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Institutions for sustainable fisheries governance – the case of the commercial Peruvian anchovy fishery

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To Andrew, Bianca and Nicole

Institutions for Sustainable Fisheries Governance – the case of the commercial Peruvian anchovy fishery

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Arias Schreiber, M., and A. Halliday. 2013**.** Uncommon among the commons? Disentangling the sustainability of the Peruvian anchovy fishery. *Ecology and Society* 18(2): 12. http://dx.doi.org/10.5751/ES-05319-180212

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Abstract

Fisheries governance is about influencing multiple actors' decisions and behaviours relative to an ocean area and the resources contained therein. How these behaviours and decisions are influenced is a matter of institutions. This research uses the Peruvian anchovy fishery as a case study. Landings of Peruvian anchovy represent almost 10 % of the worlds total fishery landings. Following the well known collapse of the anchovy fishery at the start of the 1970s, landings have recovered and have been sustained over the last two decades at around six to nine million tonnes per year. Despite this evidence of sustainability, key institutional requirements that are nowadays strongly recommended to achieve sustainable fisheries are absent in this fishery. These 'missing' requirements for sustainability include for instance individual fishing quota shares, decentralized bottom-up management and eco-labelling. In order to explore the institutional setting of this sustainable fishery, this study adopts a broad institutional approach that considers a range of institutions, including those mentioned above and others that have rarely been considered by fisheries research.

The first article of this research looks at the role and evolution of formal fisheries institutions and their relation to sustainability. Results show that General Fisheries Acts in Peru were enacted independently of trends in anchovy landings. The three Peruvian Fisheries Acts were a reflection of broader national socio-political changes and were enacted mainly to define the role of the state and private investment and to delimit foreign involvement in the fishery industry. The base-level management to deal with landings was left to secondary legislation that evolved in response to different considerations including organizational functionality, the legitimacy of management agencies, advances in science and technological innovation. To guarantee stable landings, this secondary legislation operates adaptively, in response to environmental and ecological dynamics. The article concludes that general fisheries laws in Peru do not guarantee sustainable landings on their own. However they play an important role in access rights according to current local economic and political policies that function as an umbrella providing the appropriate environment for secondary legislation and other norms to evolve towards sustainability.

The second article deals with informal institutions and the connection between sustainability and adaptation to environmental variability and climate change. As shown in this article, the sustainability of the Peruvian fishery relies heavily on institutions developed to cope with environmental change. A set of eight adaptive strategies are described. These included: decentralized installation of anchovy processing factories; simultaneous ownership of fishing fleet and processing factories (vertical integration); use of low-cost unloading facilities; opportunistic utilization of invading fish populations; low cost intensive monitoring; rapid responses and flexible management; reduction of price uncertainty by restricting supply of anchovy products (fishmeal) to match market demand; and decoupling of fishmeal prices from those of other substitute commodities. These coping strategies provide an example of how the fisheries sector and central government can act positively to reduce undesirable impacts of environmental variability and change. This experience is relevant to other fisheries, and other resource regimes, that are already being affected by global environmental change.

The third article deals with fish as a common pool resource (CPR). This article considers the extent to which institutional characteristics of the Peruvian fishery conform to design principles which are considered prerequisites for long-term successful community-based CPR. This study finds that clearly defined resource boundaries, monitoring rule enforcement and conflict resolution mechanisms among users and management authorities supported the transition towards sustainability. On the other hand, clearly defined user boundaries, collective choice arrangements and nested enterprises were in this case not required to achieve sustainability. The article analyses the strengths and limitations of current and past institutional arrangements in the Peruvian anchovy fishery. It comments on the extent to which design principles developed in local CPR systems are transferable to a national scale.

This research gives an account of and explores the reasons behind recent efforts to prescribe standardized institutional arrangements to overcome fisheries overexploitation. However the results of this research highlight the fact that institutions develop in context specific directions and what is a solution in one fishery could have unexpected negative consequences in others. Furthermore, the findings suggest that, in general, fisheries sustainability cannot be achieved relying on one or two institutional changes. The sustainability of the Peruvian anchovy fishery is the result of a multi-faceted and continuing process of historical transformation. Taken together, these results also suggest that rather than concentrating in a particular set of mostly economic institutions, a broad institutional approach is a more appropriate attitude to understanding and managing the complexity of fisheries systems.

Zusammenfassung

Die Steuerung der Fischerei wirkt durch ihren Einfluss auf mehrere Akteure und deren Entscheidungen und Verhaltensweisen in Bezug auf einen Meeresraum und die darin enthaltenen Ressourcen. Wie diese Verhaltensweisen und Entscheidungen beeinflusst werden, ist eine Frage des institutionellen Vorgehens. Dieses Forschungprojekt nutzt die peruanische Sardellenfischerei zur „case study". Nach dem in der Wissenschaft häufig verwendeten Beispiels des Zusammenbruches der Sardellenfischerei zu Beginn der 70er Jahre haben sich die Anlandungen erholt und blieben in den letzten zwei Jahrzehnten nachhaltig bei etwa 6 Mio bis 9 Mio Tonnen pro Jahr. Die Anlandungen der peruanischen Sardellen repräsentieren ca. 10% der weltweiten Fischereianlandungen. Trotz dieser Hinweise auf Nachhaltigkeit wurden wichtige institutionelle Anforderungen, die heute für eine nachhaltige Fischerei dringend empfohlen werden, in der peruanischen Sardellenfischerei nicht angewandt. Zu diesen „fehlenden" Anforderungen gehören zum Beispiel individuelle Fangquoten, dezentrales Bottom-up-Management und ein Öko-Umweltsiegel. Um den institutionellen Hintergrund dieser sich als nachhaltig erweisenden Fischerei zu erfassen, untersucht diese Studie den Regelungsrahmen einer großen Anzahl betroffener Institutionen.

Der erste Artikel dieser Forschung beschäftigt sich mit der Rolle und Entwicklung der formellen Institutionen der Fischerei und ihrer Beziehung zur Nachhaltigkeit. Die Ergebnisse zeigen, dass Fischereigesetze in Peru unabhängig von Trends in der Sardellenanlandung verordnet wurden. Die bis heute erlassenen drei peruanischen Fischereigesetze sind ein Spiegelbild einer umfassenderen gesellschaftspolitischen Veränderung und wurden vor allem erlassen, um die Rolle des Staates und der privater Investoren zu definieren und ausländische Beteiligung an der Fischereiindustrie zu beschränken. Das Management im Umgang mit den Fischanlandungen wurde auf die untergesetzliche sekundäre Verwaltungsebene verschoben, die sich in Reaktion auf Veränderungen in den Bereichen Organisationsstruktur und Legitimität der Managementagenturen sowie Fortschritte in Wissenschaft und technologische Innovationen entwickelte. Um stabile Anlandungen zu garantieren, arbeitet diese sekundäre Gesetzgebung adaptiv, in Reaktion auf die Umwelt und ökologische Dynamik. Die Untersuchung zeigt, dass die allgemeinen Fischereigesetze der Fischerei in Peru allein keine nachhaltigen Anlandungen garantieren können. Dennoch spielen sie eine wichtige Rolle als übergeordnete Ebene und geben geeignete Rahmenbedingungen für die sekundäre Gesetzgebung und andere Normen in Richtung Nachhaltigkeit.

Der zweite Artikel beschäftigt sich mit informellen Institutionen und den Zusammenhang zwischen Nachhaltigkeit und die Anpassung an Umweltvariabilität und Klimawandel. In diesem Artikel wird aufgezeigt, dass sich die Nachhaltigkeit der peruanischen Fischerei stark auf Institutionen stützt, die durch verschiedenste Maßnahmen auf Veränderungen der Umwelt reagieren. Acht Anpassungsstrategien werden beschrieben. Dazu gehören: die dezentrale Installation von Fischmehlfabriken, gleichzeitiger Besitz von Fischereiflotte und Fischmehlfabrik (vertikale Integration), Verwendung von Low-Cost-Entladeeinrichtungen, opportunistische Nutzung von eindringenden Fischpopulationen, intensive Low-Cost-Überwachung, schnelle Reaktionen und Flexibilität der Verwaltung, Herabsetzung von ökonomischer Unsicherheit durch Einschränkung des Angebots von Sardellenprodukten (Fischmehl)

und die Entkopplung von Fischmehlpreisen von jenen anderer Fischmehlersatzrohstoffe. Diese „coping-strategies" sind ein Beispiel dafür, wie Fischerei und Zentralregierung positiv zusammen arbeiten können, um Nachhaltigkeit trotz Einwirkung von Umwelt- und Klimaveränderungen zu sichern. Diese Erfahrung ist relevant für andere Fischereien und andere Regime von Ressourcen, die bereits von globalen Umweltveränderungen betroffen sind.

Der dritte Artikel befasst sich mit Fisch als Common Pool Ressource (CPR). Dieser Artikel betrachtet das Ausmaß, in dem institutionelle Merkmale der peruanischen Fischerei den Grundsätzen, die als Voraussetzungen für eine langfristig erfolgreiche ‚community-based' CPR gelten, entsprechen. Diese Studie stellt fest, dass die Anwendung klar definierter Grenzen für die Nutzung von Ressourcen, intensiver Überwachung und der Durchsetzung der Mechanismen zur Konfliktlösung durch die Nutzer und die Verwaltung eine Entwicklung der Fischerei in Richtung Nachhaltigkeit unterstützt. Auf der anderen Seite sind klar definierte Nutzergrenzen, „collective choice" Arrangements und verschachtelte Unternehmen nicht erforderlich, um Nachhaltigkeit zu erzielen. Die Untersuchung analysiert die Stärken und Grenzen der aktuellen und vergangenen institutionellen Arrangements in der peruanischen Sardellenfischerei. Der Artikel untersucht, ob „design principles", die aus dem Studium der lokalen nachhaltigen CPR-Systeme entwickelt wurden, auf die nationale Ebene übertragen werden können.

Diese Forschung untersucht die Gründe hinter den aktuellen Bemühungen um einheitliche institutionelle Regelungen, mit dem Ziel die Übernutzung der Fischerei zu überwinden. Allerdings zeigen die Ergebnisse dieser Forschung, dass Institutionen im Bezugsrahmen zu entwickeln sind und dass die Lösung der Probleme für die eine Fischerei unerwartete negative Auswirkungen für eine andere haben könnte. Darüber hinaus legen die Ergebnisse nahe, dass im Allgemeinen in der Fischerei Nachhaltigkeit nicht unter Berufung auf ein oder zwei institutionelle Veränderungen zu erreichen sein wird. Die Nachhaltigkeit der peruanischen Sardellenfischerei ist das Ergebnis eines vielschichtigen und anhaltenden Prozesses von Transformationen. Zusammengenommen weisen die Ergebnisse darauf hin, dass die Komplexität von Fischereisystemen erst durch Forschung, die weit über die Untersuchung von wirtschaftlichen Institutionen hinaus geht und unter Einbeziehung aller beteiligten Institutionen zu verstehen und zu managen ist.

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1. Introduction

Natural resources provide essential goods and services to humankind, support the livelihoods of much of the world's population and have considerable cultural significance in different locations around the globe (Charles 2004). Moreover the unsustainable exploitation of natural resources is a major problem worldwide. Current rates of deforestation in the world's forests are at 13 million hectares per year (Chazdon 2008), almost 75% of the world's commercial fish stocks are currently being fished at, or above mean sustainable yields (FAO 2010), at least 25% of all mammals are threatened with extinction (Schipper et al. 2008) and the use of water resources worldwide has increased six-fold during the last century (Birol et al. 2006). Uncontrolled increases in natural resource extraction and consumption, probably as a result of current human population growth are threatening long-term ecological and human well-being. They thus pose a tremendous challenge that casts doubt on the ability of future generations to sustain their livelihoods and cultural heritages.

As mentioned by Dovers (2001), virtually every discussion of sustainable use of natural resources concludes that our current institutional setting is undeniably part of the problem and that substantial reforms are required. Sustainability involves more than science and education, technological innovation and flexibility to adapt to unexpected and changing conditions; it also demands new outlooks, new world views and new institutional arrangements (Dovers 2001, Symes 2006, Schlüter et al. 2009, Vatn 2009). Thus a critical question for transdisciplinary[1] research relies on which institutional arrangements are to be promoted and implemented (Dovers 2001).

The research presented here discusses the relation between sustainability and social institutions of one of the most important sources of food, income and livelihoods for the current human's population: fisheries. Globally, fish provides more than 1.5 billion people with almost 20 percent of their average per capita intake of animal protein, and three billion people with at least 15 percent of such protein (FAO 2010). As a source of livelihood, it is estimated that capture fisheries and aquaculture employed 44.9 million people in 2008 and 520 million people relied on income from seafood production in 2006 (Smith et al. 2012).

Despite the importance of fisheries for food security and global livelihoods, fisheries provide probably the most conspicuous example of the unsustainable exploitation of natural resources. Many of the world's fisheries are in a deplorable state (Beddington et al. 2007, Jackson 2010). Revealing that the unpleasant fisheries trend is not necessarily hot from the oven, fisheries collapses (defined as a 90% reduction of a wild fish stock) have been the reason for the declining global fish catches since the late 1980s (Pauly et al. 2003); and nearly one in four fisheries collapsed during the period 1950–2000 (Mullon et al. 2005). Furthermore, in contrast to the successes experienced by conservation efforts to maintain terrestrial biodiversity (Hoffmann et al. 2010), the number of fishery collapses has been stable over time since the 1950s showing no signs of improvement in the overall management of fisheries (Mullon et al. 2005) [2].

Fisheries collapses and the concomitant ecological, social and economic crisis are evidently a widespread problem, involving a variety of marine species, fisheries systems and geographical areas. Examples of fisheries collapses can be found for small-scale fisheries like the Chilean abalone fishery in South America (Leiva and Castilla 2001) and in larger industrial-scale fisheries like the Atlantic cod fishery off Newfoundland and Labrador (Hutchings and Myers 1994, Roy 1996) and the cod and haddock fishery of the North Sea (Holden 1991). It seems that factors identified as contributing to the unsustainability of diverse fisheries have, in almost all cases, similar origins and causes, which differ only in the various scales and degrees of importance in which they are considered and displayed (Bodiguel et al. 2002).

There is some disagreement among fisheries scholars on how to confront the global fisheries crisis. Indeed, there is even disagreement on the current status of global fish stocks and general ocean health (Hilborn 2007a, Bromley 2008). As explained by Bromley (2008), on one side, a group of mostly marine ecologist led by Daniel Pauly and more recently Boris Worm; continually report on the poor status and distressing future of the world's oceans and their ecosystem services. D. Pauly and his colleagues speculated provocatively that with continued trends of overfishing, only jellyfish and plankton would remain to be harvested in a near future (Stokstad 2009). B. Worm and co-authors predicted the global collapse of all taxa currently fished by the year 2048 (Worm et al. 2006). This article was apparently the last straw that broke the camel's back. After Worm's article, various scholars started to call for a more accurate and rigorous analysis of the condition of world's fisheries (Hilborn 2007a). These scholars were mainly fisheries biologists (Bromley 2008), who claimed that the alarmists were careless and misguided (Hilborn 2007a). Worm's article was so heavily condemned that he wrote a revised version of his study, in cooperation with his disagreeing colleagues (Stokstad 2009, Worm et al. 2009). More recently, Pauly's article on decreasing mean trophic levels has also been reported to present methodological problems (Branch et al. 2010).

In order to analyse the world's ocean crisis, ecologists pay more attention to the status and conditions of marine ecosystems where fisheries play an important role whereas fisheries biologists concentrate in the status of exploited fish stocks and actively support data gathering and modelling (Bromley 2008). According to this author, despite their mutual distrust, in the intense debate between ecologists and fisheries biologists, the two groups seem to have at least one thing in common. Neither view disputes the responsibility of flawed management and governance for the current and foreseen worrying situation. As stated by Bromley both sides attribute the problem to "a lack of political will to make the difficult decisions concerning the extraction of biomass from the oceans" (Bromley 2008: 8). This difficult decision requires social coordination or governance (Kemp et al. 2005) and can only be carried through by *governing* the oceans, understood to mean "the purposeful effort to steer, control or manage (sectors or facets) of society"(Kooiman 1993:2). It is also about guiding and promoting behaviour, public and private, individual and collective, relative to an ocean area and the resources and activities contained therein (Cicin-Sain and Knecht 1998). How this behaviour is influenced is a matter of institutions.

Thus fisheries collapses have recently been often attributed to *institutional failure* or the persistence of inappropriate institutional arrangements (Bodiguel et al. 2002, Hilborn et al. 2005, Hilborn 2007b, Loucks 2007, Spagnolo and Sabatella 2007, 2010). Under this premise, those fishermen who overexploit and deplete fish stocks are simply responding rationally to the "institutions" or "rules of the game" presented to them (De Alessi 2008). One of the most common inappropriate economic institutional settings leading to unsustainable fisheries identified until now, is the problem of weak or absence of property rights (Beddington et al. 2007, Grafton et al. 2007, Costello et al. 2008, Griffith 2008, Bromley 2009, Ostrom 2009a). As stated by De Alessi "property rights define who has the right to do what with a resource, including whether to exploit, conserve or deplete it" (De Alessi 2008:4). In the case of fisheries, established rules on who can access the fish at sea are commonly missing and almost everyone has the right to go out to sea, go fishing and make a profit from it. Fisheries exploitation is thus usually open access (FAO 1998, Arnason et al. 2009). In these situations Hannesson (2004:1) writes "fish accessible to anyone will be captured as quickly as possible by those who first discover them, for otherwise they will be taken by somebody else". As a result, Hanneson explains, something that seems rational for each individual fisher (to take the largest amount of fish at the shortest time possible) could turn into a frantic battle for the resource, with critical consequences to the fishermen and to the ecosystem providing the fish (Hannesson 2004). This author continues arguing that when fishermen fish as fast as they can, big and small fish are caught at the same time. This mainly leads to two problems: First, juveniles who have never spawned are caught, reducing the ability of the fish stock to repopulate. Second, since fish grow and generally gain weight with age, if fishermen could wait rather than race for the fish, it would be more effective for them to capture a few older and bigger fish than many small fish. But without being sure whether restricting their fishing in the future will bring larger benefits, no one has an incentive to leave anything behind (Hannesson 2008). In that sense, clearly defined property rights over fish stocks would appear to be one institution that is necessary for sustainability (Grafton et al. 2006, Anderson and Holliday 2007, Costello et al. 2008).

Related to the problem of property rights, the national jurisdiction over fishing stocks has been identified as playing an important role in fisheries sustainability (Morris 2008). The lack of institutional fit between a fish population and its management authority seems to have contributed to the collapse of the Canadian northern cod (Hannesson 2008) and to be the reason for the critical state of many highly migratory fish stocks like some tuna and tuna-like species and other small pelagics (Sullivan 1998, Munro et al. 2004, Allen et al. 2010). In this case, however, it has been argued that, while the full allocation of fish stocks to a national economic jurisdiction is a necessary condition for sustainability, it is not sufficient in itself (Hannesson 2008).

Co-management, or the participation of interested parties (stakeholders) in the management of the fishery (Jentoft et al. 1998, Wilson et al. 2003, Jentoft 2004), together with adaptive management (Hilborn and Sibert 1988, Mahon et al. 2008), have also been identified as further institutions promoting sustainable fisheries. Co-management entails the participation of stakeholders other than governmental managers in the process of management. It allows a more adequate definition of the situation and enables the coordination and development of more refined and robust management responses (Westley 1995, Ebbin 1998). Adaptive management responds to the fact that sustainable management systems are inevitably confronted to surprises and have to relate and adjust to a complex, non-linear and ever-changing environment (Sandström and Rova 2010).

The present research seeks to complement our understanding of the various social institutions governing a sustainable fishery in a developing country. The study takes a "broad institutional approach" (de la Torre-Castro and Lindström 2010). It analyses a range of institutions, including those mentioned above (property rights, national jurisdiction, co-and adaptive management), and some others that have rarely been considered by other institutional analyses of fisheries such us legal frameworks and coping strategies to deal with climatic events. The first article looks at the role and evolution of formal institutions and their relation to fisheries sustainability. Its main aim is to understand the purpose of fisheries law and to evaluate, how "rigid" institutions are able to co-exist with ever-changing adaptive management decisions and practices. The second article deals with informal institutions and with the connection between sustainability and adaptation to environmental variability and climate change. As shown here, the sustainability of the Peruvian fishery relies heavily on institutions developed to cope with environmental change. A set of eight adapting strategies are described, providing an example of how the fisheries sector and central government can act positively to reduce undesirable impacts of environmental change. This experience is relevant to other fisheries, and other resource regimes, that are already being affected by global environmental change. Expanding institutional analysis to address theoretical advances in the study of common property resources (CPR), the third article considers the extent to which institutional characteristics of the Peruvian fishery conform to design principles which are considered prerequisites for long-term successful community-based CPR (Ostrom 1990, Cox et al. 2010). The third article deals with fish as a common pool resource; where it is difficult to exclude users, and exploitation by one user reduces the resource availability for others (Ostrom 1990). The article analyses the strengths and limitations of current and past institutional arrangements in the Peruvian anchovy fishery, and considers how these experiences can inform understanding of institutional arrangements that encourage sustainability in the management of CPR.

1.1 Research rationale and limits of the research

Rationale

This research is about governance institutions of a sustainable commercial fishery: the Peruvian anchovy fishery (Mondoux et al. 2008, Arias Schreiber 2012). Governance, while sometimes defined as "what governments do" (Paavola and Adger 2005:354), has a broader meaning in recent social research which goes beyond the actions and decisions of government. Governance is defined as "the process of steering or guiding societies toward collective outcomes that are socially desirable and away from those that are socially undesirable" (King et al. 2008:xxi). Governance in this sense involves interaction between a wide range of actors, including private enterprises, civic organisations, communities, political parties, universities, the media, and the general public (Chuenpagdee and Jentoft 2009). In this case, the sustainability of the anchovy fishery is the socially desirable collective outcome steered by the process of governance; this process of governance includes interactions between, among others, private fishing companies and the Peruvian government.

Institution, is a contested concept, that in one of its earlier and wider definitions, dating back to the sixteenth century, is described as "an established law, custom, usage, practice, organization, or other element in the political or social life of a people" (Henningham 1995 cited by Connor and Dovers 2004:10). Institutions may be formal (laws) or informal (customary), local, national or global, political or economic (Dovers 2001, Adger 2003). In this regard, the present research deals with (1) the role of fisheries *law* and the achievement of sustainable landings in the anchovy fisheries; (2) the *practices* of fishing companies and the governmental management authorities aimed at maintaining fishery catches in the presence of environmental (biophysical) variability and extreme climatic events; and (3) a comparison between the "*elements* [in political and social life] or design principles" (Ostrom 1990:90) that govern sustainable management of fisheries at the community level and those elements that have contributed to the sustainability at a national level of the Peruvian commercial anchovy fishery. Along the present research, institutions are defined as:

> *An institution is a persistent, reasonably predictable arrangement, law, process, custom or organisation structuring aspects of the political, social, cultural or economic transactions and relationships in a society. Although by definition persistent, institutions constantly evolve* (Dovers 2001:5).

The motives for devoting a study to fisheries institutions in Peru are various. Above all, "when it comes to the sustainability of marine resources, institutions matter" (Morris 2008:1). Institutions are relevant when we consider the realm of human-nature interactions, where the laws of nature are fixed and predetermined, and any attempt to influence the outcomes of these interactions must be translated in the reform of rules governing human behaviour and social harmony. In the words of the Brundtland report:

> *The real world of interlocked economic and ecological systems will not change; the policies and institutions concerned must* (WCED 1987:9).

Bearing in mind their normative and cultural-cognitive aspects, institutions appear "as manifestations of values, influence agents' preferences, choices and actions as well as aggregate economic and environmental outcomes" (Paavola and Adger 2005:360). To explore the sustainability of the Peruvian anchovy fishery as an aggregate outcome of the choices and actions of the actors involved is one important motivation of the present research.

Although there is general agreement that institutional change is essential for the sustainable management of natural resources, there is no consensus on which institutions will provide the more appropriate and desirable results (Acheson 2006). The case of marine resources is not an exception. For instance, based on Vatn (2009), the problem of sustainable use of natural resources and institutions arises from the interdependencies of human behaviour and choice in a pervasive physical world that is all interconnected. "Interdependencies of human behaviour and choice" refers to the situation, specifically in relation to environmental issues, where any action performed by rational and selfish humans affects inevitably other human beings. According to Vatn (2009), humans affect other humans' lives, acting in accordance with institutions that arbitrarily separate the interconnected natural system and the responsibilities for dealing with it. They act in accordance with institutions that tend to separate and define boundaries in ways that provide incentives for investment to generate economic growth. Vatn advocates a substantial transformation of the current ill-fitted institutional framework (Vatn 2009). This scholar states that the establishment of property rights to foster fisheries sustainability will not constitute a sufficient or a necessary institutional setting. With these statements, Vatn presents a rationality that goes against the institutional reform of fisheries that has most often been advocated during the last decade, namely: the establishment of property rights to overcome the overfishing problem (Costello et al. 2008, Bromley 2009). Following Vatn's logic, as an alternative, networking has been suggested as a desirable integrative institution. Networking stimulates beneficial collective action, especially when linked with strategic development, common knowledge and the evolution of common rules (Carlsson and Sandström 2008, Crona and Hubacek 2010, Parsram and McConney 2011). However, networking is difficult to implement since its underlying principles are currently not sufficiently understood (Carlsson and Sandström 2006). In many cases, including all people in an area with an interest in the same resources into one organisation is not feasible (Rydin and Falleth 2006). These debates highlight the complexity of the issues, particularly for an interconnected global resource such as fisheries. Which institutions could provide the basis for a sustainable, globalized, and purely commercial fishery, which is also a *de facto* open access fishery? Some possible answers to this question will be explored in this research by looking at different current and historical institutional settings of the Peruvian anchovy fishery.

Institutions that are nowadays strongly recommended to achieve sustainable fisheries, such as quota shares, decentralized bottom-up management or eco-labelling, have not been implemented in the sustainable Peruvian anchovy fishery. In contrast to the stress that is often placed on to the importance of property rights or governmental regimes (Acheson 2006, Bromley 2009, de la Torre-Castro and Lindström 2010), the present study suggests that the balance of interests between different actors, mediated through institutions, is crucial to maintain fisheries management and sustainability. As mentioned previously, this study adopts a broad institutional approach. The first two articles stem from the premise that environmental institutional arrangements develop as responses to events occurring in the social (first article) and biophysical (second article) settings in which they operate (Young 2010a). The inherent complexity of fisheries systems requires parallel efforts to improve the science on which resource management is based and to develop institutions to manage resources in the face of unexpected change and uncertainty (Miller et al. 2010, Dankel et al. 2012).

A second motivation for the present study was to engage with institutions as an area of scientific research and as a reality shaping individual and collective behaviour; in both senses, institutions are problematic. Not only is the number of institutions vast, they develop and interact in horizontal and vertical multi-level and cross-sectorial domains. The interest in environmental institutions has produced a significant body of interdisciplinary research on local and international level institutions mainly focusing on local common property arrangements and international conventions (Ostrom 1990, Young 1996, Walker et al. 2009, Cox et al. 2010, Young 2010b). In the field of local use of natural resources, this body of research has identified a number of "design principles" that characterise successful local level governance institutions (Ostrom 1990). On the international level, interdisciplinary research encompassing economics, political science, sociology, and anthropology has demonstrated under what circumstances international environmental institutions are likely to be effective (Paavola and Adger 2005, Walker et al. 2009). However, there is relatively little research on national level environmental governance institutions (Paavola and Adger 2005), which interact with but cannot simply be scaled up or down from local or international governance levels. Blueprint solutions for local governance challenges cannot simply be scaled up; they are inevitably tied to and influenced by other levels and areas of governance (Ostrom 2007, 2009a). Similarly, international action against ozone layer destruction, deforestation or global climate change cannot simply be transferred downward to national policy strategies (Paavola and Adger 2005). Research on national level of environmental governance is limited and understanding of interactions between the levels and contexts of governance remains to be developed (Paavola and Adger 2006).

The present research places emphasis on social institutions operating on the national level. These not only constitute a field of considerable theoretical interest; research at this level is also essential in order to understand and identify institutional reforms at the nation/territory level. Institutions at the national level play a crucial role in setting the framework for local action (Lehtonen 2004) and structure the arena where policies are decided. At the national level, this research is not directly about fisheries policy; it is about institutions that have been proven to enable better policy and governance and the idea that both of these are mediated through institutions.

A third motivation for this study was to address an imbalance in research on fisheries institutions. Despite the fact that developing countries have contributed to more than two-thirds of global fish production during the last decade (The World Bank 2009), lessons for large-scale sustainable fisheries come even today almost exclusively from western developed countries (Murawski 2010). Furthermore, with a few exceptions (Iceland, Norway, New Zealand), this research comes from countries where fisheries do not play an important role in national economies (see Hilborn et al. 2005, Table 1). The bulk of fisheries research in developing countries has been reduced to the field of artisanal small-scale fisheries rather than commercial fisheries, ignoring the crucial economic contribution of the later to the economies of countries like Chile, Peru, India, Indonesia, Thailand, Namibia; to name but a few.

Finally; landings of the Peruvian anchovy fishery account for nearly 10% of the total world's ocean landings (Sánchez and Gallo 2009). Peruvian anchovy is the world's most exploited fish in terms of volume (Bertrand et al. 2010) and its fishery has been described as the as the most intense and successful fishery worldwide (Chavez et al. 2008). Given this reputation, a study of this fishery appears to be important in itself.

Limits of the research

Considering the scale and scope of the subject matter, this thesis is inevitably constrained in what it can cover. The first constraint in this research relates to the term sustainability and its contested nature (Jamieson 1998, Davison 2008). It is a fact that "while nearly everyone favours sustainability, few agree on what the term actually means" (De Alessi 2008:1). The attention here is on institutions concerned with the environmental dimension of sustainability or "biological sustainability", rather than the social, cultural and economic dimensions. In this context, an "unsustainable situation occurs when a natural capital (the sum total of nature's resources) is used up faster than it can be replenished" (Younes and Rostamzadeh 2011:3476). Biological sustainability requires that resource users limit the exploitation of natural resources at or below a rate at which they can be replenished naturally. As stated by Hindson and co-authors:

> *Fishing can be said to be sustainable when it can be carried out over the long-term at an acceptable level of biological and economic productivity, without leading to ecological changes that reduce options for future generations* (Hindson et al. 2005:10).

Limiting the scope of the present research to this dimension allows an effective measure of sustainability. The lack of such a measure can undermine research on broader-based sustainability of natural resources. Secondly, restraining the scope to landings sustainability responds to the fact that, at least in the case of fisheries resources, biological sustainability of targeted species, must precede (but not preclude) all other measures of sustainability (Acheson 2006, Beddington et al. 2007). Pelagic fish stocks however are largely driven by environmental variability which makes young fish recruitment fluctuate by at least more than one order of magnitude every year (Lehodey et al. 2006). Sustainable exploitation in this context means adapting the annual catch volume in accordance with environmental conditions and the activity and capacity of the fishing fleet to the size of the stock at each particular time (Hannesson 2008). Dealing with pelagic fish stocks, declining landings and biomass stock levels do not necessarily indicate unsustainable exploitation; on the contrary this could be a reasonable adjustment to adverse environmental conditions (Mullon et al. 2005).

A second limitation of the present study is related to institutional change and interplay. Institutional change, viewed either as the spontaneous emergence of institutions through evolutionary processes or as the deliberate creation of institutions through power dynamics in the political process (Vatn 2005, Hodgson 2006, Kingston and Caballero 2009), is considered in this research only implicitly. Prior to understanding how institutional change happens and how to achieve changes that will promote sustainable management of natural resources, there is a need to know what kinds of institutions could be most appropriate to achieve this aim. The latter question is the focus of this study. Thus the two first articles of this research focus on the historical evolution of fisheries institutions in relation to changes in the social and biophysical environment. The third article reviews the institutional history of the Peruvian anchovy fishery in the light of current theory on the institutional characteristics of sustainably managed common property resources. Processes or drivers that might have affected the historical development of the present Peruvian fisheries institutional setting are not explained and cause-effect relations are only suggested. Further analysis will be required to explain the processes that led towards the institutional transitions described. Institutional interplay, i.e. the situation by which the content, operation and outcome of one institution interact and are significantly affected by other institutional arrangements (Stokke 2000), is another topic not considered in the present study.

