Maritime Studies
a SpringerOpen Journal

RESEARCH Open Access

A chain of fools: or, why it is so hard to stop overfishing

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Abstract

We fish too much, and by doing so, we threaten marine ecosystems and people's livelihoods. But the curious thing is: we have known this for a long time. Nonetheless, we continue to overfish. How is that possible? Why can we not stop? This paper recounts our search for an answer. We start by giving an overview of how scientists explain overfishing, and suggest that the riddle of its obduracy has not been addressed systematically. We conceptualize overfishing as an unplanned and unintended outcome of a chain of interrelated social and ecological events. We then analyze the chain of events leading to overfishing for two typical cases – the groundfish fishery in the Gulf of Maine and the South African abalone (*Haliotis midae*, *Haliotidae*) fishery – and two atypical cases where overfishing has stopped or been substantially reduced – the Patagonian and Antarctic toothfish (*Dissostichus eleginoides, Nototheniidae* and *Dissostichus mawsoni, Nototheniidae*) fishery in the Southern Ocean, and the Atlantic cod (*Gadus morhua*, *Gadidae*) fishery in the Barents Sea. Studying and comparing these cases reveals no sufficient set of factors to explain the persistence of overfishing. Rather, distinct pathways emerge from a concatenation of proximate and remote factors, leading to and sustaining overfishing. Understanding these pathways and their mechanisms can assist in locating leverage points for intervention aimed to stop overfishing.

Keywords: Overfishing; Causal complexity; Social-ecological regime; Proximate and remote factors

Introduction: old news

In September 2012 the US Department of Commerce classified New England's groundfish fishery a disaster. Granting New England's fishery this low status followed from recent studies showing that the groundfish stocks had not recovered despite austere regulations over the last 15 years (NOAA 2012). The suggested 70% catch reductions needed to restore the stocks would prove detrimental for the dwindling number of groundfish fishers and their communities. A likely reason for the slow recovery of New England's groundfish stocks is that they have simply been overfished for too long (Acheson 2011; Acheson and Gardner 2014). New England is by no means an exception; numerous studies show how overfishing remains a significant and persistent threat to marine fish populations (Worm et al. 2009) despite recent examples of populations recovering and rebuilding (Hilborn 2007).

Many of the marine ecosystems worldwide that are listed as vulnerable have reached this point after centuries of overfishing (Roberts 2007). Indeed, overfishing has been a consistent

theme throughout human history. It occurred perhaps for the first time during the Middle Ages when fishers emptied European rivers and estuaries of sturgeon and salmon (Barrett et al. 2004). In 1289, King Philip IV of France complained: *"every river and waterside of our realm, large and small, yields nothing due to the evil of fishers and the devices of their contriving"* (Roberts 2007, p. 25). The ensuing crisis in the European freshwater fish supply in the 11th and 12th century was a prelude to a cascade of similar stories of overfishing in seas around the globe: from the collapse of whaling in the 19th century to the cod crisis in Newfoundland in the beginning of the 1990s (Roberts 2007).

What is remarkable is that people have long been aware of the dangers of overfishing. When the otter trawl was used for the first time in the United Kingdom in the 19th century it caused a storm of protest from fishers who were afraid that trawling would decimate stocks and destroy the sea floor (Thurstan et al. 2013). There are even examples of pre-modern fisheries governance trying to limit fishing effort, such as in 1668 when the General Court of Massachusetts ordered that: *"no man shall henceforth kill any codfish, hake, haddock, or Pollock, to be dried for sale in the month of December or January, because of their spawning time"* (Bolster 2008, p. 41).

But if overfishing is indeed such an old problem, and if the negative consequences for society and nature have always been so obvious and well-known, why do we - in the 21st century - still fail to put an end to it? To illustrate this point: from the 1950s up to this day fishing intensity has redoubled (Watson et al. 2013), despite the poor status of many of the global fisheries (Worm et al. 2009). In this paper, we present our search for answers to this riddle; answers that explain why overfishing is so difficult to stop.

To this purpose we first conceptualize overfishing as an unplanned and unintended outcome of a chain of interrelated social and ecological events, and consider how earlier studies have dealt with this complex causality. We focus in particular on the ideas of 'ratchets' (Pitcher 2000), 'marine systems' (Perry et al. 2011) and 'regimes' (Howarth et al. 2013). Based on this brief review we introduce a distinction between proximate and remote causal factors. In the remaining part of the paper we present a study of the historical co-development of fisheries, marine governance, and marine ecosystems of the groundfish fishery in New England, the abalone fishery in South Africa, the toothfish fishery in the Southern Ocean, and the cod fishery in the Barents Sea. The final sections of the paper discuss the results of the analysis for our current knowledge of overfishing.

Metaphors

Sumaila and Pauly recently presented an insightful image of our common failure to prevent overfishing. They argue that these failures resemble a 'march of folly' (Sumaila and Pauly 2011). The metaphor usefully captures the collective failure to manage fisheries. A march is an organised, social activity and proceeds steadily and relentlessly. Moreover, a march implies that no individual is in charge. It is as if the collective group becomes a single entity that moves in a regular and singular direction: the march, in other words, produces a *"merger between self and the surrounding group"* (McNeill 1997, p. 10). The metaphor works less well, however, to capture the obduracy of overfishing. Marches are typically used to create social cohesion and discipline in groups of individuals (McNeill 1997). In contrast, the obduracy of overfishing seems to be more a

result of a lack of social cohesion and discipline. We therefore propose to tweak the metaphor somewhat. Imagine that the march is not performed by a drilled platoon of soldiers but by a group of chained prisoners: a so-called chain gang. A chain gang is not well ordered or drilled. Some prisoners walk slowly, others faster; some lean to the right, others to the left; some trip, taking others with them in their fall. But all of them remain chained together at hands and feet. No one stands outside and no one is in charge. This vivid image of the cumulative effects of people's dependence on each other (to which we would also add people's dependence on nature) comes from the sociologist Elias. He invokes the image to highlight that people often fail to comprehend the larger chains of dependence that they form together. "[…] *being hemmed in and moved uncomprehendingly hither and thither in ways which none of them intended, they cannot help being preoccupied with the urgent, narrow and parochial problems which each of them has to face … They are too deeply involved to look at themselves from without.*" (Elias 1956, p. 232).

