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THE PERUVIAN ANCHOVETA FISHERY: HISTORY, GOVERNANCE, INNOVATION AND MANAGEMENT LEADING TO SUSTAINABILITY

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IVAN ORLIC

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THE PERUVIAN ANCHOVETA FISHERY: HISTORY, GOVERNANCE, INNOVATION AND MANAGEMENT LEADING TO SUSTAINABILITY

By

Ivan Orlic

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ABSTRACT

THE PERUVIAN ANCHOVETA FISHERY: HISTORY, GOVERNANCE, INNOVATION AND MANAGEMENT LEADING TO SUSTAINABILITY

By

Ivan Orlic

The largest single-species fishery in the world, Peruvian anchoveta (*Engraulis ringens*), consistently yields 6-10 million metric tonnes (MMT). Peru is the principal worldwide exporter of fishmeal and fish oil (>30%), and the anchoveta fishery has socioeconomic influences extending well beyond providing tens of thousands of jobs in the fishery supply chain in Peru, making its sustainability truly critical.

This thesis is divided into two chapters. The first reviews the oceanographic and historical setting for the development of the Peruvian anchoveta fishery, focusing on its governance structures. The second revisits and updates the development on the fishery, moving into an assessment of the current and future state of its management and new challenges in light of a recent regulatory policy shift to individual vessel quotas (IVQs). A preliminary evaluation of its effects on industry and environmental resiliency and sustainability is followed by a case-study to analyze the role of entrepreneurial leadership and innovation in the development of the anchoveta industry in Peru, emphasizing not only the technological and infrastructure development of the fishery, but also the role of corporate culture and social responsibility related to the success of the anchoveta fishery. These innovations are concluded to have had a critical influence on the fishery, its fleet operations and productivity, workforce, capitalization and growth, and on the sustainability of anchoveta stocks and their resilience.

Dedication

To my mother, whose gentle unconditional support keeps me believing in myself, and my father, in whose professional achievements I found inspiration only surpassed by that from his wise words.

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LIST OF ABBREVIATIONS

ACAF Advisory Committee on Animal Feedingstuffs

CCRF Code of Conduct for Responsible Fisheries

CEP-Paita Centro de Entrenamiento Pesquero de Paita

DL Decreto de Ley

DS Decreto Supremo

EEZ Economic Exclusive Zone

EU European Union

EPCHAP Empresa Pública de Servicios Pesqueros de Comercialización de Harina y Aceite de Pescado

ENSO El Niño Southern Oscillation

FAO Food and Agriculture Organization of the United Nations

FIN Fish Information Network

FONDEPES Fondo Nacional de Desarollo Pesquero

IADB Inter-American Development Bank

IFFO International Fishmeal and Fish Oil Organization

IMARPE Instituto del Mar del Perú

ITP Instituto Tecnológico Pesquero

ITQs Individually Transferable Quotas

IVQs Individual Vessel Quotas

LD Law Decree

MMT Million metric tonnes

PDO Pacific Decadal Oscillation

PESCAPERU Empresa Pública de Harina y Aceite de Pescado

PRODUCE Ministerio de Producción

RM Resolución Ministerial

SBS Sociedad de Banca y Seguros

SES Social Ecological System

SNP Sociedad Nacional de Pesquería

TAC Total Allowable Catch

TOGA Tropical Ocean Global Atmosphere

UNCLOS United Nations Convention on the Law of the Sea

WCRP World Climate Research Programme

INTRODUCTION

The Peruvian anchoveta fishery is the largest single-species fishery in the world, accounting for about 10% of the total world marine fish landings (FAO 2008) and a potential biomass of 15-20 million metric tonnes (MMT, Pauly 1992, Ñiquen *et al.* 2000). The fishing industry in Peru produces about 30-40% of the global production of fishmeal and fish oil, worth between US$ 1 and 1.7 billion annually (PRODUCE 2005, PRODUCE 2008, Tacon 2003). The anchoveta fishery has socioeconomic influences extending well beyond providing tens of thousands of jobs in the fishery supply chain, making its sustainability truly critical not only to the local economy, but also the Peru's trade balance and the international markets and industries that depend on the resulting exports (Agüero 1996; Deligiannis 2000; Roemer 1970). This thesis, divided into two chapter, evaluates the Peruvian anchoveta fishery's history and current state, with a focus first on fishery governance through time (Chapter 1), and then on the role of industry innovations in enhancing sustainability, and the effects of the new quota regime instituted in 2008 on the current state of the fishery (Chapter2).

After examining the fishery's oceanographic conditions and productivity, the first chapter of this thesis, *International Governance of the Peruvian Anchoveta Fishery*, examines the actors and interactions that play a role in governance of the fishery throughout its development. The fishery's history is examined in detail and its current condition and challenges discussed. Chapter 2, *Innovation, leadership and management of the Peruvian anchoveta fishery: approaching sustainability*, revisits the history of the fishery and its productivity, placing more emphasis on regulatory changes through time. Much attention is given in this section to the recent policy shift in Peru from using a global quota system to allocate harvest, to individual vessel quotas (IVQs) in 2008, examining whether the intended improvements on fishery profitability, efficiency, resilience and sustainability have been attained. In addition, a case-study approach is used to analyze the role of entrepreneurial leadership and innovation in the development of the anchoveta industry in Peru, emphasizing not only the technological and infrastructure development of the fishery, but also the role of corporate culture and social responsibility related to the profiled company's success and enhanced performance. The case-study focuses on the private enterprise found to be the premier innovator in the industry, examining the various innovations in corporate culture, technology and corporate social responsibility and their contributions the enterprise's success. These were found to result in consistent outperformance due to enhanced fleet and factory operations and productivity This case-study relied substantially on personal communications with industry experts and company insiders in Peru, to whom we are greatly appreciative.

The two chapter in this thesis will have been published as a separate book chapters in American Fisheries Society texts. Chapter 1, *International Governance of the Peruvian Anchoveta Fishery*, is presented here in the same format as seen in the publication (Orlic and Berngartt 2008). Chapter 2, *Innovation, leadership and management of the Peruvian anchoveta fishery: approaching sustainability*, is presented in its lengthier, more complete form, providing additional information that was deemed beyond the scope intended for the manuscript submitted for publication. Because each chapter is meant to be understood independently as a publication, there is much overlap between them. The two chapters are preceded by a general introduction, and followed by a summary of both and some encompassing conclusions. References from each chapter are shown as independent References sections, though there is much overlap between them.

CHAPTER 1: INTERNATIONAL GOVERNANCE OF THE PERUVIAN ANCHOVETA FISHERY

Orlic, I., and R.M. Berngartt. International Governance of the Peruvian Anchoveta. Pages 223-242 in M.G. Schechter, N.J. Leonard, and W.W. Taylor, editors. International Governance of Fisheries Ecosystems. American Fisheries Society.

CHAPTER 1: INTERNATIONAL GOVERNANCE OF THE PERUVIAN ANCHOVETA FISHERY

Introduction

Coastal upwelling margins are some of the most productive ecosystems in the world's ocean (Barber and Smith 1981). In fact, fisheries landings from the Humboldt Current, off the coast of Peru and Chile, account for about 10-20% of the total worldwide marine fish landings (FAO 1993, FAO 1998), harvested from an area representing less than 1% of the ocean's surface. The richness of the Humboldt Current system has played a key role in the development of Peruvian history since the beginnings of civilization in the region (Marcus *et al.* 1999). The ecosystem is characterized, however, by seasonal, interannual and decadal variability and the relative abundance of a given species has been linked to habitat changes driven by such variability (Wolff *et al.* 2003). Currently, the most abundant fish species in this system is the Peruvian anchoveta (*Engraulis ringens*), with a potential annual biomass of 15-20 million tons (Pauly 1992). Even though anchoveta did not become a commercial fishing species for Peru until 1950, rapid industry growth and ensuing increases in harvest levels soon made Peru one of the largest exporters of fish products. Harvest in Peru, mostly by purse seiners, consistently yields 6-12 million metric tones (MMT) of anchoveta annually (FAO 1993, FAO 1998, PRODUCE 2004). Anchoveta is used primarily in the production of fishmeal and fish oil, with Peru producing 30% of the annual global production of such products worth about US $ 1.1 billion (PRODUCE 2004). This makes fisheries the second largest industry in Peru, with socioeconomic influences that go even beyond providing tens of thousands of jobs, to influencing development along the Peruvian coast and beyond (Agüero 1996, Deligianis 2000, Roemer 1970).

The anchoveta fishery has not developed in isolation, and the history of the fishery has had profound impacts on the status and trends in the worldwide fishmeal industry and market (Shepherd 2005), the biological processes in the Humboldt Current System (Pauly and Tsukayama 1997), and international maritime law and fishing standards (Carroz 1982, Glantz 1983). Governance of the fishery, though not always effective, has been influenced by the international community to varying degrees. This chapter will examine the actors and interactions that play a role in governance of the fishery, looking at it from a historical perspective. Particular emphasis will be placed on (1) the role of information and expertise; (2) influences on the norms and values governing the fishery; (3) the management of shared stocks; and (4) influences of the global market. The analysis will focus on the development of the governance of the fishery, and its strengths and weaknesses. Finally, several remaining challenges will be reviewed in light of current governance, fisheries ecology, industry and market capacity and resilience, and socioeconomic consequences.

Biological Foundation for Fishery Management

The prominent role of the anchoveta fishery in the Peruvian economy, and the worldwide fishing industry, is only possible because high pelagic stock biomass is sustained by the highly productive coastal upwelling system, which stretches from northern Chile through northern Peru (4°S to 24°S latitude) (Agüero and Zuleta 1992). Alongshore winds produce offshore Ekman transport of surface water, which is replaced via upwelling of subsurface water, typically from about 60m depth, (Barber and Smith 1981). This results in the shoaling of the thermocline, bringing colder, nutrient-rich water into the euphotic zone (Barber and Chavez 1983). The optimal nutrient conditions allow for extensive phytoplankton biomass growth, with the highest rates of depth-integrated primary productivity and average surface chlorophyll concentrations in the eastern tropical Pacific (Pennington *et al.* 2006). The productivity of this upwelling region is highly variable, however, and subject to fluctuations in both the intensity of upwelling and the depth of the thermocline, as they are influenced not only by local oceanographic conditions but also by oscillations in global climate patterns (Chavez *et al.* 2003).