1.2 Objectives

This research work has the general objective:

- to explore and broaden our current knowledge of governance institutions that support biological sustainability of commercial fisheries in developing countries

The specific objectives are as follows:

- to qualify some institutions commonly drawn in fisheries research to promote sustainable outcomes
- to investigate both the role played by fisheries legislation and possible factors influencing its development
- to explore the tension arising from the need for laws that simultaneously provide for rigour/stability and adaptability/flexibility in governance of natural resources
- to investigate coping strategies developed by the Peruvian anchovy fishery to deal with environmental variability and extreme climatic events
- to assess the extent to which design principles proposed by scholars of long-term successful management of community-level natural resources explain the recent sustainability of the Peruvian fishery

2. Theoretical framework

The following section provides a brief and summarized picture of various topics related to institutional theory. It was designed to provide readers unfamiliar with the field of institutional research, with a short literature review, outlining the different ideas and concepts behind the term “institution”. Various historical roots of the term institution and the pool of current schools of thought that characterize institutional analysis are also reviewed. The different theories and views reported in sections (2.1-2.3) were compiled from available literature and are not based on the results of the present research.

2.1 Theorizing institutions – a review

Institutions keep society from falling apart, provided that there is something to keep institutions from falling apart.
Jon Elster, Nuts and Bolts for the Social Sciences, Chapter 15.

Tracking institutional theory and analysis over time could turn into a very long and arduous task. Institutional research can be dated back to the Greeks and the foundations of western philosophy. As stated by Steinmo (2008) institutional theory is as old as the study of politics, dating from Plato’s *Republic* comparing different forms of government and Aristotele’s *Politics*, examining institutional structures that shape political incentives and normative values.

But despite a very long interest in the study of institutions, the use of the term has become widespread in recent years, reflecting the use of the institution concept in several social disciplines, including anthropology, economics, history and geography (Vatn 2005) and the growth in one particular field known as institutional economics (March and Olsen 1984, Hodgson 2006)

The use of the term institution is becoming more common; it is nowadays used by academic and general public in ways that mean a range of different things. In scholarly contexts but also in everyday language, the term institutions is used to refer to objects as seemingly dissimilar as a constitution, table manners, a political party, firms and organizations or even “an older member of the community reliably seated at the bar of a local pub” (Connor and Dovers 2001:4). There is hence general confusion on what exactly the term means; and many scholars have noted that, despite its popular use, even today there is no unanimity on the definition of this term (Ostrom 1986, Immergut 1998, Jentoft 2004, Vatn 2005, Hodgson 2006). The lack of a sole definition for the term "institution" is by no means new. During the earlier decades of the last century, at least two different ways to define institutions were recognized. One approach treated institutions as things in themselves which should be studied as such, and the other classified institutions as phases of human behaviour to be discovered by the study of the habits and attitudes of individuals (Allport 1927).

The confusion with the term institution could be either the source or the result of the widely different ways in which the term is used in different branches of social sciences. Some scholars for example, attribute the confusion about the term to the division between political scientists, who see institutions more like organizations, and those who see them as "rules", more typically anthropologists, economists and sociologists (Bouma 1998, Lowndes 2001, Vatn 2005, Hodgson 2006, Leftwich and Sen 2010). To complicate things further, there is also a fundamental division among scholars who consider institutions as rules. Here, the division is between those who base their position on "individualist" or "social constructivist" ontologies (Vatn 2005). For the individualist position, institutions are rules which set up the parameters for human action aimed at maximizing individual benefits. Individuals are seen as fundamental building blocks, and collective action is just the aggregation of individual actions (Shepsle 1989). In contrast to this position, social constructivist supporters share the idea that institutions not only constrain behavior, but influence individual values, perceptions and believes (Copeland 2000).

But, the confusion about the concept of "institution" could have several sources. DiMaggio and Powell have argued:

> *Institutionalists varied in their relative emphasis on micro and macro features, in their weightings of cognitive and normative aspects of institutions, and in the importance they attribute to interests and relational networks in the creation and diffusion of institutions* (DiMaggio and Powell 1991:1).

According to these authors, an institutional theory based on such different roots and interests cannot be expected to converge on a single set of assumptions or research discipline. However, some scholars have attempted to combine at least the main different emphases related to the concept of institutions in one single definition; Scott, (Scott 2001:48; 1995:33) for example defines institutions as:

> *…social structures that have attained a high degree of resilience [and are] composed of cultural-cognitive, normative, and regulative elements that, together with associated activities and resources, provide stability and meaning to social life.*

As argued by Scott, many of the confusions about institutions stem from their varying emphasis on three principal pillars or elements: cultural-cognitive, normative and regulative (Scott 2001). According to this author, institutions are cultural because they influence the individual through social processes by means of symbolic representations; they are cognitive in that they provide fundamental frameworks for shaping individual perceptions and choices. This cultural-cognitive element is about creating order in the way the world is viewed and understood, to standardize aspirations and ideas (Scott 2001). As Jentoft points out, cultural order means that "things are not questioned because they are perceived as true and self-explanatory" (Jentoft 2004:145). Cognitive order means that "knowledge defines what is valid, what is *true* or *false*" (de la Torre-Castro and Lindström 2010:78).

Box 1. The three phases in the process of institutionalization under the constructivist approach (from Vatn 2005:31)

- *Externalization: the process where subjectively constructed routines take form and are expressed. The routines are visible and the actors know their origin and can easily change them if found convenient.*
- *Objectivation: when others observe the routine as existing "facts". They have acquired an existence independent of those creating them and stand out as "things". What individuals subjectively choose has become objectively real for others.*
- *Internalization: the stage where the habit becomes the "natural order", distant from its origin as social construct. The process is also called "socialization".*

The normative element rejects the conception by which actors are viewed solely as independent rational calculators (Scott 2001). Individual choices are not taken exclusively because they should provide an optimal utility but are influenced by perceptions and internalized commitments. According to this scholar, social persons care about their relations to others; their decisions are constrained by what is socially accepted or rejected. Decisions are responsive to "the logic of appropriateness" (see March and Olsen 2006). More recently, Scott posits: "interests are framed and circumscribed by identities" (Scott 2010:6). The normative element gives meaning to a situation, determines individual goals and objectives (values) and determines what means are socially appropriate to pursue them (de la Torre-Castro and Lindström 2010). From a normative perspective, March and Olsen define institutions as:

> *…collections of interrelated rules and routines that define appropriate actions in terms of relations between roles and situations. The process involves determining what the situation is, what role is being fulfilled, and what the obligation of that role in that situation is* (March and Olsen 1989:16).

Focus on regulative elements directs our attention to the individual as an autonomous entity and to human choice as the act of optimizing individual benefits (Scott 2001). Institutions are regarded as the "rules of the game" that posit external "constraints" to individual calculations (see North 1990). Individuals who interact socially, have their own well ordered sets of preferences which remain largely unaffected by any institutional involvement (Peters 2000). The role of institutions to protect and produce interests and power is emphasized. From this viewpoint, institutions can be formal or informal and are more easily planned and strategically manipulated. Rules and regulations are backed up by monitoring and sanctioned power (Vatn 2005, de la Torre-Castro and Lindström 2010).

Considering the three pillars, and the connection or sequential order between them; Scott has recently remarked:

> *Cultural-cognitive elements provide the bedrock for normative prescriptions and regulative controls, because norms and rules must refer to institutionally constituted entities. However, they are also capable by themselves of providing a framework for order* (Scott 2010:7).

In an attempt to encapsulate particular functions and concepts of institutions in one single definition, Vatn (2005:60) presents a similar definition:

> *Institutions are the conventions, norms and legal rules of a society. They provide expectations, stability and meaning essential to human existence and coordination. Institutions regularize life, support values and protect and produce interests.*

There is certain equivalence between Scot's three pillars and the conventions, norms and legal rules considered by Vatn. However, in Vatn's argument, the sequential order between conventions, norms and rules is associated to distinct sanctioning mechanisms and the role of power. A convention, defined as "a rule saying how a thing is" (Vatn 2006:2), does not need a sanctioning mechanisms for enforcement. Examples of conventions are the use of a certain language, the Google search engine, or shaking hands when people greet one another. According to Vatn (2005), conventions are used by people in everyday life without prior self-conscious analysis and adoption; they are essential tools for coordinating activities in a social unity. Conventions can be also understood as rules channelling shared strategies (see Crawford and Ostrom 1995).

Vatn's "norms" are similar to Scott's "normative pillar" of institutions. A norm, "is a rule saying how things should be" (Vatn 2006:2). Examples of normative rules can be: "hands should be washed before dining", or "small children should go to bed before 8 pm". Vatn argues that, norms do not need a sanctioning mechanism when they become an expected order and are not perceived as social constructs any longer. However, a norm is also sanctioned by a mother not allowing the child to eat before washing hands or the child feeling guilt when staying out of bed after 8 pm, or when lying to his mother (Vatn 2006). Regarding defence of interests, norms harmonize interests through forming common values, or common ideas on what is important to individuals of the same culture. As Vatn notes in continuation, when interests cannot be harmonized, a formally sanctioned rule should be applied to avoid potential conflicts. This type of rules are called legal rules and are characterized mainly by being always backed up by a sanction procedure (imprisonment, penalties, fines, etc) accomplished by a legal authority (Vatn 2005).

The second sequential interaction between conventions, norms and legal rules is related to their role in power relations. The role of power increases substantially from a convention to a legal rule, and even conventions may be based on mechanisms to protect or assist interests (Vatn 2005, Vatn 2006). According to this author, as an example, the choice of a monetary currency (for instance the Euro) is not just a neutral convention to coordinate human relations. Thus, it is important to acknowledge the various facets or levels of human interactions; while some of them concern mere coordination, others add meaning to a situation; some emphasize common interests, while others defend the interests of a certain individual or group (Vatn 2006). However, clear dividing lines between the meaning of conventions, norms and legal rules become blurred when considering the complex and different facets and levels of human interactions.

Presenting an optimistic view of institutional theory, Hodgson (2006) argues that it is possible to arrive at a consensual definition of institutions. For this purpose, this author explains, overgeneralizations based on institutions of a particular kind must be avoided. Institutions may be defined as "systems of established and embedded prevalent social rules that structure social interactions" (Hodgson 2006:18). As this author notes in continuation, institutions are: socially transmitted (their replication depends upon the existence of a social culture and reciprocal communication), normative or potentially normative, codifiable at least within a social group, constrained by natural laws, and enlarged by technological and other institutional developments. According to Hodgson (2006), other characteristics of institutions are:

- Institutions generate stable expectations in the behaviour of others; they depend upon thoughts and activities of individuals
- Institutions not only constrain but also enable innovation and opportunities
- Institutions can be only observable through manifested behaviour (however they are not behaviour themselves). Institutions are thus subject to different interpretations of behaviour, leading to different "institutional approaches"
- Organizations are special institutions with a hierarchical structure, defined boundaries, membership rules, procedures and reward structures
- Institutions are self-reinforcing and self-perpetuating

The new institutionalism

In contrast to the disagreement or confusion over the definition of "institution", there is common agreement in reporting the resurgence of institutional research, that has been expanding since the 1960s and 70s. This noticeable recent interest in institutional research developed as a reaction to the behavioural revolution (behaviouralism) and rational choice theories that explain social and political outcomes as the aggregate consequence of individual choices (March and Olsen 1989, Shepsle 1989, Crawford and Ostrom 1995). As reported by (Shepsle 1989:134) "for behaviourists, institutions emerged out of the aggregation of individual roles, statuses and learned responses". Similarly, for classical rational theorists, institutions were a collection of individual choices based upon utility-maximising decisions. The term "new institutionalism" was coined to differentiate the current institutional approaches that emerged in reaction to these views and mark the return to a less atomistic, traditional institutional analysis. Marking a crucial point in political science towards a new institutionalism, March and Olsen's seminal article argued that "the organisation of political life makes a difference" (1984:747); and by 1996, Goodin and Kingemann (1996:25) were describing the new institutionalism movement as "the next revolution in political science" (see Lowndes 2001). But not all new institutionalism was divorced from the rational choice movement. It was Coase's article from 1937 on "The Nature of the Firm", that revealed costly market transactions, which provided the bridge between rational choice theories and the new institutionalism (Vatn 2006). Among the books most frequently referenced by proponents of this merger are E. Ostrom's *Governing the Commons* and D. C. North's *Institutions, Institutional Change and Economic Perfomance*, both first published in 1990 (Goodin and Kingemann 1996). Followers of this new institutional analysis field identified themselves as New Economic Institutionalists (NIE).

As stated by Lowndes (2001:1953):

> *The "new institutionalists" concern themselves with informal conventions as well as formal rules and structures; they pay attention to the way in which institutions embody values and power relationships; and they study not just the*

impact of institutions upon behaviour, but the interaction between individuals and institutions.

In this, there are several branches with diverse approaches being developed that follow the traditions of different social science disciplines (DiMaggio and Powell 1991, Koelble 1995, Lowndes 1996, Nielsen 2001). Koelble (1995) argues that at the heart of the disagreement between different approaches of new institutionalisms is one of the core questions of the social sciences: whether, structure, culture or individual behaviour best explains social phenomena and change. Structural influences are analysed by historical political institutionalism, cultural influences by sociological institutionalism, and the influence of individual behaviour by economic or rational choice institutionalism (Koelble 1995). DiMaggio (1998) (cited by Nielsen 2001) distinguishes three new institutionalisms: social-constructivist neoinstitutionalism (SCN), mediated-conflict neoinstitutionalism (MCN) and rational-action neoinstitutionalism (RAN). Even though this typology transcends disciplinary boundaries, the three fields are seen as originating from political science, sociology, and, economics respectively (Nielsen 2001).

Box 2. Based on diverse social disciplines, Peters (2000) differentiates between four major current new approaches to institutional analysis:

- *The sociological approach—following the normative pillar. Here the most suitable method to understand human behaviour is through the "logic of appropriateness" (March and Olsen 2006) that individuals acquire through their social context.*
- *The rational choice approach—where institutions are arrangements of rules: the "rules of the game" (the regulative pillar). For rationalist scholars, the central goal is first to uncover the laws of political behaviour and action; once these laws are discovered, models to understand and predict political behaviour can be constructed (Steinmo 2001).*
- *The historical institutionalism approach. As the name implies it, historical institutionalism is interested in unveiling the centrality of "path dependency" that shape and sustains political outcomes. Historical institutionalists stand between the normative and the rational choice views; they allege that individual behaviour depends on the individual, the context and the institution involved (Steinmo 2008)). They do not deny that individuals attempt to calculate their benefits, but argue that outcomes are the product of human interactions and institutional structures. Preferences are not fixed and are influenced by institutional contexts (Koelble 1995). However, historical institutionalists normally associate institutions with organizations, and the conventions*

promulgated by then (Hall and Taylor 1996). Historical institutionalists are firstly interested in explaining a political outcome; and then proceed to explore alternative explanations for the observed outcomes; they are engaged in developing a deep and contextualized understanding of politics (Steinmo 2001).

- *The empirical institutionalism approach. This term is employed to describe "a body of literature that asks the deceptively simple question of whether institutions make any difference in policy choices, or in political stability" (Peters 2000:3). Criticized for their minimal contribution to institutional theory, empirical institutionalists pay less attention to the meaning of the term institution; institutions are important no matter what they particularly are. Governments, which are systems created to regulate, control and direct resources, interact with social demands through institutions. The view, stemmed from the rational choice institutionalism, that institutions are conceptualized as exogenous to the individual is shared by empirical institutionalists. Individual behaviour is based on the assortment of opportunities and constraints provided by the institutional structure, while human values remain independent from the institutional context.*

The term "new institutional economics" (NIE) was coined by economist Oliver Williamson in 1975 based on the analytic tradition initiated by Coase in 1937 and 1960 (Vatn 2006) and adopted among others by economic historians (North 1981), game theorists (Schotter 1981, Harsanyi and Selten 1988) and political economists (Ostrom 1986). Despite the temporal adjective, "new" institutionalism is built upon some old assumptions concerning the human agent as the basic building block in economic theory (Hodgson 1998 cited by Olsson 1999:17). In contradiction to neoclassical models, (Vatn 2006) observes:

a) NIE envisages human beings as multi-rational and the normative function of institutions (evaluating what is right or wrong) is a rational action comparable to the calculus of an individual gain. An actor's behaviour is likely to be guided, not by impersonal historical drivers, but by a strategic calculus; this calculus will be also affected by the actor's expectations about how others are likely to behave (Hall and Taylor 1996).

b) NIE considers that preferences and values, including the evaluation of what is efficient, are not stable or given; they are influenced by institutional contexts.

c) In consequence, outcomes are not in equilibrium; they are subject to constantly evolving institutional settings; institutional arrangements are viewed as “adaptive solutions to problems of opportunism, imperfect or asymmetric information and costly monitoring” (DiMaggio and Powell 1991:9).

Thus NIE has added a strong and healthy dose of realism to the standard assumption of neoclassical microeconomic theory (DiMaggio and Powell 1991). NIE proponents believe that institutions matter, but consider that “the determinants of institutions are susceptible to analysis with the tools of economic theory” (Matthews 1986:903).

What are then the functions of institutions? Institutions are structures facilitating exchange, creating expectations that reduce uncertainty and lower transaction and transformation costs (North 1990). Lin and Nugent (1995) claim that institutions have two basic functions: economizing and redistributing. Economizing refers to the notion that institutions reduce or “economize” transaction costs of interactions and exchanges between agents. In this case, transaction costs include the costs of negotiation over a contract, of getting information about exchange opportunities, of monitoring the contract, and the costs of enforcement when one participant attempts to desert (Lin and Nugent 1995). The authors explain that redistribution is more connected to the concept of fairness rather than efficiency. Institutions like democracies, proportional income taxation or charity to the poor, cause resources to be redistributed for the sake of attaining a higher level of equality and justice (Lin and Nugent 1995).

A great deal of NIE research concentrates on topics like property rights, rent seeking and agency theory. Within this approach, institutions can be divided into formal (judicial, political and economic rules and contracts) or informal constrains (Hotimsky et al. 2006). A clear distinction must be also made between institutions, which are “the rules of the game”, and organizations, which are envisaged as “the players” (North 1990). Finally, even if the differences between old and new institutionalism have been traditionally substantial, some scholars are suggesting a tendency to merge with consequential benefits for institutional analysis (see Schlüter et al. 2009, Abrutyn and Turner 2011). In the words of Olsson (1999:3):

The road ahead for institutional theory appears to be a synthesis between microeconomics and cognitive science, i.e. an institutional microeconomics, which recognizes the path-dependence and evolutionary aspects of human thinking.

2.2 Institutions, the environment and sustainability

We have modified our environment so radically
that we must now modify ourselves to exist in this new environment.
Norbert Wiener

This section summarises the results of a selection of up-to-date literature concerned with the relation between institutions and environmental issues. A set of influential perspectives on how institutions should address current environmental problems, between and within different institutional approaches is presented. The majority of ideas and analysis presented here are rooted in the institutional economics approach. This was not intentional. But such partiality could nevertheless be expected, considering that institutional economics perspectives have been particularly attractive for understanding environmental policy design and implementation (Paavola and Adger 2005, Paavola 2007)

The principles of successful local common pool resource institutions - E. Ostrom

Political scientist Elinor Ostrom's work on the connection between institutions, local level environmental governance and policing is a pioneer and influential work. As mentioned by Ostrom, her work was underpinned by her "deep interest in how institutions were initially crafted and then how they affected the incentives and outcome of human interactions" (Ostrom 2010:2). Rooted in new institutional economics, Ostrom's theoretical framework sees institutions as rules[3]. Ostrom defined seven broad types of rules that affected the working parts of an "action situation" (see Ostrom 1986). Soon after, being strongly influenced by the work of John R. Commons, Ostrom realized that the distinguishing characteristic of rules was whether they defined an action or an event to be required, forbidden or permitted. (Ostrom 1986). To overcome the confusing and overlapping definitions of term like “rules”, “norm” and “strategies”, Crawford and Ostrom (1995) developed what the authors called a cumulative syntax for a common foundation of institutional analysis. In 1995, their article: “A grammar of institutions” was published. Ostrom’s definition of institutions is presented here as “enduring regularities of human action in a situation structured by rules, norms and strategies as well as by the physical world” (Crawford and Ostrom 1995:582).

The book “Governing the Commons” is undoubtedly Elinor Ostrom’s first masterpiece. Through a comparative analysis of empirically derived characteristics of long-enduring common-pool resources (CPR), a conceptual extension of the concept of property rights was suggested and the “eight design principles” were introduced. Property rights were understood as “bundles of rights” within a hierarchy of possible rights; while the “design principles” were not specific rules but general institutional regularities that characterised successful local common property regimes (Ostrom 1990). Ostrom’s efforts showed that institutions did not only determine the way societies use their common natural resources; but that some of them are more effective (and some more detrimental) in terms of achieving desirable collective outcomes.

More recent developments of Ostrom’s work involving various governance systems, and their effects on the sustainability of natural resources are presented in one of her latest productions: “A general framework for analyzing sustainability of social-ecological systems (SES)[4]”. Ostrom argues here that science’s inability to understand the deterioration of natural resources is due to the incompatibility of the various concepts and languages used by different disciplines; and that “without a common framework to organize findings, isolated knowledge does not cumulate” and its efforts are diluted (Ostrom 2009b:419). In response to this need, this author presents an updated version of a multilevel, nested framework that identifies 10 subsystem variables which affect the likelihood of self-organization leading to sustainable outcomes in the management of SES. The widespread use of this framework should assist the general scientific community to develop better theories to confront environmental issues (Ostrom 2009b). In dealing with environmental policies, Ostrom also calls for the development of more complex approaches and criticizes “one-size-fits-all” institutional prescriptions (Ostrom et al. 2007, Ostrom 2008). In the author’s words:

> *I suggest that institutional theorists move from touting simple, optimal solutions to analysing adaptive, multi-level governance as related to complex, evolving resource systems* (Ostrom 2008:24).

Environmental governance, conflict and interdependence - J. Paavola, O. Young and A. Vatn

Linking institutional economics with ecological economics[5] Paavola and Adger (2005), identify the concepts of "interdependence" and "positive transaction costs" as crucial for environmental governance. "Interdependence" refer to situations in which the choice of one individual influences that of another. According to these authors, attributes of resources that create interdependence divide goods into four main types known as: private good, common pool resources, toll goods and pure public goods. However attributes of resource users such as their number, heterogeneity and level of social capital should be also considered as additional sources of interdependence. As a result of their analysis of interdependencies, the authors argue that environmental solutions should consider attributes of both, i.e. on one hand the resources, and on the other their users. Furthermore, "when interdependence is complex, governance may need to be carried out at multiple levels or through multiple, overlapping governance institutions" (Paavola and Adjer 2005:357). Following this analysis, the authors explain that conflicts arise when interdependent agents cannot realise their incompatible interests in a world of scarce environmental resources. In such situations, conflict must be resolved through institutions, firstly by defining (or re-defining) initial endowments; and secondly, by specifying clear property rights or alternatively, by using environmental regulations which create other kinds of rights (Paavola and Adger 2005). Thus governance institutions have both allocative and distributive functions; they affirm or redefine initial endowments, and these are the key variables in environmental decisions (Paavola and Adger 2005). Furthermore, these authors argue that interdependence underlies the importance of social justice in environmental decisions (e.g. the need to consider losses both for present and future resources users), and of intra - and inter-generational equity within the sustainability discourse. Regarding positive transaction costs[6], Paavola and Adger (2005) explain that transaction costs, which in environmental governance typically involve administrative costs, exist because information is imperfect and costly to obtain. Their central significance has more implications in the process of institutional design.

J. Paavola (2007) acknowledges that new institutional approaches to tackle environmental governance have been extraordinarily successful in terms of academic research and policy impact. However he argues that multilevel features of governance have not yet been fully considered. Institutional analysis still has problems dealing with traditional national policies based on the enforcement of power of the state in conjunction with solutions based on voluntary cooperation (Paavola 2007). Considering what has been achieved by the study of common pool resources, J. Paavola calls for this analysis to be extended to other kinds of environmental resources. Paavola defines environmental governance as "the establishment, reaffirmation or change of institutions to resolve conflicts over environmental resources", in which the power of the state is inevitably present (Paavola 2007:94). He analyses the role of the state; however, drawing attention to a common misinterpretation of the term "governance", insists that "rather than a monolithic external actor, the government, and the state, should be understood as arenas and instruments of collective action, which are often pertinent in environmental governance" (Paavola 2007:95). Thus formal and state-centred environmental governance are a sort of collective ownership. This scholar further notes that design of governance institutions should be based on (i) functional and structural tiers, (ii) organization of governance functions; and (iii) formulation of key institutional rules (Paavola 2007).

According to King and Young et al. (2008:1) "institutions have been critical forces in shaping *real world* environmental governance systems, and therefore are significant not only for scientific but also for policy advances". The sustainable use of renewable resources is hence a consequence of the operation of systems of property or use rights that fail to give human users adequate incentives to devote energy and resources to conserve the natural environment. Consequently, strategies aimed at solving environmental problems frequently call for changes in prevailing structures of property rights, the introduction of new regulatory regimes, or the development of appropriate incentive mechanisms (e.g. charges or tradable permits) (King et al. 2008). For these authors, institutional change is needed to redirect the behaviour of those whose actions lead to irreversible anthropogenic disturbances in natural systems. Following the regulative approach, institutions are defined by Young as:

> *...sets of rules, decision-making procedures and programmes that define social practices, assign roles to the participants in this practices, and guide interactions among the occupants of relevant roles* (Young 2002:5).

Institutions that deal explicitly with environmental or resource issues are commonly identified as environmental or "resource regimes"[7], Exploring the dynamics and evaluating the problems associated with changing prevailing institutions, Young and co-authors establish that institutional effects are nonlinear, that utilitarian and normative motivations work simultaneously and that institutional interplay and fit both have to be considered (King et al. 2008). Further conclusions in Young's work are that:

(a) Institutional performance can be assessed through criteria like efficiency, equity and sustainability;
(b) Institutional design should be problem-oriented at levels that are identified through a political framing process, a process that itself changes the nature of the problem; and
(c) Science and policy interfaces (gaps) must be always taken into account.

For institutional economist Arild Vatn, environmental institutions "define the conventions, norms and legal rules that structure the relationships between people concerning their access to and use of resources" (Vatn 2006:8). This author argues that "institutions play a core role, not least in influencing how we perceive and use environmental resources but also how we are allowed and not allowed to intervene into each others' lives" (Vatn 2006:1). Similarly to Young, this author advocates a "substantial reorientation of governing economic institutions to solve current and increasingly pressing environmental problems" (Vatn 2005:21). However, other crucial factors influencing environmental issues like population pressure, the science-policy interface or poverty should also be simultaneously addressed (Vatn 2009).

Economist Vatn argues that, interconnectedness is an inherent characteristic of natural systems and it secures their quality and productivity. Due to this interconnectedness, the use of one natural resource necessarily influences other natural resources. Externalities from economic activity are a product of the relationship, or lack of relationship, between the resource and the resource regime chosen (Vatn 2005). Vatn emphasises the need to evaluate the relation between resource characteristics and choice of policy regime to achieve compatibility between individual and collective rationality. To solve collective action problems, e.g. the "tragedy" resulting from open access, one possibility is to change the regime to common property among the people who use the resources (Vatn 2006).

Vatn places emphasis on the need to adapt resource regimes to the attributes of the resource and the values of resource users; the idea that there is one institutional form that is the best solution to any problem is not only wrong, but damps creativity and reflection. This does not imply that institutional analysis is useless; on the contrary, it makes analysis of the resource attributes, the cultural views of participants and the rules themselves more important, since it is their complex interactions which determine the chances for a sustainable future (Vatn 2005).

In his book chapter "Institutions, sustainability and behaviour" Vatn (2009) emphasizes the problem of economic growth whit sustainable development. The role of institutions here should be to address interdependencies between human actions rather than to continue creating nominal independencies (property rights) to promote investments and economic growth. From his perspective "sustainability demands a shift away from institutions exclusively fostering individual rationality towards those supporting cooperative rationality" (Vatn 2009:293). Here, environmental problems are a result of the ill-fitted institutional system that has evolved disrespectful of the interlinked environmental dynamics on which the economy so fundamentally rests. The prevailing institutional system has, in contrast to the environmental system, predominately a de-linking function, that is, it divides up decisions and assigns nominal responsibilities that cut across interlinked structures in the *real* world (Vatn 2009). Thus "there is a fundamental inconsistency between our economic institutions demanding for growth and the demands for sustaining environmental and even to some extent social opportunities" (Vatn 2009:295).

Part of the problem, Vatn (2009) argues, is also the incomplete information humans have about the dynamic laws of the natural system. With complete information about the natural system, humans could impact this system avoiding unforeseen outcomes and increasing their opportunities in the short run. Vatn (2009:297-298) explains that current de-linking institutions promote "separation in space – creating high transaction costs", "separation in interests" and "separation in time – when the consequences in the physical world become evident". This scholar proposes two fundamental changes in the economic system: First, changing the operating principles of "the firm" as the basic unit of the economy; and second, building a communication channel between the new units at different levels to link their decisions and avoid undesirable impacts. Finally, Vatn (2009) asserts that the way to attain these reforms could be by reducing the power of corporations embedding them within social-political structures built on social rationality; or by institute social rationality between the firms themselves.

No panaceas and the empowerment of concerned authors - J. Acheson and D. Bromley

From a more anthropological perspective, Acheson (2006) argues that in the field of environmental conflict analysis, economic incentives (i.e. property rights) and central government control are both misleading institutional prescriptions that will prompt failure under certain conditions. Based on a range of different case studies, this scholar also shows that anthropological directives for local-level management are equally susceptible to failure. As a consequence of this analysis, Acheson concludes that in the field of natural resources management, there is no universal solution and that the precise combination of measures undertaken will have to vary with the specific resource concerned (Acheson 2006). This scholar also points to the fact that failures of resource management cannot be attributed to one or two factors but to a complex system of factors. Similar to J. Paavola, Acheson argues that rules to manage resources and the enforcement of those rules should be considered as public goods. In this case, resources and resource management are usually (but not necessarily) more easily handled when put in place by central governments (Acheson 2006).

Analysing current problems in environmental regulations, Bromley (2007) discusses two essential modifications needed to transform environmental institutions into a framework that is consistent with the imperatives of sustainability: First, environmental policy must be rescued from the "the tyranny of hubristic precision inherent in scientism[8]" (Bromley 2007:680). Second, environmental policy must be freed from the flawed demarcationist project that regards the economy as something distinct from the polity" (Bromley 2007). To alleviate the increasing environmental crisis, Bromley calls for a return to the original basic principles of societies, where collective problems are discussed and solved by authorities together with the concerned actors. This author remarks:

> *Rescuing environmental policy requires that prescriptive conceit must now give way to public discourse, debate and the offering of reasons. Achieving sustainability in environmental policy reminds us that sustainability concerns human processes, not biological or ecological processes* (Bromley 2007:681).

2.3 Institutions and sustainable fisheries

> *The fishermen find the practice as repugnant as Dr. Safina does, but, in spite of the fact that none of them (that we know of) are Ph.D.s, they are trying to do something positive to end it.*
> from the New York Times, April 14, 1998

As in the case of the global crisis of resource degradation, the overexploitation of fisheries resources during the last decades has been often attributed to institutional failure. Phrases like "only through better governance and institutional change that encompasses the public good of the oceans and societal values will fisheries be sustainable" (Grafton et al. 2008:630) or "when it comes to sustainability of marine resources, institutions matter" (Morris 2008:1) are found more and more commonly within the fisheries literature.