The image of marching in a chain gang is useful because it highlights two aspects of overfishing that are currently missing from conventional analysis and explanation. First, the image points to the extensive, global web of interdependencies stemming from economic, political, social, and ecological relations between fish, fishers, industries, governments and consumers, which is also referred to as the *"seafood supply chain"* (Pramod et al. 2014). The totality of these interdependencies between people and the rest of nature can be thought of as a social-ecological system (Berkes and Folke 1998). Moreover, the image also highlights that this social-ecological system exists semi-autonomous from the people and organisms that populate it. When an increasing number of people and organisms become interdependent on each other, the potential for individuals, or specific groups, to control the effects and outcomes of their interaction with each other, or with nature, diminishes. This is why and when the social-ecological system gains relative autonomy from the plans and intentions of any of the individuals or groups involved (Elder-Vass 2010). The social-ecological system exists because of the interdependencies between people and nature, but "*takes a course which none of the individual*[s] *has planned, determined or anticipated. On the contrary, the unplanned course of* [the social-ecological system] *repeatedly influences* the moves of each individual player" (Elias 1978, p. 95). This is a crucial insight because it means that to explain the collective outcome of human behavior, such as overfishing, one needs to include the dynamic of social-ecological interaction in time as an explanatory variable in the analysis. The second insight of the chain gang metaphor refers to the way we conventionally think about the causes and solutions to overfishing. As in Elias' image we not only have difficulty controlling the social-ecological system of which we are part (which produces overfishing), we also have difficulties perceiving it.

Economists, for example, have argued that overfishing is primarily the result of a political failure to radically privatize the use of marine environments, which they consider as an 'open access property' (Runolfsson 1997). Others point to technological creep, the continued growth of overall fishing capacity, as the main cause of overfishing (Marchal et al. 2007). Another cause is found in the collective amnesia and shortsightedness when it comes to the perception and valuation of marine biomass and biodiversity. Included here is Pauly's (1995) shifting baseline syndrome, but also the failure to economically value marine ecosystem services. Another cause for overfishing is found in

perverse subsidies, when from the 1950s several states used subsidies to modernize fishing fleets (World Bank 2009). These subsidies encouraged the growth of fishing capacity and, in so doing, contributed to overfishing. These answers are not wrong, to be sure, but they tend to highlight only one or a few single factors that are then supposed to be applicable in all cases all the time. Conventional diagnosis of overfishing tends to focus on separate parts of the marine social-ecological systems (social, economic, political or ecological aspects) (Boonstra and Nhung 2012), and assume that fixing these will solve the issue, while overfishing develops from a complex, historical concatenation of social and ecological aspects (Howarth et al. 2013). Still, there are also studies that have highlighted the causal complexity underlying the obduracy of overfishing. It is to these studies that we turn next.

The causal complexity of overfishing

A number of recent studies have used a holistic systems perspective to understand the stability and change of marine ecosystems (Ommer et al. 2012; Perry et al. 2011; Charles 2012). These studies show that marine systems seldom grow gradually towards long-term stable, climax conditions, but instead tend to bifurcate between different 'stable states' (Howarth et al. 2013). The bifurcation between alternative stable states is called 'a regime'. When social-ecological systems change within a regime it means that they *"absorb and utilize or even benefit from perturbations and changes that attain it, and so to persist without a qualitative change in the system's structure"* (Holling 1973, p. 3). Pitcher (2000) has identified three causal mechanisms that work like ratchets and maintain marine ecosystems in degraded conditions. *"Odum's ratchet"* highlights the effects of (over)fishing as a selective force on ecosystems when it removes the apex predators from marine food chains. These removals are often permanent, and can result in tropic cascades or regime shifts favoring fish with higher turnover rates (Steneck 2012). *"Pauly's ratchet"* refers to the human tendency to fail to notice gradual change, and to set goals for marine ecological restoration that are based on personal perceptions (Pauly 1995). *"Ludwig's ratchet"* refers to the increase in fishing capacity through loans, which can only be repaid with catching more fish (Ludwig et al. 1993). More fishing effort leads to reduced stock abundance, which then requires more investments in fishing capacity to make up for the loss in catches (and to pay off the loans).

Using these ideas, it becomes possible to consider overfishing as a regime, i.e. a relatively stable state, in which a degraded marine social-ecological system persists despite changes. The stability or change of an ecological regime is often the result of specific interactions between the drivers of an ecosystem (slow variables), and external shocks (fast variables) (Nyström et al. 2012). Such a two-level causality approach shares many similarities with analyses of change in social or political regimes (Mahoney and Snyder 1999), that frequently make a distinction between structural and agential causes. Structural causes refer to features of social structures, such as institutions, cultures, or value systems, while agential causes highlight the causal role of people's individual choices and strategies.

For this article we use these ideas about two-level causality to make a distinction between proximate and remote causal factors (Geist and Lambin 2002, see also Wilen 2006) that, we believe, can accommodate both ecological and social theorizing about

dynamics of social-ecological systems. Proximate factors, sometimes also called "symptoms" (Wilen 2006), are causes that are temporally and spatially close to the outcome under scrutiny. They typically include human activities at local levels, such as the expansion of fishing capacity and/or (non)-compliant behavior, but also the actions of other organisms or natural events (earthquakes, storms, etc.). Remote factors have an origin remote in time and space from the outcome to be explained, and they cannot be influenced directly by actions in the here and now. These factors can be witnessed over a range of case studies, which makes them more general. They typically include the 'causes of causes', i.e. the social and ecological factors or conditions that influence the occurrence of the proximate causes. We argue that proximate factors (i.e. individual human behavior) produce overfishing, but only through their relation with remote factors (i.e. gradual ecological changes or social-structural change) (see Table 1).

Tracing overfishing

As the collective causal mechanisms that produce overfishing consist of a set of interacting proximate and remote factors, neither the proximate nor the remote factors alone are sufficient to generate overfishing; they can only do so through their interaction with each other. In other words, both parts are necessary to make the mechanism 'work'. A method that is frequently used to identify specific causal mechanisms is process tracing. Process tracing is a within-case method *"to identify the intervening causal process – the causal chain and causal mechanism – between an independent variable (or variables) and the outcome of the dependent variable"* (George and Bennett 2005, p. 206).