Like other small pelagic fishes, anchoveta have been associated as key to the trophodynamics of ecosystems (Cury *et al.* 2000). They prey upon phytoplankton (Pauly *et al.* 1989) in addition to zooplankton (Espinoza and Bertrand 2006), thus efficiently taking advantage of different trophic levels. Anchoveta stocks are, nevertheless, subject to the variability of the system, which is dominated by seasonal and interannual frequencies. The latter are associated primarily with the El Niño Southern Oscillation (ENSO), a phenomenon characterized by either relatively warm (El Niño) or cool (La Niña) phases during the summer months, with varying return periods of 2-7 years (Ñiquen and Bouchon 2004). During El Niño, heat from the warm surface waters of the western Pacific is redistributed eastward (in association with a weakening or even reversal of the easterly trade winds), provoking a deepening of the thermocline off Peru (Wang and Fiedler 2006). While the specifics of each El Niño vary (Glantz 2001), a deep thermocline results in a decrease in nutrient flux into the euphotic zone, regardless of continued upwelling (Barber and Chavez 1983). The ensuing decline in primary production, and changes in plankton assemblage composition, leads to the disruption of the anchoveta food web (Chavez 2004, Chavez 2005). Combined with the reduction of habitat due to warmer temperatures, this is thought to lead to both a loss of anchoveta biomass and a redistribution of remaining stocks. Evidence for such stock reductions is evidenced by the historical anchoveta commercial harvest (Figure 1). In contrast, during La Niña, cold sea surface temperature anomalies and a shoaling thermocline are observed in the eastern Pacific, which together with intensified trade winds promote additional upwelling from below the nutricline. La Niña has played a role increasing anchoveta fishery yield, and aiding stock recovery when following an El Niño (Ordinola, 2002).

Interannual variability is embedded within lower frequency fluctuations of multidecadal climate variability, the most relevant being the Pacific Decadal Oscillation (PDO) which alternates between warm and cool regimes lasting about 15 to 30 years (Mantua and Hare 2002 and references therein). Although the specifics vary, warm PDO phases are characterized not only by El Niño-like conditions in the eastern tropical Pacific, with warmer water and a deeper thermocline, but also by changes in the circulation and atmospheric pressure systems (Hare and Mantua 2000, Mantua and Hare 2002, Chavez *et al.* 2003, Chavez 2005). During the episodic warming of an El Niño event, anchoveta stocks drop abruptly but recover once oceanographic conditions again favor upwelling from below the thermocline depth. In contrast, during the warm phase of the PDO, anchoveta stocks have remained relatively depleted for a period of decades. Moreover, fish population decadal-scale variations have been observed to occur synchronously for different pelagic species across the Pacific Ocean (Hare and Mantua 2000, Bakun and Broad 2003, Chavez *et al.* 2003) and remarkably even in the Atlantic (Lluch-Belda *et al.* 1989, Lluch-Belda *et al.* 1992, Bakun 2004). Notably, sardine populations off California and Japan seem to dominate when anchoveta populations off California and Peru become scarce and vice versa. Evidence for such synchronous fluctuations has been found in sediment scale deposits (DeVries and Pearcy 1982, Schwartzlose *et al.* 1999) in addition to archeological evidence dating back to the 15th century (Sandweiss *et al.* 2004).

In the modern setting, these "regime shifts" have been found to correlate well with climatic-oceanographic changes (Chavez *et al.* 2003, Alheit and Ñiquen 2004, Bertrand *et al.* 2004, Chavez 2005). In fact, a shift to the warm PDO phase has now been argued to have hindered the recovery of anchoveta stocks following the fishery collapse in the early 1970's (Chavez *et al.* 2003). But understandings of the PDO and its possible impacts on fisheries did not develop until the mid 1990's (Hare and Francis 1995), and debates regarding the dominant causal mechanisms of specific events and even long term trends during the history of the fishery are still unsettled (Chavez 2005 and references therein). It seems clear that climatic phenomena of both long and short-term periodicity interact to influence oceanographic conditions and that these in turn control biological productivity. But the mechanisms that underlie these linkages are not yet fully understood (Pennington *et al.* 2006), and neither are the controls on anchoveta stock biomass variability (Mantua and Hare 2002). Furthermore, there is even some uncertainty as to how exactly these variations interact with the commercial fishery (Bertrand *et al.* 2004).

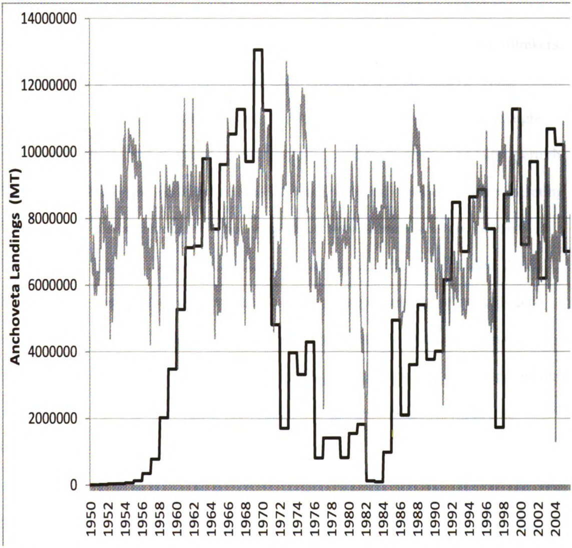

Figure 1: Anchoveta harvest numbers by year, superimposed upon the Oceanic Niño Index. The graph shows the collapse of the fishery in 1972, followed by a slow recovery period during a warm climate regime. Following the return to a cool regime and the recovery of the fishery, managers ensured that harvest levels were dropped during El Niño years, such as in 1998.

Conceptual mechanisms have been developed that shed some light on anchovy-sardine fluctuations. The species are not direct competitors, as they do not share the same ecological niche (Bertrand *et al.* 2004). With high fecundity and growth rates, anchoveta are more adapted to productive, cold coastal upwelling zones (Alheit *et al.* 1994). Sardines are more migratory and have evolved finer-meshed filtering in their gillrakers, allowing them to thrive in less productive areas (Bakun and Broad 2003). Thus, anchoveta increase their populations under conditions of high productivity and high predation pressure upon eggs and larvae. Episodic conditions, such as El Niño, perturb the system to lower productivity and smaller, more scattered plankton, while generating temporary relief from predation. This provides an "environmental loophole" that sardines can exploit to outcompete anchoveta (Bakun and Broad 2003, Bakun 2005, 2006). Furthermore, adaptive population dynamics mechanisms could enhance and maintain the species dominance alternations (Bakun and Cury 1999). In addition, Betrand *et al.* (2004) have suggested that it is through changes in the suitability and range of habitat that climatic oscillations (such as ENSO and the PDO) lead to sardine-anchoveta alternations.

Development of the Peruvian Anchoveta Fishery and its Governance Structure

1950-1972: Anchoveta boom

Anchoveta governance structures instituted during this time period continue to influence anchoveta management. Some of the weaknesses of anchoveta governance during this time period persist into the present, while others have led to valuable lessons. This era set the preliminary character for anchoveta governance, including the role of the state, the areas in which Peru would be willing to engage the international community in the governance of the fishery, and the underlying values and norms that would guide future interactions.

Even before the beginnings of the anchoveta fishery in the 1950's, the Peruvian government had positioned itself for to utilize its fishery resources for economic growth. In the late 1930's East Pacific bonito (*Sarda chilensis*) harvest became an important commercial activity, directed mainly towards the export of canned product (Trillo and Tord 2003). In 1943, largely as a response to attractive fishmeal prices in the international market and the need to increase the national export budget, a governmental Supreme Decree dictated that reduction plants should be installed in order to process fish wastes into fishmeal, ensuring maximum economic gain from fisheries (Laws 1997, Olazo 2000). In the late 1940's there was a PDO regime shift, from the warm to the cool phase (Mantua and Hare 2002), and with it came a synchronous rise in the biomass of the anchoveta and decline in sardine stocks off California (Norton and Mason 2005). With the collapse of the California fishery (documented in Steinbeck's 1945 *Cannery Row*), equipment for canning and fishmeal plants became available for utilization by an emerging Peruvian industry, signaling an early beginning for the commercial fishery (Pauly 1992, Trillo and Tord 2003). Exploiting the market gap left by the California sardine fishery, the primary uses of the anchoveta resource soon became the export-driven production of fishmeal along with, eventually, fish oil, a byproduct of fishmeal production (Roemer 1970). Export-led growth was encouraged by capital investment, technology transfers, state support and expanding international markets (Glantz 1979, Aguilar Ibarra *et al.* 2000).

As the anchoveta fishery became established, its management followed trends common to fisheries management throughout Latin America: (1) open access, (2) nationalization of industrial capacity by the government, (3) a return to private ownership (Agüero 1996). The beginnings of the anchoveta fishery were preceded by a climatic regime shift to conditions favorable for anchoveta biomass expansion, and harvests by a growing industry increased rapidly from the 1950's until 1971 (Figure 1). The extreme abundance led to the fishery being treated as an open access resource, with weak restrictions on harvest. Due to rapid industry growth, the equipment imported from the California sardine fishery was soon replaced by new Peruvian factories and vessels (Fig 2).

Throughout the 1960's, the anchoveta management was not coordinated, but was shaped by the diverse and often conflicting interests of several government agencies (Hammergren 1981). In 1960, the *Instituto del Mar del Peru* (IMARPE) was formed as a scientific institution to provide information and expertise to the government. That same year, the Sociedad Nacional de Pesqueria (SNP) was founded to unite and represent industry interests, notably lobbying against the heavy taxation regime imposed by the Belaunde administration. A drop in fishmeal prices led to the Paris Agreement (*Convenio de Paris*) in 1960, where private sectors of principal producing countries agreed to establish national quotas through government-issued export licenses. Peruvian government based these licenses on SNP's producer quotas, and effectively delegating much of its power to the private sector (Hammergren 1981). In fact, the rise in harvesting and processing capacity, combined with the open access management of the resource, led to a quick increase in the exploitation of the anchoveta, with recorded harvests reaching 8.5 MMT by 1964 (Fig 1). In 1965, following a weak El Niño, the first closed seasons were instituted in an attempt to protect anchoveta stocks during spawning (Agüero 1996, Aguilar Ibarra *et al.* 2000), but did not limit the total allowable catch (TAC, Hammergren 1981).

Then in 1968 the Peruvian military, led by Velasco, seized the government and established a military-reformist regime (Hammergren 1981). Government intervention in the fishery increased under Velasco, albeit slowly (Aguilar Ibarra *et al.* 2000). Supreme Decree No. 017-68-AG, set harvests limits to 9.5MMT in the 1967/68 season, but this was followed by an increase in set limits to 12.3MMT in 1968/69 (Olazo 2000). This increase in harvest limits was partially due to ratcheting, or pressure from business interests to increase fishing (Deligiannis 2000), because of overcapitalization, where there was a much larger fleet and processing capacity than necessary to catch and process the original quota (IMARPE 1970, Paulik 1981). With so much capital invested, the private sector used political power to increase quotas, which then encouraged even further investment of additional capital. Therefore, although quotas were put into place, these exceeded scientific recommendations of 9.5 MMT (IMARPE 1970).