First attempts to explain the connection between sustainable fisheries and institutions were however vague and recommended courses of action often at a level of generality that stopped far short of practicability. Example of recommended course of actions that leave out all details of how to achieve the stated goals include advice to build institutions that allow the implementation of required fisheries management by legitimate authorities; and to reformulate institutions to decrease market pressures on fishery resources (see Bodiguel et al. 2002). The same criticism could be made of Hilborn and collaborator's article, where key issues for the successful management of marine resources are identified (Hilborn et al. 2005). These authors conclude that sustainable fisheries will be achieved with:

> *…the establishment of appropriate institutions for governance that include a reward system, so that the individual welfare of fishermen, managers and scientists is maximized by actions that contribute to a societally desirable outcome* (Hilborn et al. 2005:47).

Over the last decades, empirical research on fisheries management has produced a large body of literature on what is indispensable for achieving fisheries sustainability. A recent review by the School of Management at the University of Ottawa in Canada lists at least fifty academic articles and reviews related to best practices in fisheries management published during the last two decades (see http://www.c-foam.management.uottawa.ca/index.html). Despite this development, and "although experience is obviously the guide" (Powles 2008:5), case studies based on successful fisheries histories are still relatively rare. Furthermore, most research emphasises a specific aspect (or perhaps two) of fisheries management, despite almost universal agreement that success in fisheries management requires success on several dimensions (Pitcher and Preikshot 2001, Fujita et al. 2010, Gutierrez et al. 2011). Based on case studies of non-successful fisheries analyzed at meetings organized by FAO over the last decade, the unsustainability of fisheries has been attributed to seven main factors (Pitcher and Preikshot 2001, Caddy and Seijo 2005, Swan and Grevobal 2006):

- (i) lack of solid governance structures
- (ii) partial knowledge of marine ecosystems
- (iii) the uncertainties associated with fisheries as complex systems
- (iv) inadequate incentives for sustainable resource use and subsidies that promote overcapacity
- (v) stock fluctuations due to natural drivers and dynamics
- (vi) growing demand for limited fish resources
- (vii) poverty and lack of choices

Derived from FAO recommendations and other fisheries literature, best management fisheries practices include (1) the use of an ecosystem approach to fisheries, (2) the use of the precautionary approach, (3) adaptive management (4) proper incentives or user rights; and (5) participatory co-management.

According to Charles (2001), fisheries conflicts and policies reflect tensions between three basic worldviews: conservation, rationalisation and social/community paradigms. The five principles for best management fisheries could be located in the three paradigms: the ecosystem and precautionary approaches and adaptive management correspond to the conservation paradigm, based on recognition of the dependence of fisheries on the state of fish stocks and its environment. Proper incentives and user rights belong to the rationalisation paradigm, based on the idea of rationalising economic performance, productivity and wealth created in fisheries. Co-management is based on the social/community paradigm and refers to the welfare of fisheries communities, their cultures, values norms and public policy debates. The three paradigms establish frameworks for proper fisheries management, and sustainability can be reached more easily if there is a balance between these three policy directions (Charles 2001).

Complementary to these views, the well-known article by Beddington et al. (2007) identifies key instruments for successful fisheries management, including a competent and legitimate management authority, a formally adopted management plan or strategy with predefined adaptive rules, and incentives based on fishers' rights and accesses. These authors note that "evidently it is currently recognized that fishery tools for appropriate management exist; unfortunately, they have not been implemented widely" (Beddington et al. 2007:1713); or in the words of Hauge et al.(2010:5):

> *In fisheries management, the problem has, in general, not been not knowing [sic] what needs to be done in a technical sense. Rather, the problem has not known how to build the institutions that make people willing or able to implement the necessary measures.*

Some of those who agree with these statements (see Bromley 2009), focus on the challenges derived from changing institutional structures in general (Morris 2008) and consequently, from an economic viewpoint, see the problem as the result of a transaction costs dilemma. Morris (2008) mentioning De Alessi's arguments, explains the failure to implement adequate management tools as the result of:

> *…the lack of acceptance by many of those with influence, specially in the realms of fisheries science, of the important role played by the institutions governing marine resources, combined with a bias on the part of government officials in favour of scientific management of fisheries* (Morris 2008:1).

But in fact, even economists, who strongly emphasize the need to restrict unregulated access and create incentives to avoid fishery collapses, have to recognize that difficulties may arise in applying pre-determined formulas (Jentoft et al. 1998, Ostrom 2007, de la Torre-Castro and Lindström 2010). While most fisheries scientists acknowledge that promising outcomes can be achieved through applying prescribed tools for institutional reform, empirical evidence suggests that these alone cannot guarantee fisheries sustainability (Ostrom 2008, Powles 2008).

A vivid example of the current state of affairs in the field of institutional reforms for the improvement of fisheries management is the debate about the use of fishing rights in the form of individual fishing quotas (IFQs). This consists of an application of rights-based management, as a regulatory tool in order to prevent overcapitalization and economic inefficiency (see Bromley 2009). Depending on the prioritised objectives for the fishery, the system of IFQs can take various forms, including individual or community quotas, transferable or non transferable quotas for a limited or unlimited period, etc. In all their variants, IFQs provide and allocate the rights holder a certain share of the fishery catch quota. While it has been shown that IFQs can smooth the transition to a lower fishing capacity, the relationship between IFQs and the achievement of conservation objectives remains suggestive but unproven (Gibbs 2008). Iceland, for instance, was among the very first countries that introduced IFQs for its fisheries. This IFQ system has led to substantial increases in the economic efficiency of Iceland's fisheries (Arnason 2005, 2008), but also to quota concentrations, causing a biased distribution of wealth and marginalising fisheries-dependent coastal communities (Pálsson 1995). Alongside the acknowledged benefits from implementing IFQ systems, it is nowadays recognized that "IFQs have often the consequence of driving small fisherman out of business and concentrating the wealth in the hands of a few, large companies" (Arnason et al. 2009:12). Bromley (2009) is strongly critical of the ideas that the use of IFQs will produce a setting in which fishing firms become exemplary stewards and efficient, fishery incomes are maximized and society is better off. He argues that "those who offer this utopian vision are themselves confused about the necessary concepts they deploy to support their optimistic allegories" (Bromley 2009:280).

A further controversial proposal to achieve fisheries sustainability is eco-labelling. Eco-labelling was originally defined simply as "making relevant environmental information available to appropriate consumers" (U.S. EPA 1993 citaed by Wessells et al. 2001:3). Eco-labels are conferred on fishery products that are deemed to entail fewer negative impacts on the environment than functionally or competitively similar products (Deere 1999), with the aim of mitigating the undesirable effects of unregulated markets on fisheries. Eco-labels are intended to induce fishermen and fisheries' managers to comply with prescribed codes of practice in line with sustainable principles (Wessells et al. 2001).

Empirical research has shown that developing countries and small-scale fisheries have been marginalized by eco-labelling schemes. In the South African hake fishery, eco-labelling stirred up internal divisions among the fishermen and entrenched the interests of the two large companies that dominated the industry (Ponte 2008).

In overall terms, the current situation regarding institutions for sustainable fisheries is similar to that of institutions and policies to promote economic growth as described by Dixit (2007):

> *There is no shortage of academic research that identifies institutions and policies to promote economic growth and development …the trouble is that for every paper that endorses one kind of institution or policy, one finds another that makes precisely the opposite claim. Each is written by a prominent economist, and contains impressive arguments and evidence to support the recommendation being made* (Dixit 2007:137).

However, Hauge et al. (2010) present a list of difficulties that impede the implementation of appropriate economic institutions and suggest that these are responsible for the inability of the world's fisheries to attain sustainability. Presenting a rather pessimistic view these authors state:

> *Unfortunately, the nature of fisheries as a common pool resource makes devising an effective governance regime particularly difficult, and thus increases the probability that some of the systemic risks associated with overfishing may eventuate* (Hauge et al. 2010:4).

Box 3. Concerns with eco-labelling raised mostly from developing countries (from Gardiner and Viswanathan 2004:4).

(1) the lack of both transparency and participation by local resource users in the development of product standards;

(2) the potential use of eco-labels by developed countries to protect domestic industries, restrict market access and erode the national competitiveness of those less able to meet foreign labelling and certification standards;

(3) fear of high costs of compliance with transnational or foreign eco-labelling schemes;

(4) the existence of institutional factors that may preclude developing countries from being sufficiently organized to institute effective, independent management schemes that comply with certification criteria; and

(5) the potential that criteria for certification schemes could have undesirable impacts on countries with differing environmental and socio-economic conditions and interests—especially given the wide gaps in income and in environmental conditions between developed and developing countries.

As a reaction to the pragmatic rational choice approaches linked to common-pool resource analysis that have dominated the fisheries management literature, Jentoft (2004) and De la Torre Castro and Lindström (2010) have suggested a new approach that may be called “a broad institutional approach”. These authors emphasize the normative and cultural-cognitive aspects that influence complex human-nature dynamics for the development of institutional arrangements that have the potential to lead to sustainability. Institutional analysis based on a broad institutional approach “seeks to understand institutions as complex and multifaceted, shaping different behavioural outcomes, as well as being shaped and re-shaped by everyday human practice” (de la Torre-Castro and Lindström 2010:77). The ignorance of cultural settings could explain some failures of institutions such as co-management, that have been successful in other settings, in fisheries management (Jentoft et al. 1998). On the other hand, top-down regulations, despite their general importance, are insufficient to promote sound management if they are not backed up by norms and cultural-cognitive institutions (de la Torre-Castro and Lindström 2010). Similarly, historical and socio-political contexts in fisheries (Evans 2009, Fidelman et al. 2012) and local culture, including myths and taboos, have also been schown to have important implications on how marine institutions function (Phillips et al. 2002, Glaser et al. 2011).

Box 4. Difficulties that are responsible for the unsustainable use of fishing resources (from Hauge et al. 2010:4):

- *The number of stakeholders involved in managing fish stocks is usually very large, with stakeholders sometimes being far apart geographically. This makes cooperation, agreeing on and enforcing rules, more difficult.*
- *The size and carrying capacity of the resource system (the oceans) is extremely large. The larger the size of a commons, the more complicated it is to implement and enforce regulations.*
- *Many fish and marine animals migrate over large distances. Fish stocks often do not remain within the jurisdiction of any one state. This means that clearly defined property rights cannot be easily assigned to all fish stocks.*
- *The rates of regeneration of fish stocks vary. Therefore the type of governance regime required will depend on the type of fish stock in question, plus other local environmental factors; environmental factors and natural oscillations also affect the size of fish populations. Exogenous factors may cause fish populations to decline or fisheries to collapse because they influence the survival rate of offspring. These need to be identified and taken into account by any management regime, but it is difficult to do so.*
- *Fishing technologies affect ecosystems in different ways. The type of ecosystem, how fish species assemble and mix plus the type of fishing technology employed all need to be taken into account in determining the best governance regime to promote the sustainability of fish stocks;*
- *Fish stocks can be hard to measure and assess accurately. Inaccurate measurement of stocks can lead to catch quotas being set too high, compared to precautionary means, or too low, compared to what is acceptable for the fishermen. Discards and/or illegal fishing in several fisheries invalidate data and assessments.*

2.4 Institutions and the sustainability of the Peruvian fishery

"…sepa Usted., Sr Ministro, que a los empresarios pesqueros
de tanto vivir en el mar, nos han crecido agallas"[9]
Luis Banchero Rossi

The following sections provide an overview of the Peruvian anchovy fishery and its institutions that are analysed in detail in the three research papers of this thesis.

2.4.1 Overview of the Peruvian fishery

Peru is one of the major fishing countries in the world and provides more than 7% of total world fish catches (FAO 2010). Fishery in Peru is, after mining, the second most important economic sector in terms of foreign currency revenue. In 2010, fisheries contributed to 7.2 % of the Peru's total exports valued at US $2.7 billion. The high production of fish in this region is due to the cold and nutrient rich waters of the Humboldt Current which is a major Eastern Boundary Upwelling Ecosystem (Bakun and Weeks 2008, Chavez et al. 2008, Montecino and Lange 2009)

Marine fisheries in Peru take place all along almost 3100 km of coastline. The country has one of the longest archaeological fisheries records in South America (Reitz 2001, Bakun and Weeks 2008, Chavez et al. 2008). Data recorded from archaeological remains, prove that a fisheries tradition has been present in the area since at least 10,000 years ago and that the diet of prehistoric Peruvian coastal communities relied heavily on marine products (Keefer et al. 1998, Sandweiss et al. 1998, deFrance et al. 2001, Reitz 2001, Sandweiss et al. 2008).

The fisheries sector in Peru currently includes marine and inland fisheries, and aquaculture. According to Peruvian law, the marine fishery sector is divided in two sub-sectors: the industrial or large-scale and the artisanal or small-scale fishery. Any fishing vessel with more than 32.6 m^3 of holding capacity belongs to the large-scale fishery. Fishermen who work for the artisanal sub-sector do not possess a fishing vessel or their vessel is less than 15 m in length and its holding capacity is less than 32.6 m^3. Based on data from 2006, the large-scale or industrial fleet is made up of 1302 licensed vessels, representing a total holding capacity of 222,264 m^3. The artisanal fishery is comprised of 5,950 vessels with a total holding capacity of 45,570 m^3 and 24,150 registered fishers

(Sánchez and Gallo 2009). Both fishing fleets operate in an area along the northeast south Pacific between Lat. 4° and 19° south and within the Peruvian Exclusive Economic Zone (EEZ). The industrial fishery targets pelagic and demersal fish while the artisanal sector targets diverse coastal fish and invertebrates (Table 1).

With the exception of 2010, when pelagic catches where negatively affected by intense warming of the local fishing areas, between 2002 and 2010 the industrial Peruvian pelagic fishery has accounted for 85 to 93 % of the country's total marine landings. This pelagic fishery is mono-specific (Bertrand et al. 2008, Checkley et al. 2009), as 99% of the catches consist of only one species, the Peruvian anchovy or "anchoveta" (*Engraulis ringens*).

The anchovy fishery

The Peruvian anchovy fishery has been described as the largest fishery that has ever existed on earth (Bakun and Weeks 2008, Aranda 2009b) and as the most intense and successful fishery worldwide (Chavez et al. 2008). Historical landings statistics show that the fishery started during the mid 1950s and that catches over the years have fluctuated between 22,000 tonnes in 1983 to more than 11 million tonnes in 1971 and 1994. Current annual catches are around 7 to 8 million tonnes (Barange et al. 2009).

The anchovy fishing fleet has the capacity to land in three days what fishing fleets from countries like Colombia, Germany, Australia, Panama, Poland and Sweden usually land in one year. The amount of anchovy landed daily during the first expansion of the fishery along the 1960s is unfortunately unknown (see Castillo and Mendo 1987), but on 16 November 2005, around thousand fishing vessels broke a new record in this fishery with almost 120 thousand tonnes landed in one day (Ñiquen and Freon 2006).

Peruvian anchovy is a small, short-lived, fast growing surface dweller widely distributed along the coast of South America. Anchovies are generally found in waters with temperatures ranging between 14 and 22 °C, with an average temperature of 19.5 °C, salinity between 34.9 and 35 ppt and depths ranging from the surface down to 70 m (Sánchez and Gallo 2009). In the spring and summer, anchovies concentrate in shoals located within 30 nautical miles offshore from the coast. In autumn and winter, they are dispersed along a broader coastal strip, which can extend as far out as 100 miles from the coast if the water temperature is low. Off Peru, two anchovy population units are recognized: the north-central stock between parallels 3°S and 16˚S; and the southern stock, from 16°S to the southern limit of the Peruvian maritime domain. The north-central anchovy stock is by far the largest (Alheit and Niquen 2004).

Anchovies in Peru are captured by around 1135 purse seiners, of which 562 are steel vessels with more than 110 tonnes of holding capacities, and 573 are made of wood and possess diverse holding capacities between 30 and 110 tonnes. None of these vessels have preservation systems on board and the length of their nets are limited by law to between 220 and 550 m, depending on the vessel holding capacity. The fleet of steel vessels is predominantly owned by large vertically integrated companies, while the fleet of wooden vessels comprises mostly individual boat owners. This fleet employs some 18,000 fishermen (Aranda 2009b).

Table 1. Marine fisheries landings in Peru by subsector between 2002 and 2010.

Subsector	Resources type	Fishing gear	Landings 2004-2010 (t)
Industrial	Pelagic	Purse seine	3.5 to 9 million
	Demersal	Bottom trawl	20 to 60 thousand
Artisanal	Jumbo Flying Squid	Jig gear	150 to 500 thousand
	Other fish + invertebrates	Diverse gears	200 to 300 thousand

Source: Peru Ministry of Production, Online Fishery Statistics 2012.

Anchovy landings are 98% processed to fishmeal and fish oil to be exported at the international market. After strong political pressure from Peruvian non-governmental organizations during the last decade, about 120,000 tonnes of anchovy annually (2% of total landings) are currently canned or frozen for human consumption.

Between 2000 and 2008 Peru has been the largest world's fishmeal producer, exporting between 1.2 and 2.3 million tonnes annually. Peru is followed by Chile, with a yearly production of ca. 1 million tonnes, China, USA, Thailand and Japan, with 300 to 700 thousand tonnes, and Denmark, Norway and Iceland with 150 to 350 thousand tonnes. Primary markets for fishmeal are the manufacturers of feeds for aquaculture (65%), pigs (24%) and poultry (7%). The principal importing markets are in Asia and Europe, where China, Japan, and Germany, respectively, are the most important importing countries. Combined purchases by these three countries account for at least 60 % of total annual production. Fish oil is sold principally for the aquaculture feed market in Europe (Denmark and Norway) and Chile; its richness in long chain omega-3 fatty acids also makes it attractive as a product for direct human consumption. In 2008 fishmeal and fish oil exports reached 1.81 million tonnes, valued at $2.01 billion US dollars, of which fishmeal represented $1.61 billion (FOB basis) and fish oil $397 million (IFFO 2009).

Anchovies are reduced to fishmeal by around 150 processing plants with a processing capacity exceeding 9000 tonnes/hour and at an average conversion rate of 4.5 tonnes of anchovy to one tonne of fishmeal. The anchovy processing industry offers a variety of fishmeal products to the international market. Among the most important fishmeal products are the steam dried fishmeal and “fair average quality” or FAQ fishmeal. Steam dried or “high protein fishmeal” is an improved quality fishmeal principally used to supply the aquaculture market. This fishmeal, commercially known as prime meal, super prime meal or LT-94 (low temperature, 94% digestibility), is made from fresh anchovies, and dried using indirect steam or vacuum dryers. It has protein contents between 68 and 72% and digestibility values between 92 and 94%. Conventional or standard FAQ fishmeal is dried using hot air and has protein contents between 65 and 67%. Processing plants produce mainly the traditional FAQ fishmeal (57% of the total), although with current investments made in new processing machinery and equipment, there is a growing trend towards the production of high quality fishmeal (Sánchez and Gallo 2009).

Around 45 fishing companies are involved in fishmeal processing and marketing. During the last decade there has been an ongoing consolidation process in the fishing industry. In 2009 the seven largest fishing companies in Peru accounted for 50% of the fishing fleet and 78% of the fishmeal production (Galarza 2010)

2.4.2 Institutions and the Peruvian fishery

The Vice-Ministry of Fisheries is the central government authority for fisheries in Peru. It is headed by a Fisheries Vice-minister and since 2001 has been one of the two vice-ministries within the Peruvian Ministry of Production (PRODUCE). The Vice Minister of Fisheries has five sectors under his/her supervision, the General Directorate of: (1) fisheries and processing, (2) aquaculture, (3) artisanal fisheries, (4) fisheries environmental issues, and (5) monitoring, control and surveillance.

Legally, Peruvian fisheries policy and management come under the umbrella of the 1992 Peruvian General Fisheries Law. Its primary aim is to regulate fishing activities in order to promote its sustainable development and ensure its continuity as an important source of food, employment and income. This act has also the aim to ensure the responsible use of marine resources and optimize economic profits in harmony with environmental and biodiversity conservation.

The main objectives of fisheries policy in Peru for the period 2011 to 2016 are as follows (Revista Pesca 2011, online at: http://revistapesca.blogspot.de/2011/09/peru-objetivos-estrategicos-y-politicas.html. Last accessed. 14.04.12)

- To achieve sustainable fisheries based on the best scientific information available and according to principles of ecosystem management
- To strengthen management plans for fishing and aquaculture
- To ensure food security and increment consumption of abundant fish species, especially in areas of extreme poverty
- To protected the quality of the environment
- To manage and develop fisheries competitively
- To organize and develop artisanal fisheries competitively
- To increase Peruvian participation in international fisheries

Industrial fishing in Peru is by law administered through management plans (Planes de Ordenamiento). The anchovy fishery is an exception and is managed in accordance to “provisional fishing regimes”. Since 1994, all management regulations have been promulgated by the Vice-Ministry of Production based on scientific reports from the Peruvian Research Marine Institute (IMARPE). IMARPE is a government scientific agency, officially defined as a specialized technical organization of the Production Ministry. In the case of the anchovy fishery, IMARPE conducts acoustic surveys to assess fish populations at least twice a year together with plankton surveys to estimate fish abundance based on egg and larvae density *in situ*. The Vice-Ministry of Fisheries uses this information to regulate fishing. All managerial decisions are signed by the Minister of Production.

The Peruvian government applies a range of management tools to the anchovy fishery including (Jackson and Shepherd 2010, Evans and Tveteras 2011):

- Closed entry for new fishing boats (by law since 1992). Old vessels can only be replaced by new ones only if they possess an equivalent holding capacity
- Statutory seasons when the fisheries are open and closed, published in the Peruvian official newspaper and online through the Ministry's internet website
- Seasonal total catch limits based on IMARPE's recommendations
- Minimum mesh size of 1/2 inch (13mm) of net aperture
- Spatial restriction allowing only artisanal boats to operate within five miles of the coast
- Temporal restrictions and ports closures when landings report more than 10% of juvenile by-catch
- 24 hour independent recording and reporting of landings at 134 unloading points
- Fines and revoking of licences for breaches of rules

Fishing companies and fishing vessels owners are required to:

- Possess fishing licences to fish within the 200 mile limit
- Present formal declarations of holding capacity
- Pay a fishing fee and a fishing duty to finance monitoring operations, both calculated according to the landings of the previous fishing season
- Install and operate security sealed satellite tracking devices when at sea

There are additional controls for the processing industry:

- Fishmeal plants must possess a working permit conferred by the Ministry of Production and a health certification from Peruvian Technological Institute (*Instituto Tecnológico Pesquero or ITP*)
- Anchovy processing plants are not authorised to receive fish coming from vessels without a valid license or not listed in the Ministries' website. The Ministry of Production will publish every day on its internet web site (www.produce.gob.pe) the name of the vessels authorised to go out fishing as well as the vessels prohibited to do so

- Processing plants must stop receiving fish if there is any failure in their processing equipment as well as in their equipment to protect the environment
- Processing plants are not allowed to operate outside the fishing season

Total Allowable Quotas and the Precautionary Approach[10]

A system of fishing quotas has been applied to regulate the anchovy fishery since 1967. However, during these early years, fishing quotas were not complied with (Roemer 1970). Reasons for breaking the rules were mainly (1) ineffective control of landings (Castillo and Mendo 1987) and (2) the self-doubt expressed in the scientific reports recommending the quotas. Phrases like "*lack of important data constrains our evaluations, however we recommend...*" were commonly used in scientific reports, which were distorted by the press to support the rebellious behaviour by fishermen against fishing quotas.

Fishing quotas for the north-central anchovy stock are currently calculated on the basis of strong scientific evidence. Since 1983, scientific evaluation cruises to gather the information needed to set a fishing quota have been carried out at least once a year (Ganoza et al. 2000). Cruises are used to estimate anchovy biomass (through acoustic methods) and anchovy spawning biomass (through eggs and larvae counts in the water column). Total allowable quotas (TAQs) are then established considering mainly two parameters: the level of recruitment[11] and environmental conditions. As a rule of thumb, the level of exploitation or the amount of fish which can be taken must ensure that at least around 5 million tonnes of spawning biomass remains at sea. This limit of five million is based on historical relations between the anchovy spawning biomass and recruitment as shown in Figure 1. Following a precautionary approach, maintaining a spawning biomass at levels close to five million will not ensure a good recruitment for the next fishing season, but will “for sure” not jeopardise it. This rule of thumb is broken only when environmental conditions indicate the occurrence of an El Niño in Peruvian waters. In that case, fishing is prohibited regardless of the spawning biomass. The second rule of thumb is the assumption that the recruitment level is not high (which could be the case as shown in Fig. 1). Recruitment is estimated to be either be low or medium and, together with environmental conditions, is used to calculate the exploitation level, which is also always set at a ‘low’ or ‘medium’ rate.

Ecosystem-based Management

> *Ecosystem-based Management is an integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers cumulative impacts of different sectors* (McLeod et al. 2005:2).

The anchovy fishery is managed by the Peruvian government based on methods applied for single-species fisheries. There are however some practices within the Peruvian management system which appear to consider and monitor the impacts of the fishery on the ecosystem. Worldwide, the Peruvian Marine Research Institute (IMARPE) is probably one of few governmental scientific agencies to include two departments (‘Sub-directorates’) responsible for carrying out research on top predators: the Sub-directorates of marine mammals and seabirds. These two departments work under the supervision of the Pelagic Resources Department which is in charge of recommending the anchovy quotas. Censuses to monitor populations of seals and guano bird species that feed mainly on anchovies are carried out annually. But more important, although informally, the opinion of the researchers of marine mammals and seabirds is at least solicited when the establishment of an anchovy quota is discussed (M. Arias Schreiber pers. obs.)

Eco- labelling

By definition, eco-labelling is “the practice of marking products with a distinctive label so that consumers know that their manufacture conforms to recognized environmental standards” (Eco-labelling Oxford English Dictionary). The Peruvian anchovy fishery started in 2009 with the procedures to apply for certification from the Marine Stewardship Council (MSC). The certification award is nowadays still in process, but if granted the anchovy fishery will be the first commercial fishery worldwide holding an MSC certification.

Overcapitalization and individual vessel quotas (IVQ)

The last General Fisheries Act of 1982 (Ley General de Pesca No. 25977) mandates that building of new vessels for fishing anchovies requires decommissioning of existing ones (Aranda 2009a). However, during the last two decades, oceanographic favourable conditions at sea followed by a recovered anchovy population and increasing international demand for fishmeal and fish oil has given the privatized fishmeal industry incentives to expand capacity (Tveteras et al. 2011). Despite the regulations, the numbers of anchovy fishing vessels and processing plants expanded during the 1990s. The number of fishing vessels increased from 950 to 1250 between 1986 and 2007 leading, for the second time in the history of the fishery, to a situation of overcapacity (Freon et al. 2008, Evans and Tveteras 2011).

Freon et al. (2008), estimated the anchovy fleet overcapacity, expressed as the proportion of unemployed present capacity, at 72% and processing overcapacity at 89%. Based on current average anchovy biomass and landings, Paredes and Gutierrez (2008), also estimated the anchovy fisheries overcapacity in 2007 and concluded that fishing fleet overcapacity was between 2.5 and 4.6 times its optimal size. For fishmeal and fish oil processing, capacity was calculated to be 3 to 5 times its optimal size. This overcapacity promoted what in fisheries management is known as the “race for fish”, i.e. behaviour aiming to capture as much fish as fast as possible during the fishing season. An effect of the “race for fish” is that the number of fishing days required to achieve a fixed TAQ is reduced. Accordingly, the annual number of fishing days in the Peruvian anchovy fishery decreased from 336 in 1987 to 49 in 2006 (Freon et al. 2008).

Introduced formally by Legislative Decree Nr. 1084 of June 2008, a management system of Individual Vessel Quotas (IVQ), locally referred to as Maximum Catch Limits per Vessel (MCLV), came into effect in January 2009 (Tveteras et al. 2011). The fix percentage of the overall allowable catch assigned to each vessel is established for each fishing season on the basis of the vessel's holding capacity and its average historical landings. Vessel quotas are a percentage of the TAC recommended by IMARPE for each fishing season. As a result of the new management system, the number of fishing days has increased from 52 in 2008 to 189 in 2009; and appears to have put an end to the "race for fish" in the anchovy fishery (Galarza 2010). Although it is still early to evaluate the impacts of the new IVQ system, the new system seems to have increased profitability of the fisheries by providing a more predictable operating environment. Knowing beforehand how much fish will be landed provides incentives to improve the production system and subsequently the quality of fish landings. Better quality landed anchovies allow investment in value-added production such as high quality fishmeal or human consumption products (canned or frozen anchovies) (Tveteras et al. 2011). The largest integrated fishmeal company in Peru reported for example that its share of steam dried (i.e., high-quality) fishmeal increased from 51% in 2008 to 76% in 2009, while its share of Fair and Average Quality (FAQ) fishmeal decreased correspondingly from 49% to 24% the same two years (Evans and Tveteras 2011). Another recorded impact of the implementation of the IVQ system has been an increase in the price of landed anchovy by almost 40% from 2008 to 2009 (Galarza 2010). Independent vessel owners who had a quota were able to get increased prices from the fishmeal companies for their catches. This shift in the balance of price negotiation power from fishmeal companies to vessel owners was largely unexpected. In this new situation, artisanal vessels that have quota permits to catch anchovies only for human consumption are sometimes caught illegally supplying fishmeal processing plants with raw material (Tveteras et al. 2011).

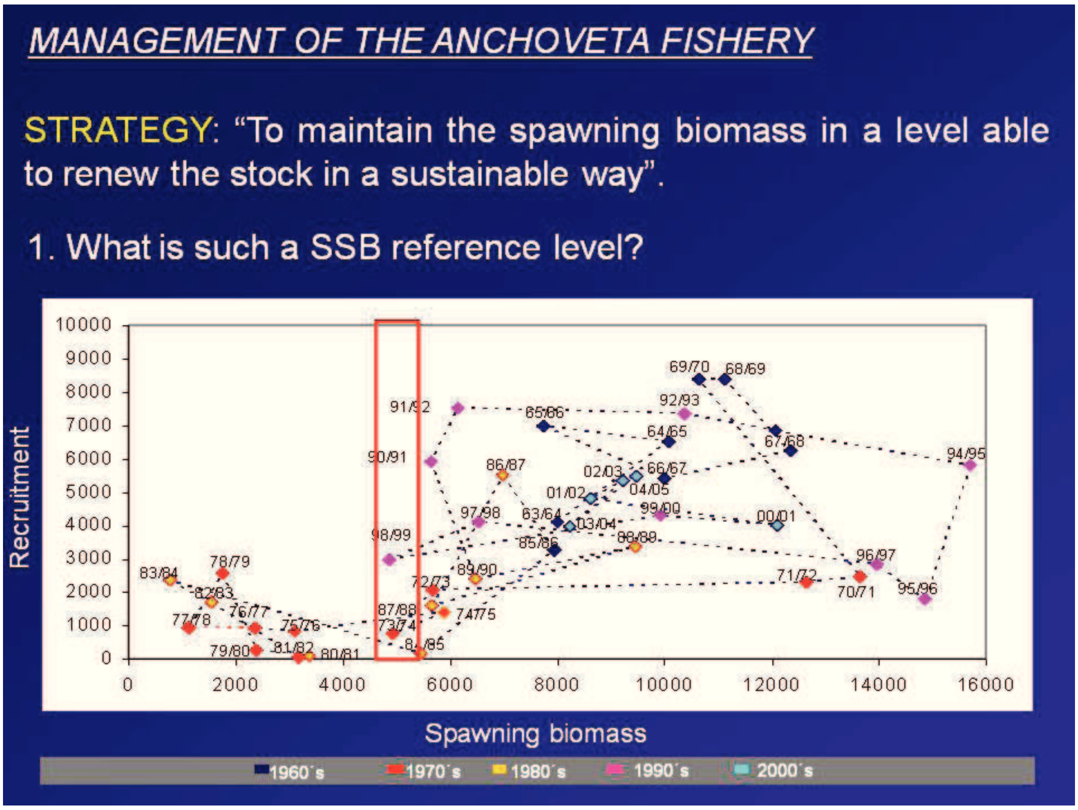

Figure 1. Section of a PowerPoint presentation made by the scientific personnel at IMARPE to explain the rationale for maintaining spawning biomass around five million tonnes based on historical spawning biomass data versus recruitment of the Peruvian north-central anchovy stock. This PowerPoint slide was presented to the Fisheries National Society (SNP) in November 2008 (Source: Erich Diaz, IMARPE)

3. Concluding remarks

This research confirms the central importance of institutions in achieving desirable social-ecological outcomes, in this case the sustainability of fishery landings. The results qualify some conclusions commonly drawn in fisheries research regarding the relation between institutions to promote sustainability. Specifically:

- The establishment of property rights in the form of quota shares was not an indispensable institution to achieve sustainable landings in the case of the Peruvian anchovy fishery. The enforcement of scientifically based precautionary fishing quotas was found to be an effective substitute for economic incentives to guide the behaviour of resource users.
- Overcapitalization in the Peruvian anchovy, especially in the case of processing factories was, at least partially, a strategy to cope with environmental variability and fish migration. Reasons to overcapitalize were not always the product of irresponsible economic decisions.
- The centralized top-down management regime of the anchovy fishery did not hamper sustainability. A top-down regime of this sort may be the most appropriate institution for large-scale commercial fisheries, where fishing companies aim to maximize profits and cooperation might be difficult to implement.
- Flexible, adaptive and rapid management together with robust monitoring of the resource and resource users played a crucial role in achieving sustainable landings in Peru. Rapid management seems to be especially relevant for fisheries targeting small pelagic species, in accordance with suggestions to promote the fitness between institutional and ecological settings.