An important first step in process tracing is the operationalization of the theoretical concept into a so-called *"systemized definition"* (Beach and Pedersen 2013, p. 46). In this case it means systemizing and operationalizing overfishing as a stable regime. Österblom et al. (2011) have suggested a simplified visualization of social-ecological interactions that can transform a relatively sustainable fishery into a relatively unsustainable fishery. A sustainable fishery is defined in this framework as a fishery that can maintain a stable, relatively high level of biomass, functional management and a high level of compliance, while an unsustainable fishery includes stable but relatively low levels of biomass and dysfunctional management with high noncompliance. In accordance with this distinction, we consider overfishing to be 'yield overfishing', i.e. a fishery that *"prevents a population from producing as much sustainable yield as it could if less intensively fished"* (Hilborn and Hilborn 2012, 3). Using this definition, we searched the fisheries science literature for rich case studies that describe and explain in detail the social and ecological processes that changed fisheries from being sustainable to

Table 1 Proximate and structural causal factors in ecological and social regimes

	Proximate causal factors	Remote causal factors
Ecological regimes	External, sudden shocks, such as a disease outbreak or change in climate forcing.	Gradual changes in underlying drivers and feedbacks of marine ecosystems.
Social regimes	People's choices, strategies and actions, such as fishers' adoption of new gear types, or political leaders changing marine governance.	Gradual changes in social structures, such as institutional or cultural changes that influence fishing practices and marine governance or technological progress.

unsustainable, and vice versa. Based on these criteria we selected 2 case studies to represent each situation (four cases in total) from the existing literature on overfishing:

- The abalone fishery in South Africa and the northeast multispecies groundfish fishery in the United States, which shifted from a relatively sustainable into a relatively unsustainable stable state.
- The cod fishery in the Barents Sea and the toothfish fishery in the Southern Ocean, which shifted from a relatively unsustainable into a relatively sustainable stable state.

The second step in process tracing consists of the conceptualization of the causal factors that produce overfishing. As proximate causal factors we identify overcapacity and non-compliance (Beddington et al. 2007). The remote causal factors, which are much more broad, have been categorized conventionally according to three social domains – civil society, economy, and the state – together with the ecological domain (see Table 2). According to Goldstone, process tracing entails: "*the difficult cognitive feat of figuring out which aspects of the initial conditions observed, in conjunction with which simple principles of the many that may be at work, would have combined to generate the observed sequence of events"* (Goldstone 1991, p. 50). In this case, the 'initial conditions' have been identified as sustainable and unsustainable fisheries, while the 'simple principles' (or causal factors) that may be at work have been conceptualised as combinations of proximate and remote causal factors. This leaves open the third and last step in a process tracing analysis to which we will now turn: the 'observed sequence of events' in our four cases.

From sustainable to unsustainable fishery

The abalone fishery in South Africa

The closure of the South-African abalone fisheries on 1 February 2008 is spectacular considering that the fishing of abalone used to be sustainable from the 1950s until the end of the 1980s with relatively low numbers of illegal fishing. In a matter of years it transformed into a fishery involving organized crime syndicates that created an 'abalone crisis' and, subsequently, the closure of the fishery.

Like most other case studies discussed in this paper, the South-African abalone fishery was originally characterized by open-access. Raemaekers et al. (2011) mention that when commercial abalone fishing began in 1949 the only management restrictions were size limits. Commercial abalone fishing is mainly carried out along the Western Cape with 4–6 divers working from small row boats or twin-engine ski boats. Subsistence abalone fishing dominated the Eastern Cape and existed as a shore-based fishing activity. Skin divers collected shells from the shore to complement other livelihood activities. As a result of the expansion of commercial fishing, commercial landings of abalone rose to 2800 tons in 1965, but afterwards quickly decreased. This decline in landings led to the initiation in 1969 of quota management in the form of a Total

Table 2 Proximate and remote causal factors producing the obduracy of overfishing

	Proximate causal factors	Remote causal factors
Overfishing regime	Overcapacity; Non-compliance	The Ecology; The Economy; The Civil Society; The State.

Allowable Catch (TAC) to restrict the exploitation of abalone. These measures were followed by the introduction of fishing licenses, closed seasons, and a reduction of the limits for bag sizes. The poaching of abalone began with the introduction of these management restrictions, but it never grew large enough to seriously threaten abalone with commercial extinction (Steinberg 2005). These measures, together with favorable natural conditions, stabilized the abalone yields between 600 and 700 tons until the 1990s (Raemaekers et al. 2011).

The end of Apartheid in 1994 influenced the transformation of the abalone fishery in a number of ways. First of all, it lifted the international trade embargo which greatly improved the possibilities to sell abalone on global markets, in particular on the Asian markets. Prices for abalone increased tremendously from USD 10 to USD 32 per kg whole mass in the early 1990s. At the same time the South African Rand devaluated, which produced a 12-fold increase in the monetary value of abalone (measured in Rand) (Steinberg 2005; Raemaekers et al. 2011). The conjuncture of the increase in the international abalone prices with the radical trade policy change quite suddenly opened up a profitable global market for South African abalone.

Second, the new political regime raised the expectations of coastal communities that were previously not able to engage in commercial abalone fishing due to Apartheid policies (van Sittert et al., 2006). With the new regime and the high abalone prices, subsistence fishers were expecting formal access and user rights to harvest this valuable marine resource. The government tried to meet these expectations through several reforms of fisheries policies between 1998 and 2003. Initially these reforms only involved a reallocation of fishing rights within the existing commercial abalone fishery. As mentioned, this fishery was predominantly based at the Western Cape and was run by five white-owned companies. The needs and demands of the subsistence sector were not recognized, and the reform initially granted formal user rights to only 10% of the TAC to subsistence fishers (van Sittert et al., 2006). Moreover, as Raemaekers et al. (2011) mention, the reallocation process was long, cumbersome and lacked stakeholder consultation. Moreover, and not surprisingly, stakeholders were suspicious that the whole reform process was corrupt and only benefitted elites (Hauck, 2009). As a result, different groups of subsistence fishers that had not received the formal rights that they felt entitled to became engaged in illegal fishery (Hauck, 2009).

Third, the large profits that could be made with the abalone fishery attracted Chinese crime syndicates that had already established extensive South-African networks, trading shark fins, drugs and people (Steinberg 2005). Taken together, these factors – democratization, high prices, a failed fisheries policy reform, and the presence of organized crime – helped to create a major illegal fishery for abalone in the 1990s and 2000s (Raemaekers et al. 2011). The illegally caught abalone was sold on a growing black market, mostly in Asia (Hauck and Sweijd, 1999).