Upon confirming the constitutional status of fisheries resources as state property, the military-reformist government increasingly exercised more control over the fishery through the establishment of new strategic institutions. The Ministry of Fisheries was created in 1970, absorbing IMARPE in addition to housing the new *Empresa Pública de Servicios Pesqueros del Perú* (EPSEP), with responsibility over artisanal fishers, and the *Empresa Pública de Comercialización de Harina y Aceite de Pescado* (EPCHAP), which was to take over the marketing and sales of fishmeal and fish oil (Aguilar Ibarra *et al.* 2000). During its first year, the Ministry of Fisheries allowed record landings of 12.5 MMT, which was initially applauded as evidence of renewed competence (Hammergren 1981). Recorded catch data also does not take into account that underreporting was rather frequent at the time, and the actual harvest in 1970 has been estimated to be as much as 15MMT (Castillo and Mendo 1987). In spite of this limitation, historic catch data (Fig 1) still reflects major trends in stock fluctuations (Alheit and Ñiquen 2004).

Surprisingly, although El Niño has been known to have a dominant effect on anchoveta stocks, Peruvian fisheries policy was not especially responsive to the oceanographic phenomenon from 1958 through 1978. Instead, regulations were responsive mostly to landing statistics and pressures from vested interests (Hammergren 1981). Furthermore, the failure of the Peruvian government to enforce harvest limits exhibits the weakness of the state in implementing policy. Another limit which was not enforced involves the creation of new fishmeal plants. As early as 1956, Supreme Resolution No. 217 attempted to halt the construction of fishmeal plants, with the intention that more anchoveta would be locally designated for human consumption, but plant numbers actually kept increasing (Figure 2). In fact, ratcheting triumphed again, and the plant construction ban was lifted in 1959 (Laws 1997). While Peru has had a tradition of a strong state control, these instances illustrate how the state was unable to manage the anchoveta fishery effectively without enough support from industry and the market.

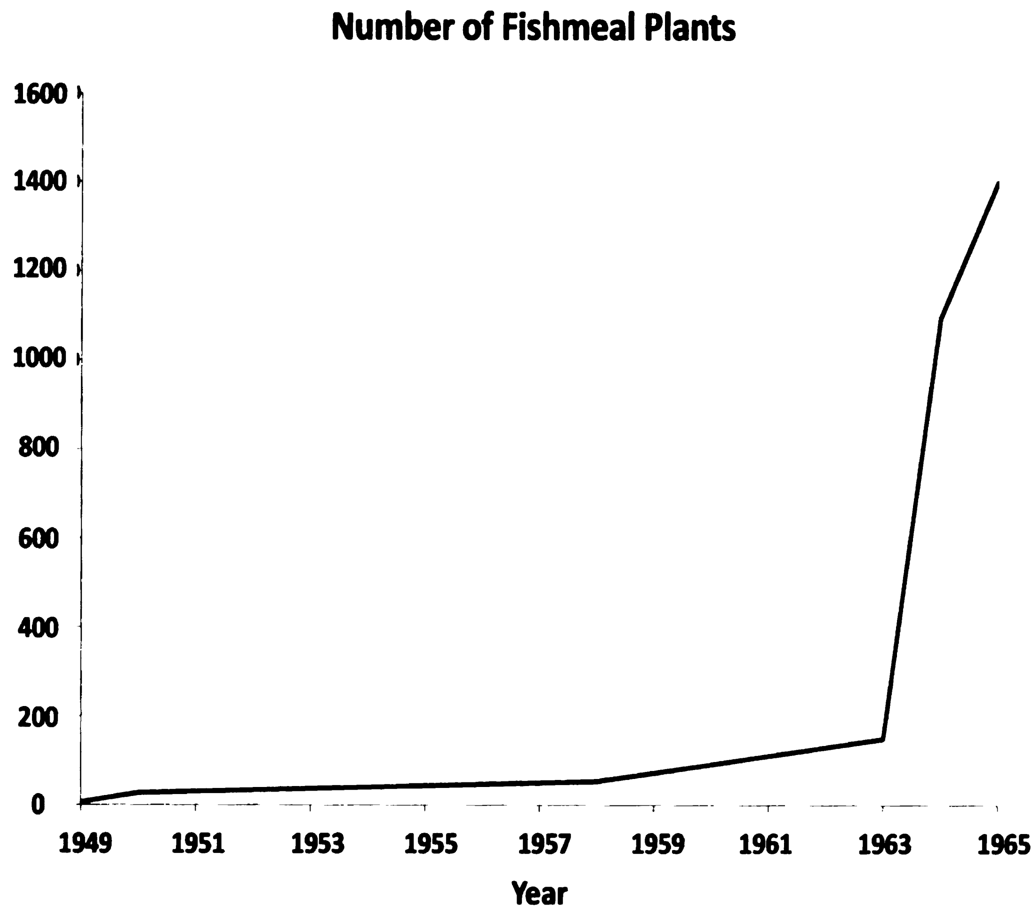

Figure 2: Number of fishmeal plants in Peru, 1949-1965 (adapted from Olazo 2000).

Fishery governance is not solely the purview of the state, and economic interests and stakeholders must be actively involved (Jentoft 2005). One of the primary roles of the state in the governance of a fishery is the provision of information and expertise (Jentoft 2005). Although the state created IMARPE (*Instituto del Mar del Peru*) in 1960 to fulfill this role, IMARPE has no legislative power to ensure that the fishery is managed within the biological limits of the anchoveta (Hammergren 1981). When different branches of government have different goals, such as economic development and resource protection, discrepancies in the ensuing recommendations develop (Jentoft 2005). For anchoveta, there was a fundamental disconnect between the reality of overharvesting, the vision of the government agencies, and the desires of the fishery industry (Hammergren 1981). Without a common vision amongst these three groups, anchoveta governance was inefficient and its enforcement ineffective.

In contrast, Peru was quite efficient in aligning itself with several states within Latin America regarding the establishment of a worldwide maritime law regime to protect its fisheries and economic interests – even though the outcome of these international debates could have placed limits on the exploitation of Peru's marine resources. It began in 1947 when Peru followed Chile and Argentina in declaring sovereign rights to its coastal regions to 200 nautical miles (nmi, Garcia-Amador 1974, Paulik 1981). With this declaration, Peru became embroiled in a decades-long drama that eventually led to the 1982 United Nations Convention on the Law of the Sea (UNCLOS). Before the UNCLOS treaty, multiple countries were claiming jurisdictional rights for fishing, mining and security of their coastal oceans. Peru's claim to a 200-nmi jurisdiction were driven primarily by a desire ensure exclusive access to a potentially major economic resource (Sanger 1986, Paolillo 1995). In the years that followed the first claims, Peru joined Chile and Ecuador in leading the way for the establishment of coastal rights throughout South America, first with the Santiago Declaration of 1952, and then with the Montevideo and Lima Declarations of 1970 that reaffirmed the use of natural resources and sovereign rights within a 200 nmi limit (Garcia-Amador 1974, Paolillo 1995). With these actions, Peru aligned itself with the Latin American block of states that were influential in the development of the 1982 UNCLOS Treaty. Right of access to natural resources was pitted against countries' right of passage of ships and warships, overflight by airplanes, and even the rights of geographically disadvantaged nations (Sanger 1986). The exact extent of a state's rights to its coastal areas was intensely debated, with some states proclaiming that it should be a maximum of three miles, and others arguing for a much wider area of rights. Support by African nations, and then by North America and Japan, eventually helped influence the inclusion of a 200-nmi exclusive economic zone (EEZ) in the 1982 UNCLOS Treaty (Carroz1982). Though a signatory, Peru has not yet ratified UNCLOS.

Developments during this period served to establish patterns of international governance, for example, in the areas that Peru chooses to interact with the international fishing community regarding the anchoveta fishery. Peru not only engaged the international community in dialogues regarding international maritime law, but also in fisheries technology. While most of the Peruvian fleet and processing capacity was built within Peru, much of the knowledge regarding both the marketability, harvesting and processing of anchoveta were gained from other countries (Roemer 1970). In addition, in the early 1960's the IMARPE began collaborating with the United Nations' Food and Agriculture Organization (FAO) towards studying and monitoring the fishery (Thompson 1981). But Peru was not equally effective at applying foreign knowledge to policy-making. For example, the California sardine fishery collapse due to overfishing in 1949 did not set a precedent for more conservative anchoveta management. In addition, willingness to engage the international community did not extend into joint management of the southern anchoveta stock which is shared with Chile (Agüero and Zuleta 1992).

Most of these events were influenced by the drives this time period to exploit and manage the anchoveta resource. The resource was developed primarily as an export market and, under the influence of worldwide fisheries and the international market, was soon dominated by fishmeal and fish oil. During this time period, the World Bank funded fisheries development without concern for their sustainability. The anchoveta industry was viewed as a secure means of providing wealth, not only for individuals, but also for government development programs. These economic views of the anchoveta as a resource would also contribute to characterize future governance of the fishery.

1972-1973: Anchoveta Collapse

By 1970 scientists at IMARPE had warned of the possibilities of the collapse of the anchoveta resource (IMARPE 1970, Clark, 1976). The government responded by enacting the 1971 General Fisheries Law to promote sustainable exploitation (Olazo 2000). However, few actions were taken to restrict harvest, and the regulations that were established were not strictly enforced (Deligiannis 2000) as neither industry nor government heeded the warnings (Aguilar Ibarra *et al.* 2000). The reasons for this inaction lie within the larger political trends in Peru and throughout Latin America. Strong, new leaders have been supported in the hope that they will rescue the populace from poverty, strong class divisions, and a host of other social problems (Morón and Sandborn 2005). This has led countries through varying governments and times of instability. During the early years of the anchoveta fishery, governments changed rapidly, ranging from fully authoritative governments under a military junta to democracy (Sheahan 1999, Morón and Sandborn 2005). The wealth derived from the fishmeal industry led these different governments to view the resource as a powerful and endless source of revenue, and soon its management became primarily driven by this goal (Deligiannis 2000). Thus, the 1972 collapse of the fishery came as powerful shock to government.

The collapse of the anchoveta fishery was likely due to a combination of (1) overfishing, (2) an unfavorable ecosystem regime shift (related to the warm PDO phase), and (3) a strong El Niño event (Bakun and Broad 2003, Bertrand *et al.* 2004, Ñiquen and Bouchon 2004). IMARPE had estimated the maximum sustainable yield (MSY) to be around 9.5 MMT (IMARPE 1970). In the 1969-1970 fishing season, the 9.5 MMT in anchoveta landings were achieved by April and the government, under pressure from industry, allowed for continued harvesting to reach 12.5 MMT (Thompson 1981). Early in 1971, the El Niño conditions concentrated anchoveta in small remaining upwelling plumes adjacent to the coast, making the stocks especially vulnerable to seine fishing (Csirke 1988, Beverton 1990, Alheit and Bernal 1993), and allowed for record catches in early 1972 (170,000 MT per day, Thompson 1981). Following the ensuing crash, government closed the fishery for almost a year (Aguilar Ibarra *et al.* 2000), and anchoveta exploitation between 1972 and 1976 was only permitted for a total of 18 months (Thompson 1981). While the exact contribution of overharvesting to the crash remains uncertain, it is possible that it would not have been as devastating had reasonable harvest limits been implemented. Although it is not possible to control the climate-related factors that contributed to the anchoveta collapse, knowledge of their linkages is fundamental to management. Furthermore, understanding governance also helps to explain certain aspects of the collapse, as stakeholder disconnects, the nature of state engagement with the international fisheries community, and the underlying norms and values of the fishery, all contributed to the loss of anchoveta stocks.