This study has gone some way towards enhancing our understanding of the role of a variety of other institutions. In this regard, the study concludes that:

- Formal institutions in particular Peruvian Fisheries Acts provided the basis for sustainable management by clearly establishing user boundaries, i.e. determining who is permitted to participate in the fishery, considering both national and international resource users.

- Base-level management to deal with sustainable landings was left to secondary legislation that evolved in response to different considerations including organizational functionality, the legitimacy of management agencies, advances in science, technology and innovation. Management agencies enacting secondary legislation also demonstrated learning capacity including the ability to learn from experience.
- The development of institutions in the Peruvian anchovy fishery was significantly influenced by environmental variability and uncertainty; however physical system characteristics were not only a source of restrictions but also provide opportunities such us the legitimacy of the scientific agency.

The results of this research support the idea that institutional arrangements develop as responses to events occurring in the social and biophysical settings. They have also shown that not all institutions that have been identified as relevant for the success of community-based fisheries management played a role in a state regulated national level fisheries. Further research on institutions for sustainable national-level resources is required to improve understanding of this key issue for the management of the world's fisheries.

In addition, the effects of export markets, the legitimacy of research agencies, the individual contribution of certain decision makers along the history of the fishery; the resource user's ability to learn from experience, are the most conspicuous examples of institutions that play an important role in this fishery. Further investigation into these topics is strongly recommended.

This research also gives an account of and explores the reasons behind recent efforts to prescribe standardized institutional arrangements to overcome fisheries overexploitation. It highlights that institutions develop in context specific directions and what is a solution in one fishery could have unexpected negative consequences in others. These findings suggest that fisheries sustainability will not be achieved by relying on one or two institutional changes. The case of the Peruvian anchovy fishery indicates that the achievement of sustainable landings has been the culmination of a long, and continuing historical process of transformation. The study identifies no one organization, rule, belief, custom or other type of institution that can explain the current situation of this Peruvian fishery.

Taken together, these results also suggest that, rather than concentrating on a particular set of mostly economic, institutions; a broad institutional approach is a more appropriate tool to better understand and manage the complexity of fisheries systems. In doing so, the attributes of both the resources and the resource users should be considered. In regard to the resources, their abundance, rate of renewal, distribution boundaries, etc; but also their cultural value and the local ecological knowledge of the resource should be regarded as influential settings. The management of pelagic fish, for example, clearly needs extensive monitoring linked to adaptive and rapid management. This simple rule has been institutionalized in the Peruvian anchovy fishery (see Box 1). The rule together with appropriate modern technology seems to be a crucial reform in the trajectory towards its current sustainable landings.

Box 5. The institutionalized rule: rapid and adaptive management

"*… I've finally understood the trick for managing anchovy. Since the anchovy is quick, and adapts rapidly to the conditions at sea and only lives three years, its management has to be rapid too*" (M. Ñiquen, Director of the Pelagic Resources Research Department at IMARPE, October 2007).

"*…the anchovy fishery is the only Peruvian fishery not managed on the basis of Management Plans but on the basis of so-called Provisional Management Regimes"* (R. Gallo, Vice-Ministry of Fisheries, November 2008).

"…the extraction of anchovy has to be rapid because the anchovy you don't catch today, you'll never catch" (J. Sarmiento, Fishing Company Pesquera Austral, November 2008).

In the case of the resource users, the need for a broad approach is even more obvious. Institutions that work for a fishery in which fishermen livelihoods depend on their daily catch, do not necessarily work for a fishery in which transnational fishing companies work to maximise wealth. As shown by this research, the influence of the state in the latter case is central. If fisheries sustainability relies on institutional reforms, in the case of commercial industrial fisheries, these reforms should be kept under state control in order to balance different and conflicting interests.

Notes

[1] Transdisciplinary research is defined here as a holistic type of research that includes the intersection of various disciplines from the natural and social sciences, and also stakeholders knowledge.

[2] Fisheries collapses considered in this study are an effect of overfishing; it is acknowledged however, that depletion of fish stocks cannot be attributed to fishing alone. Natural driven ecosystem regime shifts as well as anthropogenic sources like pollution, habitat destruction and human introduced invasive species in ecosystems also have an impact upon fish populations.

[3] Rules are defined as "*potentially linguistic entities that refer to prescriptions commonly known and used by a set of participants to order repetitive, interdependent relationships. Prescriptions refer to which actions (or states of the world) are required, prohibited, or permitted*" (Ostrom 1986:5).

[4] Ostrom explains the term SES as follows: "*All humanly used resources are embedded in complex, social-ecological systems (SESs). SESs are composed of multiple subsystems and internal variables within these subsystems at multiple levels analogous to organisms composed of organs, organs of tissues, tissues of cells, cells of proteins, etc"* (Ostrom 2009b:419).

[5] Ecological economics is an interdisciplinary field of academic research that aims to address the interactions and co-evolution of human economies embedded in natural ecosystems over time and space (Xepapadeas 2008). Much of what ecological economists do involves understanding sustainability in the context of preserving natural capital based on economic, rational approaches.

[6] see Coase. (1937), The Theory of the Firm, *Economica,* vol. 4, 386-405; Coase (1960), The Problem of Social Cost, *Journal of Law and Economics,* vol. 3, 1-44.

[7] Resource regime is defined as "*consisting two main points: (1) The property regime that governs the use and the transfer of the right to a resource, (2) The rules that govern transactions resulting from the use of the resource. There are four kinds of property regimes: private property, common property, state property and open access. While the three first regimes are varieties of ownership, in the latter there is no property – everybody has the right to use the resource"*(Vatn 2005:260).

[8] Scientism is the idea that "*the approaches and attributes of the natural sciences constitute the proper model of guiding other actions; it sequesters and mocks reasoned dialogue and seeks to trump reason-giving with reductionist truth claims* (Bromley 2007:680).

[9] Unfortunately a straightforward translation of this sentence to English is problematic. The literary translation is: "*You should know, respectable Minster, that anchovy business people in Peru have grown gills, from spending too much time at sea*". To "*have gills"* in Spanish means "*to have the guts for doing something*".

[10] According to FAO, the precautionary approach for fisheries is defined as: *A set of agreed cost-effective measures and actions, including future courses of action, which ensures prudent foresight, reduces or avoids risk to the resources, the environment, and the people, to the extent possible, taking explicitly into account existing uncertainties and the potential consequences of being wrong* (FAO 1996:4)

[11] In fisheries biology, recruitment can be defined as the amount of fish added to the exploitable stock each year due to growth and/or migration into the fishing area.
Source: http://www.nefsc.noaa.gov/fbi/age-man/gl

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ABSTRACT

Landings statistics of the Peruvian anchovy fishery show that the fishery went through a phase of explosive and uncontrolled growth from its establishment in the mid-fifties until its collapse in 1972. After the collapse, a second phase from 1973 to 1984 was characterized by unfavorable warm ocean conditions and low catches. A third phase, from 1984 to the present, with propitious ocean-environmental conditions and modern governance, can be further divided into a controlled growth period (1985–1994) and a sustainable landings' period (1995 to present). The most recent period of the third phase has enabled the fishery to maintain its catches and be labeled as one of the most sustainable fisheries worldwide. This article highlights the evolution of the legal system that provides for the current sustainable landings and governance of this fishery. Results show that General Fisheries Acts were enacted independently of failures to sustain anchovy landings. The three Peruvian Fisheries Acts were a reflection of broader national socio-political changes and were enacted mainly to define the role of the state and private investment and to delimit foreign involvement in the fishery industry. By contrast, the enactment of secondary legislation to control quotas and fishing seasons increased as the fishery moved towards stable landings. During this phase, enacted secondary legislation showed also a clear peak during strong positive sea surface anomalies driven by the El Niño Southern Oscillation (ENSO) 1997–1998, providing evidence of rapid adaptive management. The role of Fisheries Acts in defining access rights at the national level from a multilevel governance approach is discussed and further key elements that contributed to the transition towards sustainability are suggested.

1. Introduction

Nearly one in four fisheries has collapsed during the period 1950–2000 with no apparent sign of improvement in this trend [1]. To confront these crises in fisheries and improve the management of fish stocks, twenty-first century approaches have recognized the importance of complex adaptive social–ecological system concepts [2–7]. However analysis of linked social and ecological processes has revealed shortcomings of sustainable resource management based on purely ecological and economic foundations [8]. During the last decade, a multi- and transdisciplinary perspective has been deemed necessary if fisheries are to become sustainable [9–13]. The role of fisheries governance, based on both legal and informal institutions, in the attainment of sustainable fisheries is one of the new research areas identified. An empirical approach to dealing with some of these issues, is to analyze legal instruments employed in successful cases of fisheries management that have evaded the conventional pattern of overfishing and non-recovery after a collapse [7,13–16].

One exceptional contemporary example of successful fisheries governance system is the Peruvian commercial anchovy fishery. This fishery represents almost 10% of worldwide marine fisheries landings [17] and 80% of all Peruvian landings [18]. It has been described as the largest mono-specific fishery that has ever existed on earth [19,20] and as the most intense and successful fishery worldwide [21]. Recently the fishery has allowed Peru to be placed first in a report ranking 53 marine countries by the sustainability of their fisheries [22].

Current annual anchovy catches by around 1200 purse seine vessels, usually operating within 60 miles from the coast, are around 7–8 million tonnes [23]. This fishery represents at least 7% of Peru's total foreign exchange earnings and employs some 18,000 fishermen [24]. About 140 factories process anchovy into fishmeal and fish oil for export to the international market. In 2008 fishmeal and fish oil exports reached 1.81 million tonnes, valued at US $2.01 billion, of which fishmeal represented $1.61 billion (FOB basis) and fish oil $397 million [25].

Like most pelagic fisheries, since its establishment, the anchovy fishery has been highly vulnerable to drastic natural stock fluctuations, due to the sensitivity of these fish species to ocean-climate variability [26]. Historical anchovy landings show significant variation between years, mostly due to inter-annual climate variability,

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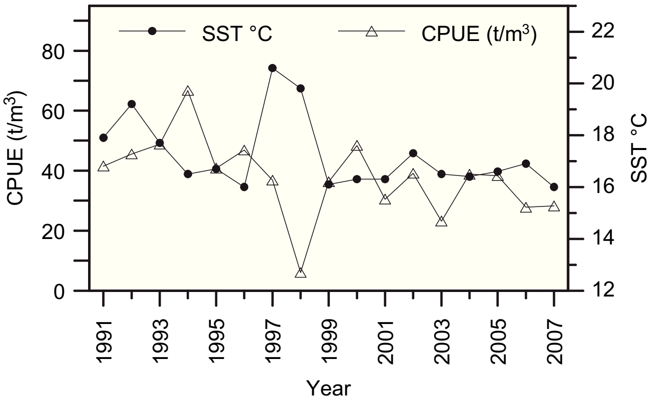

Fig. 1. Catch per unit effort of anchovies and average sea surface temperature (SST) in northern Peru for the period 1995 and 2007. Impacts of the ENSO 1997–1998 on the fisheries and the environment are shown.
(*Source*: IMARPE).

of which the warm phase of ENSO or El Niño is the most critical component [27,28]. On top of inter-annual variation, inter-decadal ecosystem regime shifts, caused by lasting periods of warm or cold sea temperature anomalies have been also identified [29–31]. These anomalies are related to the approach or retreat of warm subtropical oceanic waters to the coast of Peru and Chile. Dramatic decreases in anchovy landings registered in 1972–1973, 1982–1983 and 1997–1998 have been attributed to the impacts of severe ENSO occurrences [27,28] (although the 1972–1973 decline was most likely caused by a combination of overfishing and ENSO conditions [32,33,37,55]); while, natural inter-decadal ecosystem regime shifts produce switches from anchovy dominated to sardine dominated configurations, reflected in the long-term historical landings trends of the fishery [28–30].

Thus a learning process has occurred, and anchovy fishery policies have developed from a highly fragmented, reactive decision making system, ignorant of resource management issues, during the first two decades of the fishery [35–37], to the current governance system that is able to cope with at least inter-annual variability [25,38] and ensure the ecological and economic sustainability of the fishery. This last governance system or resource regime has allowed annual anchovy landings during non-ENSO years, to stabilize between 23 and 48 t/m^3 annual catch per unit effort (CPUE), expressed in tonnes of anchovy per total fleet holding capacity (Fig. 1); and between six and ten million tonnes of catches from 1995 to the present (Fig. 2a).

This article explores the evolution of the legal system that provides the basis for the current sustainable landings and governance of the anchovy fishery. Based on analysis of historical legal material, fishery statistics and environmental data, the article aims to investigate both the role played by fisheries laws and possible factors influencing its development, and the contribution of other key elements that contributed to the transition towards sustainability. First, the section with Materials and methods and the current anchovy fishery management as a background information is described. The Results section presents the relation between law and fisheries landings development, and the structure and content of the principles of the three Peruvian Fisheries Acts are examined. The role of secondary legislation[1] establishing quotas and temporal/spatial fishing restrictions is also considered in this section. Following Winter's analytical framework for fisheries laws originally named the "legal clinic for fisheries" [12, p. 319], the Peruvian acts are reviewed in the light of available literature on sustainable fisheries law. The Discussion section suggests key legal and non-legal institutional elements that contribute to sustainable fisheries landings from a multilevel governance perspective. This section also briefly discusses the use of Winter's analytical framework; and the tension between the need for a degree of legal certainty that simultaneously provides for adaptability and flexibility in governance of natural resources (see [39]). The article finishes with a section with Conclusions and a final remark.

2. Materials and methods

Legal material, from the establishment of the anchovy fishery until 2007, was collected and reviewed together with fishery statistics and environmental data from the Peruvian coast. Legal material included principal legislation prior to the enactment of the first General Fishery Act in 1971, the three General Fisheries Acts and their implementing regulations; and a historical database on the enactment of secondary legislation setting up quotas and limiting fishing effort through closed seasons, areas and prohibitions to fish during some days of the week. This database consisted of law enacted between 1965 and 2007. After 2007, the establishment of a system of individual vessel quotas for the anchovy fishery radically changed the regulation of management, and the situation after 2007 is not covered by this paper.

Oceanographic data consisted of sea surface temperature (SST) anomalies and occurrence of strong ENSOs, while fishery data included annual landings, fishing fleet and processing capacity of fishmeal factories. These data series covered the period between 1960 and 2007.

To explore the relation between the developments of legal instruments and the fishery transition towards sustainability, the enactment of fisheries acts was plotted against fishery landings and the occurrence of strong ENSO events. Further, numbers of enacted secondary legislation were plotted also against landings, ENSOs and SST anomalies. In both cases, oceanographic data (strong ENSO occurrences and SST anomalies) were used to clarify the environmental influence on the fishery and filter our visualization of possible legal impacts.

Structure and principles ("basic norms") from the three fisheries acts were compared and a semi-quantitative application of Winter's analytical framework [12] was performed. This framework consists of a list of 60 questions on topics to be covered by a national fishing law, which enables a diagnosis of the fitness of this law for the regulation and management of a sustainable fishery. To analyze the potential management failures of the Peruvian Fishery Acts, a ranking point system between three and zero was adapted to the framework. The ranking system assigned points to each answer of the list according to the following scale: three points: the content of the law covers this topic "clearly or in depth"; two points: the law covers this topic "basically"; one point: the law does not cover this topic at all; and zero point when the question was not applicable. Under this ranking system a law that ensures good practices of fisheries management should score between 120 and 180 points (two and three points times sixty questions, respectively).

2.1. Background setting—current management of the Peruvian anchovy fishery

Government management and control of fisheries in Peru is the responsibility of the Vice-Ministry of Fisheries in the Ministry

[1] Secondary or delegated legislation refers to law made by an executive authority under powers given to them by primary legislation. For the Peruvian legal system, executive acts consist of five different administrative dispositions, including in order of precedence: Supreme Decrees, Supreme Resolutions, Ministerial Resolutions, Directorate Resolutions, and a fifth level containing several miscellaneous written regulations.

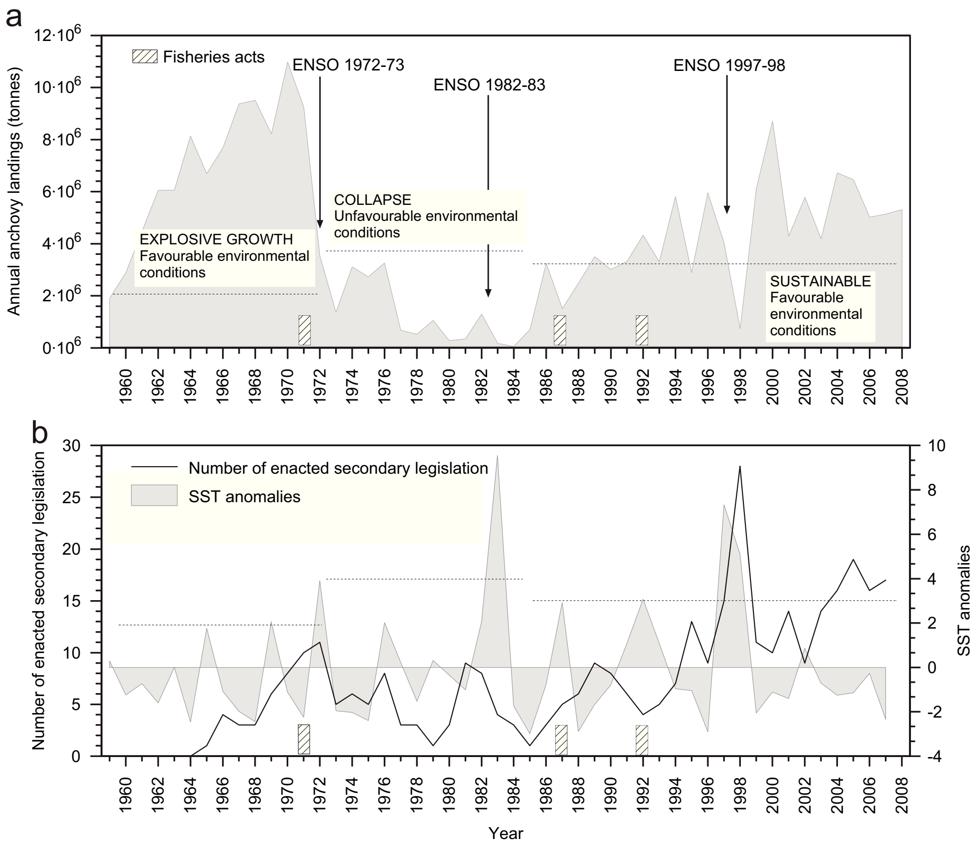

Fig. 2. (a) Historical annual anchovy landings, fisheries phases, strong ENSO events and enactment of General Peruvian Fisheries Acts and (b) number of enacted secondary legislation regulating anchovy quotas and close seasons, versus sea surface temperature anomalies in northern Peru between 1959 and 2007.

of Production (PRODUCE, by its Spanish acronym).[2] Within the Vice-Ministry of Fisheries, the General Directorates of Fishing Extraction and Processing, and Monitoring, Control and Surveillance share responsibility for anchovy fisheries management. Both offices are kept informed and advised by the Peruvian Marine Research Institute (IMARPE), whose institutional objective is to provide the scientific basis for the sustainable management of marine resources.

The Peruvian anchovy is a small, short-lived, fast growing pelagic fish widely distributed along the coast of South America. Off Peru, two population units are recognized: the north-central stock between parallels 3°S and 15°S; and the southern stock, from 15°S to the southern limit of the Peruvian maritime domain [40,55]. The north-central anchovy stock is by far the larger [23]. The government applies two different management schemes for the northern-central and the southern stock, the latter being exploited simultaneously by Peru and Chile.

Fishing of the northern stock is closed twice annually, during the austral summer and winter, in order to protect fish spawning peaks and recruitment periods respectively. Since 1983, one to four surveys to assess the abundance and spatial distribution of pelagic fish populations have been carried out each year by IMARPE [41]. The Total Allowable Catch (TAC) for both the north-central and southern anchovy stocks is estimated based on the results of these surveys. PRODUCE publishes TACs for each fishing season based on current biomass estimations and drawing on the results of biological and oceanographic monitoring carried out by IMARPE personnel simultaneously at almost 100 landing sites. During 2009 for example, a TAC of 2 million tonnes was established for the second fishing season of the northern-central stock (Ministerial Resolution 446-2009-PRODUCE), based on IMARPE's biomass estimation of 6.7 million tonnes [42]. Landings for this season were 1.9 million tonnes [43]. Temporary closures of fishing areas, for a minimum of three days, are also imposed when the reported presence of juveniles (fish length less than 12 cm) exceeds 10% of total landings. Reports of catches and lengths come from real-time verification of landings carried out by IMARPE and dispatched daily to the Vice-Ministry. Based on these daily reports, once the TAC has been reached, the Ministry of Production orders the closure of the fishing season, banning not only anchovy fishing and landings but also fishmeal processing. In the case of the southern anchovy stock, although some efforts have been made in the past to coordinate its management in cooperation with Chilean authorities, usually no TAC is applied and the fishing season is open all year around.

Measures to control fishing effort by reducing or limiting the number of anchovy vessels have been enacted by secondary legislation since 1971, and in 1992 the most recent General Fishing Law stopped the issue of new licenses. Licenses for new fishing vessels are authorized only to replace broken-up units, taking care that total holding capacity remains the same.

On a daily basis during the fishing season, the Vice-Ministry of Fisheries publishes online the list of vessels with authorization to fish for anchovy, as well as the ones that are prohibited to do so. Fishmeal processing plants also need to be certified by the Ministry and are not allowed to receive catches from unauthorized vessels or from the artisanal fleet (vessels with less than 30 tonnes of holding capacity). Further regulations to manage the fisheries include a ban on the use of purse seines with mesh sizes

[2] In July 2002 the Peruvian congress decreed Law 27799 reorganizing the nation's administration system and merging the Industry and Fisheries Ministries in a single institution. This new institution is named Production Ministry or PRODUCE and the highest fisheries governing agency inside it is the Vice-Ministry of Fisheries.

Table 1
Summary of legal instruments to regulate the Peruvian anchovy fishery before enactment of the first General Fisheries Act.

Year	Legal instrument	Issue
1961	Law Nr. 13825	Apply 14% tax on fishmeal exports
1962	Decree Law 14195	Regulating installment of fishmeal factories
	Decree Law 14228	Fishmeal exports allowed only through cooperatives
1963	Supreme Decree 16	Setting up the National Fisheries Council
	Supreme Decree 18	Establishing exporting quotas and a new licenses' system for fishmeal processing plants
	Supreme Decree 77	Officially recognizing the Peruvian Fishmeal Consortium
1964	Law Nr. 15048	New tax system for fishmeal exports
	Supreme Decree 7	Establishment of Peruvian Marine Research Institute
1965	Supreme Decree 05-65	First anchovy closed season
1967	Law Nr. 16694	Law for Fisheries Promotion
1968	Law Nr. 17403	Setting import free taxes for fishmeal equipment
1969	Decree Law 180261	Establishment of Ministry of Fisheries
1970	Decree Law 18196	Establishment of Fisheries Development Fund
	Decree Law 18253	Establishment of State Company for commercialization of fishmeal and fish oil

smaller than half an inch (13 mm), and the obligation for all anchovy vessels to carry onboard sealed satellite positioning systems. Carrying out more than one fishing trip per vessel per day and fishing the northern anchovy stock within 5 miles of the coast are both prohibited.

Since 2004, monitoring and control of landings and of compliance with fishery regulations have been carried out by an independent Swiss company (SGS), which records landings 24 h a day at 134 unloading points. The costs of uploading and landing inspections are met by the fishing industry through a system of payments equivalent to 1.40 US dollars per metric tonne of landed anchovy. The ban on fishing within five miles of the coast is controlled by the General Monitoring, Control and Surveillance Directorate using a Satellite Monitoring System (*Sistema de Seguimiento Satelital* or SISESAT).

A management system of Individual Vessel Quotas (IVQ), locally referred to as Maximum Catch Limits per Vessel (MCLV), was established in July 2008 (Legislative Decree 1086) and is currently being implemented for both anchovy stocks. The fixed percentage of the overall allowable catch assigned to each vessel is established for each fishing season on the basis of the vessel's holding capacity and its average historical landings between 2004 and 2007. Vessel quotas are a percentage of the TAC recommended by IMARPE for each fishing season.

3. Results

3.1. Fisheries acts and fishing phases

Starting in the mid-fifties, the anchovy fishery in Peru went through a first phase of explosive and uncontrolled growth coupled with favorable ocean conditions, until its collapse in 1972 (Fig. 2a). By 1960, the annual catch reached 2 million tonnes of anchovies and since then three General Peruvian Fisheries Acts have been enacted in 1971 (Decree Law[3] 18810), 1987 (Law 24790) and 1992 (Decree Law 25977). Regulations before the First Act were directed towards taxing profits and the assignment of competences to new fishing agencies. Table 1 summarizes the principal fisheries regulations enacted by the Peruvian government during the phase of explosive and uncontrolled growth (period 1959–1971).

[3] Decree Laws are laws promulgated by the executive in *de facto* exercise of the legislative prerogative.

At the end of the first phase, a revolutionary military left-wing government took office establishing the Ministry of Fisheries and enacting the First General Fisheries Act. The principal motivation was the government's desire to exercise more direct control over important sectors of the economy, especially those in the hands of strong private groups or with substantial foreign capital investment [36].[4]

Following the anchovy collapse, a second phase between 1973 and 1984 was characterized by an environmental regime shift with unfavorable warm water conditions and low catches. No fisheries acts were enacted during this phase.

A third phase from 1984 to the present, characterized by propitious environmental conditions and modern management has enabled the anchovy fishery to maintain its catches and be sustainable. This third period can be further divided yet into a growth period (1985–1994) and a sustainable period (1995 to present). During the growth period the second and third General Fisheries Acts were enacted.

3.2. Structure and principles of fisheries acts

The first General Fishery Act was organized in 12 sections and 129 articles, whiles the second and third consisted of 10 and 12 sections and 112 and 90 articles, respectively. As shown in Table 2, all the three Fisheries Acts followed basically the same structure with some minor changes. The section on fishing communities and foreign capital guidelines was left out following the more liberal policies of the last acts. On the other hand, sections regarding aquaculture and fishing by foreign flag vessels had to be added according to the development of these fishing activities in Peru. Institutional coordination was included as a chapter in the second section of the First and Second Act, but was included as a section in the Third Act. Artisanal fishing was almost excluded in the First Act (Article 26 allowed only Peruvian fishers and vessels to have access to artisanal fisheries). This fishery was extensively regulated by the Second Act (Section 4, Chapter 6 of the act, plus 16 articles in the respective implementation regulation) and was devoted an entire section in the Third Act.

Basic norms or principles of the three Fisheries Acts are presented in Table 3. According to the three laws, marine resources from the coastline and within 200 nautical miles of the coast are the property of the Peruvian state. This jurisdiction was

[4] By 1971, the fishing industry was responsible for 35% of the total foreign currency revenue of Peru and only four fishing companies were annually producing more than 100,000 tonnes of fishmeal, from which two were foreign capital enterprises [45].

Table 2
Comparison of structure between the three General Peruvian Fisheries Acts from 1971, 1987 and 1992.

First Fishery Act	Second Fishery Act	Third Fishery Act
1. Basic norms	1. Basic norms	1. Basic rules
2. The fishing sector	2. The fishing sector	2. Fisheries management
3. The fishing process	3. Aquaculture	3. Fisheries practices
4. Fishing rights	4. Fishing practices	4. Artisanal fishing
5. Fishing incentives system	5. Fishing rights and the fishing communities	5. Aquaculture
6. Foreign capital guidelines	6. Procedures	6. Concessions, authorizations, permits and fishing licenses
7. Fishing communities	7. Infringement and sanctions	7. Fishing by foreign flag vessels
8. Authorizations, permits, licenses and concessions	8. Contracts and fishing records	8. Fishing general records
9. Bans and sanctions	9. Fishing incentives system	9. Fishing incentives system
10. Contracts fishing and records	10. Special, complementary, transitory provisions	10. Institutional coordination
11. Final provisions		11. Bans, infringements and sanctions
		12. Transitory and final provisions

Table 3
Comparison of principles or "basic norms" between the three General Peruvian Fisheries Acts.

Basic norm	Fishery Act (year)	Statement
Marine resources ownership	1971	State domain—from the coastline and within 200 miles.
	1987	State property—from the coastline and within 200 miles.
	1992	Nation assets—from the coastline and within 200 miles.
National fisheries tasks	1971	Integral use of marine resources as a public good and for the interest of society.
	1987	Rational exploitation of marine resources and aquaculture; to address mainly direct human consumption fisheries.
	1992	Source of food and employment ensuring responsible use of marine resources.
State role	1971	To manage marine resources promoting, supervising and controlling fishing activities.
	1987	To assess, protect, plan and manage marine resources considering social welfare.
	1992	To regulate integral management and rational exploitation of marine resources.
Use rights	1971	The state promotes maximum national involvement deciding limits and procedures for foreign participation.
	1987	The state promotes the involvement of any corporate or company organization concordant with the democratic principles of the national constitution. It encourages the contribution of national investment to the industry, while foreign investment remains subject to pertinent Peruvian legislation.
	1992	The state promotes ample involvement and encourages foreign investment in the fisheries sector subject to pertinent Peruvian legislation.
Economic units	1971	Any person working for a fishing company providing capital or labor represents one single economic unit. The state promotes their involvement in the company's property, management and profits.
	1987	Article omitted.
	1992	Article omitted.
Marine resources exploitation	1971	Involves research, withdrawal, processing and marketing phases.
	1987	Involves research, withdrawal, processing, marketing and services phases. It is carried out after obtaining a granted license from the Fisheries Ministry.
	1992	It is recognized to be a permanent but an irregular occupation given the random nature of marine resources.
Fisheries Ministry role	1971	To regulate, guide, and control marine resources exploitation to ensure species conservation, economic efficiency and maximize social welfare.
	1987	To be responsible for the management of marine resources and guide fishing policies.
	1992	To decide according to available scientific and socio-economic information on the management, quotas, fishing bans, fishing gears and further management tools to ensure protection and rational exploitation of marine resources.

underpinned by the "Declaration of the 200 nautical mile Maritime Zone", jointly proclaimed and signed by Chile, Peru and Ecuador at the First Conference on the Exploitation and Conservation of the Maritime Resources of the South Pacific in August 1952.