Alongside these social changes, the marine ecosystem also began to change. Stock assessments from 1988 until 1993 discovered that West Coast rock lobster (*Jasus lalandii, Palinuridae*) moved southwards and increased predation on juvenile abalone (Tarr et al., 1996). The lobsters also preyed on urchin beds and, in so doing, destroyed sheltering possibilities for the abalone. The lobster migration hampered the abalone recruitment and consequently contributed to the stock decline (Blamey et al., 2010; Day and Branch, 2002).

In response to the growth of abalone poaching, the South African government began a number of interventions in the early 2000s that used both coercion and market-based incentives to sustain the abalone fishery (for more details, see Hauck, 2009; Raemaekers et al. 2011). Despite these efforts, Raemaekers et al. (2011) conclude in their review that poaching continued unabated. First of all, there was a lack of communication and consultation with stakeholders from the coastal communities, which created a lot of misunderstanding, confusion and suspicion and delegitimized policies in the eyes of fishers. Second, there were instances of corruption where crime syndicates bribed government officials. Third, the large investments in enforcement lacked continuity and funding. Finally, the abalone poachers adapted. Snorkeling from the shore performed by individual divers was replaced with organized offshore scuba diving from motorboats, and the poachers also moved to new coastal areas or poached at night. The technology that allowed these adaptations, including the evasion of law enforcement, were high-speed vessels, cell phones and GPS equipment (Raemaekers et al. 2011).

The failure to stop poaching meant that South African fisheries management lost much of its legitimacy. Fishers with legal rights to catch abalone were increasingly facing restrictions and therefore diminishing profitability, while illegal fishery continued unabatedly. Legal fishers thus felt that they bore the costs of stricter rules, while illegal fishers gained greater profits because the rules were not enforced and the poachers faced less competition from the legal fishery. Legal fishers had an incentive to allow poaching to continue since the illegal abalone that was seized was sold, and contributed to the annual government budget. Moreover, commercial abalone fishers found that the fisheries reform had negatively influenced their profitability. Granting more fishing rights only meant that they had to share a diminishing annual TAC. For these reasons legal right holders (both commercial and subsistence fishers) also engaged in the illegal abalone fishery (Raemaekers et al. 2011). Hauck (2009) therefore concludes that the government intervention in the South African abalone fishery alienated legal fishers and thereby indirectly and unintentionally contributed to the prevalence of poaching.

New England groundfish fishery

The New England groundfish fishery was not always considered a disaster (see Introduction). In 1976, when the US congress passed the Fisheries Conservation and Management Act (FCMA), the future looked much brighter than today. With this Act in hand, the Federal Government claimed ownership of a 3–200 mile zone around its coast. Until then the Gulf of Maine (GOM) was under open-access. It was used by US and Canadian fishers, but also European and Soviet fishers (Bubier and Rieser 1986; Österblom and Folke 2015). The foreign fleet increased overall fishing pressure tremendously since North-American fleets also intensified, as they were afraid to lose out in the competition with the foreigners. To survey the effects of fishing, the US government began bottom trawl surveys, which quickly revealed the precarious situation of most of the GOM stocks (Layzer 2006). The foreign fleet activities, together with the rapid decline in fish stocks and the wholesale impotency of transnational agreements made in the International Commission for the Northwest Atlantic Fisheries (ICNAF), increased the urgency to act.

With the FCMA in place the US could now ban foreign fleets from fishing in their Exclusive Economic Zone (EEZ). Part of the FCMA was the creation of the

New England Fisheries Management Council (NEFMC), a regional council consisting of representatives of the National Marine Fisheries Service (NMFS); the heads of the state fisheries agencies; and representatives from the fishing sector. The NEFMC was ordered to draft so-called Fishery Management Plans (FMP). The motives and hopes related to the instalment of the FCMA and the NEFMC were internally contradictive. People from the government and fishing sectors saw the exclusive US. jurisdiction over the offshore fishing grounds as a possibility to keep foreign fishing out and to vitalize the domestic fleet. The US government granted this wish with the provision of several subsidies and loans (Hennessey and Healey 2000. Marine scientists, environmentalists and civil servants hoped that the new management structure would regulate fisheries and protect stocks (Hennessey and Healey 2000; Layzer 2006). The combination of these two contradictory messages – modernization and expansion of the fisheries while, at the same time, introducing limitations – created a *"rush for permits"* (Apollonio and Dykstra 2008, p. 31): 1,200 fishing licenses were issued in 1977, while in 1979 the number increased to 2,191— a growth of 83% (Acheson 1984).

The first FMP was created by the NMFS and became notorious for the introduction of catch quotas for each species of groundfish (Acheson 2011). These quotas were fished up rapidly and the boats were forced to stay at home by the middle of the year, which infuriated the fishers. According to their view the fishing pressure in the GOM substantially decreased with the exclusion of the foreign fleets, which accorded with the unexpectedly high landings that many experienced (Bubier and Rieser 1986). The fishers questioned the accuracy of the data that was used to set the quotas. The ensuing discussions and accusations between the fishers and the NMFS created suspicion and mistrust that has never really been resolved since then (Hennessey and Healey 2000, p. 196). The fishers saw the NMFS as *"incompetent bureaucrats backed by unreliable science threaten*[ing] *their livelihoods"* (Layzer 2006, p. 67).

It was this context and atmosphere that made non-compliance a structural feature of the New England groundfish fishery. King and Sutinen (2010) estimated that 12-24% of its catch is illegal. Types of non-compliant behaviour include: misrepresenting catches, smuggling, misrepresenting gear use, excessive discards, not following mesh size, area or seasonal limitations (Bubier and Rieser 1986; Hennessey and Healey 2000; Brewer 2011). Weak enforcement made non-compliance a persistent structural feature of the New England groundfish fishery (Acheson 1984; Sutinen et al. 1990), which in turn led to much more widespread rule breaking. Fishers who under normal conditions would be inclined to abide by the law also began breaking rules, since *"fishers who obeyed the law caught fewer fish, suffered economic hardship, lost prestige in the eyes of other fishers, and lost their credibility as effective captains* (Miller and Pollnac 1978 cited in Hennessey and Healey 2000, p. 196). Another important effect of pervasive non-compliance was that it frustrated the efforts of the NMFS to acquire reliable stock assessments (Bubier and Rieser 1986).