The military government decided to nationalize the fishmeal industry, expropriating both the fishing fleet and the fishmeal processing facilities (Laws 1997, Trillo and Tord 2003). The anchoveta collapse was used as justification for the agenda of state ownership, claiming that the state must aid an ailing industry (Glantz 1979, Hammergren 1981, Agüero 1996). Thus, the fleet and processing facilities were nationalized into a corporation known as PESCAPERU (*Empresa Pública de Producción de Harina y Aceite de Pescado*) in 1973. The expropriation process, opposed by the SNP, involved somewhat controversial appreciation of private sector holdings (Hammergren 1981). As a centralized entity with over 1200 vessels unloading to over 106 factories, PESCAPERU had greater flexibility to consolidate holdings and restructure effort, and become more efficient. Incorporating all 27,000 workers to avoid unemployment, however, meant PESCAPERU remained overexpanded. The agenda of expanding food fishing quickly led to the overexploitation of stocks of food fish in 1973-1975. In addition, the diversification to other species for fishmeal production raised complaints from a canning industry, which successfully lobbied against it (Hammergren 1981).

In providing information and management expertise, the government was lacking in international collaboration. While information on risks of overharvesting was available from the California sardine fishery crash, this information was only consulted by scientists within IMARPE. Studies of the sardine fishery had already suggested climate variability as a possible contributor to the collapse of the California industry (Hare and Francis 1995), but this information was neglected by Peruvian management. Even during the collapse period and under an authoritative military government, ratcheting was allowed to occur, as industry became indirectly involved in regulating the fishery once again (Deligiannis 2000). Priorities for both sides were primarily driven by profits rather than by sustainability concerns.

The biological collapse of anchoveta stock itself was not the sole reason for the devastation of the fisheries industry. Aided by international organizations such as the FAO and the Inter-American Development Bank (IADB), Peru had been heavily investing in infrastructure development (Lemay 1998). Open access to the fishery combined with funding and loan opportunities led to the overcapitalization of the industry, in the form of excess fleet and processing plants (Lemay 1998, Gréboval and Munro 1999), a situation that was recognized as a problem (IMARPE 1970). This was worsened by the establishment of closed seasons for the fishery, which created incentives for businessmen to invest in more and larger boats to better compete for a share of the total quota before the next closure (Clark 1976, Gréboval and Munro 1999). Technological innovations ensued, which continuously increased fishing effort (Paulik 1981). Overcapacity had two important impacts on the anchoveta fishery. First, it promoted ratcheting, leading to the high and increased quotas (Deligiannis 2000). Second, while excess capacity remained profitable when anchoveta were abundant, the excess capacity became a detriment after the collapse, as built-up debt could not be consolidated (Clark 1976, Hammergren 1981).

The shock caused by the fishery collapse had many socioeconomic and political consequences within Peru in addition to repercussions throughout the global food market (Glantz 2001). Although much of the governance was developed prior to 1972, the collapse would force a new paradigm: the fishery is not invulnerable and the resource is not unlimited. This lesson would not only be useful within Peru, but it would evolve into a case study used worldwide. Fisheries are liable to the intrinsic variability of ocean ecosystems. Therefore, development based on fisheries can be unstable, especially in the face of inadequate management

1974-1989: Sardines and political turmoil

Transition to new leadership (Morales Bermúdez) occurred within the military government in 1975. The government, in view of overcapacity, reduced the fleet and processing capacity by almost 50%, but anchoveta catches remained low, and PESCAPERU still operated with net losses which had to be subsidized by the state (Trillo and Tord 2003). Recognition of these problems led to re-privatization, and return to private ownership of the fleet started in 1976, while that of the processing facilities began in the 1980's (Hammergren 1981, Agüero 1996). Anchoveta remained closely regulated, as government dictated that private harvesting be re-directed to other species. Effort diversification, however, did not solve overfishing but instead extended it to new species (Aguilar Ibarra *et al.* 2000).

The nationalization of fisheries had not proven successful, but did set a new precedent in fisheries governance and redefined the role of the state. From this period, the enactment and enforcement of fishery regulations became more proactive. Although the fishery was re-privatized, industry would no longer dictate harvest regulations. Prior to the collapse, the roles of state and industry were out of balance, with the state unable to control exploitation of the resource. During the sardine era, a more balanced relationship between the state and industry emerged to govern the fishery.

From 1972 until the early 1990's, anchoveta biomass and harvest remained relatively low (Figure 1), temporally coinciding with the 1976-1998 warmer phase of the PDO, and an increase in sardine stocks (Chavez *et al.* 2003). Anchoveta harvests continued, with signs of stock recovery being stifled by a 1976-1977 El Niño that forced several closures during 1977 (Aguilar Ibarra *et al.* 2000). Starting in 1971, sardine (*Sardinops sagax*) spawning increased as stocks expanded along the coast, and sardines (as well as jack mackerel, *Trachurus murphyi*) became more abundant, leading to exponential increase in sardine landings from 1974 to 1976 (Alheit and Bernal 2003, Alheit and Ñiquen 2004). This period was thus characterized by a shift in fishing effort, from an anchoveta to a sardine dominated fishery, but with more diverse harvesting of several important species from 1972 into the 1980's (Trillo and Tord 2003).

The fall of the military junta and the return to democracy in 1980 brought a period of ineffective governance under both Belaúnde Terry (1980-1985) and Alan Garcia (1985-1990). Not only had corruption spread throughout government, but during the 1980's Peru was also fighting the terrorist organization *Sendero Luminoso* (Shining Path). Economic development was stymied and during these years, which were characterized by the highest rates of inflation ever seen in Peru (with over 2,000,000 % cumulative over 1985-1990), as well as the Latin America debt crisis (Cruz Saco 1995). The political and social occurrences in other sectors of governance interfered with the ability to manage the fishery.

During the sardine era, only minimal changes were made to fleet regulations, but other new regulations were put in place. In 1980 regular seasonal anchoveta and sardine closures began, and between 1982-1984 closures during spawning, area closures, fish size limits and gear regulations were all introduced in addition to the traditional TAC limits (Agüero 1996, Olazo 2000). In spite of these restrictions, anchoveta abundance dropped to its lowest point during the strong El Niño event of 1982/83, with a harvest of only 0.024MMT (Olazo 2000). A year of excellent recruitment followed, thus marking the resurgence of anchoveta stocks (Alheit and Ñiquen 2004). But as a consequence of consistently low biomass estimates, IMARPE became involved in attempting to understand the ecology of the fishery. In addition, interactions between the Peruvian government and the international community improved. In 1985 the World Climate Research Programme (WCRP) launched a 10-year Tropical Ocean Global Atmosphere (TOGA), to monitor oceanographic conditions in the equatorial Pacific (Broad 2003, Glantz 2001). In 1987 and 1989, international conferences were held regarding anchoveta ecology and management. While previous international exchange had been technology and harvest oriented, these conferences were centered on anchoveta biology and ecosystem dynamics. The conferences produced two reports written by experts from around the world to consult on the anchoveta (Pauly and Tsukayama 1987, Pauly 1989).

The shock of the collapse of the fishery and the fall of the military junta provided an opportunity for change to occur. But progress remained slow, hindered by the social and political turmoil. Nevertheless, real changes did occur in the interactions and norms of governance that would impact the sustainability of the anchoveta fishery. Furthermore, even without direct involvement of other countries in anchoveta fishery management, an added role for the international community in anchoveta governance did develop.

1990-2000: Anchoveta under Alberto Fujimori

In 1990 Alberto Fujimori was elected, promising social and political change (Sheahan 1999). He was successful in initiating sweeping changes throughout Peru, bringing an end to the *Sendero Luminoso* terrorist movement and implementing neo-liberal economic policies that included extensive privatization (Aguilar Ibarra *et al.* 2000). The changes that followed impacted the anchoveta fishery and, the General Fisheries Law (LD 25977, 1994) stemming from Fujimori's government is still the guiding legislation of fisheries management today. A strong state role in fisheries was realized under Fujimori, in contrast to the ineffectiveness of the past. Fisheries regulations passed during this time period were both maintained and enforced. While industry still controlled the usage of

harvest, management of the fishery was guided by both biological knowledge and proper management information. The latter is attained in consultation with international community. International engagement beyond the purely biological and technological information aspects is partially to avoid any possibility of another collapse. In its consultations with international experts regarding fishery management, the state has expanded its role in providing information and expertise and has more fully incorporated IMARPE into governance of the fishery. These developments are in accordance with the creation of the Code of Conduct for Responsible Fisheries and a change in the funding priorities of the World Bank.

In 1992, with funding from the World Bank, an international symposium on future management was held in Lima (Loayza, 1994). This symposium focused on individually transferable quotas (ITQ's) as a way to end overcapitalization of both fleet and factories (Taira 1994). ITQ's assign property rights to the resource, removing the incentive for overcapitalization and overfishing, and giving fishers a stake in the future health of the resource (Gréboval and Munro 1999, Perman *et al.* 2003). An ITQ system can be highly profitable, increasing the efficiency of companies that are able to compete under it. But in an overcapitalized fishery, most companies cannot be assigned a large enough quota to balance return on investment, resulting in low or negative profits, with dire social and political consequences. Although the ITQ system had been implemented in other countries, it was not established in Peru due to the reservations by the fishmeal industry, which still is politically powerful (Morón and Sandborn 2005). Therefore, the 1992

General Fisheries Law remained the guiding legislation, which bases management upon seasons, quotas and gear restrictions, with a shared total allowable catch set for the year.

Fisheries governance under Fujimori was also refocused into two other areas: (1) diversifying fisheries activities beyond anchoveta, and (2) developing anchoveta-derived products for direct human consumption. While the anchoveta is the most abundant species in Peru's coastal areas, other species such as Giant Squid (*Dossidicus gigas*), Yellowfin tuna (*Thunnus albacares*), and Chilean seabass (*Dissostichus eleginoides*) can diversify Peru's commercial fishery industry. The *Instituto Tecnologico Pesqueria* (ITP) has focused more on the production of anchoveta products for direct human consumption. Efforts were also made to aid in further development of the artisanal fishing fleet, consisting of the subsistence fishing within 5 miles of the coastline (where extraction by the commercial fleet is not permitted). Organizations such as the *Fondo Nacional de Desarrollo Pesquero* (FONDEPES), and the *Centro de Entrenamiento Pesquero de Paita* (CEP Paita) give technical support and training to artisanal fishers.

In 1995, Peru became a signatory to the Rome Consensus on World Fisheries (FAO 1995), agreeing to manage its fisheries according to the Code of Conduct for Responsible Fisheries (CCRF, FAO 1995). Following the signing of the Consensus, Peru enacted legislation to improve fisheries sustainability. These included a series of Ministerial Resolutions that require (1) limiting entry of new vessels into the fishery, (2) monitoring vessels and their harvests, and (3) setting new targets for the reduction of pollutants discharged to water by fishmeal plants (Olazo 2000).