It is worth noting here also that the term "rational exploitation" is a synonym for "sustainable use" and was widely used in Peru before the latter term gained worldwide currency after the Rio Declaration in 1992. This term is still often used commonly to avoid what are regarded as unsuitable Spanish translations of the word "sustainable" ("*sostenible*" or "*sustentable*"). Thus rational exploitation was understood by the authors of the First Act to mean exploiting natural resources in a way that ensures it can be maintained in the future. The contrary term "irrational exploitation" is frequently used to describe the unsustainable harvest of Peruvian guano (seabird's excrement used as a fertilizer) during the 19th century. The overexploitation of guano led to the establishment in 1909 of the national Guano Administration Company with the aim of managing and restoring guano production. This represents one of the first and most effective examples of sustainable exploitation of a natural resource undertaken by a government [50] and has had a profound influence on subsequent natural resource legislation, including the three fisheries acts.

With the exception of a basic norm related to use or access rights, minor differences are shown between most of the principles stated by the three acts. Access rights were a reflection of broader national socio-political changes and were intended to regulate the role of the state and private investment and to delimit foreign involvement in the fishery industry. The first Peruvian Fisheries Act was enacted in March 1971 under a dictatorial military government. This regime (1968–1975) was characterized by left-leaning policies and was driven by a desire for radical structural economic, political and social change to give justice to the poor of Peru. It nationalized entire industries, expropriating companies to consolidate them into single industry-wide government-run entities. The aim was to increase government control over economic activities by enforcing the monopolistic status of these entities and preventing any private and foreign activity in those sectors. This government brought to an end a long Peruvian tradition of limited government involvement in economic and social development and at the same time altered the relative political influence of those participating in policymaking [36]. The 1971 General Fishery Act was a reflection of the socio-political changes introduced during this period. The Act promotes maximum national involvement in the fishery sector, setting limits on foreign participation. The law aims to "obtain the optimal development of the Peruvian fisheries compatible to the rational exploitation of marine resources". The first Fisheries Act has the following specific objectives:

a. Optimal use of marine resources.
b. High productivity.
c. Improved nutritional status of the Peruvian population.
d. Fair distribution of economic income obtained from the exploitation of marine resources between the state, labor and capital.

Among the purposes of the Fisheries Ministry, the fishing industry reorganization to permit fair participation by workers in the management of the industry's organization and the distribution of profits, the reduction of salary differentials among workers in the industry, in accordance with the then government's revolutionary policies, and the promotion of a "peruanization" of the fishing industry were established.

For the pelagic fishery, the main changes introduced by this law were in Article 37, which decrees that fishmeal marketing is carried out exclusively by the state; Articles 64 and 70, which establish the so-called "fishing communities" to represent the employees in any fishing company, with the right to receive 20% of the net income of each company; and finally in a transitory regulation requiring anchovy fishing companies to reduce their foreign capital to at least 51% of their total capital.

Two years after this Act, the government passed Decree Law 19999 setting up the State Company for Fish Meal and Oil Production known as *PESCA PERU*, which was given exclusively responsible for the fishery and processing of anchovy in Peru. In line with this law, the entire anchovy industry was expropriated by Decree Law 20000. One thousand two hundred and fifty-six fishing vessels and 105 anchovy processing plants passed to the administration of *PESCA PERU*. The new state company was now also responsible for around 27,000 workers including vessel crews and employees of processing plants [36]. Government bonds were given to ship and factory owners in exchange for their property. At the same time the fishery collapsed and landings in 1973 were less than 1.5 million tonnes, compared to 10 million tonnes in 1971 [35,36] (Fig. 2a). The assets of the industry at the time of collapse were estimated at 120 million US dollars, compared to debts of 227.5 million US dollars [45].

The second Peruvian Fisheries Act was enacted in 1987 by the second democratically elected government following 12 years of military dictatorship. This left-wing government was controlled by a populist social democratic political party with President Alan Garcia as the head of the country. Article 3 of this Act stresses the promotion and control by the state of the rational exploitation of marine resources considering social welfare (Table 3). Nationalized anchovy vessels had been returned to the private sector in 1976 by Decree Law 21558; and the rights of the fishermen to participate in company ownership, management and profits according to the First Act (the "fishing communities") had been also repealed in the late 1978 (Decree Law 22329). Both laws had been enacted to make private capital investment in the industry more attractive [51] and the need to ensure that national social and democratic principles guided the fishery policy had to be emphasized. President Alain Garcia's administration (1985–1990), recognizing that these state-private sector conflicts were gradually undermining fisheries management, emphasized the importance of cooperation in formulating sectoral development priorities [37].

Considering use rights, again here, close to the start of the document, Article 4 declares that the state exploits marine resources, promoting the involvement of any individual, corporate entity or company, encourages the contribution of national investment to the industry, while foreign investment remains subject to pertinent Peruvian legislation (Table 3). However, the specific objectives of this new law remain literally the same as in First Act. New purposes of the Fisheries Ministry related to the anchovy fisheries included: (a) to carry out scientific and technological research to address the best species exploitation rate and environmental potential and (b) to integrate different fishing activities within all the companies involved. Government attempts to express its concerns for the development of the fisheries sector for human consumption, besides the establishment of policies for the anchovy industry, were exposed in further purposes of the Ministry of Fisheries, as: (a) to regulate withdrawal, industrialization, diversification and production and yield enhancement of fish products for human consumption, (b) to develop and promote aquaculture and artisanal fisheries, and (c) to supervise and control fish supply for internal markets limiting exportation and advertise regularly nutritional advantages of fish to enhance its consumption. A novel purpose related to the supervision and control of entrance and use of marine resources in natural reserves was also introduced.

The third General Fisheries Act was enacted in 1992 by a right-wing democratically elected government. Here, Article 3 underlines the promotion by the state of foreign investment in the fisheries sector under the regulations established by Peruvian legislation. The law adopts a neo-liberal perspective and emphasizes the application of free-market policies. It aims to regulate the fishing sector to promote its sustainable development as a source of food, employment and income; guarantee responsible use of marine resources, optimizing economic profits in harmony with environmental protection and biodiversity conservation.

No special functions are defined for the Ministry of Fisheries; however, the basic norms insert an article to protect the environment from pollution, and a second one to regulate foreign flag vessels operations.

3.3. Secondary legislation and fishing phases

During the first phase of uncontrollable growth of the fishery, the first legal regulation to set up a closed season was declared in 1965. According to Supreme Decree 05-65 the fishery was closed for the month of August 1965 and fishing was banned during weekends. In January 1966, a three-month winter closed season was declared, lasting from mid-May to mid-August (Supreme Decree 05-66-PE), and the first TAC of seven million tonnes for one year was established. Additionally, the landing of catches with more than 50% of juvenile anchovy by-catch was prohibited. In 1967, a closed season was declared from July to September.

Two reasons have been identified for the acceptance and enforcement of the closed season ban by the industry at this point. First, the closed season was planned for southern winter months, when anchovy shoals were more dispersed and difficult to fish [46] and weather and sea conditions were also adverse. Second, the fishermen and plant processing owners could make use of this closed season to repair and maintain their vessels, fishing gears, equipment and facilities [36]. Scientists from IMARPE also welcomed this regulation enthusiastically, since research on anchovy reproduction had already identified a major spawning peak during winter months [47,48]. On the other hand, quota limits were not complied with and anchovy landings at the end of the sixties greatly exceeded the annual limits of 8 and 9 million tonnes that were recommended by IMARPE [21,46,49]. Annual number of enacted secondary legislation regulating quotas and close seasons increased from one in 1965 to a maximum of 10 in 1972 simultaneously to the ENSO 1972–1973 (Fig. 2b).

During the collapse phase of the fishery, succeeding the establishment of the Ministry of Fisheries and the enactment of the first Fisheries Act, specific regulations for the management of the anchovy fishery for closed seasons and quota limits were all established by means of Ministerial Resolutions. This procedure was grounded legally on a Supreme decree enacted in 1977 (Supreme Decree 03-77-PE). During this collapse period of low catches (1973–1984), the number of enacted secondary legislation fluctuated between five and ten with a very slight increment during the moderate ENSO of 1976, but no relation with positive SST anomalies during the strong 1982–1983 ENSO event.

An increasing trend in the number of secondary legislation can be observed between 1994 and 2007, which coincides with the sustainable landings phase of the fishery. In this phase, the exceptional peak of 28 enacted secondary legislation establishing quotas and/or fishing areas during the most recent strong ENSO event in 1997–1998 was recorded (Fig. 2b).

3.4. The analytical framework towards a sustainable fisheries' law

The results of applying Winter's framework are presented in Table 4. Almost no differences were observed between the First and the Second Act, while the Third Act improved coverage of topics like management and its guidelines and tools, surveillance and enforcement (due in part to new available technologies), and control of fisheries. According to these results, only the third Fisheries Act (121 points) scored just enough to guarantee good management practices for this fishery.

4. Discussion

Anecdotal evidence suggests that it was the passing a new law that set off the development of the anchovy fishery. Law 12283, passed in April 1955, extended the application of Law 10753, which reduced the export tax applied to mineral and agricultural companies, to fishery exports [44]. It was probably this law that triggered the expansion of the anchovy fishery. However it was probably also favored by other concurrent factors, including the replacement of cotton fishing nets by nylon ones in 1956, the availability of low cost second-hand vessels and fishmeal processing plants following the collapse of the Californian sardine fishery, and an increasing fishmeal demand from the USA and European countries [35,45].

4.1. Legal instruments and the transition to sustainable landings

The transition towards sustainable landings in the case of the Peruvian anchovy fishery has been a result of co-evolutionary processes of alternating slow and rapid change occurring at different scales. According to Loorbach [52], this is the way transitions occur, leading from one relatively stable state to another. Legal instruments to manage the fisheries have been part of this change process and have contributed to the sustainable state in which the fishery is currently placed. When considering also secondary legislation, this case study coincides with formal institutions of long-lasting resource use systems where operational rules had been devised and modified over time according to a set of higher level rules; these higher-level rules might themselves be modified slowly over time [53].

Peruvian fishing law evolution has followed socio-political and economic policies transformation in the country. With the partial exception of the third Fisheries Act and the establishment of management systems for different marine resources and fisheries, the structure, basic principles and contents (according to Winter's framework, see 3.4) showed no significant differences to explain a transition towards sustainable fisheries based merely on new regulations. Fisheries acts have apparently had little direct influence on the way the anchovy fishery has been managed on the operational level. The acts were a manifestation of broader national socio-political changes and expressed general attitudes towards the exploitation of natural resources that mirrored the political ideologies of the governments of the day. The three General Peruvian Fisheries Acts were not changed or adapted in response to crises in the fishing sector or their economic and social consequences. In fact the anchovy fishery collapsed shortly after the enactment of the first General Fisheries Act in 1971 (Fig. 2a). No relation is observed between the enactment of fisheries acts and the occurrence of extreme ENSO events of 1971–1972, 1982–1983 and 1997–1998, which dramatically impacted anchovy's fishmeal production and marketing [27,28]. When new management measures were introduced, for example the adoption of Geographical Positioning Systems (GPSs) to control compliance of restricted fishing areas in 2001, or the introduction in 2007 of new procedures for inter-sectoral collaboration in response to a request by the newly established Ministry of the Environment, this was achieved by amending the implementing regulations, while in each case the act itself remained in force.

This apparently minor influence of fisheries acts on the sustainability of the fishery is explained by the fact their principal role was to define rules of access to the resource at a sectoral and national level. Fisheries acts were used to outline the role of the state and private investment and to delimit foreign involvement in the fishery industry. In the case of common pool property resources like fisheries, the definition of clear access boundaries has been described as the first design principle for robust institutions in adapting complex social–ecological systems [53]. Boundary rules relate to who can enter the area, harvest and manage the resource, and potentially exclude others from doing so. Although typically enforced by external officials, such rules impact on the presumption that a participant has about the likely levels of trustworthiness and cooperation of the others involved [53]. The vast current literature on the benefits of implementation of Individual Transferable Quotas and community fishing rights at local (household) levels is a reflection of the importance accorded to this thesis by the international scientific community. However, there has been very little work done to clarify access rights needed at different and higher levels of governance. This example relating to the impact of laws on the anchovy fishery provides new insights into this key element of fisheries governance.

Table 4
Winter's analytical framework applied to the three General Peruvian Fisheries Acts.

Checklists of potential management failures	1971	1987	1992
Is the law taken seriously?	0	0	0
Are binding rules of international fisheries law transposed and applicable in the country?[a]	0	0	2
Does the constitution contain rules relevant for fisheries?	2	2	2
What is the formal quality of the relevant laws?			
Is there a specific law on fisheries?	3	3	3
Is the legal language precise and in line with general legal doctrine?	3	3	3
Does the law cover all elements of fisheries management?			
Principles	2	2	3
Instruments of promotion	3	3	3
Instruments of management	1	1	3
Structures and competences of institutions	3	3	3
Delegation of powers for specified issues	2	2	2
Definitions of infringements and sanctions	2	2	3
Access to courts for affected parties and NGOs	1	1	1
Subtotal fisheries management	**14**	**14**	**17**
Was the law properly promulgated and disseminated?	3	3	3
Is the law's relationship (hierarchy, *lex specialis*) with other laws unambiguous?	2	2	2
Is the law compatible with constitutional requirements?	1	3	3
Is the law compatible with principles of international law?*	0	0	2
What is the formal quality and content of any sub-legal norm?			
Are they based on and consistent with higher ranking law?	2	3	3
Are they compatible with other sub-legal norms?	3	3	3
Are they appropriated promulgated and disseminated?	3	3	3
Do they impose sanctions for infringement?	2	2	3
Subtotal sub-legal norms	**10**	**11**	**12**
What material standards guide the application of fisheries management instruments?			
Are fish resources defined as a common good?	2	2	2
Is sustainable use of fish resources defined?	2	2	2
Are ecosystems effects to be considered?	1	2	3
Is the precautionary principle to be applied?	0	0	2
Do measures have to be based on best available scientific knowledge?	2	3	3
Subtotal guides for fisheries management	**7**	**9**	**12**
How are responsible institutions shaped?			
Is allocation of competences to legislate and administer between the levels of government clearly defined?	3	3	3
Is the environment ministry involved in decision making on fisheries management?[b]	0	0	0
Does the law provide for participation of fishermen's associations and environmental NGOs?	3	1	1
Have self-regulatory structures been established?	1	1	1
Is transparency of decision making ensured?	1	1	1
Subtotal institutions	**8**	**6**	**6**
Is distribution justice ensured?			
Are inshore areas reserved for artisanal fishing?	1	1	3
Is fishing in the EEZ nationalized?	3	3	3
Are quota for individual effort and catch allocated according to fair criteria?	1	1	1
What informational resources are provided on?			
Is there research on stocks and ecosystems?	3	3	3
Monitoring of catch in the EEZ?	2	2	3
Monitoring of fishing capacity?	1	1	1
Data banks?	2	2	3
Access to stakeholders and the public to fisheries related information?	1	1	2
What promotional measures are taken?			
In the case of under-capacity: are promotion policies in line with sustainable catch limits?	2	2	2
In the case of overcapacity: are promotion policies re-orienting towards reducing capacity?	1	1	1
What management tools are applied?			
Catch limitation	2	2	2
Effort limitation	2	2	2
Technical measures: prohibition of destructive methods, selectivity of nets, reduction of by-catch, etc.	2	2	2
Marine protected areas: pollution prevention, nature protection, recovery and species management zones	1	2	2
Time and area limitation protecting spawning and nursery	3	3	3
Organization: bottom-up in the coastal zone, participatory top-down in EEZ and high seas	2	2	2
Subtotal management tools	**12**	**13**	**13**
How effective are surveillance and enforcement mechanisms?			
Does surveillance cover strategic topics (catch, by-catch, landings, transhipments, foreign catch)?	2	2	3
Do fishermen, buyers and port authorities have recording duties? Are they reliable, and cost-effective?	1	1	1
What safeguards are in place against corruption?	1	1	1
How qualified is the inspection personnel?	1	1	3
Are technical equipment is available?	1	1	3
Are legal remedies available for affected parties?	1	1	1
Are legal remedies available for public interest groups?	1	1	1

Table 4 (*continued*)

Checklists of potential management failures	1971	1987	1992
Subtotal enforcement	**8**	**8**	**13**
Is there flag state control over fisheries in the high seas and foreign EEZs?	0	0	0
Participation in regional fisheries commissions	0	0	0
Licensing of vessels	3	3	3
Catch limitations	0	0	0
Control of landings	0	0	0
Vessel monitoring systems	0	0	0
Subtotal fisheries in the high seas	**3**	**3**	**3**
Is there port state control of landings from vessels flying foreign flags and fishing in high seas and foreign EEZs?	1	2	3
Total score	**94**	**99**	**121**

[a] Only applicable for the Third Fishery Act from 1992.
[b] Peru did not have a Ministry of the Environment until 2008.

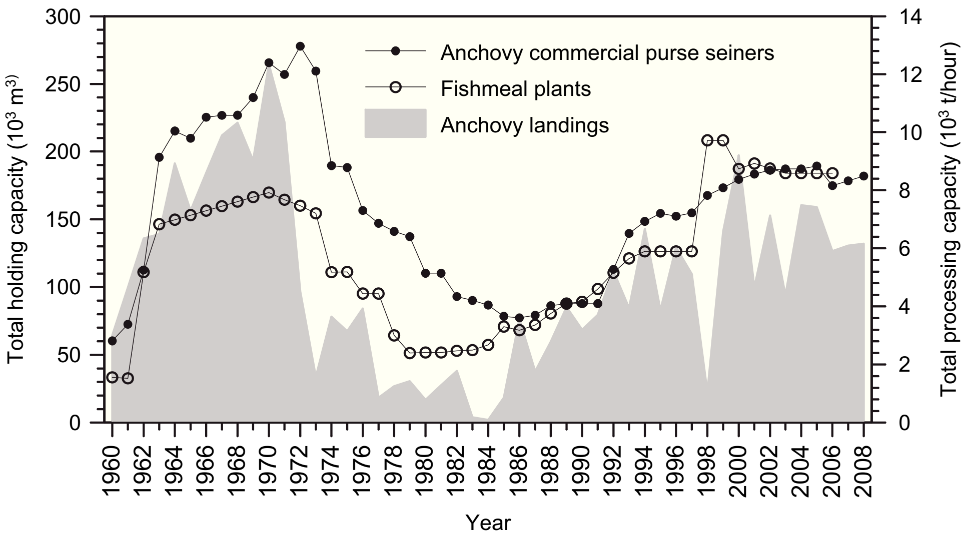

Fig. 3. Historical total holding capacity of the Peruvian anchovy commercial purse seines, and processing capacity of fishmeal plants between 1960 and 2008. (*Source*: IMARPE).

Evidence suggests that both restriction of access and maintenance of biological productivity are necessary conditions to achieve sustainability [16]. The reason why the anchovy fishery did not enter a sustainable phase after the first Fishery Act can be explained with respect to these conditions and suggests two possible non-exclusive propositions, which are discussed below.

First, although the acts defined access limits at national levels, Peruvian restrictions to limit access at local (fishing companies), operational levels have been generally poorly implemented. Thus, within the broad boundaries to participation defined by law, vessels entering the fishery have operated under a *de facto* open-access regime [56]. As shown in Fig. 3, there is a strong relation between the historical evolution of total holding capacity of the anchovy fleet and fluctuations in landings, implying failures to limit the activity of vessels authorized to take part in the fishery. Overcapacity of the anchovy fleet and processing capacity has been a consistent feature of this fishery [20,45,49,54,55] and this condition did not change when the fishery entered the sustainable phase in 1994. Due to new neoliberal policies and the recovery of pelagic stocks between 1990 and 1995, the private sector found optimal conditions to invest in vessels and plant modernization and construction. As a result, the anchovy fleet capacity experienced a fast expansion [56]. The General Fisheries Act of 1992 required vessel construction for anchovies to be balanced by decommissioning older boats. Many firms were authorized to build vessels for the sardine and jack-mackerel fisheries but means were finally found to access the anchovy fisheries as well [56]. Furthermore, in 1998, the government passed Law 26920 which authorized owners of wooden boats larger than 30 m^3 to join the anchovy fleet. Around 600 wooden artisanal vessels were legally incorporated into the anchovy fishing fleet adding 35,000 tonnes to the total holding capacity.

However, there is no broad evidence that open access regimes are largely incompatible with sustainable management of fisheries [14]. Maintenance of biological productivity depends more on the management agencies' choice of harvest levels and their ability to enforce these limits; thus defining property and access rights will not automatically lead to full efficiency in fishing; for that to happen the path of TACs over time must also be optimal [13]. That seems to be the case of the Peruvian fishery, where TAC allocation has improved since the implementation of seasonal acoustical cruises to estimate pelagic fish biomass in 1983 [41]. After attainment of the cumulative TAC, the manner in which recent secondary legislation not only ban further fishing activities but simultaneously also fishmeal processing is also important. The clearly identifiable smell of burning fish, detectable even some miles away from the factories, makes it impossible for illegal fishmeal reduction to go unnoticed, and supports compliance of processing bans. The prompt recovery of the anchovy fishery after the last ENSO of 1997–1998 could also be an indicator of healthy maintenance of biological productivity during the sustainable landings period. As reported by Gulland [57] and later confirmed by Caviedes and Fik [33], only when ENSO events are associated with extremely high fishing levels, do significant barriers exist to a recovery in anchovy landings. Gulland's claims are based on the little discernible impact of the two ENSOs of 1957 and 1965; after which the anchovy fishery recovered a few months of their onset. Caviedes's conclusions are based on a model comparison between ENSO impacts on Peruvian and Chilean fisheries. In both cases, the negative impacts of ENSO events on the biomass of anchovies are not disputed; the studies focus on the time-span required for its recovery to pre-ENSO levels and subsequent resurgence of the fishery.

Second, contrary to the enactment of fisheries acts, secondary legislation in the form of ministerial resolutions has noticeably increased in number during the sustainable landings phase of the fishery. The higher number of regulations related to quotas and closed periods or areas during the ENSO 1997–1998 is a reflection of the adaptive approach to management adopted during this phase. During the 1972–1973 ENSO, a similar pattern could be observed to a minor extent, however, the lack of strong scientific evidence at that time [57] coupled with policy decisions that feared social discontent and unemployment and an important source of foreign capital for the country [33],[5] prevented the success of such regulations to avoid the collapse of the fishery. During the sustainable phase, not only were policy and practice modified in accordance with new ecological knowledge as required by adaptive management practices [58], but updates in the allowable catch by IMARPE were made in a timely fashion consistent with the biology of the species [15] (anchovy is a short-lived fish species with a short life span of around three years and age at first maturity at one year [47]).

In the context of efforts to attain the sustainability of the anchovy fishery, a major challenge has been to develop the ability to respond to rapidly changing conditions and uncertainty both in the natural environment and in socio-economic and political systems. Moreover, although the impacts of ENSO are now relatively well understood, the frequency and intensity of its occurrence remain a source of uncertainty for fishermen and managers [28,34,35]. Even less well understood are the impacts of natural driven inter-decadal regime shifts which were first reported by scientists only after 50 years of commercial fishing [29–31]. Thus for the Peruvian fishery, the adoption of adaptive and rapid management in accordance with ecological conditions should also be considered as a key element to the transition towards sustainability.

4.2. Multilevel fisheries governance

Multilevel governance has been described as a "system of continuous negotiation among nested governments at several territorial tiers—supranational, national, regional and local" [59]. It is practised not only in Europe, from where it originates, but also in the current management of resources in distant developing countries. This case study, showing the role of the Peruvian state defining national policies towards use of natural resources, reinforces the theory that power of central governments under multilevel governance systems has not been eviscerated and remains the primary governance level [60]. According to Pierre and Peters [61, p. 68], "*the new* [*multilevel*] *governance … does not mean the end or decline of the state but its transformation and adaptation to the society it is currently embedded in*". Nevertheless, under the multilevel governance approach, economic-fishery policies in Peru have evolved, both ceding power to supranational institutions and adopting new policy instruments that involve partnerships with the private sector [62]. Supranational institutions like the Food and Agricultural Organization of the United Nations (FAO) have played a role in influencing the most recent Peruvian Fishery Act, for instance by putting pressure on the government to adopt fishery management plans and environmental protection measures (see Table 4). These themes were included in the law but to enact a new fisheries' act was taken by the Peruvian state alone. Not even the Rome Declaration on the implementation of the Code of Conduct for Responsible Fisheries adopted by Peru in 1999 had a straightforward effect on fisheries legislation.

Regarding other institutional arrangements beyond the state like networks, informal norms or agreements between actors, there is no doubt of their key role in fisheries governance in Peru; however, these kinds of arrays take place under existing legal and structural frameworks that remain in place. As shown in this study, the function of the state and its political administrative system should not be neglected in the study of multilevel governance of sustainable fisheries.

4.3. Winter's analytical framework for fisheries law

Although the knowledge of the role of laws to support fisheries sustainability is limited or has been restricted to analyze non-compliance, Winter [12] identifies good laws in fisheries as the ones that create legal certainty, integrate higher rank human rights and resource protection obligations, clarify objectives, set out rights and duties of fishers, determine governmental competences, limit administrative discretion, provide enforcement tools and allow for judicial review of administrative measures. Some of these features are covered by the current Peruvian Fisheries Act, as reflected in the score obtained, but some potential management failures remain a threat under the current legislation. The top-down management of the fishery, no legal remedies for affected parties, general public and NGOs, and no safeguards in place against corruption, are worth mentioning here. It is understandable, however that the availability of new technologies like satellite positioning systems, and even text messages and the internet has improved enforcement of surveillance and control. This fact explains the major score obtained by the third Fisheries Act and has certainly contributed to ensure appropriate fisheries management practices during the sustainable landings phase of the fishery.

Regarding the potential use of this innovative semi-quantitative tool, some difficulties appeared when comparing laws over such a long period of time. Many terms, principles, fishing practices and technologies were not available at the time the first Peruvian act was enacted, causing some problems for interpretation of results. Only the first question: is the law taking seriously; appears unfeasible to answer without a specific research to address this topic. Considering this question, already in the First Act some sections of the law were definitely taken seriously. The implementation of the "fishing communities" and the limitations towards foreign participation in the fishing industry are some examples, while the increment of the nutritional index of the Peruvian population or the requirement for which each fisherman should be registered and in possession of a boarding permit was not really compelled.

Winter's framework is nevertheless a worthy and promising first attempt to quantify the potential of a fisheries' law; and further development of the methodology should be encouraged. The tool could be used for instance for semi-quantitative comparisons of national fisheries laws between countries.

4.4. Legal certainty and adaptability

Laws are the governmental instruments that provide frameworks for many of the interactions between the members of our society, and legal relations are fundamental to creating order in societies, not least in the form of economic relations [63]. Complex social–ecological fisheries systems are shaped by laws

[5] By 1971 the anchovy industry was responsible for 35% of all Peruvian foreign currency supplies [45].

of nature and simultaneously by human-made laws. According to Ebbesson [39] legal certainty is an important virtue of law; and does not as such necessarily prevent adequate flexibility in administrative decision-making concerning health, the environment or the use of natural resources. In the case of the anchovy fishery, the law not only does not contest flexible adaptive management but supports the settings in which this adaptability takes place. The name given to the Fisheries Acts, as "General Acts", mirrors the intention to enact fisheries principles leaving operational management issues to secondary legislation or non-legal norms. Finally, legal human-made certainty added to environmental uncertainty appears to reduce the total system uncertainty and promote sustainable transitions.

5. Conclusions

Although specific lessons for fisheries management do not come in black and white and in fisheries management we should never claim successes, only achievements [7], the future of fisheries sustainability will depend on our ability to understand the key elements of these achievements and apply them well [14]. This study provides some insights in key elements of achievements of the Peruvian anchovy fishery, and does not purport to fully explain the complex dynamics that have steered the anchovy fishery towards sustainable landings in recent years. However, legal instruments in this case have been certainly part of the broad range of activities that fisheries management has consisted of, many of which are often overlooked by outsiders [16]. Fisheries acts in Peru define access rights to the fishery and regulate the fisheries sector within national, economic and political dimensions. To achieve sustainable landings goes beyond the tasks of these acts and should be addressed by sub national governance levels. The base-level governance to manage landings is left to secondary legislation that evolves according to different tools like institutional and organizational functioning, agencies legitimacy, science, technologies and innovations, or even experience and learning capacities. This secondary legislation and further institutions should operate linked to environmental and ecological settings and be adaptive to guarantee stable landings. Following this analysis fisheries laws in Peru cannot guarantee sustainable landings on its own. After defining access rights and political strategies, what Gerd Winter does define as "a sustainable fisheries law" works as an umbrella to allow secondary legislation and other norms to evolve towards sustainability. Further research is necessary to reveal if specific secondary legislation and informal institutions, once established to undertake sustainable landings, are robust to national, political or economic adjustments.

It seems also important to mention here that similar studies that have provided material for the discussions above are all taken from fisheries research with detailed data from developed countries like the US northeast Atlantic, Australian and New Zealand fisheries [64]. However, current worldwide fishery statistics show that nine of the top twelve top fishing countries are developing countries [17] and these countries have contributed to more than two-thirds of total fish production during the last decade [65]. Under these conditions it appears imperative to direct more efforts towards case studies in developing countries, where not only artisanal but also important commercial fisheries take place. South Africa, Mexico, Indonesia, Chile are just some examples to be mentioned.

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Article 2.

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Article

Coping Strategies to Deal with Environmental Variability and Extreme Climatic Events in the Peruvian Anchovy Fishery

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Abstract: The Peruvian anchovy fishery is the largest worldwide in terms of catches. The fishery started during the mid 1950s, and since then it has been highly dependent on natural stock fluctuations, due to the sensitivity of anchovy stocks to ocean-climate variability. The main driver of anchovy stock variability is the El Niño Southern Oscillation (ENSO), and three extreme ENSO warm events were recorded in 1972–1973, 1983–1984 and 1997–1998. This study investigates the evolution of coping strategies developed by the anchovy fisheries to deal with climate variability and extreme ENSO events. Results showed eight coping strategies to reduce impacts on the fishery. These included: decentralized installation of anchovy processing factories; simultaneous ownership of fishing fleet and processing factories; use of low-cost unloading facilities; opportunistic utilization of invading fish populations; low cost intensive monitoring; rapid flexible management; reduction of fishmeal price uncertainty through controlled production based on market demand; and decoupling of fishmeal prices from those of other protein-rich feed substitutes like soybean. This research shows that there are concrete lessons to be learned from successful adaptations to cope with climate change-related extreme climatic events that impact the supply of natural resources. The lessons can contribute to improved policies for coping with climate change in the commercial fishery sector.