To resolve this situation the NEMFC, which was dominated by the fishery sector, introduced in 1982 a new Atlantic Demersal Fishery Plan (ADFP) with the backup of New England's members of Congress (Hennessey and Healey 2000; Layzer 2006). These delegates supported the NEFMC after which the NMFS backed down and grudgingly accepted NEFMC's plan. The ADFP excluded quota management and only

featured regulations that the fishing sector would accept (mesh size limitations, closed areas and seasonal limits). The council also explicitly assumed that stock conditions were in much better shape than what the scientific assessments showed (Hennessey and Healey 2000, p. 198). The chairman of the council during those years declared: *"Things are not as bad as they seem. Some years will be lean, some will be fat, but overall you will never really destroy the resource.* […]. *You could close the fishery on Georges Bank. In four or five years, you might have all the codfish anybody could want. In the meantime, you put an enormous number of people out of business"*. (quoted in Layzer 2006, p. 69–70)

Another major event in the recent history of New England's groundfish fishery was the decision in 1984 of the International Court to demarcate a new international border in the GOM between the US and Canada. The New England fishers now became excluded from the Grand Banks, the Gulf of Saint Lawrence, Labrador, and parts of the GOM. The effect of this decision was that more and more fishers were crowding the inshore waters of the GOM. Total catches plummeted between 1982 and 1988 with 30% to 50%, and the spawning stock declined so much that scientists in 1994 believed it had *"collapsed"* (Acheson and Gardner 2011, p. 1010).

Revisions of the FCMA in 1989 and 1996 legally obliged the councils to have the condition of the stocks improved as quickly as possible. In New England the Conservation Law Foundation (CLF) seized on this opportunity to file suit in 1991 and 2003 against the NEFMC for failing to prevent the overfishing of cod, haddock (*Melanogrammus aeglefinus, Gadidae*) and yellowtail flounder (*Pleuronectes ferruginea, Pleuronectidae*) in the GOM (Hennessey and Healey 2000; Layzer, 2006). This policy change and the deteriorating stock conditions, together with the risk of being sued by environmentalist NGO's, pressured the council to impose further limitations during the 1990s. The fishing sector vehemently opposed these restrictions during the 1990s (Snyder 2006); each new restriction was fought over (Acheson and Gardner 2011). The council did not give in to these protests but continued to suggest stricter limitations. It realized that not responding or responding slowly to new scientific stock assessments could mean losing management authority and having the federal government stepping in. Or, in the words of Phil Coates, chairman of the council's groundfish committee: *"If we don't take action in a timely manner, this matter is going to be taken out of our hands, and others will take it for us"* (Layzer 2006, p. 73). The management of New England's groundfish fishery thus became stricter, especially during the 1990s. Policymakers tried to soften the effects of these changes for fishing families with the help of Federal assistance programs, e.g. loan restructuring, community planning grants, job counseling, restraining grants for individual fishers and buy-outs (Hennessey and Healey 2000). The most recent form of aid came from the granting of a disaster status in September 2012 by the US Department of Commerce.

From unsustainable to sustainable fishery

Toothfish fishery in the Southern Ocean

Toothfish fishery currently represents the most profitable fisheries in the Southern Ocean. These fisheries, developed primarily around the sub-Antarctic Islands but increasingly conducted closer to the Antarctic ice edge, followed after the near eradication of marine mammals and the depletion of a number of finfish stocks in the region. A large-scale Illegal, Unreported, and Unregulated (IUU) fishery for toothfish developed

in the 1990s, during a time when licensed fisheries were also developing. The illegal and unregulated fishery threatened to result in the collapse of these newly discovered and commercially valuable fish stocks, and endangered seabirds that got trapped in fishing gear. A number of unique management measures and combined efforts from governments, the fishing industry and environmental NGOs, led however to a substantial reduction of non-compliance and improved prospects for sustainable management.

Historical overexploitation of Antarctic fur seals (*Arctocephalus gazelle, Otariidae*) and whales led to a dramatic reduction of marine mammals in the Southern Ocean during the 18th and 19th century (Ainley and Blight 2008). This development is thought to have contributed to an increase in Antarctic krill (*Euphausia superba*, *Euphausiidae*), a main prey for many marine mammals in the region. Fishing for Marbled rockcod (*Notothenia rosii, Nototheniidae*) and Mackerel icefish (*Champsocephalus gunnari, Channichthyidae*) began in the late 1960s and 1970s, but these stocks were rapidly overexploited (Kock 2001, Ainley and Blight 2008). During the 1980s, fishing operators therefore started to target Antarctic krill. As a source of marine protein, Krill is critical for the Antarctic food web and recovery of depleted mammal populations (Croxall and Nicol 2004). The threat of a rapidly increasing krill fishery in the Southern Ocean in the 1980s contributed to the establishment of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), also often termed 'the krill commission'.

The establishment of CCAMLR in 1983 led to the closures of many fisheries that had previously been overexploited (Ainley and Blight 2008). A few years later Soviet vessels, which had been developing several Antarctic fisheries, including exploratory fisheries for toothfish, ceased their activities when the Soviet Union collapsed. Instead, Chilean and Argentinean vessels started to fish for toothfish, most notably around the UK controlled sub-Antarctic islands of South Georgia, in the early 1990s. The UK government invested substantially in monitoring and enforcement, in part as a consequence of political sensitivities between Argentina and the UK related to the Falkland Islands (Islas Malvinas). In the mid-1990s, IUU fishing, moved eastwards, spreading to South African, French and Australian territories, thereby representing an international crisis and a critical issue for CCAMLR to address. In 1997, the scientific committee of CCAMLR concluded that non-compliance in the toothfish fisheries was leading to the "likely collapse" of fish stocks and seabirds, but CCAMLR had limited ability to develop effective policy measures. NGO reports, developed in unconventional collaborations between fishery officials and the licensed fishing industry, contributed substantially to an initial reduction of non-compliance (Österblom and Sumaila 2011, Österblom and Folke 2013).

After some time with a relatively compliant fishery, IUU fishery exploitation returned and increased during the early 2000s. Now, illegal fishing operators were well organized, with new purpose-built vessels, and coordinated fleets operated by a "hard core" of professional, non-compliant actors (Agnew 2000, Österblom et al. 2010). Their operations included refueling vessels, coordination of fleet movements, espionage on the Australian coastguard and bribery of ports inspectors. The future catches of the licensed fishing industry were substantially threatened by the increase in IUU, leading legal fishers to begin investing in the collection and dissemination of information on IUU fishing (Österblom and Sumaila 2011). The legal industry invested in private

investigations, rewarding schemes for industry informants, public outreach campaigns and political lobbying to raise public and political awareness. The Coalition of Legal Toothfish Operators (COLTO) was established and gained observer status in CCAMLR in 2003, where they managed to contribute to the growing political pressure to reduce IUU fishing (Österblom and Sumaila 2011).