Another PDO phase shift in 1998-1999 returned the oceans to the cooler temperatures and stronger currents which characterized the boom period of the anchoveta fishery (Alheit and Ñiquen 2004, Chavez *et al.* 2003, Mantua and Hare 2002). By 1994, harvest levels reached heights not seen since the late 1960's and, with the exception of the 97-98 El Niño event, anchoveta catches remained high (Fig 1). Current management of the fishery has been conducted under the legislation that was mostly enacted during the Fujimori era, with harvests being held to levels recommended by IMARPE. Additionally, since Ministerial Resolution No 781-97-PE (Dec 3rd 1997) declared both the sardine and anchovy fisheries as fully exploited resources, restricted access to both fisheries was instituted such that fishing permits were no longer awarded except to replace vessels.

An especially strong El Niño occurred in 1997-1998 which was anticipated, monitored and its impacts forecasted (Carr and Broad 2000, Broad *et al.* 2002). The Peruvian government devised task force to minimize damage from heavy rains and floods (Zapata Velasco and Sueiro 1999, Fujimori 2002) but its impact on the Peruvian economy is still estimated around US $ 3 billion (Glantz 2001). The Ministry of Fisheries, following IMARPE's recommendations, applied more extensive anchoveta bans with smaller quotas in a conservative policy, but these were instated after early landings had already exploited the ever-vulnerable, shoaling anchoveta stocks (Zapata Velasco and Sueiro 1999). Depleted anchoveta stocks left the industry with accumulating debt and bankruptcy which even threatened some of the local banks (Broad 2003, Zapata Velasco and Sueiro 1999).

2001-2006: Anchoveta today

In November 2000, Fujimori left the country in political disgrace. However, governance of the fishery has continued on a similar trajectory under succeeding presidents (Toledo 2001-2006, Alan Garcia 2006-). Governance now consists of multiple interactions between industry, technical experts, management bodies within Peru, political trends in Latin America, international agreements, foreign experts, and international agencies (Figure 3). This structure carries strengths, weaknesses and much history. Initially, anchoveta governance involved unbalanced interactions, first with industry, and then with the state dominating decision-making processes. Following the return to democratic leadership and fishery private ownership, governance interactions became more balanced. Governance has evolved into a complex series of interactions, but retains original characteristics of information sharing and focus on commercial exploitation of the resource, with a new management philosophy that also concentrates on sustainable use and diversification of the fishery.

At the state level IMARPE provides biological and management expertise such that decision-making is more closely informed by both the ecology and the management considerations. In addition, FONDEPES, ITP, and CEP-Paita provide expertise regarding technology and sanitation, aiding in the management of the artisanal fishery and the development of products for human consumption. Industry now conforms to the regulations. It also provides direct linkages to the foreign fishmeal markets. Decision-making authority now rests with the Vice-Ministry of Fisheries, a sub-division of the Ministry of Production, after the abolishment of the Ministry of Fisheries in August of 2002 under President Toledo.

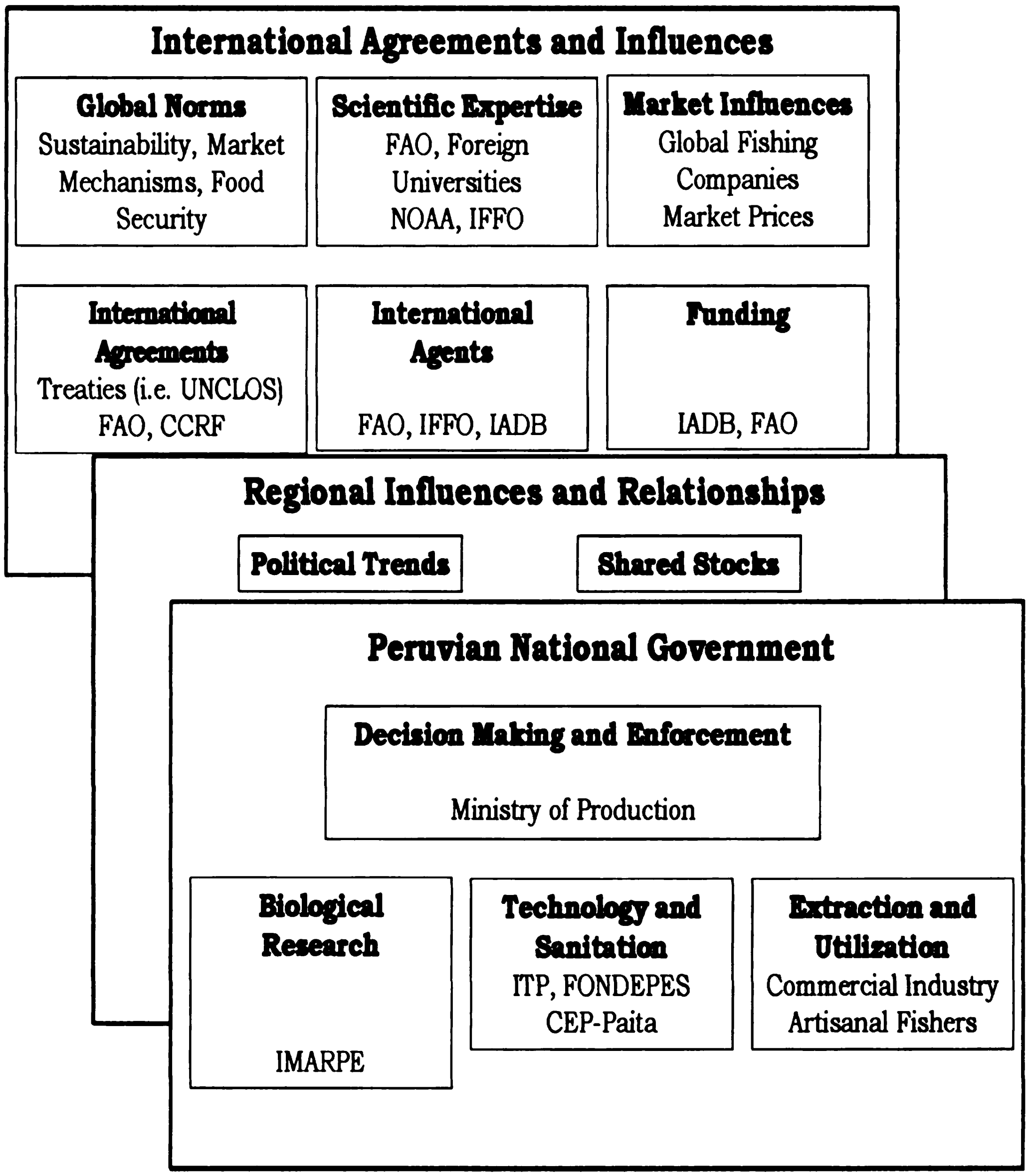

Figure 3: Governance interactions of the Peruvian Anchoveta Fishery.

Anchoveta management in Peru has become more robust over time, producing informed and enforced regulations. IMARPE conducts acoustic surveys to assess biomass regularly in order to set quotas, and there are two seasonal closures to protect both spawning and juvenile growth. Short term closures are also instituted adaptively, in response to anchoveta juveniles in catch exceeding preset limits. The fishery is of closed access, with new vessels only being allowed as replacements. Furthermore, all commercial vessels, which must operate outside the 5nmi limit reserved for non-anchoveta artisanal boats, are fitted with an industry-financed satellite vessel monitoring system, which allows the government to monitor their real time movements and position. Construction of fishmeal processing plants is also regulated by permits from both the Ministry of Production and the Ministry of Health. (FIN 2006, PRODUCE 2006).

Fisheries management interactions at the regional scale are limited. While the bulk of the biological production and 85% of the harvest of the anchoveta lies within the northern stock of Peru (6° to 14° south latitude), the southern stock of anchoveta (14° to 24° south latitude) transverses national boundaries and is shared with Chile (Agüero and Zuleta 1992). Fishing by one country impacts the other and a concern is that without a shared management plan the stock will be overfished as the two countries compete for the same stock. Ideas such as a shared fisheries management zone and overarching quotas across the region are being proposed as beneficial to both countries, both ecologically and economically (Agüero and Zuleta 1992, Agüero 1996). Another benefit of this scheme stems from the behavior of anchoveta during El Niño, when stocks in southern Peru migrate further south into Chile, and outside of the Peruvian EEZ (Ñiquen and Bouchon 2004). A shared fishing zone encompassing the southern anchoveta stock could help to mitigate the impacts of El Niño on the Peruvian fishing industry, while allowing Chilean fishers to access Peruvian waters in other years. Barriers to international management still exist, but advances are continually being made. In 2002, the Integrated Management of the Humboldt Current large Marine Ecosystem project was born, seeking to develop effective governance measures for the entire ecosystem, based science as well as consensus between governance actors (IMARPE 2002).

At the international scale, some of the most important governance actions occur within the global fishmeal market, where efforts are officially coordinated through the International Fishmeal and Fish Oil Organization (IFFO). Fishmeal is considered to be amongst the best feeds for both livestock and aquaculture because it does not contain non-digestible material and is high in protein and other nutrients (Shepherd et al. 2005). However, fishmeal has been banned as a ruminant feed in the European Union (EU) since 2001 (regulation EC999/2001, now regulation 1234/2003), claiming a potential hazard of prion disease contamination (FIN 2006). Having met all of the Commission's safety standards and the control protocol for the detection of contaminants being in place, it has been proposed by IFFO and others that the ban be lifted. Though it has already been amended to allow for some inclusion of fishmeal in calf feeds, the remainder of the ban is undergoing bureaucratic review (FIN 2006). The EU fishmeal ban stands as an example of how foreign politics can affect the anchoveta industry in Peru via the international market, in this case diminishing demand. Peruvian fishmeal has been found to be largely free of chemical contaminants (Canadian Food Inspection Agency 2003) and not to harbor diseases such as prion-based pathogens (ACAF 2001).

Peruvian fishmeal is shipped internationally for use in livestock production and aquaculture. Demand and trade in the product has been increasing, and is expected to increase in the future as aquaculture continues to expand in Asia and other regions the world. Receiving 20-40% of Peruvian fishmeal exports, China represents Peru's most important buyer (PRODUCE 2004). With the increasing demand and the inability to increase the amount of production of anchoveta, prices will likely continue to increase.

Future Challenges

Future challenges for the anchoveta fishery are complex, diverse and will affect all scales of governance. Sustainable development can only be accomplished through looking at the entire of a complex social ecological system (SES). Solutions directed at only parts of the system will likely miss interactions that influence the future sustainability of the resource (Walker *et al.* 2006). In the case of the Peruvian anchoveta fishery and its future sustainability, this will mean addressing its governance at both the national and international scale, in addition to climate predictions and their implementation into policy.