Keywords: anchovy fishery; Peru; ENSO; extreme climatic event; climate change

1. Introduction

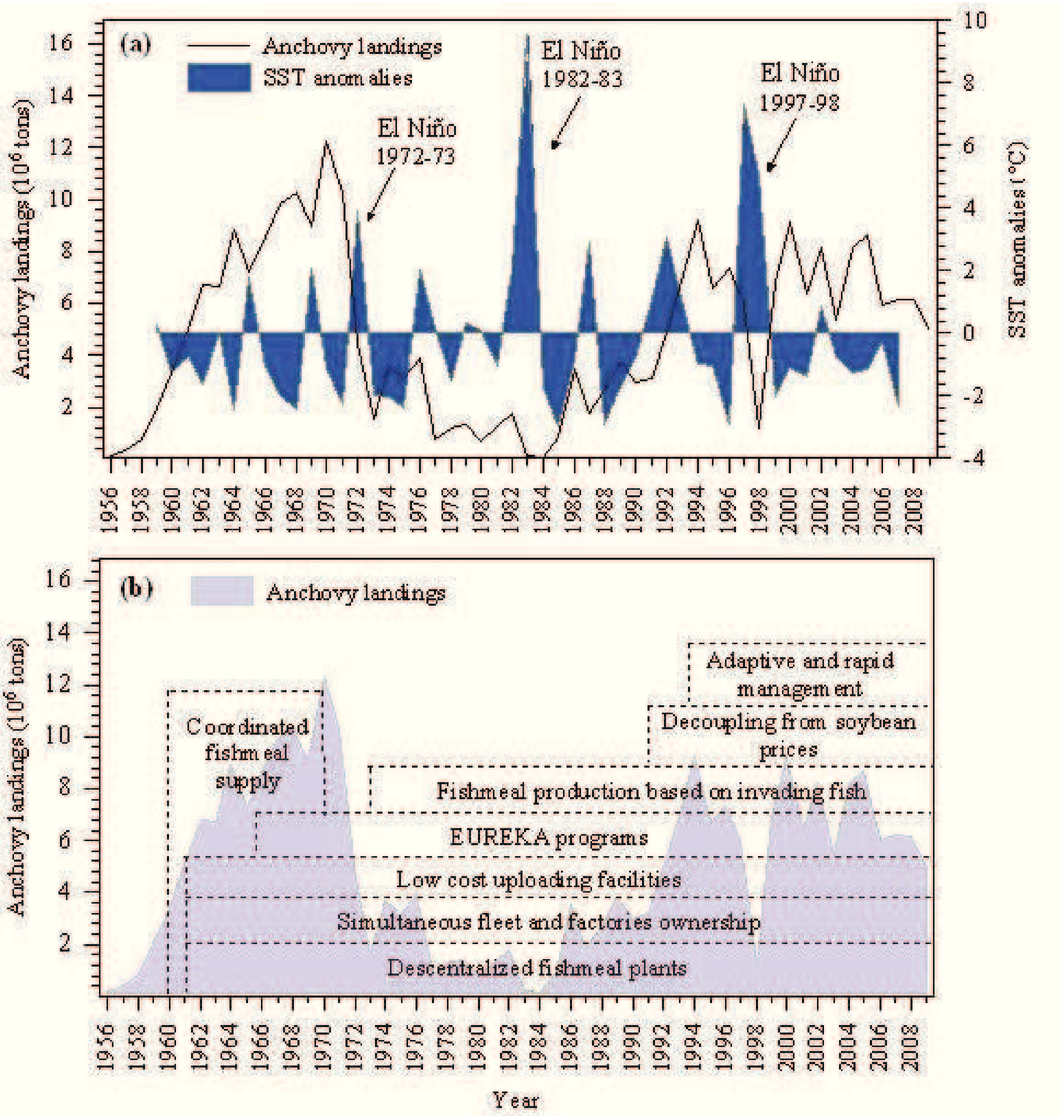
Capture fisheries and aquaculture supplied the world with about 142 million tons of fish food in 2008 and provided 3 billion people with at least 15% of their average per capita animal protein intake [1] These fishery activities, so important for nourishing and ensuring the livelihoods of large sectors of the world population, are closely linked to weather and climate dynamics, and are more affected by these than any other category of food production [2]. While weather conditions directly affect fishing, environmental climate variability determines the distribution, migration and abundance of fish [3]. Fisheries-climate links have been the subject of research since at least the establishment of the International Council of the Exploration of the Sea (ICES) in 1902 [4]. More than a century later, the United Nations Food and Agriculture Organization (FAO) states that "the fisheries sector is not unfamiliar with the issue of climate variability and it is experienced in dealing with variability on a range of time scales" [5].

The Peruvian anchovy fishery has been described as the largest fishery that has ever existed on earth [6-8] and as the most intense and successful fishery worldwide [9]. Annual current catches are around 7–8 million tons [10] captured by almost 1200 purse seiners locally known as *bolicheras* [11]. Ninety nine percent of anchovy catches are reduced to fishmeal and fish oil by around 140 processing factories [6,12]. The fishery is mono-specific [13,14]; since at least 90% of the catches consist of one fish species: anchovy or *anchoveta* (*Engraulis ringens*).

Peruvian anchovy, like any other pelagic fish species, are highly sensitive to ocean-climate variability and show drastic stock fluctuations [9,15-17]. Historical landings statistics show that the fishery went through a first phase of frenzy and uncontrolled growth from its establishment in the mid-1950s until its collapse in 1972. After the collapse, a second phase from 1973 to 1984 was characterized by unfavorable warm ocean conditions and low catches. A third phase, from 1984 to the present, with propitious ocean-environmental conditions and modern governance, can be further divided into a second growth period (1984–1994) and a sustainable landings period (1995 to present) [10,18,19].

Thus, anchovy catches in Peru are dependant on inter-annual and multi-decadal variability driven by climatic conditions in the Pacific Ocean [9]. The most important climatic factor affecting this geographical area is the Pacific coupled ocean-atmospheric circulation pattern known as El Niño Southern Oscillation (ENSO) [3,20]. The ENSO cycle consists of a warm period (El Niño) and a cold period (La Niña) and is characterized by respectively anomalous cooling or warming of the eastern Pacific. In Peruvian waters, El Niño (the warm ENSO period) usually lasts for a few weeks to a few months. Sometimes an extremely warm event can develop lasting for a much longer time [21]. The effects of El Niño events in Peru have long been observed and three major impacts have been identified: (i) it increases coastal sea temperature by up to 8 °C, (ii) it reduces plankton productivity and (iii) it creates a more tropical predator-prey environment [3]. As a result, anchovy catches are, broadly, negatively correlated to sea surface temperature (SST) anomalies; SST is the principal indicator used to measure the duration and intensity of El Niño events in Peruvian waters (Figure 1a).

Figure 1. (**a**) Peruvian anchovy landings, sea surface temperature (SST) anomalies and three El Niño extreme events since 1956 and (**b**) Evolution of coping strategies to reduce impacts of climate variability and extreme events.



Unfortunately for purposes of prediction, the interval between El Niño events is very irregular. It is not uncommon to have six or seven years' interval, but some events have been separated by as little as one year [22] Although current understanding and modeling of El Niño has improved remarkably over the last decade [23,24], the predictability of El Niño is still an open question [25]; and our ability to forecast its evolution is far from perfect [24].

Three El Niño episodes of exceptional intensity and duration were recorded in 1972–1973, 1982–1983 and 1997–1998 [3,14,26] (Figure 1a). Although the relation between climate change and El Niño events has been debated during the last decades [27-32], recent research has revealed that 43% of extreme El Niño events have occurred since the start of the 20th century and 30% during the post-1940 period [33]. These results suggest that ENSO may operate differently under natural (pre-industrial) and anthropogenic background states [33]. The aim of this study is to investigate the evolution of coping strategies developed by the Peruvian anchovy fishery to deal with environmental variability and extreme El Niño events, whose frequency can be expected to increase under current climate change scenarios [33,34].

2. Field Study Methodology

The study area was the Peruvian coast between latitudes 03°30' S to 18°20' S and longitudes 72°W to 84°W, which is dominated by the Humboldt–Peru eastern boundary current system. The coastal ecosystem is characterized on the marine side by intense upwelling and associated high productivity, which however are variable between years and decades [35]; and on the land side by an almost 2,250 km long narrow desert strip.

Semi-structured interviews with key informants were carried out during October 2008 and November 2009. Interviews were carried out at the Vice-Ministry of Fisheries (10 interviews), the *Instituto del Mar del Perú* or IMARPE (8 interviews) and the private fishery sector (9 interviews) (Annex 1). Interviewees were selected on the basis of length of experience and period of time in post, in order to obtain information covering at least the period during and between the last two strong ENSO events in 1982–1983 and 1997–1998. Since the interviewer herself worked for IMARPE between 1994 and 2001, interviewees were approached via email or telephone with support from ex-colleagues currently working directly for the government or the fishing industry. All government officials were interviewed at their offices with previous permission from their superiors.

Extensive documentary analysis based mainly on internal reports, yearbooks, fishery magazines and grey literature was also undertaken. Historical fishery data was gathered from the anchovy database at the Pelagic Resources Department of IMARPE.

As an output of the interviews, four impacts of extreme El Niño events on the anchovy fishery were identified and used to analyze the evolution of coping strategies. These impacts were as follows:

First Impact: Changes in distribution of anchovy shoals with consequent relocation of anchovy fishing grounds
Second Impact: Decrease in anchovy biomass and invasion of foreign tropical species into anchovy fishing grounds
Third Impact: Management regulations rapidly out-of-date
Fourth Impact: Uncertain changes in fishmeal prices

3. Results and Discussion

The fishery system can be broken down into three interacting subsystems: resource, resource users and resource management [36] or resource units produced by the fishery, the users of that system and the governance system [37]. Our results show that Peruvian fishing companies (resource users) and anchovy management authorities (resource management) have together developed at least eight strategies to cope with the impacts of climate variability and extreme El Niño events (Table 1).

Table 1. Strategies developed by the Peruvian anchovy fishery to deal with environmental variability and extreme climatic events.

Impact	Coping strategy	Implementation
Changes in the distribution of anchovy shoals	Scatter geographical distribution of fishmeal plants along the coast	Fishery companies
	Simultaneous ownership of fishing vessels and processing factories	Fishery companies
	Low-cost uploading facilities	Fishery companies
Invasion of foreign species into anchovy fishing grounds	Fishmeal production based on invading fish	Fishery companies
Management regulations rapidly out-of-date	EUREKA program	Management authorities
	Rapid and flexible management	Management authorities
Uncertain changes in fishmeal prices	Fishmeal production based on market demand	Fishery companies
	Reducing price dependence from soybean production	Fishery companies

Five of the eight strategies were developed at the start of the rapid growth phase of the fishery during the 1960s (Figure 1b). These strategies were a response to seasonal stock variability and the impacts of minor El Niño events in 1965 and 1969 [22,38]; however, they played an important role in diminishing the effects of subsequent, more extreme events. One strategy was put in place as the fishery started to collapse during the extreme 1972–1973 El Niño event. The remaining two strategies have been developed since 1994, during the sustainable landings phase of the fishery [18].

3.1. First Impact: Changes in Distribution of Anchovy Shoals with Consequent Relocation of Anchovy Fishing Grounds

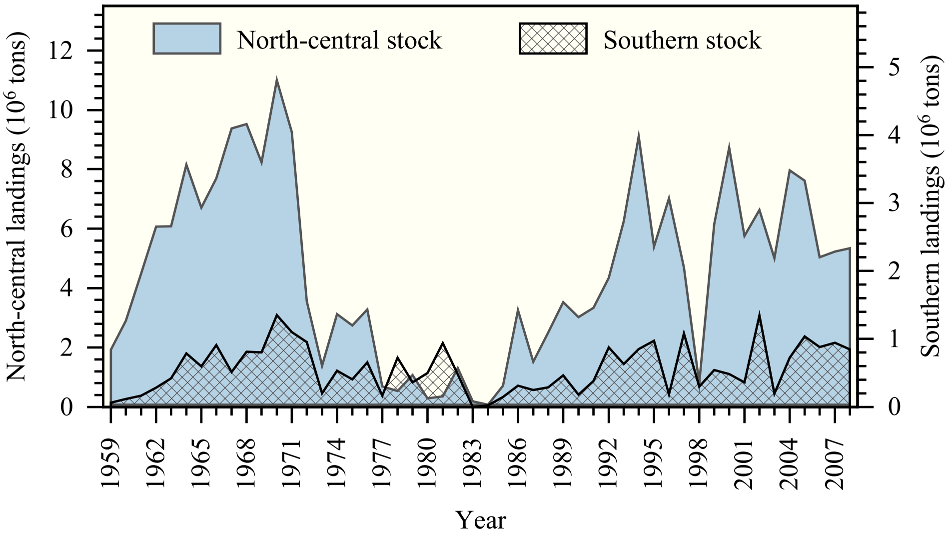
The sensibility of anchovy shoals to climate variability was identified on a very early stage of the fishery and was documented in the second "historical report" of *Instituto de Investigaciones de Recursos Marinos* or IREMAR in 1962. This report records a sharp decline in landings in ports of northern Peru during January 1962, and suggests this was likely due to the migration of anchovy shoals or to changes in local sea temperature [39]. Some years later Roemer [40] noted that "anchovy fishing is not uniformly good along the coast and the fortunes of any one zone vary from season to season or even from month to month". As a result of this observed variability, before the onset of the first extreme 1972–1973 El Niño and even prior to the minor events of 1965 and 1969, three coping strategies to deal with changes in the relocation of anchovy fishing grounds were early on put in place.

3.1.1. Coping Strategy 1: Scatter Geographical Distribution of Fishmeal Plants along the Coast

The Peruvian anchovy is a small, short-living, fast growing surface dweller widely distributed along the coast of South America [35]. Off Peru two population units are recognized: the north-central stock, from about latitude 4° S to 15° S, and the southern stock from 15° S to the southern limit of the

Peruvian maritime domain [10,35,41]. Fishing usually takes place between latitudes 5° S and 14° S, targeting on the north-central anchovy stock, which is by far the most productive [10] (Figure 2).

Figure 2. North-central and southern stock Peruvian anchovy landings between 1959 and 2008 (*Source*: IMARPE).



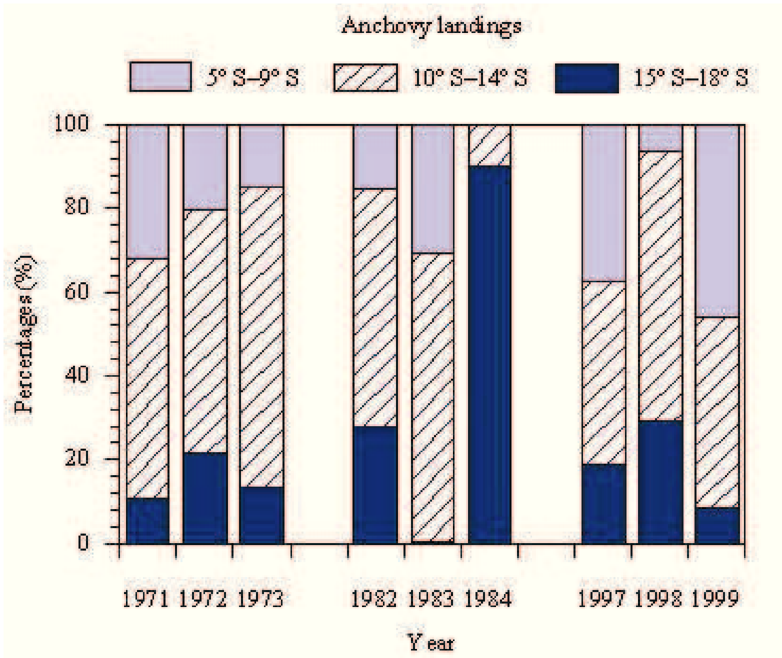
Anchovy fishing and processing started in 1955 in the port of Chimbote (09°05' S), and in Callao (12°05' S), the port that serves Lima [42]. In 1960, when anchovy landings started to increase rapidly, fishmeal processing was concentrated around Callao, where 31 factories (of a total of 85) were in operation [40]. Two years later, the first official census of fishmeal factories carried out by IREMAR reported 110 fishmeal plants operating at 15 different locations. Only three of the 110 factories were situated south of latitude 14° S (southern Peru) but a tendency to decentralize towards the south was observed [43,44]. In 1963, the number of processing plants increased to 149, with eight located south of 14° S. At that time, 15 fishing companies were responsible for 52% of total fishmeal production, of which 11 owned at least two factories in different locations [45].

The El Niño 1965 caused the number of fishmeal factories in operation to decrease from 157 in 1964 to 131 in 1967 [40] but the number increased again to 185 in 1968 [46]. This year, ten out of 63 fishing companies were responsible for 50% of total fishmeal production, and all of them owned at least two factories located in different areas [42]. The largest fishing company, which produced 15.3% of total fishmeal, owned nine fishmeal plants, which were located in the ports of Chicama (07°50' S), Chimbote (09°05' S), Supe (10°48' S), Callao (12°05' S) and Pisco (13°42' S) [42].

Thus, unpredictable changes in fishing grounds motivated fishing companies to own more than one fishmeal plant and to locate them strategically at different sites along the coast. The companies recognized that the only long-run protection against poor fishing as a result of anchovy stock movements was to spread the risk by operating plants in two or more zones [40]. The flat Peruvian desert provided spacious building sites for factories and space for huge inventories, which need little or no protection due to the stable arid weather [47]. On the other hand, lack of water supply, electricity, manpower and landing facilities were important factors that limited the expansion [48]. Nevertheless fishmeal plants increased from 27 in 1956 to 171 in 1966, and when the first fishing quota limit of 9.5 million ton of anchovy was set up by the government in 1967, total processing capacity was able to handle 3.8 times the given quota. Excess capacity had clearly become a problem [40]. Since then, overcapacity of the anchovy fleet and processing capacity has been a consistent feature of the anchovy fishery [11,12,46,49].

During El Niño 1972–1973, when anchovy availability decreased in the north fishing grounds, the fishery migrated to the south. This was made possible by the availability of fishmeal processing facilities along the entire coast. As shown in Figure 3, landings in the south (1972) and in the center grounds (1973) increased when anchovy moved from their northern fishing grounds. In 1984, anchovy landings in the north of Peru were banned; and 90% of landings were reported in southern Peru. The same pattern was observed in 1998 when 94% of the landings came from south latitude 10° S.

Figure 3. Anchovy landings in percentages from the northern (5° S–9° S), central (10° S–14° S) and southern (15° S–18° S) fishing grounds during the 1971–1972, 1982–1983 and 1997–1998 extreme El Niño events (*Source*: IMARPE).



3.1.2. Coping Strategy 2: Simultaneous Ownership of Fishing Fleet and Processing Factories

In response to the high risk element inherent in the availability of fish, anchovy processing companies attempted to achieve greater control over raw material supply by operating their own fishing fleets [40]. This practice of vertical integration also developed during the 1960s and, by 1962, 61% of fishing vessels were fishing to supply fishmeal plants owned by the same company [44]. In 1966, a sample of 51 fishmeal plants processing 60% of the catch revealed that 70% of the anchovy caught were landed by boats belonging to fishmeal plants [40]. An important consideration was the desire to avoid being reliant on independent fishermen. Fishermen could otherwise make life difficult for processing companies by taking a hard line in the negotiation of landed anchovy prices. They could decide to sell their catches to other companies or, even more critically, to migrate away from areas of poor fishing. Roemer [40] states that:

The consensus among plant owners is that they would prefer not to worry about the additional organization and higher fixed costs involved in operating individual fleets. However the independent fishermen have proved unreliable, not always keeping to their contracts and quickly deserting areas of poor fishing. Thus a plant maintains a fleet to guard against low capacity utilization or shut down in case the fishing in its area worsens.

3.1.3. Coping Strategy 3: Low Cost Uploading Facilities

In places where harbor facilities were in bad condition, not sufficient or did not exist at all, which was the case at most of the ports locations, a system of unloading barges known locally as *chatas* was set up to assist the transport of anchovy from the fishing vessel. A *chata* consists of a floating platform about 20 m long, which supports a long pipeline that is used to transport the anchovy from a fishing vessel offshore to the factory (Figure 4) The longest pipeline attached to a *chata* in Peru is 1 km long and was built in Puerto Chicama (07°42' S), where rough sea conditions are unfavorable for unloading procedures. By 1962, 36% of the fishing vessels used *chatas* to unload their anchovy catches [44].

Figure 4. Unloading barge or *chata* transporting anchovy from the fishing vessel to the fishmeal factory on the Peruvian coast.

3.2. Second Impact: Decrease in Anchovy Biomass and Invasion of Foreign Tropical Species into Anchovy Fishing Grounds

As reported by Ñiquen and Bouchón (2004) [14], a remarkable decrease in anchovy biomass and increase in the biomass of other pelagic species was observed in Peruvian waters during the 1972–1973, 1982–1983, 1997–1998 events. During extreme events, two important anchovy predators migrate deeper into the anchovy area, horse mackerel (*Trachurus murphyyi*) [22] and jack mackerel (*Scomber japonicus*) [50]. The biomass of both species in the anchovy habitat more than doubles; at the peak of the 1972 and 1976 El Niño events it increased 3.5-fold [3]. At the same time, sardines (*Sardinops sagax*) move closer to the coast [51] and seem to do well or even thrive during El Niño events [3].

3.2.1. Coping Strategy 4: Diversification within and beyond Fishmeal Production

As a result of decreases in anchovy biomass, the fishery is forced to diversify its catches to target other pelagic resources like sardine, jack or Pacific mackerel, and long-nose anchovy (*Anchoa nasus*) [14], and use these foreign species to produce fishmeal.

This behavior was first recorded later than the previous strategies described, during the onset of the extreme event of 1972–1973 (Figure 1b). In 1962, less than 1% of the fishmeal production came from fish species other than anchovy [48]. This percentage did not change until 1973, when landings of other pelagic fish suddenly increased [52] (Table 2). During the El Niño 1972–1973, three million tons of sardines, horse and jack mackerel were reduced to fishmeal to prop up the industry [53].

Table 2. Percentages of anchovy and other spp. contribution to total small pelagic fisheries production, before, during and after the three extreme El Niño events.

Year	Anchovy	Sardines	Horse mackerel	Jack Mackerel	Long-nose anchovy
1969	99.9	0.0	0.0	0.1	0.0
1970	99.9	0.0	0.0	0.1	0.0
1971	99.8	0.1	0.1	0.1	0.0
1972	99.2	0.1	0.4	0.2	0.0
1973	86.3	7.5	2.4	3.7	0.0
1974	93.1	1.9	3.4	1.6	0.0
1980	30.2	62.1	5.2	2.5	0.0
1981	47.5	49.8	1.5	1.3	0.0
1982	52.1	45.7	1.5	0.7	0.0
1983	9.4	82.8	6.1	1.8	0.0
1984	0.8	90.4	6.0	2.8	0.0
1985	19.9	76.7	2.0	1.4	0.0
1996	83.3	11.6	4.2	0.6	0.3
1997	80.9	11.1	5.3	2.5	0.2
1998	30.7	36.9	9.5	11.5	11.5
1999	88.9	4.4	1.1	5.2	0.4
2000	94.8	1.5	2.5	1.1	0.1
2001	83.8	0.6	10.7	4.3	0.5

Between 1980 and 1985, anchovy stocks were at their lowest carrying capacity, the results of a regime shift that turned the ecosystem from an anchovy to a sardine dominated environment [54]. This period lasted from 1970 to 1985, when anchovy landings started to recover, and is linked to an ecosystem dynamic related to the movement of warm subtropical oceanic waters towards or away from the coasts of Peru and Chile [26]. Under these circumstances, a new sardine fishery developed in Peru from 1977 to 1990 with a landing peak of 3.5 million tons of sardines in 1988 [19]. The sardine fishery was only for human consumption and the high percentage of sardine landings during El Niño 1982–1983 (Table 2) is due to this fishery. Following the 1982–1983 El Niño, anchovy landings reached a historical low of 25,000 tons in 1984 (Figure 1a), but there is no evidence that other pelagic species were exploited to maintain the collapsed fishery during this period.

During the extreme 1997–1998 El Niño sardines and mackerels again contributed to sustaining the fishmeal industry (Dioses and Cárdenas, pers. comm.). Sardines were illegally used for fishmeal production in preference to the long-nose anchovy, which is not considered an edible fish in Peru. Higher percentages of mackerel landings from 1999 to the present (Table 2) are a response to the efforts of the government and Peruvian fishing companies to promote diversification towards fishing for the human consumption market.

Thus the strategies of the fishing companies to cope with dramatic resource variability have been to first keep the fishmeal industry supplied with tropical fish species that invade anchovy fishing grounds during extreme El Niño events. Fishmeal production, in contrast to the seafood fishery, does not depend on the abundance of specific species and can opportunistically switch from anchovy to other fish when necessary. Secondly, fishmeal companies will diversify and direct their fishing activities to human consumption target species.

3.3. Third Impact: Management Regulations Rapidly Out-of-Date

From 1965, the management of the anchovy fishery in Peru was based on a system of fishing quotas, closed seasons and other restrictions on fishing effort [12,55,56]. Government management and control is responsibility of the Ministry of Production (PRODUCE) and the Vice-Ministry of Fisheries. Management decisions are taken based on reports from the government' S marine research institute IMARPE, whose institutional objective is to provide scientific support for the sustainable management of marine resources. The government applies two different management schemes for the northern-central and the southern anchovy stock, the latter being exploited simultaneously by Peru and Chile [57].

Between two and four acoustic surveys to assess the abundance and distribution of pelagic fish populations and to estimate the quota or Total Allowable Catch (TAC) for both anchovy stocks have been carried out yearly by IMARPE since 1983 [13]. TACs are calculated from current biomass estimations and draw upon the results of biological monitoring that is carried out at all landing sites [10]. Once the TAC is reached, the Vice-Ministry of Fisheries orders the closure of the fishing season, banning not only anchovy fishing but also fishmeal processing. Fishing of the northern stock is usually divided into two fishing seasons, each with its own quota: a summer season from October to March and a winter season from April to September [12]. In the case of the southern anchovy stock, usually no TAC is applied and the fishing season is open almost all year around. Temporary closures of landing ports, for a minimum of three days, are also imposed when the reported presence of juveniles (<10 cm long) exceeds 10% of total catches [18]. Reports come from daily real-time verification of landings.

A management system of Individual Vessel Quotas (IVQ), locally referred to as Maximum Catch Limits per Vessel (MCLV), was established in July 2008 (Legislative Decree Nr. 1086) and is currently being implemented for both anchovy stocks [6,9].

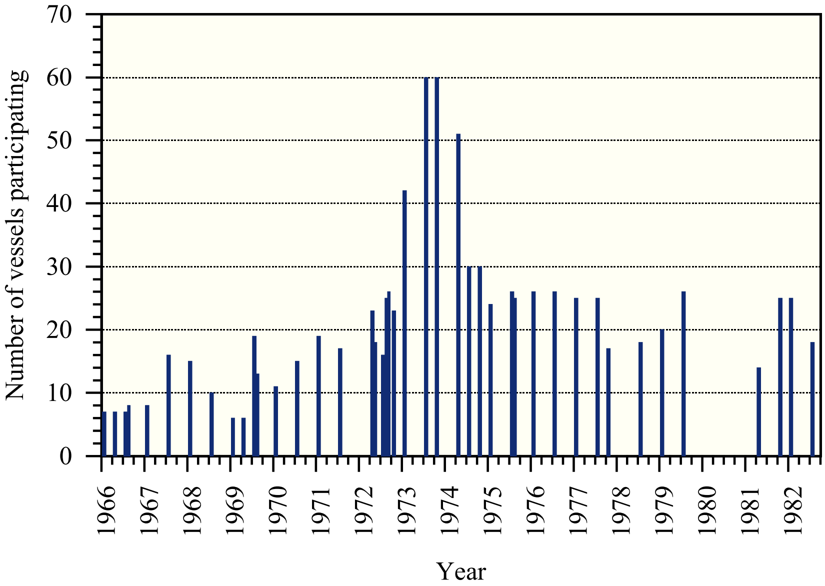
During extreme El Niño events, routine application of catch quotas and fishing closures is no longer effective and management regulations have to adjust fast to rapidly changing conditions. For example, the El Niño 1997–1998 developed so rapidly that each month from June to December 1997 a new monthly record high was set for SST in the eastern equatorial Pacific [58]. In response to such rapid change in the environment, the management and governance system is forced to mirror the dynamics of the ecosystem and become just as rapid in order to increase the chances of survival of the fishing industry. Two strategies have been developed by the Peruvian fisheries management agencies to deal with such fast changing situations: low cost additional monitoring and flexible fisheries regulations.

3.3.1. Coping Strategy 5: Low Cost Monitoring

The first strategy developed to cope with rapidly changing conditions at sea was to attain additional monitoring capacity. This was achieved through the establishment of the so-called EUREKA cruises in 1966 [41,59] (Figure 1b). Revenues from taxes imposed on the industry based on the value of landed anchovy are, by law, allocated to directly cover operational and research costs of the Vice-Ministry of Fisheries and IMARPE. When anchovy shoals suddenly decrease, tax collection also falls and is not enough to cover the additional monitoring that is required to determine when fishing can restart. In these circumstances, so-called EUREKA cruises are undertaken. EUREKA cruises are based on legal agreements by which the fishing companies allow IMARPE to use their fleet as scientific platforms in order to monitor biological conditions and anchovy stocks in real time [10]. Scientific and technical personnel from IMARPE are sent to the main fishing ports, from where anchovy vessels set sail simultaneously to perform oceanographic sampling and carry out experimental fishing. Fishing companies that take part are selected from among those entitled to sign an agreement by drawing lots. The costs of these cruises are totally covered by the companies, thus notably reducing not only governmental expenses but also the delays involved in planning and implementing conventional large scale research cruises. The fishing companies involved are allowed to process the anchovy catches obtained from the experimental fishing to recover some of the associated financial costs.

The first EUREKA program was carried out in February 1966, in response to the onset of the mild El Niño event in December 1965. From then until 1982, when the first large acoustical evaluation cruise was undertaken, 59 operations were carried out. As shown in Figure 5, the number of EUREKA cruises increased in frequency during El Niño 1972–1973, as well as the monitoring effort, shown in this case by the number of vessels taking part. Since 1982, monitoring of anchovy stocks and conditions at sea has been carried out by an annual program of acoustic surveys and one ichtyoplankton survey, supplemented by at least two annual oceanographic cruises. However, when necessary EUREKA cruises are still implemented; the most recent one was undertaken in April 2010.

Figure 5. EUREKA cruises and number of fishing vessels participating between February 1976 and September 1982.



3.3.2. Coping Strategy 6: Rapid Management and Flexible Legal Instruments

Rapid management of the Peruvian anchovy fisheries is a response to the impossibility of calculating a long term optimal catch and the challenge of coping with rapid and unpredictable environmental change. Uncertainty arrives with every El Niño, since no two El Niño events are exactly alike [60] and each El Niño always behaves different from its predecessor. For example, it forms more quickly, or at a different time of the year, and has different impacts on marine species; so researchers and forecasters are surprised once again [61]. "Loose" or flexible management rules are a response to this uncertainty.

Management and control of Peruvian fisheries activities is currently regulated according to the most recent General Fisheries Act of 1992. This law requires that a management plan for each fishery should be applied in accordance with principles of long-term sustainable use and maximum economic and social benefits (Chapter 2, Law Decree 25977). Since the enactment of the most recent Fisheries Act Implementing Regulations in 2001 (Supreme Decree 029-2001-PE), management plans have been established for almost all commercial fisheries. These plans have been implemented for the demersal hake fishery since 2003; the giant squid fishery since 2001; highly migratory tuna-like fishery since 2001 (revised 2003); and even for the pelagic jack and horse mackerel fishery since 2001 (revised 2007). However there is no management plan in operation for the anchovy fishery. This is not accidental or unintended but reflects the intention of the government to avoid the use of legal instruments that could restrict or delay a rapid management decision process. Legally, anchovy is managed under "Provisional Fishing Regimes", drawn up in accordance with IMARPEs scientific recommendations, and approved by the signature of the Minister of Production.

An example of rapid management of the anchovy fishery is the provisional closure of landing harbors when juveniles account of more than 10% of the catches. According to IMARPE scientists, it takes the government less than two days from the delivery of a report by IMARPE of high juvenile capture rates, to the resulting closure of the port concerned. The legal department of the Vice-Ministry of fisheries draws up the ministerial resolution one day after the arrival of IMARPE' S report; the same day the minister signs it, and the next day the resolution is published in the daily official Peruvian newspaper "El Peruano". The port is closed on the same day after the publication in the newspaper. According to Chavez *et al*. (2008) [9]:

> *Fisheries decisions in Peru are made in quasi real time using the most recent observations. It is probably the only place in the world where this rapidly "adaptive" management style is possible. Government bureaucracy and slow data analysis usually mean that the management decisions are implemented for yesterday' S conditions and problems.*

3.4. Fourth Impact: Uncertain Changes in Fishmeal Prices

As in all market-based economic activity, commercial fisheries are beset by both supply side and demand side problems [62]. Thus market prices for fishmeal are determined by the interaction of delicately sensitive market demand and supply curves; and have fluctuated violently during the entirely history of the fishery [47]. When due to El Niño events, fishmeal production supply decreases, prices should increase and vice versa. As a result of a drop in catches due to El Niño 1965, fishmeal prices went up from an average price of US$ 108.50 per metric ton in 1964 to US$ 207.50 in early 1965 [47]. Prices then fell as catches increased and oceanographic conditions returned to normal. This scenario changed when prices of other protein feed substitutes like soybean, sunflower, palm kernel, cotton seed, entered the market. The existence of substitute products means that if fishmeal harvesting inefficiencies become excessive and as a result prices increase, fishmeal is replaced by other products from the world protein market [47].