Subsequent and substantial government investments in offshore monitoring capacity (surveillance vessels, aircrafts and satellite surveillance), combined with convictions of illegal fishers, an increase in compliance mechanisms (black-listing of IUU vessels, an electronic catch documentation scheme to ensure traceability of products, and vessel monitoring systems), and improved collaboration and information sharing, has provided substantial deterrents for non-compliance in the Southern Ocean (Österblom and Bodin 2012). A limited number of illegal vessels are still observed operating in the region, but there are indications that many vessels have now moved elsewhere. The reduction of non-compliance in the Southern Ocean is substantially improving the prospects for recovering fish stocks and seabird populations in the region (Österblom and Folke 2013).

Barents sea cod fishing

The Barents Sea is one of the most productive marine ecosystems in the world, where cod, Atlantic herring (*Clupea harengus, Clupeidae*) and capelin (*Mallotus villosus, Osmeridae*) constitute the main commercial species. Large, economically valuable spawning cod concentrate in Norwegian waters, whereas smaller juvenile (and less valuable) cod are more abundant in Russian waters. The stock has been jointly managed by Norway and Russia (the former Soviet Union) since 1977 and despite challenges from non-compliance in the 2000s, has a biomass that is currently well within the boundaries of sustainability.

Stocks of right whales (*Eubalaena glacialis*, *Balaenidae*) walrus (*Odobenus rosmarus, Odobenidae*) and sperm whales (*Physeter macrocephalus, Physeteridae*) were depleted in the Barents Sea during the 1800s, and were followed by exploitation of common minke whales (*Balaenoptera acutorostrata, Balaenopteridae*) (Nakken 1998). Although cod fisheries had been conducted for hundreds of years, it only developed as a major commercial activity with the development of trawl fisheries in the early 1900s (Eide et al. 2013). The cod stock was at a historical high after the Second World War (Dankel et al. 2008), but generally decreased until the mid-1970s (Bjørndal and Lindroos 2012). Norwegian herring stocks instead became the main target species during the 1950s and 60s, but they collapsed in the 1960s following the start of purse seine fisheries (which used synthetic nets, combined with acoustic instruments and net handling machinery). Depletion of herring stocks increased purse seiner exploitation of capelin, with subsequent stock collapses in the 1970s. Capelin is the most important prey for cod, and this capelin collapse generated poor conditions for cod in the 1970s (Dankel et al. 2008).

The Joint Soviet-Norwegian Fisheries Commission was established in 1975. Both parties had a strong interest to maintain cooperation in this politically sensitive region across the iron curtain (Eide et al. 2013) and the agreement was mutually beneficial. Soviet state owned companies were not as concerned about profitability - they did not benefit from world market prices as all catches were landed in the Soviet Union

for the domestic market. The Communist system prioritized maximum food production, i.e., volume in production rather than profits, resulting in a focus on quantity rather than value (Eide et al. 2013). The Norwegian market based economy, in turn, was driven by profitability concerns.

The fall of the Soviet Union in 1991 and the emergence of a Russian market economy changed the conditions for cooperation. Russian, private owned companies now operated under similar incentives for profitability as their Norwegian counterparts. However, the Russian market (unable to pay world market prices for cod) was not attractive to the new privately owned Russian companies. Instead, Russian vessels started to increase their activities in Norwegian waters where fish were larger and more valuable (Eide et al. 2013). Landings of Russian catches in Norway, where the prices for cod were higher, became permitted in the early 1990s (Eide et al. 2013) and Russian vessel owners also maintained and repaired their vessels in Norway, resulting in the closure of Russian onshore fish processing plants, decreasing overall fishing activities in the Murmansk region and a perception of a crisis in Russian northern fisheries (Ivanova 2005). The collapse of the Soviet Union also resulted in a rapidly increasing overcapacity in Russian waters, as the distant water fleet concentrated here (Ivanova 2005). The collapse also resulted in a termination of state subsidies covering expenses for fuel, maintenance and other support activities – changes which resulted a dramatic fall in Russian revenues (Ivanova 2005). Official estimates suggest this resulted in substantial non-compliance during 1990–1994 (Eide et al. 2013). However, no illegally caught cod was officially reported during 1995–1999 (Eide et al. 2013) and interviewed Russian fishermen described Norwegian coast guard inspections as an important deterrent for non-compliance at the time (Hønneland 2000).

In the early 2000s, Russian President Putin introduced a political reform which centralized Russian decision-making (Ivanova 2005). The Russian government introduced a new framework for quota allocation, where quotas were auctioned to the highest bidder. The auction system, only in effect between 2001 and 2003, has been described as "*one of the most crucial decision-making failures of the federal fisheries administration*" (Ivanova 2005, p.52). The auction system, intended as a cost-recovery scheme, resulted in many companies going bankrupt and leading to increased non-compliance (Ivanova 2005, Eide et al. 2013). The high value of quotas resulted in the attraction of foreign investors, criminal elements, corruption and bribery (Ivanova 2005). Official estimates between 2000 and 2006 indicate substantial illegal catches from both Norwegian and Russian vessels. The direct mechanisms for high levels of Norwegian non-compliance are less clear, but may have been associated with Norwegian overcapacity (Standal 2008) combined with decreasing economic activities in northern Norwegian fisheries (Perry et al. 2011). Other sources suggest substantially higher levels of Russian non-compliance (Burnett et al. 2008).

Non-compliance during the first decade of this century was however gradually eliminated through Russian and Norwegian cooperation. Measures taken include a ban on transshipment to vessels flying flags of convenience, prior notification of landing requirements and seafood industry cooperation. Norway has also entered into a number of bilateral agreements to ensure port control of cod landings in EU countries, the Faroe Islands, Russia, Canada, Greenland and Morocco (Burnett et al. 2008). These initiatives together have contributed to a recent decrease in non-compliance

(Burnett et al. 2008). This time period also saw changes leading to a consolidation and diversification of the Norwegian fishing industry, with e.g., the introduction of market mechanisms (Perry et al. 2011). As a consequence of reduced non-compliance and improved environmental conditions, the current (measured in 2012) biomass of Barents Sea cod is higher than ever before, the stock is above existing reference point limits, the fishing mortality is below the threshold level and many fishing activities are certified by the Marine Stewardship Council (Fishsource 2013).

