRANG]** Anglers **[GBRFISLAR]** Large trawlers, including foreigners **[GBRINS]** Inshore fishers, inshore fleet **[GBRBUSFIS]** National Federation of Fish Friers **[SCOBUSFIS]** Scottish fish processors, Scottish Fish Merchants Federation	Direction of interests different to [FIS]
[ENV] Environmental representatives; eNGOs	**[ENV]** Non-specified environmental groups **[ENVCEP]** Royal Commission on Environ. Pollution **[ENVGRP]** Greenpeace **[ENVMCS]** Marine Conservation Society **[ENVOCE]** Oceana **[ENVPEW]** Pew Charitable Trusts **[ENVRSP]** Royal Society for the Protection of Birds **[ENVSNS]** Save the North Sea **[ENVWIT]** Wildlife Trust **[ENVWWF]** World Wildlife Fund	Similarity of direction of impact
[SCI] Scientists	**[GBRSCI]** Centre for Environment, Fisheries and Aquaculture Science, Government scientific chief advisor, Fisheries Research Services , Royal Society, individual scientists **[EECSCI]** International Council for the Exploration of the Sea, Scientific, Technical and Economic Committee for Fisheries	Similarity of direction of impact
[CVL] Civil society actors	**[GBRCVL]** Consumers, calls to political action, New Economics Foundation **[GBRELI]** Elites, authors, House of Lords, Church of Scotland, Royal Family, former ministers, chefs **[GBRMED]** Media, Sunday Times **[MNC]** Multinational cooperation	Similarity of direction of impact

Table A3: Frequency of interactions between Number of years during which actor groups in the UK North Sea cod fishery interacted with each other over out of 17 years (1998-2014), and number of meetings during which actor groups in the NW English inshore fisheries out of over 14 meetings of the Technical, Science and Byelaw Subcommittee of the North Western Inshore Fisheries and Conservation Authority (2011-2014). Initiators of action in rows, recipients in columns. Intensity of interactions, the number of single actions that the actor groups exchanged in total, is given in parenthesis for each interaction combination.

Actors	Civilians	eNGOs	Executive	Fishing industry	Other fisheries	Political opposition	Scientists
North Sea cod fishery							
Civilian actors		2 (2)	5 (14)	6 (14)			1 (1)
eNGOs	1 (1)		17 (77)	12 (34)	1 (1)		3 (6)
Executive	4 (6)	6 (18)	16 (162)	17 (228)	6 (10)	5 (17)	7 (22)
Fishing industry	4 (5)	7 (13)	17 (241)	7 (11)	1 (1)	3 (4)	10 (25)
Other fisheries			7 (12)	2 (3)			
Political opposition			8 (115)	6 (36)	2 (3)	3 (8)	6 (10)
Scientists	3 (3)	1 (1)	9 (22)	6 (11)			4 (4)
Northwest England inshore fishery							
Actors	**Civilian actors**	**Environ-ment**	**Executive**	**Fishing industry**	**Other fisheries**	**Scientists**	**Superior admin.**
Civilian actors		1 (1)	5 (7)	1 (1)	1 (1)		
Environment	4 (5)	1 (1)	11 (39)	8 (15)	2 (2)	1 (1)	3 (3)
Executive	8 (25)	12 (57)	13 (91)	14 (179)	3 (8)	11 (24)	10 (31)
Fishing industry	5 (5)	4 (6)	13 (101)	9 (31)	4 (8)	2 (3)	3 (3)
Other fisheries	2 (3)		3 (6)			1 (3)	
Scientists		4 (5)	11 (28)	6 (18)		1 (1)	
Superior administration		1 (1)	5 (6)	1 (1)			