Based on monthly data of fishmeal and soybean prices between 1981 and 1999, it was found that fishmeal and soybean were strong rich protein meal substitutes [63] and that total supply and demand of these two protein meals were determinants of fishmeal prices. Given the vast environmental variability exacerbating the supply side for the anchovy industry, it is not surprising that mechanisms to cope with the demand side were evolved. Fishing companies developed two strategies to cope with unpredictable changes in fishmeal prices.

3.4.1. Coping Strategy 7: Coordinated Fishmeal Supply

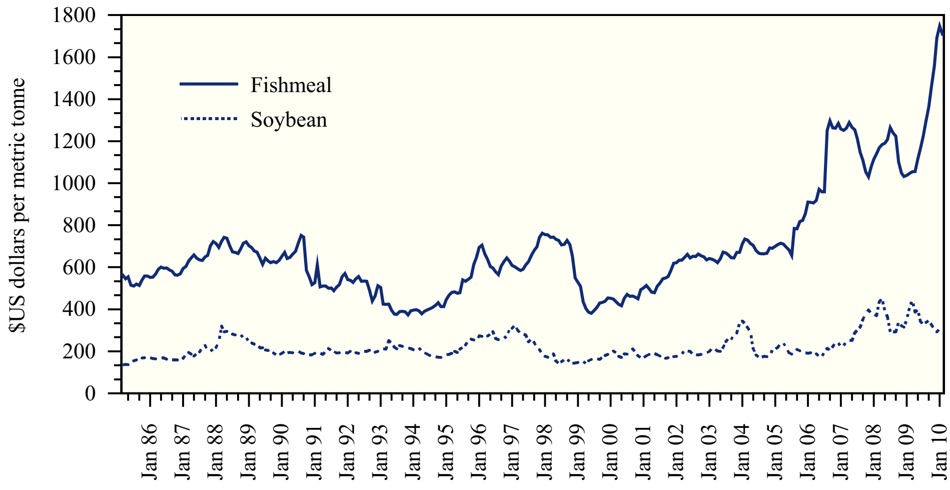
In 1960 the problem of excessive supply and subsequently lower prices (fishmeal price fell from US$ 174 to US$ 60 per metric ton) was met by establishing a system of export quotas for each fishing company [40]. This was implemented at a national level by the Peruvian Fisheries Consortium [55,64], which represented at least 80% of fishing companies in Peru and functioned as a sales cooperative; and at an international level by the Fishmeal Exporters Organization (FEO) [40,65]. FEO, an association of the most important fishmeal exporting countries, was responsible for promoting sales of fishmeal, acting as a clearing house for information on fishmeal production and markets and establishing a system of export quotas for participating nations [40]. Increasing demand for fishmeal in the international market some years later led to the abandonment of the quota system [40]. The Consortium' S operation ended in 1970, when the Peruvian government, prior to nationalizing the industry, set up the *Empresa Publica de comercialización de Harina y Aceite de Pescado* or EPCHAP

(State Company for Fishmeal and Fish-oil Marketing) and any unauthorized, independent sale of fishmeal was banned. EPCHAP ceased operations in 1978, leaving fishmeal marketing once again in hands of the producers. FEO is still functioning nowadays under the name of International Fishmeal and Fish-oil Organization, or IFFO.

3.4.2. Coping Strategy 8: Reducing Linkage of Fishmeal Price with Soybean Production

The second measure to combat market price uncertainty by the Peruvian industry was the decoupling of the fishmeal price from dependence on prices of soybean meal. Kristofersson and Andersen [66] found that the historically strong price relationship between fishmeal and soybean meal has weakened since the late 1990s (Figure 6). For these authors, the most likely reason for this change was increased demand for specialty uses of fishmeal, not only from aquaculture but also from the pork and poultry industries. The study however did not take account of the fact that during the 1990s, Peruvian fishmeal producers took the risk of investing in new technologies to improve fishmeal protein quality and digestibility. By offering a better quality product, which could not be substituted with soybean meal, high fishmeal prices would no longer be dependant on soybean crops levels. The period between 1992 and before the onset of the 1997–1998 event, known by the anchovy fishmeal sector as the period of "industrial re-conversion" was characterized by an increase of special high-protein meal production from 40,000 metric tons in 1992 to 366,000 metric tons in 1994 [67]. "Special or high protein fishmeal" is an improved quality fishmeal used to principally supply the aquaculture market. This fishmeal, commercially known as prime meal, super prime meal or LT-94 (low temperature, 94% digestibility), is made from fresh anchovies, and dried using indirect steam or vacuum dryers. It has protein contents between 68% and 72% and digestibility values between 92% and 94%. The name was given to distinguish them from the conventional or standard fishmeal „Fair Average Quality" or FAQ fishmeal, which is dried using hot air and has protein contents between 65% and 67%.

Figure 6. Fishmeal and soybean prices between 1986 and 2010 showing a decoupling around 1992.



During the same period a decrease in the conversion rate, that is, tons of anchovy needed for the production of one ton of fishmeal, took place. This conversion rate fell from the standard historic average of 5.11 in 1992 to 4.7 in 1996. This change was only possible as a result of private investment in fleet and processing equipment estimated at US$ 400 million between 1991 and 1995 [68]. The investment decision was also taken partly in response to a promising increase in demand for good quality fishmeal from the aquaculture sector, mainly from China.

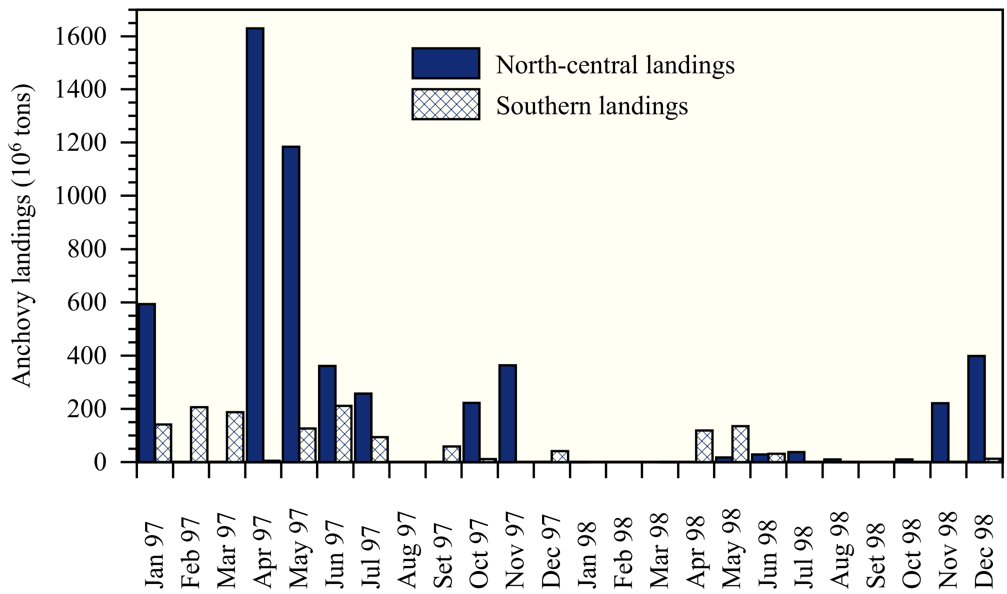
4. Recent Trends

Anchovy landings collapsed after the El Niño 1972–1973 and reached their lower historical records after the 1982–1983 event, however the fishery recovered rapidly after the extreme event of 1997–1998 (Figure 1a). Several factors contributed to this rapid recovery. On the anchovy stock or resource side, a healthier anchovy population fished much more carefully and under improved management together with appropriate cooler oceanographic conditions reduced the minimal impact of the 1997–1998 extreme event. On the resource users and resource management or governance side [36,37]; the availability of coping strategies developed since the onset of the fishery also played an important role, as discussed bellow:

4.1. Adaptation to Changes in Anchovy Fishing Grounds

After the 1972–1973 and 1982–1983 El Niño events, the southerly migration by anchovy during the first months following the onset of a strong El Niño episode was recognized as a predictable pattern [35]. El Niño 1997–1998 arrived around March 1997 and low catches of anchovy in the north started to be reported on June (Figure 7). Catches in the north-central area did not recover until the end of the warm SST anomalies in August 1998. During the first semester of 1998 it was only the landings in southern Peru that sustained the fishery; and 70% of the catches were registered south of latitude 14° S. This behavior was largely expected and facilitated by fishing fleet migration and the availability of 10 fishmeal plants located south of latitude 14° S at that time [69].

Figure 7. Anchovy landings during the 1997–1998 extreme ENSO warm event.



Recent data indicates that there are currently 142 fishmeal processing plants at 24 locations along the Peruvian coast [70]. In 2008, 40 fishing companies with authorization for fishmeal reduction were officially registered, of which seven were responsible for 68% of total fishmeal production [71]. These most productive companies owned 281 fishing vessels and 72 processing factories equivalent to 54% of total Peruvian fishing vessels holding capacity and 66% of processing capacity, respectively [71]. Each company works with their own *chatas*. Table 3 shows the currently spatial distribution and reduction capacity of fishmeal factories belonging to the principal fishing companies.

Geographical distribution of fishmeal plants shows a processing power concentration between latitudes 9° S and 11° S and 8% of their processing capacity located south of latitude 14° S. This distribution of processing capacity enables the industry to adapt to drastic changes in distribution of anchovy fishing grounds.

Table 3. Latitudinal distribution of fishmeal processing capacity (tons/hour) from the largest fishing companies along the Peruvian coast in 2010 (*Source*: PRODUCE).

Latitude	**Tecnología de Alimentos S.A.**	**Corporación Inca S.A.**	**Pesquera Exalmar S.A.**	**CFG Investment S.A.C.**	**Pesquera Diamante**	**Pesquera Hayduk**	**Austral Group S.A.**	**Total percentage (%)**
5° S	150	170			70	138		528 (9%)
6° S								
7° S	352	259	60	80		180		931 (15%)
8° S								
9° S	374	407	90	164	125	100	80	1,340 (22%)
10° S	80	142		76	80	60	113	551 (9%)
11° S	391	80	134	80	202	120	100	1,107 (18%)
12° S								
13° S	249		100	40	178	80	120	767 (13%)
14° S								
15° S	140							140 (2%)
16° S	141			145	80			366 (6%)
17° S	131	90				78	100	399 (7%)

4.2. Adaptation to Changes in Abundances of Fish Stocks

Before 1997, heavy lobbying from the fishmeal industry had given rise to a series of government regulations that allowed the use of sardines for fishmeal reduction, whatever its capture size (Ministerial Resolutions No. 678, 772 and 798-97-PE). However this practice was politically unpopular in a country where human food insecurity is still a problem. In 1998, when Ministerial Resolution 409-98-PE issued permits for sardine fishing, but exclusively for the canning industry, these permits were illegally used to supply the fishmeal industry, concerned by the scarcity of anchovies. A more general ban on the use of edible fish species like sardines and mackerel for fishmeal reduction was introduced in 2002. The ban aims to support the canning industry for local consumption (Supreme Decree 001-2002).

In response to these politically motivated changes, the anchovy industry has two options. Firstly, they can supply their processing plants with other anchovy-like fish species that arrive during ENSO warm events. The use of the long-nose anchovy during 1997–1998 (Table 2) shows that to some extent this is already happening. Secondly, the industry can diversify to reduce its reliance on fishmeal production. Again this process is already underway. During the last decade, the most productive fishing companies in Peru have started to invest in equipment to process canned and frozen fish.

4.3. Adaptation by Improved Monitoring and Flexible Management

The 1982–1983 El Niño focused international attention on the study of the origin, prediction and impacts of the El Niño around the world [61]. During 1997–98, international agencies provided support for research projects by IMARPE, under the umbrella of "El Niño research". In 2000, the Inter-American Development Bank and the World Bank financed a project to locate four oceanographic buoys to monitor oceanographic conditions along the Peruvian coast; and two Fish Aggregating Devices attached to oceanographic detection equipment. These installations send real-time oceanographic information to El Niño research institutes in Peru. A further project finances the salaries of scientific personnel for the expanded ENSO monitoring program that has been underway since 1998.

During the last decade, the Peruvian government has enforced the law to use revenues from the anchovy fishery to cover the overall costs of fisheries management [72], regardless of the fishery involved. This applies to revenues from the auction of fishing rights for other species to international fishing fleets. These auctions are held when, for example, large biomasses of giant squids or tunas are detected within the Peruvian Economic Exclusive Zone, for which the country does not possess the appropriate fleet and processing facilities. As in the case of the fishmeal production, which is no longer dependent on only one fish species, here again there is opportunistic behavior, in this case by the government management agency. This helps to ensure a steady income to cover fishery management costs, even during periods of drastic environmental change.

At the height of the 1997–1998 El Niño, the number of ministerial resolutions related to quotas and fishing closures in the anchovy fishery recorded its historical peak of 28 [18], reflecting a rapid response in changes in management regulations according to environmental conditions.

4.4. Adaptation to Changes in Fishmeal Prices

When the 1997–1998 El Niño arrived, high-protein fishmeal accounted for 45% of total exports compared to standard fishmeal. Fishmeal prices reached their peak of US$ 700 per metric ton between the end of 1997 and beginning of 1998, a price that had not been recorded since 1973 [73]. Landings after El Niño 1997–1998 recovered rapidly to 7.8 million metric tons in 1999 and 9.9 million metric tons in 2000; and the economic impact on the industry was notable moderate. According to Santivañez and Santivañez (2003) [67], it was the improvement in conversion rate and export price increment of high protein fishmeal that gave the industry capacity to mitigate the economically impact of the last extreme El Niño.

The conversion rate between 2001 and 2005 has been reported to be at 4.45 [74]. In 2008, Peruvian fishing companies placed on the market 625,400 metric tons (44%) of fishmeal quality FAQ and 783,100 metric tons (56%) of high-protein fishmeal [70], and prices have risen their historical records at about US$ 1500 per metric ton. China is the major customer accounting for more than half of total Peruvian fishmeal exports. [75].

4. Conclusions

The development of coping strategies to deal with environmental variability and extreme events in the Peruvian anchovy fishery has been a long and dynamic process with strategies emerging or receding during different phases of the fishery. The process has not been a painless one, and strategies have sometimes led to conflicts between the fishery sector and Peruvian fishery policies. Conflicts in the fishery sector have arisen for instance with governmental attempts to promote fisheries of edible species to improve local fish consumption; or to reduce overcapitalization of fishmeal factories due to both uncontrollable growth of processing capacity and the importance of having the capacity to move south during an El Nino event. In these cases a trade-off between the resource users and the governance subsystems appears to offer a resolution. It will be very difficult for the anchovy fishery to use edible fish for fishmeal production with the arrival of the next El Niño; however, the Peruvian government will probably not interfere with the dilemma of overcapitalization of fishmeal factories.

It is also clear that the strategies presented here have developed to cope with short term perturbations like El Niño and may be less efficient to deal with variability at larger scales of environmental change. For research and policies in the commercial fishery sector, there are however some important lessons to be learned from this experience. The first one concerns the advantages of a “division of labor” in the development of coping strategies to deal with extreme events. Some resources will be more robust or resilient to new environmental conditions. In our case study, anchovy stocks have evolved diverse adaptations to cope with El Niño effects which include opportunistic feeding [76] and migration to coastal, deeper and southern cooler waters [77]. On top of these adaptations, resource users and management authorities have evolved their own coping strategies. Although our list of strategies is most likely not exhaustive, it shows that the process was clearly system-wide, sometimes reactive, sometimes bottom-up; and included high levels of information transfer between the resource, the resource users and the resource management subsystems. New technologies like the investment for high protein fishmeal processing equipment or the use of acoustic equipment to evaluate anchovy populations; and innovative ideas like low cost uploading barges have also played an important role.

Second, fishermen have always adapted to changes in their environment by using their knowledge accumulated through past experiences and have been force to react to surprises. Fishermen’ S past experience alone will no longer be a reliable guide to the extent of change predicted by climate change. This case study suggests that it was prior experience of adaptation that prepared the Peruvian fishery to cope relatively successfully with the three extreme events that took within a period of 15 years between each event, forcing the evolution of coping strategies in a relative short period compared with the life-history of the fishery. The strategies continue to diminish the effects of minor events like the 2002–2003 El Niño. However as is commonly stated in Peru: “the only thing we know about El Niño is that sooner or later it is going to come". The same could be stated for climate change and the only aspect that we can be sure is that it is going to come and we should prepare ourselves for that time. A culture of preparedness is tangible in the Peruvian society and the challenge will be to foster this way of life to prepare societies for climate change.

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Conflict of Interest

The authors declare no conflict of interest.

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Annex 1.

List of interviewees:

From The Vice-Ministry of Fisheries

1. Director General de Extracción y Procesamiento Pesquero
2. Subdirector de Consumo Humano
3. Subdirector de Consumo Humano Indirecto
4. Jefe de Oficina de Base de Datos
5. Ex-director General de Extracción y Procesamiento Pesquero
6. Director General de Seguimiento Control y Vigilancia
7. Director de Inspección y Fiscalización
8. Director de Seguimiento, Vigilancia y Sanciones
9. Jefe oficina de Sistema de Seguimiento Satelital
10. Asesor Programa de Control y Vigilancia para la Pesca Marítima

From the Instituto del Mar del Perú (IMARPE)

1. Director Ejecutivo
2. Asesor Director Ejecutivo
3. Director Científico
4. Asesor Director Científico
5. Director de Investigaciones de Recursos Pelágicos, Neríticos y Oceánicos
6. Jefe de Unidad de Investigaciones en Recursos Transzonales y Altamente Migratorios
7. Jefe de Unidad de Investigaciones en Dinámica de Poblaciones
8. Jefe de Laboratorios Costeros

From the fishing private sector

1. Gerente General de la Sociedad Nacional de Pesquería (SNP)
2. Jefe de la Oficina de Economía y Estadística Pesquera (SNP)
3. Jefe de Oficina de Asuntos Ambientales (SNP)
4. Representante de la SNP en Consejo Directivo del IMARPE
5. Ex-gerente de PESCA PERU
6. Director de Flota y Abastecimiento – Pesquera Hayduk S.A.
7. Director de Investigación, Planificación y Desarrollo – Pesquera Diamante S.A.
8. Jefe del Departamento de Flota – CFG Investment S.A.C.
9. Departamento de Flota - Pesquera Austral

Article 3.

Arias Schreiber, M., and A. Halliday 2013**.** Uncommon among the commons? Disentangling the sustainability of the Peruvian anchovy fishery. *Ecology and Society* 18(2): 12. http://dx.doi.org/10.5751/ ES-05319-180212

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Research, part of a Special Feature on Cooperation, Local Communities, and Marine Social-ecological Systems: New Findings from Latin America

Uncommon among the Commons? Disentangling the Sustainability of the Peruvian Anchovy Fishery

Milena Arias Schreiber [1] and Andrew Halliday [2]

ABSTRACT. The term "commons" refers to collectively exploited resources and their systems of usage; a synonymous term is common pool resources. Fisheries are typical common pool resources and also one of the most conspicuous examples of unsustainable use of natural resources. We examine one of the few globally important fisheries that is held to be sustainable, the Peruvian anchovy fishery, and considers the extent to which the institutional characteristics of the fishery conform to design principles that are considered prerequisites for long-term, successful, community-based common pool resources. Results showed that greater conformity to the principles was found in the sustainable phase of the fishery, compared to its unsustainable phase. For this case study, the conditions that supported the transition towards sustainability were: clearly defined resource boundaries, monitoring of rule enforcement, and conflict resolution mechanisms among users and management authorities. On the other hand, clearly defined user boundaries, collective choice arrangements, and nested enterprises were not required to achieve sustainability. The study concludes that the design principles are a valuable tool for analysis and understanding of large-scale common pool resource systems. At the same time it suggests that the application of the principles to a wider range of systems can generate new insights into what is required for successful management of common pool resources.

RESUMEN. Los "bienes comunes" se refieren colectivamente a los recursos explotados y sus sistemas de uso, y también se conocen como recursos de propiedad común (CPR). Los recursos marinos han sido considerados tradicionalmente como CPR y como uno de los ejemplos más conocidos de uso no sostenible de los recursos naturales. Este trabajo examina una de las escasas pesquerías importantes a nivel mundial que se considera sostenible -la pesquería de la Anchoveta peruana (*Engraulis ringens*), considerando el grado en que las características institucionales de esta pesquería se ajustan a los principios de diseño de gobernanza de recursos comunes que se consideran requisitos previos para el éxito a largo plazo en la gestión de CPR. Los resultados obtenidos mostraron que una mayor observancia y conformidad con los principios de diseño durante la fase sostenible de la pesquería, en comparación con su etapa insostenible. Para este caso de estudio cabe destacar que una clara definición de los límites de uso del recurso, la aplicación de reglas de supervisión y mecanismos de resolución de conflictos entre los usuarios y las autoridades de gestión, han sido todos ellos factores que han apoyado la transición hacia la sostenibilidad de la pesquería. Por otro lado, una clara definición de los límites de uso por parte de los usuarios, la elección de acuerdos colectivos y la unión entre empresas no han sido requisitos para lograr la sostenibilidad de la pesquería. Concluimos que el diseño de principios constituye una valiosa herramienta para el análisis y la comprensión de los grandes sistemas de CPR. Al mismo tiempo, este estudio sugiere que la aplicación de los principios a una gama más amplia de sistemas puede generar nuevos conocimientos que permitirán una gestión exitosa de los CPR.

Key Words: *anchovy fishery; common pool resources; design principles; Peru; sustainability*
anchoveta peruana; recursos comunes; diseño de principios; Perú; sostenibilidad

INTRODUCTION

Global fisheries are one of the most conspicuous examples of unsustainable use of natural resources. Despite the considerable scientific attention devoted to marine resource management, many of the world's fisheries are still in a deplorable state (Beddington et al. 2007). Nearly one in four fisheries collapsed during the period 1950–2000 (Mullon et al. 2005), where collapse is defined as a 90% reduction of a wild fish stock. There has been a continuous decline in global catches since the late 1980s (Pauly et al. 2003).

Most wild fisheries are based on the exploitation of common pool resources. Fisheries are a typical common pool resource (Feeny et al. 1990, Neiland 2006, Cox et al. 2010), showing the attributes of costly exclusion of potential users and substractability, i.e., when exploitation by one user reduces the resource availability for others (Ostrom et al. 1999). This paper examines one of the few globally important fisheries that is held to be sustainable, the Peruvian anchovy fishery (Mondoux et al. 2008), and considers the extent to which the institutional characteristics of the fishery conform to principles that are considered prerequisites for the sustainability of common pool resources.

Until the 1980s, research into common pool resources was under the sway of the paradigm of the "tragedy of the commons". This holds that multiple individuals, acting independently, and rationally consulting their own self-

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interest, will ultimately deplete a shared limited resource even when it is clear that this is not in anyone's long-term interest (Hardin 1968). However, from the mid 1980s, this view was increasingly challenged. Evidence that some common pool resource systems were robust over long periods of time while others failed stimulated the search to identify the features that distinguished successful from unsuccessful efforts (Ostrom 1990).

In 1990, Elinor Ostrom proposed a set of eight “design principles” of common pool resources management regimes that are long-lasting (Ostrom 1990); these are “general institutional regularities” that can be observed among common pool resource systems “that were sustained over a long period of time” (Ostrom 2009*a*). Since then, the validity of these principles has been the subject of intense scrutiny, both from a theoretical and an empirical perspective (Ostrom 2009*a*, Cox et al. 2010). In a review of 91 studies, Cox et al. (2010) found that empirical evidence was broadly supportive of the principles. Some minor modifications to the principles were also proposed as a result of the review (see Table 4 in Cox et al. 2010). However, empirical evidence considered to date relates almost exclusively to small-scale common pool resource systems, where the “community of users” is often a local community such as a village or a cooperative. Cox et al. (2010) conclude “we remain uncertain as to whether the principles may apply to systems at a variety of scales”.

Thus there is clearly the need for empirical studies to assess the extent to which the design principles are applicable to large-scale common pool resource systems. The Peruvian anchovy provides an excellent opportunity to do so. Firstly, it is undeniably a large scale enterprise. This fishery represents almost 10% of worldwide marine fisheries landings (FAO 2010) and has been described as the largest monospecific fishery that has ever existed on Earth (Bakun and Weeks 2008, Aranda 2009*b*). Anchovy fishing takes place over an area of approximately 14,000 km^2 in the coastal waters of north and central Peru between 4° and 15° S, where around 1300 purse seiners target only one fish species: the Peruvian anchovy *Engraulis ringens*. Secondly, the social and institutional characteristics of the fishery are clearly distinct from those of more widely studied small-scale common pool resource systems. The “community of users” consists not of village residents but of wealthy capitalists who have direct access to the highest levels of government and operate out of fortified compounds equipped with state-of-the-art manufacturing and communications technology. The link to local livelihoods that is considered a key feature of sustainable small-scale common pool resource systems (Cox et al. 2010) is entirely lacking: 99% of anchovy catches are converted to fishmeal in Peru to be exported to international markets for aquaculture and animal food. Thirdly, the fishery is currently considered to be sustainable. Indeed it has been described as the most intense and successful fishery worldwide (Chavez et al. 2008), and was recently placed first in a report ranking 53 marine countries by the sustainability of their fisheries (Mondoux et al. 2008).

Table 1. Design principles of robust, long-term, common pool resources during the unsustainable growth phase (1960–1972) and the sustainable phase (1994–2009) of the Peruvian anchovy fishery.

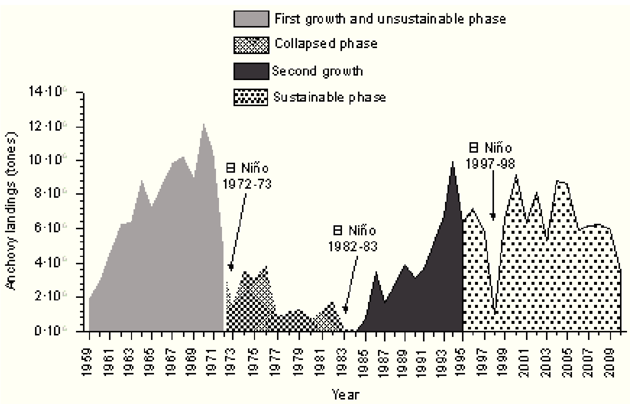
Design principle	Unsustainable phase	Sustainable phase
Clearly defined		
User boundaries	No	No†
Resource boundaries	No	Yes
Congruence		
Between rules and local conditions	Yes	Yes
Proportional equivalence between costs and benefits	Yes	Yes
Collective choice arrangements	No	No
Monitoring		
Rule enforcement	No	Yes‡
Resources	Yes	Yes
Graduated sanctions	No	Yes
Conflict resolution mechanisms		
Among users	Yes	Yes
Among users and management authorities	No	Yes
Minimal recognition of rights to organize	Yes	Yes
Nested enterprises		
Users	Yes	Yes
Management authorities	No	No

† Only at national levels, i.e., if foreign multinational or only national companies are allowed to participate in the fishery. (For details see Arias Schreiber 2012.)
‡ Since 2003.

Finally, the fishery has not always been set on a sustainable landings course, and various different phases of the fishery can be identified for the purposes of comparative analysis. Based on landings statistics, four distinct phases of the Peruvian anchovy fishery can be identified (Arias Schreiber 2012). Following its establishment in the mid 1950s, the anchovy fishery soon entered a phase of explosive and uncontrolled growth, which by the end of the 1960s was clearly unsustainable. This “unsustainable growth phase” culminated in a collapse in 1972, triggered by the extreme El Niño event of 1972–73. After the collapse, a second phase from 1973 to 1984 was characterized by unfavorable oceanic conditions for anchovies and low catches. A third phase, from 1985 to the present, can be further divided into a second growth period from 1985 to 1993 and a sustainable landings period from 1994 to the present (Fig. 1). During the sustainable phase annual anchovy catches have stabilized at between 5 and 9 million tonnes in years with propitious oceanographic conditions, and have recovered quickly from perturbations caused by climatic variations, including the extreme El Niño event of 1997-98 (Arias Schreiber 2012). In 2009 a new management system for the fishery was introduced, based on quotas for individual fishing vessels, which substantially altered some key, long-standing, institutional features of the fishery (Aranda 2009*a*, Arias Schreiber 2012). In institutional terms, this represents the beginning of a further new phase for the fishery, although it is too early to assess its impacts, if any, on the sustainability of landings.

This article reviews the design principles proposed by Ostrom (1990), as modified by Cox et al. (2010), for the successful long-term management of common pool resources in the light of experiences during both the unsustainable and sustainable phases of the Peruvian anchovy fishery. Specifically, we address the following questions: (1) whether the design principles can explain the recent sustainability of the fishery; (2) whether institutional differences between the unsustainable and sustainable phases of the fishery provide evidence to support the design principles; and (3) whether the Peruvian experience suggests further modifications to the design principles that would enhance their applicability to large-scale common pool resources.

Fig. 1. Historical Peruvian anchovy landing, major El Niño events, and phases of the fishery.



METHODS

This article is the result of semistructured interviews carried out at Peruvian fishery institutions between October and November 2009. Ten key informants were interviewed at the Vice-Ministry of Fisheries, eight from the Peruvian Marine Research Institute (IMARPE), and nine from the private fishery sector. Interviewees were selected on the basis of length of experience and period of time in post, in order to obtain as much information as possible from the beginning of the fishery to the present (see list of interviewees in Appendix 1). Three interviewees had been involved with the anchovy fishery since the 1960s (two from IMARPE and one from the industry), two since the 1970s, ten since the 1980s, five since the 1990s and seven since the start of this century. The article also draws on the experience of the first author as a scientific officer at IMARPE from 1994 to 2001. The questionnaire used during the interviews is shown in Appendix 2.

Interviews were triangulated with intensive documentary analysis from published material and other sources including internal reports, yearbooks, fishery magazines, and legal databases. Historical statistical data including anchovy landings, number of fishing vessels, fishing effort expressed in fishing days per year, fishmeal prices, and anchovy exports were obtained from the Pelagic Resources Department of IMARPE.

RESULTS

The compliance by the Peruvian anchovy fishery with Ostrom's design principles for long-lasting governance regimes of common pool resources (as modified by Cox et al. 2010) across the sustainable and unsustainable phases of the fishery is shown in Table 1.

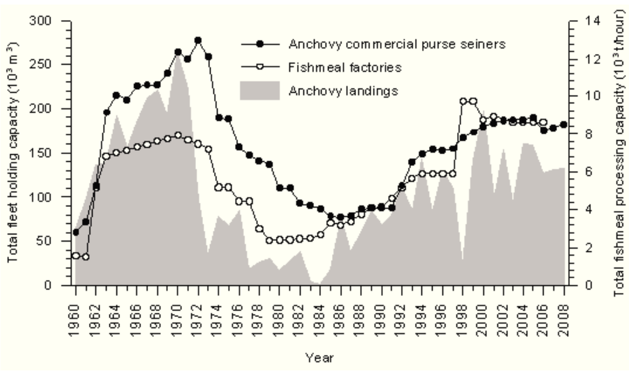
Principle one: clearly defined boundaries

This principle contains two components: *1A User Boundaries*, understood as clear boundaries between legitimate users and nonusers, and *1B Resource Boundaries*, i.e., boundaries that define the resource system and separate it from the larger biophysical environment (see Table 4 in Cox et al. 2010). In summary, user boundaries of the Peruvian anchovy fishery have been permeable, although perhaps decreasingly so in recent years; resource boundaries have been increasingly clearly defined.