Discussion: social-ecological feedbacks generate complex interactions

First we will explain the obduracy of overfishing for our two typical cases: the groundfish fishery in New England and the South African abalone fishery. Using the two-level causal model introduced earlier, we highlight how proximate and remote factors interact to create distinct causal pathways that lead to overfishing. After this exercise we will contrast these findings with the two atypical cases – the toothfish fishery in the Southern Ocean, and the cod fishery in the Barents Sea – to see why overfishing in these cases was less obdurate, and why people succeeded in shifting fisheries onto a causal trajectory towards sustainable management (Hilborn 2007).

Comparing overfishing in South Africa and New England for the proximate factors quickly reinforces earlier research that singles out both the existence of overcapacity and non-compliance as necessary causes. Overcapacity can be observed in South Africa when in the beginning of the 1990s the fishers' population was growing extensively, especially through the growth in the (legal and illegal) subsistence fishery and the involvement of crime syndicates in abalone fishery. In New England overcapacity comes into existence at the end of 1970s through a combination of technological progress, ambiguous fisheries policies, and juridical control over the Gulf of Maine. Non-compliant behavior is also instrumental in causing overfishing both in South Africa as well as New England. In the former, non-compliant behavior is observed for the large group of subsistence fishers and the smaller group of professional illegal abalone fishers who were connected to international networks of crime. Studies of fishing in New England show that illegality after the 1970s spreads beyond a small group of hardcore violators to groups of fishers that under normal circumstances would comply with regulation (King and Sutinen 2010). The cases clearly show that these two factors, overcapacity and non-compliance, are individually necessary and jointly sufficient to cause overfishing. We expect that this conjuncture of necessary, proximate factors is probably sufficient to also explain overfishing in other parts of the world.

We now turn to an analysis of the remote factors to explain why these two proximate factors have become structurally persistent, or obdurate, in both cases. With process tracing we were able to identify the following remote factors that were causally related with overcapacity: (1) *higher prices*; (2) *technological progress*; (3) *subsidies*; and (4) *reduced fish abundance*. With respect to non-compliance, we identified five remote factors: (1) *reduced fish abundance*, here again, because it leads to an illegal race for fish; (2) *feelings of relative deprivation*; (3) *low legitimacy*; (4) *low control and enforcement*. The relationship between these remote factors and the proximate factors is characterized by *equifinality*, i.e. the remote factors are individually sufficient, but not necessary, for the existence of either overcapacity or non-compliance. More concretely, this means that specific

combinations of remote factors highlighted here produce overcapacity and non-compliance in the two cases.

To explain the obduracy of overfishing in South Africa and New England we need to take a closer look at the different causal relations that exist between the remote and proximate factors that we have identified (see Figure 1). In some cases these causal relations exist with positive feedbacks, which means that overfishing becomes self-reinforcing (Österblom et al. 2011), possibly explaining why it is often so difficult to halt overfishing. From our analysis we are able to highlight two of these positive feedbacks:

Reduced fish abundance-overcapacity-overfishing feedback – Diminishing catches means that there comes to exist a surplus of fishing capacity. The existence of overcapacity creates an incentive to increase fishing effort because fishers will try to get a return from their investments. This mechanism has alternatively been called 'Ludwig's ratchet' (Pitcher 2000) or 'sunk-cost effect' (Janssen and Scheffer 2004). In combination with non-compliant behavior it leads to overfishing, which leads to reduced stocks.

Low legitimacy-non-compliance-overfishing feedback – Due to low legitimacy of fishery policy, fishers do not consider regulation morally binding and fish illegally. Non-compliant behavior, together with overcapacity, leads to overfishing. Overfishing leads to the perception that government regulation is failing, which erodes its legitimacy even further.

What are the implications of this analysis for fisheries management; what intervention possibilities exist that can make overfishing less obdurate? A closer look at the two atypical cases – the toothfish fishery in the Southern Ocean and the cod fishery in the Barents Sea is instructive here. These two relatively sustainable regimes also went through periods when they were relatively unsustainable as a consequence of a combination of overcapacity and non-compliance. During the early 1990s and 2000s there was a 'gold rush' movement of fisheries to the Southern Ocean, while the early 2000s showed a peak in illegal catches in the Barents Sea. These periods of overfishing were

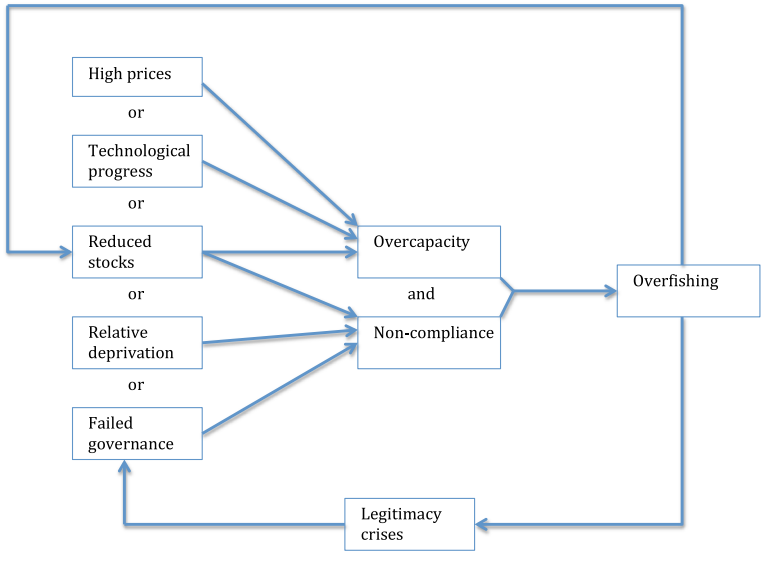

Figure 1 A two-level model of overfishing. The arrows indicate causal relations.

caused by combinations of increasing prices for fish stocks and the inflow of fishing capacity from elsewhere, which resulted in an overshoot of fishing capacity together with policies that created incentives for non-compliant behavior. Nevertheless, overfishing was reduced over time: how did this shift come about?