Within Peru, the primary challenges include monitoring and predicting the variability within the Humboldt Current System, and preparing the industry to withstand pressures that can result from these instabilities. The belief that the 1972-73 collapse of fishery was due primarily to overfishing has disguised the impact of the climatic processes that may have caused a decline in the anchoveta stocks regardless of the level of fishing. The quick recovery of anchoveta stocks following the 1997/98 El Niño event, on the other hand, may have been catalyzed by a strong La Niña event that followed it, unlike the successive El Niño events in the 1970's and 1980's (Bertrand *et al.* 2004). Still, uncertainty remains as to the linkages between anchoveta and multi-decadal climate variability, partially because the catch data and biomass estimates only represent about the last 60 years (only about two PDO cycles). With the monitoring networks now established, it is already possible to observe the development of El Niño's. But even accurate forecasts do not necessarily yield useful management decisions (Glantz 1979, Broad 2003, Broad *et al.* 2002). Sustainability may depend on proper adaptive management before, during and after El Niño events. In addition, both bottom-up and top-down controls on the dynamics of pelagic resources must be acknowledged and accounted for in management programs (Wolff *et al.* 2003).

A further challenge involves the problem of overcapitalization. A system of ITQs within the fishery has been suggested to control the potential for overharvesting and to improve the economic efficiency by discouraging overcapitalization (Aguilar Ibarra *et al.* 2000, Hidalgo 2002). Over the years, an increase in fleet hold capacity resulted in quotas being reached increasingly faster, followed by yet further reductions in legal fishing season. In fact, this led to an anchoveta fishing season of only 54 days in 2006 (PRODUCE 2006). Under an ITQ system, production cost would be reduced by removing the need to compete for harvests within short seasons. An additional challenge here is to manage the conflicts that arise between corporations within the fishmeal industry. While ITQs would improve the efficiency of large-scale corporations, smaller businesses often do not have the means to compete and it is unclear how to include artisanal fisheries in the scheme.

Controversies regarding the suitability of ITQs in developing nations remain (Aguilar Ibarra *et al.* 2000), and it may be possible that a better solution exists for Peru. One such solution could be to ascribe ITQs to commercial vessels while ascribing a global quota to artisanal fishers. In this way, ITQs could still reduce overcapitalization and increase commercial efficiency, while protecting the artisanal sustenance fishery.

Locally, the potential for fisheries to aid with widespread malnourishment has been obvious for some time. Governments have passed legislation towards this goal before, but without significant results. This is partially because reforms have failed to focus on the critical problem of distribution and storage. Banning the use of jack mackerel for fishmeal production, for example, will not likely provide more fish for direct human consumption if there is no adequate infrastructure to maintain its freshness long enough to distribute it. Similarly, recent efforts to divert some of the anchoveta harvest towards human consumption have yet to achieve progress. It should be noted that there is a further product outlet problem here, since the total anchoveta demand is far exceeded by the supply, and the storage capacity needed to maintain the huge volumes of catch fresh would probably be cost prohibitive. Even with conceivable amounts of human consumption, if exploitation continues to yield such high catch volumes, fishmeal and fish oil production are the only economically and logistically viable alternatives for the bulk of harvest. Nevertheless, developing these output channels and storage infrastructures to increase human consumption may contribute to solving the problem of malnourishment.

There is evidence that the fishmeal industry, both within Peru and on a global level, believe that the current high stock levels are the natural state of the system. Reports by IFFO on the sustainability of marine resources used in fishmeal production state that worldwide production has leveled off due to the recovery of the Peruvian anchoveta stocks, and that the trend is expected to continue (Shepard *et al.* 2005). Publications by the Peruvian fishmeal industry indicate a similar belief (Trillo and Tord 2003). International trade has increased in recent decades, but in the last few years the value of those exports has increased even more. For governors this poses the choice between exploiting market opportunities to earn foreign exchange, and safeguarding the interests of fishermen and consumers. The lessons learned from the collapse of the fishery must be remembered, and economic interests must not prevail over the sustainability of the anchoveta and its ecosystem. To address these concerns, Peru must take an ecosystem management perspective, focusing not only on the productivity of the anchoveta, but also the underlying ecosystem influencing that productivity. Much focus should be on anchoveta biomass assessments, and better understanding the linkages to climate. Peru will then be better prepared to manage its fishing industry during times of low biomass, and perhaps support it through special programs to ensure solvency during times when harvest sales may not even cover extraction costs.

There is still much progress to be made in the development of effective fisheries governance in Peru. The continuation of independent management of the shared stock with Chile is indicative of Peru's state-centric focus of fisheries governance, although the development of a shared scientific program is a definite step forward. As pressures on the fishery increase, either due to climate change or to increasing market pressures from fishmeal demand, governance of the anchoveta fishery will continue to be more essential.

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CHAPTER 2: INNOVATION LEADERSHIP AND MANAGEMENT OF THE PERUVIAN ANCHOVETA FISHERY: APPROACHING SUSTAINABILITY

1. Introduction

Harvested from an area representing less than 0.1% of the ocean's surface, fisheries landings from the Humboldt Current, off the coast of Peru and Chile, account for 10-15% of the total worldwide marine fish landings (FAO 1998, FAO 2008). With a potential biomass of 15-20 million metric tonnes (MMT), Peruvian anchoveta, *Engraulis ringens*, supports the largest single-species fishery in the world (Pauly 1992, Ñiquen *et al.* 2000). Even though anchoveta did not become a commercially exploited species until the 1950's, fishing has played a key role in the country's development since the beginnings of civilization in the region (Marcus et al. 1999). Since 1950, rapid industry growth and ensuing increases in harvest levels soon led Peru to become one of the largest exporters of fishmeal and fish oil in the world (FAO 2008). Currently only second to mining as the largest industry in Peru, the fishing industry produces about 30-40% of the global production of fishmeal and fish oil, worth between US$ 1 and 1.7 billion annually (PRODUCE 2005, PRODUCE 2008, Tacon 2003). The anchoveta fishery has socioeconomic influences extending well beyond providing tens of thousands of jobs in the fishery supply chain, making its sustainability truly critical not only to the local economy at fish ports, but also the Peru's trade balance and the international markets and industries that depend on the resulting exports (Agüero 1996; Deligiannis 2000; Roemer 1970).

After describing the fishery's oceanographic conditions and management history, this chapter discusses the current policy shift in Peru from using a global quota system to allocate harvest, to individual vessel quotas (IVQs), examining whether the intended improvements on fishery profitability, efficiency, resilience and sustainability have been attained. In addition, a case-study approach is used to analyze the role of entrepreneurial leadership and innovation in the development of the anchoveta industry in Peru, emphasizing not only the technological and infrastructure development of the fishery, but also the role of corporate culture and social responsibility related to the profiled company's success and performance. The case-study focuses on the private enterprise found to be the premier innovator in the industry, examining the various innovations in corporate culture, technology and corporate social responsibility and their contributions the enterprise's success.

2. Physical Setting – Bio-Physical Oceanography and Anchoveta Ecology

Peruvian anchovy, or anchoveta, is a marine, pelagic, coastal species, abundant in large schools principally 80-150 km from the coast. Anchoveta stocks are sustained by the highly productive coastal upwelling Humboldt current system, stretching from northern Chile through northern Peru (4°S to 24°S, Figure 4; Agüero and Zulueta 1992). Wind driven upwelling of subsurface water from below the thermocline brings nutrient-rich water to support high primary productivity in surface waters (Barber and Smith 1981, Barber and Chavez 1983, Paulik 1971, Pennington *et al.* 2006). Fish productivity of this region is exceptional and even exceeds that of other regions of similar primary productivity (Bakun and Weeks 2008, Chavez *et al.* 2008). Peru's coastal productivity is highly variable, due to fluctuations in both the intensity of upwelling and the depth of the thermocline, as they are influenced not only by local oceanographic conditions but also by oscillations in Pacific and even global climate patterns (Alheit and Ñiquen 2004, Bakun 1990, Chavez *et al.* 2003).

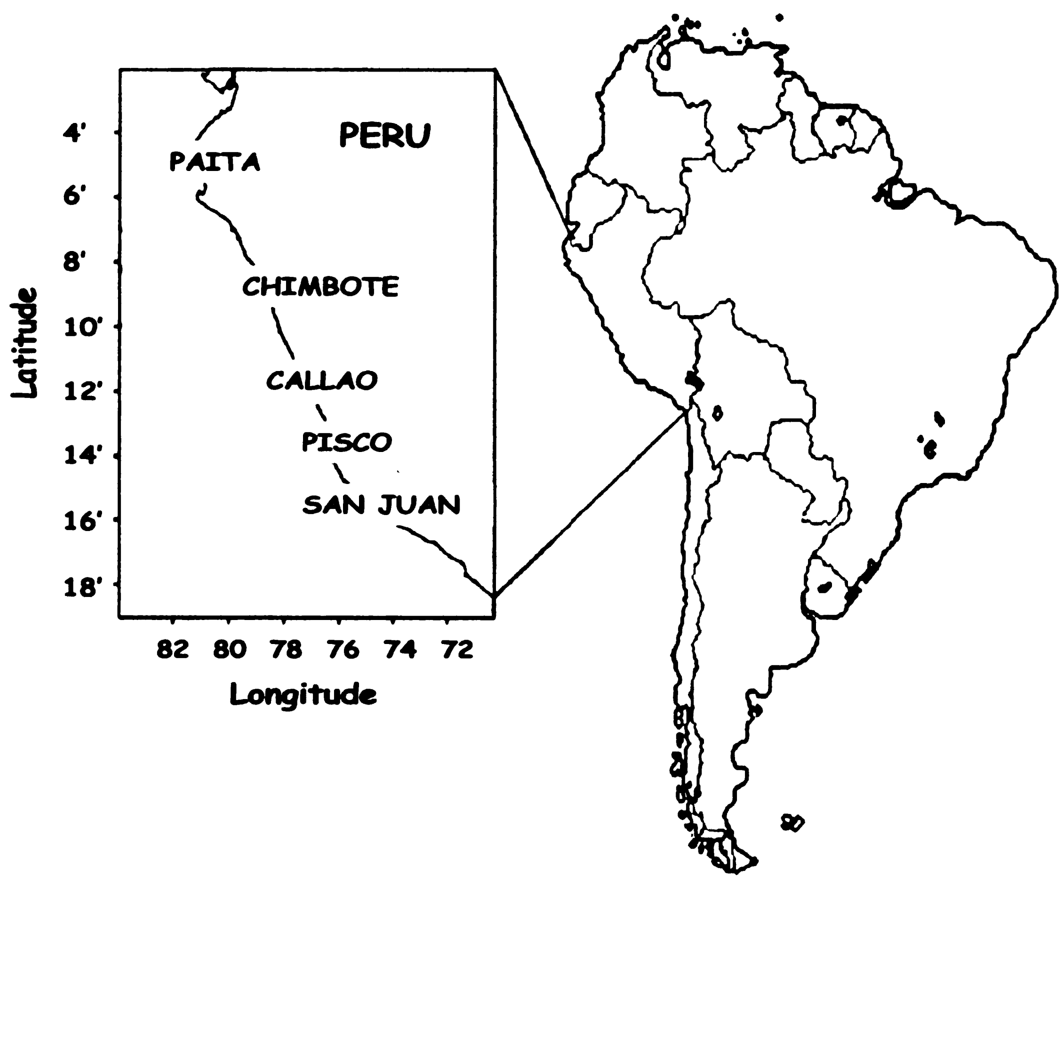

Figure 4: Map of South America, highlighting the major fishing ports in Peru.