In relation to user boundaries, exclusion of outsiders in marine fisheries is difficult to achieve and this fishery has been no exception. However, different conditions have governed entry into the two activities that make up the Peruvian anchovy fishery: fishing and processing. Within the community of users, two distinct groups can be recognized: firstly the large fishing companies, which operate the processing plants and also own fishing fleets that directly supply these plants; and secondly, independent boat owners who sell anchovy to the processing plants under informal contracts. Along the history of the fishery, there has been no effective limitation on access to the fishery resource. As a consequence, the number of fishing vessels in this fishery has broadly followed changes in the abundances of anchovies rather than being a response to management regulations to exclude outsiders (Fig. 2). Entry to the processing industry has followed the same dynamics, leading to a historical overcapitalization of both fishing vessels and processing factories (Ibarra et al. 2000, Thorpe et al. 2000, Fréon et al. 2008, Aranda 2009*a*). In both sectors, the response to the problem of "free riders" has been to incorporate them into the formal sector, rather than to attempt to enforce exclusion.

Although attempts were made to limit access to the fishery through a system of fishing licenses as early as 1956, these served only to increase corruption and speculation and the system was abandoned in 1962 (Thorp and Bertran 1978). Thus, during the unsustainable phase, any person with enough financial capital to build and put a fishing vessel to sea was allowed to do so. The availability of apparently inexhaustible stocks of anchovy fuelled a frenzy of shipbuilding that persisted throughout the 1960s and early 1970s (Aranda 2009*b*). Vessels were constructed, with or without qualified labor, in empty lots and in the streets of Callao, Peru's major port (Roemer 1970). Expansion was further fuelled by foreign investment. Capital assets in the fishery coming from foreign companies increased from 12% in 1960 to more than 40% in 1967 (Thorp and Bertran 1978). The size of the fleet increased spectacularly from 52 registered vessels in 1953 to 1309 in 1972, although even this was down from the maximum of 1744 boats in 1964 (Aranda 2009*b*).

Fig. 2. Historical evolution of Peruvian anchovy landings, anchovy fishing vessels, and fishmeal factories between 1960 and 2008. Anchovy landings (shaded area) correspond to landings presented in Fig. 1.



Subsequent efforts, to set limits on the number of vessels and processing plants also had limited success in avoiding a *de facto* open access fishery (Thorpe et al. 2000). Following the collapse of the fishery in 1972, the anchovy fishing fleet was nationalized and large numbers of vessels were decommissioned. However the fishery was returned to private ownership just four years later. The number of fishing vessels grew moderately during the sustainable period and the fleet's total holding capacity increased from around 150,000 m^3 in 1994 to 220,000 m^3 in 2008. This increase was partially a consequence of a measure (Law 26920; Congreso de la República del Perú 1998) by which wooden vessels with holding capacities between 30 and 110 tonnes were officially recognized as part of the anchovy fishing fleet from January 1998 (Aranda 2009*b*). This incorporated an important group of 'free-riders' into the formal fishery, by legalizing the activities of the small-scale fleet which, before then, had been fishing anchovy illegally (Bermejo 2004).

During the unsustainable phase, user boundaries to the processing industry were indirectly restricted by market forces. A sharp decline in fishmeal prices in 1959–60, due to excessive supply of fishmeal on the international market, prompted the private sectors of the principal fishmeal-producing countries to establish an international arrangement aimed at stabilizing the market, which is known as the "Paris Agreement" (Roemer 1970). This established national quotas for fishmeal sales, which were to be organized through export licenses for fishing companies issued by the respective governments (Hammergren 1981). The Peruvian government recognized fishing companies associated under the National Fisheries Society (Sociedad Nacional de Pesquería, SNP), and Supreme Decree 18 empowers this organization to act as the government's agent in assigning export licenses in conformity with world market quotas ("Perú ratifica ..." 1961). Within the SNP, the Peruvian Fishing Consortium was established for this purpose. However, between 1961 and 1963 export quotas for Peruvian fishmeal were regularly exceeded (Roemer 1970) due to the activities of unassociated fishing companies, which accounted for between 15 and 20% of the total ("Número equivocado ..." 1962*a*). These "free riders" took advantage of improved prices to sell their fishmeal through channels that bypassed the Consortium. In response, the Peruvian government required every company, by Law-Decree 14228, to join the Consortium as the only channel for export of fishmeal from Peru ("Número equivocado ..." 1962*a*). After 1963, international fishmeal prices stabilized and the country quota system was soon abandoned. However, the Consortium continued in exclusive charge of Peruvian fishmeal marketing until 1966, when three other organizations were also legally permitted to engage in marketing (Roemer 1970, Hammergren 1981).

Since then, in practice, entry into the processing industry has been limited by the ongoing consolidation process in this fishery sector (Garcia 2007) that has led to the current situation where seven large companies own more than 50% of fishing vessels' holding capacity and at least 50% (72 units) of the processing factories (Bendezú 2008).

The boundaries of the resource, i.e., the anchovy stock, have been progressively defined since 1970, when the first tagging experiments were carried out by IMARPE to determine the habitat and distribution of this resource ("Marcación ..." 1970*a*). Since 1973, two anchovy populations units have been recognized off Peru: the north central stock from 04°30' to 15° S, and the southern stock from 15° S to the southern limit of the Peruvian maritime domain. To the west, anchovy populations extend up to 100 nm offshore (Checkley et al. 2009). Since Chile, Peru, and Ecuador declared their respective 200 nm Exclusive Economic Zones (EEZ) as early as 1953, the north central stock is defined by natural boundaries and is contained entirely within Peruvian waters. Under normal oceanographic conditions, fishing targets this stock, which is also by far the most productive (Barange et al. 2009). The southern stock, by contrast, is defined partly by natural and partly by political boundaries, i.e., the maritime border with Chile. Catch quotas and closed seasons have been given separately for each population stock since 1983 (Ganoza et al. 2000).

Principle two: congruence

Congruence refers to the harmonious fit between rules for resource use and local conditions—cultural or ecological. This principle also contains two components: *2A Congruence with local condition*s, in the sense that appropriation and provision rules are congruent with local social and environmental conditions, and *2B Proportional equivalence between costs and benefits*, the former being determined by provision rules and the latter by appropriation rules. The Peruvian anchovy fishery has complied, since its inception, with the principle of congruence in both senses of the term.

Congruence between rules and local environmental conditions of the resource has always been an important feature of the Peruvian anchovy fishery. The first closed season was declared by ministerial resolution in 1965 and lasted for one month ("Agosto ..." 1965), i.e., during the spawning peak of the anchovy population (Checkley et al. 2009). Simultaneously, measures were taken to prohibit the landing of catches if 50% or more of the catch consisted of fish of 12 cm or less, and a ban on weekend fishing was introduced. In 1966 the closed season was extended to three consecutive months from June to August (Tsukayama and Palomares 1987). In 1967 the government imposed another 6-week closed season during the height of the fishing season in February and March (Roemer 1970) with the aim of protecting juvenile anchovy in the recruitment phase. In these years, catch quota limits were also imposed, with annual limits of between 8 and 9 million tonnes, in line with IMARPE's assessments of sustainable yields (Clark 1976, Chavez et al. 2008). These practices have continued in the sustainable phase. In general management measures, such as the closure of the fishery or quota regulations, are adjusted on an *ad hoc* basis in response to information from monitoring data and recommendations from IMARPE. Since 1994, any management measure has had to be backed up by a written recommendation from IMARPE. Agreement exists between scientists and politicians that dynamic changes in anchovy stocks call for an equally dynamic response. A recommendation by IMARPE, for example to suspend fishing at one or more ports, can be implemented in a matter of days (Arias Schreiber et al. 2011). Moreover, numbers of ministerial resolutions enacted to regulate the fishery tend to increase during El Niño events, which initiate periods of stress and instability for the resource, providing evidence of adaptive governance capacity in response to local environmental conditions (Arias Schreiber 2012).

Congruence between costs and benefits for resource users during both phases of the fishery has been always high since taxes, fishing licenses, and funds to cover management, monitoring, and scientific research have generally been calculated based on tonnes of landed anchovy, or tonnes of fishmeal exported. As an example, Law-Decree 14265 of December 1962 established a tax of 25 Peruvian Soles (around US$1)/t of anchovy landed ("Regalo de Pascua ..." 1962*b*). The same principle is used nowadays, for example to calculate the cost of fishing rights. According to Supreme Decree 024-2006-PRODUCE of November 2006 (Gobierno del Perú, Ministerio de la Producción 2006*a*), fishing rights are valued at 0.25% of the export FOB price of fishmeal per tonne of anchovy landed. These straightforward practices have enabled the fishery to maintain the equivalence between costs and benefits in a way that can be perceived to be fair by the resource users.

Principle three: collective choice arrangements

Collective choice arrangements authorize resource users to participate in making and modifying their rules. The extent to which this principle has applied to the Peruvian anchovy fishery is open to interpretation.

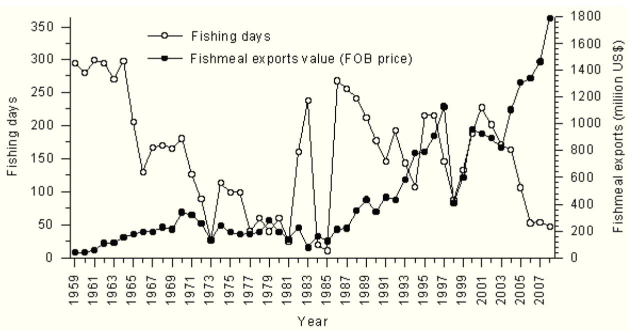
Collective choice arrangements are considered to favor effective resource management by drawing on local knowledge of the resource. In the context of the Peruvian anchovy fishery, "local" has a somewhat different meaning and a national organization, the SNP, has been the principal channel for user participation in decision making. The SNP was created in 1952 as a nonprofit civil cooperative association. During the 1960s, it engaged in intensive lobbying on behalf of the industry around the two major areas of dispute between the government and the fishing companies: taxation and credit policy (Hammergren 1981). It exerted considerable political influence over the development of the anchovy fishery during the 1970s (Caravedo 1979), and this influence has continued during the sustainable phase, although more subtly.

The SNP defines itself as a civil association representing the Peruvian private fishery sector and counts on around 70% of the anchovy fishing companies being among its members. However, in practice, the SNP provides limited representation of users in rule making. It does not represent independent boat owners, who are grouped in other associations. Moreover, the way the SNP functions excludes most members from participating in modifying the operational rules. Decisions inside the SNP are based on a proportional voting system, in which the number of votes per fishing company depends on its fishmeal production in the previous 15 months (Roemer 1970). This voting system invests decision-making power in a small number of large companies. The influence of these powerful companies is further increased by the existence of informal networks that provide close links between them and key personnel in government decision-making agencies (see Principle seven below).

Principle four: monitoring
This principle contains two components: *4A Monitoring to ensure rule enforcement*, and *4B Monitoring the resource.* In summary, monitoring of both rule compliance and resources has become more extensive, intensive, and effective during the sustainable phase, compared to the unsustainable phase.

With regard to rule enforcement, during the unsustainable phase monitoring of landings was undertaken by personnel from IMARPE who had no authority to enforce compliance. Resources were inadequate to monitor the large number of vessels involved and the high number of permitted fishing days, i.e., on average 223 days/year (Fig. 3). Controlling fishermen's behavior was also difficult, because tracking technology to follow fishermen at sea was not available and monitoring of landings was ineffective, resulting in an underestimation of at least 20% in official landings statistics for the period 1952 to 1982 (Castillo and Mendo 1987).

Fig. 3. Annual number of anchovy fishing days and value of Peruvian fishmeal exports, 1959–2008.



Following the establishment of the Ministry of Fisheries in 1970, a Department for Monitoring, Control, and Surveillance was set up; however, the lack of proper financial support and appropriate technology resulted in poor performance. In the sustainable phase of the fishery, the number of vessels was somewhat reduced, and the average annual number of fishing days was also reduced to 141 days (Fig. 3). However, monitoring such a large industry still posed considerable challenges, and in response to these challenges new regulations were introduced to facilitate monitoring and reduce costs. Since 1999, each fishing vessel has been obliged to pay fishing rights ("*derechos de pesca*") equivalent to around US$3/t of anchovy landed. The funds generated are used to finance the operation of the Vice-Ministry of Fisheries and its associated institutions, including IMARPE. Sanctions for nonpayment include the confiscation of the fishing license. In addition, the use of Vessel Monitoring System with satellite tracking systems in each fishing vessel has been required by law since 2000 (Supreme Decree 001-2000-PE; Gobierno del Perú, Ministerio de Pesquería, 2000); costs (around US$200 monthly for equipment and services) are covered by the ship owners. Likewise, landings at all ports are simultaneously monitored by IMARPE and inspectors from the Fishing and Landing Monitoring and Surveillance Program. This program, launched in 2003, transferred surveillance of compliance with anchovy fishery regulations to an independent international company financed by the fishing companies. Annual costs of the program are capped at US$7 million, and these funds are raised by a levy of US$1.40/t of landed anchovy. The Swiss company Société Générale de Surveillance (SGS) and a Peruvian company Certificaciones del Perú (CERPER) are currently employed to undertake this independent monitoring.

Monitoring of the anchovy population (resources) started as early as the end of the 1950s (Castillo and Mendo 1987) and intensified after 1960 with the establishment of the Peruvian Research Institute for Marine Resources, which in 1964 was renamed IMARPE (Barange et al. 2009). Collection of anchovy landing data started in 1959 (Doucet et al. 1962), and collection of size structure data of landed fish started in 1961 (IMARPE 1965). In 1966, in response to the high costs involved in monitoring the resource at sea, IMARPE initiated the so-called Eureka cruises (Arias Schreiber et al. 2011). These were established by legal agreements by which the fishing companies allowed IMARPE to use their fleet as scientific vessels in order to monitor anchovy populations in real time (Barange et al. 2009). Scientific and technical personnel from IMARPE were sent to the main fishing ports, from where anchovy fishing vessels set sail, to perform experimental fishing and oceanographic sampling. The fishing companies involved were allowed to process the anchovy catches to recover some of the associated financial costs (Arias Schreiber et al. 2011).

During the 1970s, new acoustic techniques were developed based on echo-integration of data from digital echosounders to estimate fish populations. Since 1982, the Peruvian government via IMARPE has monitored anchovy populations using these techniques through twice-yearly hydro-acoustical cruises along the geographical range of the anchovy population (Ganoza et al. 2000). The results of these cruises are used to calculate the catch quotas for the two annual anchovy fishing seasons. Thus the adoption of new technology has made monitoring relatively easier during the current, sustainable phase of the fishery. Current annual expenses of IMARPE are around US$15 million (De La Puente et al. 2011), from which about 60% is used to monitor anchovy populations (M. Ñiquen, *personal communication*). However these apparently very high monitoring costs represent less than 1%

of annual export values of the anchovy industry, which are estimated at US$1000 to 1500 million over the last decade (Fig. 3).

Principle five: graduated sanctions

Effective graduated sanctions are seen as a mechanism for ensuring rule compliance by ensuring transparency and building trust between resource users (Ostrom 2009*a*). Sanctions were not applied during the unsustainable phase of the Peruvian anchovy fishery. In the sustainable phase, graduated sanctions have been introduced, but their application has been only partially effective.

Sanctions were neither clearly identified nor enforced during the unsustainable phase of the fishery. By-laws of the First Peruvian Fisheries Act from 1971 (Gobierno del Perú 1971*a*) established graduated sanctions for different fishing infractions for the first time; these ranged from fines between 1000 and 1 million Peruvian Soles, to the permanent confiscation of fishing licenses (Supreme Decree 011-71-PE, Art. 273; Gobierno del Perú 1971*b*). More recently, in the sustainable phase of the fishery, legal sanctions have been imposed according to: (1) the type or nature of infraction, (2) the offender’s intention, (3) the degree of damage caused to the marine environment or amount of benefits illegally obtained, and (4) records of previous offenses (Supreme Decree 012-2001-PE, Art. 149; Gobierno del Perú, Ministerio de Pesquería 2001). However, even with legally graduated sanctions during the sustainable phase, users in this period regularly avoided being sanctioned by appealing sentences and transferring their cases to the Peruvian judicial system where corruption is still quite widespread (De La Puente et al. 2011). In 2008, five judges were removed from their positions for having allocated illegal fishing licenses (R. Rey; quoted in Gobierno del Perú, Ministerio de la Producción 2008).

Principle six: conflict resolution mechanisms

Management of common pool resources is considered to be an inherently conflictive activity; rapid, low-cost local arenas for resolution of conflicts among users are necessary to prevent conflicts from spiraling out of control (Ostrom 2009*a*). Moreover successful resolution of conflicts can spark learning and change (Dietz et al. 2003). In the Peruvian anchovy fishery, formal arenas for resolving conflict have long existed, and these have further developed in the sustainable period.

Since 1952, the SNP has been the institution responsible for providing facilities for resolution of conflicts between resource users. Procedures for resolving conflicts between users and government agencies have been available since the establishment of the Ministry of Fisheries in 1970. By contrast, they were absent during the unsustainable period. Throughout the 1960s, government decisions affecting the fishing sector were made by a variety of agencies for which fishing policy was not a primary concern (Hammergren 1981). Consequently the most important decisions affecting the fishery were not made by any of these agencies, but came out of the Ministry of Finance and the Congress. As a result, resolution mechanisms were difficult to implement when conflicts of interest arose.

Since the Ministry of Fisheries was set up in 1970, it has been the practice of the Peruvian government and diverse members of the fishing sector to establish so-called “Sectorial Working Commissions” to discuss and give advice to the authorities when conflicts arise or the fishery enters a crisis period, i.e., during extreme El Niño conditions. For example, by Supreme Resolution 005-70-PE-ODP of February 1970, the Ministry of Fisheries set up a Commission to perform a feasibility study for the establishment of a quota system for the supply of anchovy to processing factories (“Comisión estudiara ...” 1970*b*). The Commission, composed of members of the Ministries of Fisheries and the Treasury, and one member of the SNP, had one month to present its results. A similar commission was set up in 2006 to evaluate the problem of overcapacity of the anchovy fishing fleet (Ministerial Resolution 215-2006-PRODUCE; Gobierno del Perú, Ministerio de la Producción 2006*b*). Although the impact of such commissions in the decision-making process is varied, these practices could have reinforced networking and learning processes, particularly during the sustainable phase.

Principle seven: minimal recognition of rights to organize

This principle refers to rights, granted by governments to resource users, to organize to manage the resource independently of government (Cox et al. 2010). It appears to presuppose a conflict of interest, or at least of perspective, between local users and external government agencies operating at a larger scale. These conditions apply only partially to the Peruvian anchovy fishery, which operates at a national level—the same as government—and where the dividing line between government and resource users has sometimes become blurred.

The organization of users of the anchovy fishery under the auspices of the SNP has always been recognized by Peruvian authorities. Indeed, the government’s official recognition of the Society as being responsible for setting fishmeal export quotas in the 1960s has even been described as a delegation of the state's policy-making functions to the fishing companies (Hammergren 1981). As mentioned above, throughout the sustainable period, intensive lobbying by the SNP has continued. The SNP does not have an official role in deciding on rules for the management of the fishery. However, one of the seven members of IMARPE’s Board of Directors is by law a representative of the Society, and there is also one member of the SNP in the governmental Committee for Monitoring the Fishing and Landing Surveillance Program. The real influence of the SNP is greater than this modest official representation suggests, and over the years numerous directive personnel at

IMARPE and the Fisheries Ministry, up to the highest level, have been selected because of their strong relations to the SNP. This influence can be seen in specific policy decisions, such as the establishment of the Individual Quota System in 2008, which has been widely attributed to be a response of the Society's demands.

Principle eight: nested enterprises

This design principle relates to the arrangement of governance activities in multiple layers of small-scale organizations nested in ever larger organizations. The reliance of the Peruvian anchovy industry on industrial-scale fish processing means that it is an inherently large-scale enterprise. Moreover, as users are private companies, the dominant paradigm is of competition on the market rather than cooperation. Thus the opportunities for nesting are limited.

In the unsustainable phase, fishing companies were associated only within the SNP, which comprised around 60% of users and which in 1960 became a member of the International Fishmeal and Fish oil Organization (IFFO). During the sustainable phase, there has been some "nesting" at larger scales: fishing companies associated in the SNP are also part of the Peruvian Exporters Association (ADEX) and the Peruvian National Confederation of Private Business Associations (CONFIEP) which is member of the International Organization of Employers (IOE). The management organization, the Ministry of Fisheries, has been a single and centralized institution since its establishment in 1971. This situation has continued throughout the sustainable phase, although formally, since 2001, the Vice-Ministry of Fisheries has operated as one of the two divisions within Ministry of Production. Although the Peruvian government has undergone a process of decentralization since 2002 and Regional Fishery Directorates have been established, with some role in the management of other fisheries, anchovy fisheries management remains the sole responsibility of the central Vice-Ministry of Fisheries.

DISCUSSION

Although the conditions and principles for long-lasting, successful, common pool resources, as described by Ostrom, have been mainly applied to management undertaken by traditional communities with almost no intervention from the government, they offer an excellent point of departure for analysis of institutional settings of larger common pool resource systems and, specifically, commercial fisheries. This is confirmed by the results of our study, which demonstrate that the design principles can be usefully applied to inform the analysis of a large-scale common pool resource. Most of the principles were found to be relevant for a study of the Peruvian anchovy fishery. Moreover, the validity of the principles as indicators of the sustainability of common pool resource management is at least partially confirmed by the fact that greater conformity to the principles was found in the sustainable phase of the fishery, compared to the unsustainable phase (Table 1).

It is recognized that the principles do not offer a recipe for success and cannot be applied in a mechanical way (Ostrom et al. 1999, Bruns 2007, Ostrom 2009*b*). Like previous empirical studies (Cox et al., 2010), this one has suggested some ways in which the principles could be modified or expanded. Our study suggests that controls on catches can be an effective alternative to restricting the number of users. A dynamic decision-making system is necessary to respond effectively to variations in resource availability. Finally, management rules need to be adapted to the specific biological characteristics of the resource being managed. On the other hand, the design principles alone are insufficient for analysis of the rich experience of more than half a century of common pool resources considered in this study. At times it was difficult to constrain our account within the (self-imposed) analytical structure, based around "testing the design principles".

One of the main challenges in applying the design principles to asses our case study fishery was the difficulty of showing causality between institutional characteristics and the sustainability of resource use. While the design principles suggest a set of institutional features that favor sustainability, they do not provide a procedure for analyzing their role within the wider, complex social-ecological system. Specifically they do not take explicit account of the role played by the physical and ecological settings, and/or distinctive characteristics of the resource involved. A number of commentators have signaled the need to give more consideration to the properties of the resource itself (Cox et al. 2010). This certainly applies in our case, given that Peruvian anchovy stock fluctuations, like other pelagic fish stocks, are highly driven by environmental oceanographic conditions. In addition to improved management institutions, the phase of sustainable landings of the fishery has also coincided with medium-term favorable oceanographic conditions for anchovy stocks. Furthermore, a natural resource may be inherently more or less susceptible to sustainable use. The Peruvian anchovy, as an abundant, fast-breeding, and highly mobile species, adapted to living in a highly unpredictable biophysical environment, might appear to be innately resilient to bad management, particularly as alternative resources, such as sardine and other pelagic fish, are often available to sustain the fishing industry when anchovy stocks are low.

Our results showed that for this case study, clearly defined user boundaries, collective choice arrangements, and nested enterprises were not required to achieve sustainability. It can be argued here that the choice of the Peruvian government has been to relax user boundaries while clearly defining the amount of resources that the users are allowed to withdraw. This has been achieved through a quota system that guarantees the natural replenishment of the resource. Catch quotas that were not complied with during the unsustainable phase, are currently enforced by not only closing the fishing season when the quota is attained but also by simultaneously banning fishmeal processing. The clearly identifiable smell of burning fish, detectable even some miles away from the factories, makes it impossible for illegal fishmeal reduction to go unnoticed, and supports compliance (Arias Schreiber 2012).

A criticism that has been made of the design principles from the perspective of community-based management of common pool resources is that they appear, incorrectly, to assume resource users are “coherent wholes without internal conflict or heterogeneity” (Cox et al. 2010). This study provides evidence that this criticism is also valid at larger scales. In the Peruvian anchovy fishery, power relations among the resource users are important and arguably play a key role in determining patterns of resource use. Regarding collective choice arrangements, it is probably not surprising that for common pool resources at larger scales, the right to define and modify rules is limited to the most important and powerful users. The anchovy fishery represents at least 7% of Peru’s total foreign exchange earnings; and in 2010 fishmeal and fish oil exports reached 1 million tonnes, valued at US$1.9 billion (SNP 2010). In this context is it hardly surprising that government fishing policies are respectful of the fishing industry elite’s demands, and pay less regard to internal power relations and potential conflicts with other users.

The experience of the Peruvian anchovy fishery also confirms the importance of "fit" between administrative boundaries of a common pool resource system and natural ecological boundaries. Peruvian authorities have had a greater degree of control over the north central stock, which is wholly within Peruvian waters, than over the southern stock, which is shared with Chile. For example, closed seasons for the southern anchovy stock implemented in Peru have not been reciprocated by Chilean authorities, leading to complaints by Peruvian fishermen that they were “leaving the anchovies in the water for the Chileans to catch”. Consequently, although some efforts have been made in the past to coordinate the management the southern anchovy stock in cooperation with Chilean authorities, usually no catch quota is applied and the fishing season is open all year around (Arias Schreiber 2012). This is a further dimension of "congruence" whose importance has been noted by other authors (Hanna et al. 1995, Anderies et al. 2004), but not explicitly recognized in the design principles as currently formulated.

It can be argued that a further feature of the Peruvian anchovy fishery favoring its persistence has been the speed of decision making based on intense resource monitoring. Speed and flexibility of responses to changing conditions are likely to be key attributes of sustainable systems for managing common pool resources, particularly when the resource itself is inherently dynamic and unpredictable as in the case of the Peruvian anchovy. On the other hand, when monitoring results are not regarded as legitimate, or are not transmitted to management authorities in a timely manner, this can hinder the fishery's sustainability. Waters in northern Peru are perhaps the best-monitored large ecosystem in the world, allowing for unusually effective management of fisheries in spite of internal (economic) and external (environmental) challenges (Chavez et al. 2008). It is probably the only place in the world were management authorities are informed on fishing landings on a daily basis (M. Espino, *personal communication*) and where management decisions have, by law, to be backed up by a scientific report.

On the other hand, rapid decision making is inevitably "top-down" in nature, so this might well contradict the principle of "collective choice agreements", as it is generally understood, at least in specific instances. This highlights the fact that not all the principles have to be complied with for common pool resource management to be successful. It also suggests that compliance with the principles might be achieved through a number of possibly quite different institutional arrangements. As mentioned before, in the Peruvian case, a notable feature of collective choice arrangements was the dominance of powerful stakeholders within the user group, with close links with officials who were invested with decision-making capacity in the responsible government agencies. This raises the interesting question of whether this kind of "top-down" decision making could also provide a viable model at a community level.

External markets have been identified as another key driver of change in common pool resource systems. The demand for products from common pool resource systems and how resource users respond to this demand can be expected to have large impacts on determining patterns of resource use. Market forces are often considered as a destabilizing influence when they affect hitherto self-sufficient community-based common pool resource systems (Cox et al. 2010). Relations between the Peruvian anchovy fishery and the global market for fishmeal are complex and suggest that such clear-cut conclusions regarding the role of market forces are not applicable in this case (Arias Schreiber et al. 2011). However, this is also outside the scope of the present study.

Coming back to our initial question: is the case of the Peruvian anchovy fishery “uncommon” among “the commons”? The answer is no. The history of this fishery tells us that lack of proper institutions, including regulations, results in overexploitation and collapse. However, as in Ostrom’s cases, the history of this fishery (until now) has not ended up in a “tragedy”. Our results show that Ostrom’s eight design principles only partially explain the success of the anchovy fishery. This result is perhaps not unexpected, given that this study was dealing with a large-scale fishery governed at the national level. At this level, scientifically recognized and controlled boundaries of resource use, congruence or institutional fit with ecological and cultural conditions, managed participation, careful monitoring, and frequent interaction between resource users and governmental management authorities can be considered as key principles of sustainable common pool resource systems.

The study of the Peruvian anchovy fishery confirms the design principles as a valuable tool for analysis and understanding of large-scale common pool resource systems. At the same time it suggests that application of the principles to a wider range of systems can generate new insights into what is required for successful common pool resource management. At present it appears that interest is focused on local-level common pool resources and, secondarily, on global issues such as climate change. Our study suggests that there is also much to be learned from investigating common pool resource management that takes place at the level of nations. After all, in a world of nation states, this is still the scale at which many, if not most, key decisions are taken.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/5319

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APPENDIX 1. List of interviewees:

From The Vice-Ministry of Fisheries:

1. Director General of Fish Extraction and Processing
2. Sub director of Fish for Human Consumption
3. Sub director of indirect Human Consumption
4. Head of the Vice -Ministry Data Base Office
5. Ex-Director General of Fish Extraction and Processing
6. Director General of Monitoring, Control and Surveillance
7. Director of Inspection and Auditing
8. Director of Monitoring, Infringements and Penalties
9. Head of Satellite Tracking System Office
10. Advisor to the Marine Fisheries Control and Surveillance Program

From the Peruvian Marine Research Institute (IMARPE):

1. Executive Director
2. Advisor to the Executive Director
3. Scientific Director
4. Advisor to the Scientific Director
5. Director de of Pelagic Resources, Neritic and Oceanic Resources Research Department
6. Head of Trans-zonal and Highly Migratory Resources Research Unit
7. Head of the Population Dynamics Research Unit
8. Head of IMARPE's Coastal Laboratories

From the fishing private sector

1. General Manager of the National Fisheries Society (SNP)
2. Head of the Office of Economics and Fisheries Statistics (SNP)
3. Head of Office of Environmental Affairs (SNP)
4. SNP's member at IMARPE's Directorate Council
5. Ex-President of PESCA PERU
6. Director of Fleet and Supplies – Fishing Company Pesquera Hayduk S.A.
7. Director of Research Planning and Development – Fishing Company Pesquera Diamante S.A.
8. Head of Fleet Department – Fishing Company CFG Investment S.A.C.
9. Fleet operator - Fishing Company Pesquera Austral

APPENDIX 2. Format of semi-structured interviews (page 1 of 2)

Date:
Name:
Current position/job:
Previous positions/jobs:
How long have you been involved with Peruvian fisheries management/ research/ industry/ business?
How long with the anchovy fishery?
Can you tell me which major differences do you remember regarding the following topics (see below) between the 1960s (if applicable), 70s (if applicable), 80s (if applicable), 90s (if applicable) and nowadays?
When and why you think that the things (related to each topic) changed?

Topics:

- Formal and informal difficulties for new companies to join the fishery
- Formal and informal difficulties for the entrance of new vessels to the fishery
- Anchovy fishery licenses

- Knowledge of anchovy fishing stocks, monitoring and survey techniques
- Geographical distribution of the northern-central anchovy stock

- Rule enforcement and sanctions
- Payments of fishing licenses, permits, taxes, other.

- Relations between the fishing industry, the government and the Peruvian Marine Research Institute (IMARPE)

Which were the main sources of conflicts among the fishing companies during the 1960s (if applicable), 70s (if applicable), 80s (if applicable), 90s (if applicable)? How were these conflicts resolved or not?

Which are the main sources of conflicts among the fishing companies nowadays? How are these conflicts resolved or not?

APPENDIX 2. Format of semi-structured interviews (page 2 of 2)

Which were the main sources of conflicts between the fishing companies and the government (including IMARPE) during the 1960s (if applicable), 70s (if applicable), 80s (if applicable), 90s (if applicable)? How were these conflicts resolved or not?

Which are the main sources of conflicts between the fishing companies and the government (including IMARPE) nowadays? How are these conflicts resolved or not?

Why do you think that anchovy landings have been relatively stable during the last two decades? Why has the anchovy fishery not collapsed like it happened during the early 70s?

Declaration in accordance to Article 6 (5) of the Doctoral Degree Examination Regulations (Promotionsordnung) of the University of Bremen

Herewith, I declare that:

1. This work was compiled without any unauthorized help;
2. No materials or references other than those cited were used;
3. Those sections that are quoted or referenced from other pieces of work are clearly marked.

Milena Arias Schr.

Bremen, October 2012

MSc. Milena Arias Schreiber