First of all, both cases are located in politically sensitive regions, which means they have a history of transnational governmental interaction. In the Barents Sea, the Norwegian government and the former Soviet Union had already established a working relationship. Similarly, the countries owning parts of the Southern Ocean had already organized a transnational governmental organization for management: CCAMLR. In both cases this multi-government deliberation created levels of trust that enabled governments to jointly monitor and control fishing effort. Moreover, considerable human and technical capacity for surveillance existed to address non-compliance, as these countries put large emphasis on border protection security in these politically sensitive regions.

A crucial factor in both cases was that multi-government intervention to ban illegal fishing was discussed and aligned with efforts from the fishing industry and environmental NGOs. Second, governments were able to reduce illegal fishing due to characteristics of the toothfish and the cod fisheries. The fishery in the Southern Ocean is performed by a relatively small group of companies, which means that the conditions for control and enforcement are easier (Raakjær Nielsen 2003). In the Barents Sea enforcement could be improved because there were only a limited number of sites where the fish could be landed. Third, in both cases, relative feelings of deprivation did not play any significant role, perhaps because there were no major social inequalities that fishers perceived and felt disadvantaged by. Lastly, we need to mention serendipitous changes, such as when climate dynamics in the Barents Sea contributed to the growth and stabilization of the cod stock.

In terms of our two-level model of overfishing it means that the successes in the Southern Ocean and the Barents Sea can be explained from how non-compliance was reduced. Overcapacity and non-compliance are individually necessary and jointly sufficient to cause overfishing, which means that non-existence of one of these two will lead to a reduction of overfishing. It implies that there are two major pathways for intervention: reducing overcapacity or improving compliance. Which one of these to focus on (or whether to use both) depends crucially on how these factors are embedded within more remote ecological, social, political, and economical contexts. Orchestrating major changes in some of these remote factors (e.g. global market economy) often lies beyond what conventional marine policy can do, which means that it is often more efficient to instead adapt policies in the light of these changes. Other studies have pointed out how political or ecological change can create windows of opportunity to deliberately break undesirable social-ecological feedbacks (Gelcich et al. 2010). Our analysis points out that being able to do so requires first an identification of leverage points in the causally complex processes that lead to overfishing.

Towards a convict shuffle

Why does overfishing continue to be a problem? In our search for an answer we showed how current analyses too strongly emphasize single-factor explanations suggesting that there are only primary causes to consider, such as profit maximization, or

non-compliant behavior. Analysis and comparison of two typical case studies of overfishing shows that overfishing becomes obdurate through complex temporal and cross-scale interactions between the combination of proximate factors – overcapacity and non-compliance – and a set of highly contextual remote social, economic, political and ecological factors. The specific dynamic interaction between these factors - the causal process - differs per case.

Does this make halting overfishing a hopeless cause? We do not think so. Applying the two-level model that we constructed from comparing our typical and atypical cases shows that overfishing is not necessarily a deterministic process. Our analysis suggests that the social-ecological feedbacks underpinning unsustainable or sustainable regimes can result in either vulnerabilities or opportunities for addressing the problem of overfishing. For fisheries management policies this means that there is little hope for a universal, one-size-fits-all approach to end overfishing. Any policy solution first needs to understand overfishing as a specific emergent outcome of social-ecological interactions and feedbacks. With this paper we provide a framework that can identify highly specific remote factors as well as more generally observed proximate factors that contribute to overfishing.

Although the identification of causal complexity is done retrospectively, we do believe that this knowledge can be used to stimulate thinking that can anticipate overfishing and related stock collapses. Outcomes of historical case study comparisons can be used to construct 'historical scenarios' (Staley 2010). These scenarios are based on the knowledge and insights from the comparative historical analysis of overfishing. The purpose of these scenario exercises is not to predict the future, but to show how human and environmental forces can interact and in so doing manipulate the future in different directions. Each scenario describes how these driving forces might plausibly behave in the future, based on how those forces have behaved in the past (Schwartz 1991). The scenarios can provide insights into how social context, governance, ecological dynamics, technological progress and human adaptability interact in unique ways with overuse as a possible outcome (see also Österblom et al. 2013). The historical scenarios can also stimulate creative thinking about the future, and increase possibilities for reflection and learning from history among stakeholders that are engaged in natural resource management.

In ending this paper we would like to return to the chain gang-metaphor we introduced earlier. Prisoners that form a chain gang have to adapt their walking to each other to avoid tripping. Such an adapted walk is called a 'convict shuffle'. A 'chain gang' also refers to a formation of cyclists, or skaters, who ride closely within each other's slipstream, and whereby the lead of the formation rotates frequently. The convict shuffle as well as the cycling formation are such closely integrated groups that no one would be able to avoid hitting or tripping into one another when pace or direction suddenly changes. We believe that much the same holds true for fisheries management that aims to halt overfishing. Just as for cycling or walking in a chain gang, it requires readiness to adapt to changes in overcapacity and non-compliance stemming from more remote ecological, social, economic and political causes. But, if we fail to account for and adapt to the causal complexity of overfishing, we'll remain chained as fools, and we already know from the song how that will end: *"One of these mornings the chain is gonna break. But up until the day, I'm gonna take all I can take"* (Aretha Franklin 1967).

Competing interests
The authors declare that they have no competing interests.

Authors' contribution
WB and HÖ performed the case studies, and WB drafted the manuscript. Both authors read and approved the final manuscript.

Acknowledgements
We would like to thank Jason D. Whittington and two reviewers of Maritime Studies for helpful comments on an earlier version of this paper. Wiebren Boonstra is financially supported by the FORMAS Project Grant (No. 2009-252) 'Regime Shifts in the Baltic Sea Ecosystem' and FORMAS Project Grant (No. 2013-1293) 'Working knowledge in Swedish coastal fishery - Making cultural capital visible for sustainable use of coastal sea- and landscapes'. Henrik Österblom received financial support from Stockholm University's strategic marine environmental research funds through the Baltic Ecosystem Adaptive Management Program. Mistra supported the research for this paper through a core grant to the Stockholm Resilience Centre. This paper is a deliverable of the Nordic Centre for Research on Marine Ecosystems and Resources under Climate Change (NorMER), which is funded by the Norden Top-level Research Initiative sub-programme 'Effect Studies and Adaptation to Climate Change' and also contributes to the Nereus Program funded by the Nippon Foundation.

Received: 7 February 2014 Accepted: 19 August 2014
Published online: 04 December 2014

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doi:10.1186/s40152-014-0015-4
Cite this article as: Boonstra and Österblom: **A chain of fools: or, why it is so hard to stop overfishing.** *Maritime Studies* 2014 **13**:15.