Interannual variability is embedded within lower frequency fluctuations of multi-decadal climate variability, the most relevant being the Pacific Decadal Oscillation (PDO) which alternates between warm and cool regimes lasting about 15 to 30 years (Mantua and Hare 2002 and references therein). Although the specifics vary, warm PDO phases are characterized not only by El Niño-like conditions in the eastern tropical Pacific, with warmer water and a deeper thermocline, but also by changes in the circulation and atmospheric pressure systems (Hare and Mantua 2000, Mantua and Hare 2002, Chavez *et al.* 2003, Chavez 2005). In contrast to El Niño events, a PDO warm phase has been characterized by anchoveta stocks remaining relatively depleted for a period of decades. Fish population decadal-scale variations have been observed to occur synchronously for different pelagic species across the Pacific Ocean (Hare and Mantua 2000, Bakun and Broad 2003, Chavez *et al.* 2003), and remarkably even in the Atlantic (Lluch-Belda *et al.* 1989, Lluch-Belda *et al.* 1992, Bakun 2005). It has been observed that sardine populations off California and Japan seem to dominate when anchoveta populations off California and Peru become scarce and vice versa, arguably due to basin-scale ecological regime shifts. Evidence for such synchronous fluctuations has been found in sediment scale deposits (DeVries and Pearcy 1982, Schwartzlose *et al.* 1999) in addition to archeological evidence dating back to the 15th century (Sandweiss *et al.* 2004), and even longer term and more dramatic changes have been discussed (Gutiérrez *et al.* 2008, Sifeddine *et al.* 2008).

These basin-wide multidecadal ecological changes associated with the PDO, or regime shifts, have been found to correlate well with climatic-oceanographic conditions (Chavez *et al.* 2003, Alheit and Ñiquen 2004, Bertrand *et al.* 2004, Cahuin *et al.* 2009). Understandings of the PDO and its possible impacts on fisheries did not develop until the mid 1990's (Hare and Francis 1995), and debates regarding the dominant causal mechanisms of specific events and even long term trends during the history of the fishery are still unsettled (Chavez 2005 and references therein). It seems clear that climatic phenomena of both long and short-term periodicity interact to influence oceanographic conditions and that these in turn control biological productivity, impacting fisheries. In fact, a shift to the warm PDO phase has been argued to have hindered the recovery of anchoveta stocks following the fishery collapse in the early 1970's (Chavez *et al.* 2003). But the mechanisms that underlie these linkages are not yet fully understood (Pennington *et al.* 2006), and neither are the controls on anchoveta stock biomass variability (Mantua and Hare 2002), though much progress has been made (Cahuin *et al.* 2009). Alheit and Bakun (2010)provide the most recent review of basin scale linkages and bio-physical linkage mechanisms. There is even some uncertainty as to how exactly these stock variations interact with the commercial fishery (Bertrand *et al.* 2004).

Conceptual mechanisms have been developed that shed some light on anchovy-sardine stock fluctuations. The species are not direct competitors, as they do not share the same ecological niche (Bakun and Cury 1999, Bertrand *et al.* 2004). With high fecundity and growth rates, anchoveta are more adapted to productive, cold coastal upwelling zones (Alheit *et al.* 1984). In contrast, sardines are more migratory and have evolved finer-meshed filtering in their gillrakers, allowing them to thrive in less productive areas (Bakun and Broad 2003). Thus, anchoveta increase their populations under conditions of high productivity and high predation pressure upon eggs and larvae. Episodic conditions, such as El Niño, perturb the system to lower productivity and smaller, less dense plankton populations, while temporarily reducing predation pressure. This provides an "environmental loophole" that sardines can exploit to outcompete anchoveta (Bakun and Broad 2003, Bakun 2005, 2006). Furthermore, adaptive population dynamics mechanisms (e.g. density dependence) could enhance and maintain the species dominance alternations (Bakun and Cury 1999). In addition, Betrand *et al.* (2004) have suggested that it is through changes in the suitability and range of habitat that climatic oscillations (such as ENSO and the PDO) lead to sardine-anchoveta alternations. These are all important considerations to both explain the past anchoveta population trends and better manage stocks in the long term.

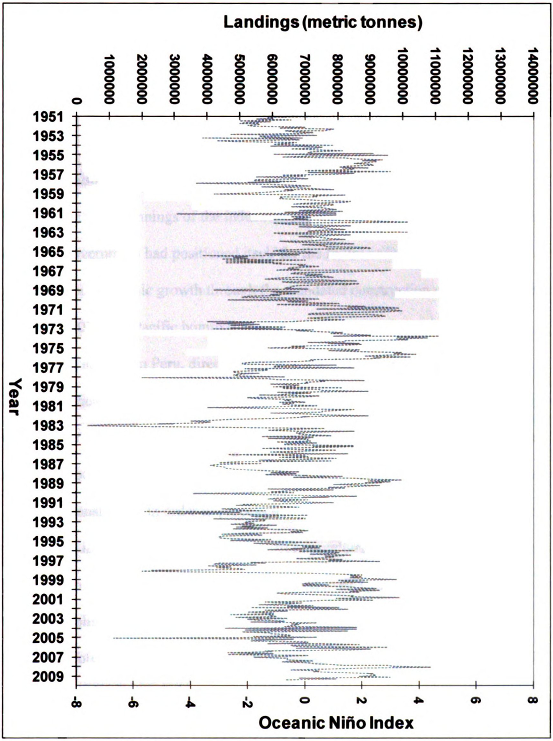

Figure 5: Anchoveta Landings (bars, FAO 2009), and Oceanic El Niño index data (line, NOAA; retrieved from ftp://ftp.cpc.ncep.noaa.gov/wd52dg/data/indices/soi)

3. Fishery History

As the anchoveta fishery became established, its management followed trends common to fisheries management throughout Latin America: (1) open access, (2) nationalization of industrial capacity by the government, followed by a (3) a return to private ownership (Agüero 1996).

3.1 Pre-Industrial: Fishing before 1954

Even before the beginnings of the industrialized anchoveta fishery in the 1950's, the Peruvian government had positioned itself for the future utilization of anchoveta resources for economic growth through the mandated construction of fishmeal plants. In the late 1930's East Pacific bonito (*Sarda chilensis*) harvest became an significant commercial activity in Peru, directed mainly towards the export of canned product to North America and Europe (Trillo and Tord 2003). Then, in 1943, largely as a response to attractive fishmeal prices in the international market and the need to increase the national export budget, a governmental Supreme Decree dictated that reduction plants should be constructed in order to process fish wastes into fishmeal (Table 1), adding value to the industry by creating fishmeal from previously discarded materials (Laws 1997, Olazo 2000). Peru also effectively aligned itself with other Latin American states for the establishment of maritime law to protect its fisheries and economic interests. In 1947 Peru followed Chile and Argentina in declaring sovereign rights to its coastal regions to 200 nautical miles (nmi, Garcia-Amador 1974, Paulik 1971; Table 1), as a way to ensure exclusive access to potentially important economic resources (Sanger 1986, Paolillo 1995). This was followed by the *Declaración de Santiago* in 1952, where

Ecuador, Peru and Chile formed a strategic alliance regarding property rights, sovereignty and marine resource protection (Paulik 1971, Table 1). International efforts beyond this declaration eventually led to the 1982 United Nations Convention on the Law of the Sea (UNCLOS).

In the late 1940's there was a PDO regime shift, from the warm to the cool phase (Mantua and Hare 2002), and with it came a synchronous rise in the biomass of the anchoveta off the coast of Peru and decline in sardine stocks off California (Norton and Mason 2005). With the collapse of the California fishery, equipment for canning and fishmeal plants became available for utilization and was imported by an emerging Peruvian industry, signaling the beginning for the commercial fishery (Pauly 1992, Trillo and Tord 2003). Exploiting the market gap left by the collapse of the California sardine fishery, anchoveta became the primary fish used in the export-driven production of fishmeal and eventually, also fish oil, a byproduct of fishmeal production (Roemer 1970). Export-led growth in Peru was encouraged by capital investment, technology transfers from abroad, state support, loose regulations, and expanding international markets (Glantz 1979, Aguilar Ibarra *et al.* 2000).

3.2 Anchoveta Boom: 1954-1972

The development of the modern day anchoveta fishery was preceded by a climatic and ecological regime shift favorable for anchoveta, and harvests by a growing industry increased rapidly from the mid 1950's until 1971 (Figure 5). Extreme abundance led to the fishery being treated as an open access resource, without significant barriers to entry.

Due to the rapid growth of this industry, the equipment imported from the California sardine fishery was soon replaced by new Peruvian factories and vessels. But while most of the Peruvian fleet and processing capacity was now domestic, much of the knowledge regarding both the marketability, harvesting and processing of anchoveta was gained from abroad (Roemer 1970).

While Peru has had a tradition of a strong state control, clear examples from the anchoveta fishery illustrate how the state was unable to manage the fishery effectively without support from the industry or market. As early as 1956, Supreme Resolution No. 217 banned the construction of new fishmeal plants (Table 1), intending that more anchoveta go towards domestic direct human consumption rather than fishmeal exports. However, plant construction continued (Figure 10). In fact, political pressure from large, overcapitalized business interests to increase fishing led to the plant construction ban being lifted in 1959 (Laws 1997).

Throughout the 1960's, management of the anchoveta fishery was shaped both in response to landings statistics and to the diverse and often conflicting interests from several government agencies. Declining fishmeal prices had led to the Paris Agreement (*Convenio de Paris*) in 1960, where private sectors of principal producing countries agreed to establish national quotas through government-issued export licenses. In 1964, the *Instituto del Mar del Peru* (IMARPE) was formed as a scientific institution to provide information and expertise regarding oceanographic conditions and marine resources to the government (Table 1). The *Sociedad Nacional de Pesqueria* (SNP) was founded in the same year, to unite, represent and lobby for the industrys' interests. The Peruvian government then effectively delegated much of its authority to the industry by issuing export licenses based on producer quotas (Hammergren 1981). The open access management of the anchoveta resource gave rise to increasing harvests and processing capacity, and thus increased anchoveta exploitation, with recorded harvests reaching 8.5 MMT by 1964 (Figure 5). In 1965, following a weak El Niño, the first closed seasons were instituted (Table 1), in an attempt to protect anchoveta stocks during the spawning period (Agüero 1996, Aguilar Ibarra *et al.* 2000), but the total allowable catch (TAC) was not limited (Hammergren 1981). IMARPE began collaborating with the United Nations' Food and Agriculture Organization (FAO) towards studying and monitoring the fishery in the early 1960's (Thompson 1981), but in retrospect it seems surprising Peruvian fisheries policy was not even more responsive to ENSO cycles.

In 1968 the Peruvian military seized the government and established a military-reformist regime under Velasco (Table 1), where government intervention in the fishery greatly increased through new mandates and the establishment of new strategic institutions: the Ministry of Fisheries was created in 1970, absorbing IMARPE in addition to housing the new *Empresa Pública de Servicios Pesqueros del Perú* (EPSEP), with responsibility over artisanal fishers, and the *Empresa Pública de Comercialización de Harina y Aceite de Pescado* (EPCHAP), which was to manage the marketing and sales of fishmeal and fish oil (Hammergren 1981, Aguilar Ibarra *et al.* 2000).

Upon establishing the constitutional status of fisheries resources as state property in 1968, quotas were enacted which regularly disregarded scientific recommendations not to exceed the estimated 9.5 MMT Maximum Sustainable Yield (MSY, IMARPE 1970). Supreme Decree No. 017-68-AG set harvests limits to 9.5MMT, but was followed by a quota increase to 12.3MMT (Table 1; Olazo 2000). This increase was partially due to political pressure, and the continued encouraging for industry overcapitalization through industry competition often referred to as the "Olympic race" for fishery quota (IMARPE 1970, Paulik 1971, Deligiannis 2000). During its first year, the Ministry of Fisheries had allowed record landings of 12.5 MMT, initially applauded as evidence of renewed competence (Hammergren 1981). It should be noted that recorded catch data also does not take into account underreporting and, in fact, the actual harvest in 1970 has been estimated to be as much as 15MMT (Castillo and Mendo 1987). But in spite of this source of error in the data, historic catch (Fig 1) still reflects major trends in stock fluctuations (Alheit and Ñiquen 2004).

Although IMARPE (*Instituto del Mar del Peru*) was created in 1960 to fulfill this role, it has no legislative power to ensure that the fishery is managed within the biological limits of the anchoveta (Hammergren 1981). When different branches of government have different goals, such as economic development and resource protection, discrepancies in the ensuing recommendations develop (Jentoft 2005). For anchoveta, there was a fundamental disconnect between the reality of overharvesting, the vision of the government agencies, and the desires of the fishery industry (Hammergren 1981). Without a common vision amongst these three groups, anchoveta governance was inefficient and its enforcement ineffective, leading to harvesting in excess of recommended levels.

Early governance of the fishery was shaped by the drive to manage the resource for maximum exploitation. The industry was developed primarily to supply an export market and, in response to international demand, was soon dominated by fishmeal and fish oil production. During this early period, the World Bank funded fisheries development in Peru, with socio-economic objectives trumping ecological sustainability. The anchoveta industry was viewed as a secure means of providing wealth, not only for individuals, but also for government development programs.

3.3 Anchoveta Collapse: 1972

By 1970 scientists at IMARPE had warned of the possibilities of the collapse of the anchoveta resource due to overfishing (IMARPE 1970, Clark, 1976). The government responded by enacting the 1971 General Fisheries Law to promote sustainable exploitation (Olazo 2000; Table 2). However, few actions were taken to restrict harvest, and the regulations that were established were not strictly enforced, as neither industry nor government heeded the warnings (Aguilar Ibarra *et al.* 2000, Deligiannis 2000). The reasons for this inaction lie within the larger political trends in Peru and throughout Latin America at that time. During the early years of the anchoveta fishery, governments changed rapidly, ranging from fully authoritative governments under a military junta to those that were democratically established (Morón and Sanborn 2005). The wealth derived from the fishmeal industry led these different governments to view the resource as a powerful and endless source of revenue, and soon its management became primarily driven by maximizing revenue (Deligiannis 2000).

The collapse of the anchoveta fishery in 1972 came as a shock to the Peruvian government. It was likely due to a combination of (1) overfishing, (2) an unfavorable, decadal-scale ecosystem regime shift, and (3) a strong El Niño event that year (Bakun and Broad 2003, Bertrand *et al.* 2004, Ñiquen and Bouchon 2004). In spite of anchoveta landings having reached the estimated maximum sustainable yield (MSY) of 9.5 MMT by April 1970 (IMARPE 1970), the government allowed for continued harvesting which ultimately reached 12.5 MMT (Thompson 1981). Early in 1971, the El Niño conditions concentrated the anchoveta stock into small remaining upwelling plumes adjacent to the coast, making them especially vulnerable to seine fishing (Csirke 1988, Beverton 1990, Alheit and Bernal 1993), and allowed for record catches in early 1972 (170,000 MT per day, Thompson 1981). Following the ensuing crash, the government closed the fishery for almost one year (Aguilar Ibarra *et al.* 2000), and anchoveta exploitation between 1972 and 1976 was only permitted for a total of 18 months (Thompson 1981). The shock caused by the fishery collapse had many socioeconomic and political consequences within Peru in addition to repercussions throughout the global food market (Glantz 2001), and would eliminate government views that the fishery resource was virtually unlimited. Fisheries are subject to the intrinsic variability of ocean ecosystems, and fisheries-based socioeconomic development can therefore be unstable, especially in the face of inadequate regulations or their enforcement.

Code	Year	Type	Policy	Description	Implication and Notes
	1943	Legislation	Mandated construction of fishmeal plants for residual processing	Canneries produced fishmeal from residual fish sources	
	1946	Jurisdiction	Ministry of Agriculture creates the Fisheries Directory	First body dedicated to fisheries management	
	1947	Declaration	Peru declares Economic Exclusive zone	Sovereignty declared over the first 200 nautical miles along the coast	Allowed exlusive marine resources access to Peruvian operators
	1949	Jurisdiction	Ministry of Agriculture's Fisheries Directory is renamed Fish and Game Directory	Directory jurisdiction expanded to manage hunting	
	1952	Declaration	Declaración de Santiago	Comisión Permanente del Pacífico Sur (CPPS) is formed between Ecuador, Peru and Chile	Agenda for marine resource protection and sovereignty
RS 217-56-AG	1956	Legislation	Fishmeal plant construction permit suspension	Construction of new fishmeal plants is banned	Promoting direct human consumption of anchoveta
	1959		Fishmeal plant construction permit ban lifted		
	1961	Jurisdiction	Ministry of Agriculture's Fish and Game Service reorganized into Fisheries Service	Fisheries Service exclusively manages fisheries	
	1964	Legislation	Instituto del Mar Peruano (IMARPE, Peruvian Institute of the Ocean) created	The official scientific body in charge of studying marine fisheries in Peru	The beginning of science based decision making
	1964		Sociedad Nacional de Pequería (National Fisheries Socelty) is founded	A private sector group meant to represent and lobby for industry interests	
	1968	Government	Military Junta seize Peruvian government	Agenda of state ownership begins with tight controls on valuable resources	
RS 017-68-AG	1968	Legislation	Supreme Decree establishes anchoveta quota	9.5 Million Metric Tonne per year anchoveta quota established	Considered Maximum Sustainable Yield
DL 051-8107-PE	1970	Jurisdiction	Ministry of Fisheries created, independent of Ministry of Agriculture	Whole ministry dedicated to fisheries management	Absorbs IMARPE, and artisanal fishers user groups

Table 1: Anchoveta Fishery Legislation 1943-1970

3.4 Government Control and PESCAPERU: 1973-1980

The fishery's collapse was used as justification for the new military government's state ownership agenda (Glantz 1979, Agüero 1996). In 1973, the fishmeal industry was nationalized as part of the new military government's expansive agenda. This was done through the expropriation of both the fishing fleet and the fishmeal processing facilities from the private sector (Laws 1997, Trillo and Tord 2003), involving controversially low valuation estimates of private sector holdings (Hammergren 1981). A public corporation known as PESCAPERU (*Empresa Pública de Producción de Harina y Aceite de Pescado*) was formed under state ownership and control. (Table 2) As a centralized entity with over 1200 vessels unloading to over 106 factories, PESCAPERU had greater flexibility to consolidate holdings and restructure effort, and become more efficient. Incorporating all 27,000 workers to avoid unemployment, however, meant PESCAPERU remained overcapitalized. State agenda of increasing direct consumption fisheries by the Peruvian populace led to further exploitation of food fish stocks (mackerel, *Scomber japonicus peruanus*, and jack mackerel *Trachurus murphyi*) in 1973-1975.

Government proved an unsuccessful industry manager, operating independently of international collaboration, and largely disregarding new scientific information, or private industry management expertise and technical know-how largely unexploited. Studies of the sardine fishery suggesting climate variability as a contributor to the California industry collapse (Hare and Francis 1995) were largely ignored. Even under an authoritative military government, private political pressure still existed, as the industry became indirectly involved in regulating the fishery once again. Priorities for both state and private industry were primarily driven by profits rather than by sustainability concerns (Deligiannis 2000).

3.5 Sardine Regime: 1973-1989

From 1973 until the early 1990's, anchoveta biomass and harvest continued, but remained low, averaging under 2.5MMT per year (Figure 5), with signs of stock recovery being stifled by a 1976-1977 El Niño that forced several closures during 1977 (Aguilar Ibarra *et al.* 2000). The 1976-1998 warmer phase of the PDO was characterized by an increase in sardine (*Sardinops sagax*) spawning and biomass as stocks expanded along the Peruvian coast (Chavez *et al.* 2003), leading to exponential increase in sardine landings from 1974 to 1976 (Alheit and Bernal 2003, Alheit and Ñiquen 2004). This period was thus characterized by a shift in fishing effort, from an anchoveta to a sardine dominated fishery, but with more diverse harvesting of several important species (including sardine and jack mackerel,) from 1972 into the 1980's (Trillo and Tord 2003).

Transition to new leadership (Morales Bermúdez) in the Peruvian government occurred in 1975, during the military regime. Aware of the overcapacity issues, fleet and processing capacity were reduced by almost 50%; but anchoveta catches remained low during this time period, and PESCAPERU still operated with net losses and continued to have to be subsidized by the state (Trillo and Tord 2003). Recognition of such unprofitability led to government led privatization, with the return to private ownership of the anchoveta fishing fleet starting in 1975, while that of the fishmeal processing facilities began in the 1980 (Hammergren 1981, Agüero 1996; Table 2). Anchoveta remained closely regulated, as government dictated that private harvesting be re-directed towards jack mackerel and other food fishes. Effort diversification, however, did not solve the anchoveta overfishing problem, but instead extended it to other species (Aguilar Ibarra *et al.* 2000).

The return to democracy in 1980 brought a period of relatively ineffective governance under both Belaúnde Terry (1980-1985) and Alan Garcia (1985-1990), as not only had corruption spread throughout the Peruvian government, but during the 1980's Peru was also fighting the terrorist organization *Sendero Luminoso* (Shining Path). Economic development in Peru was stymied and during these years, which were characterized by the highest rates of inflation ever seen (with over 2,000,000 % cumulative increase between 1985-1990), as well as the Latin America debt crisis (Cruz Saco 1995). Political and social circumstances interfered with the ability to manage the fishery, and together with the economic situation (hyperinflation and unemployment), were disrupting to business and the fishery industry as a whole.

However, a few key regulations were passed into legislation during these years. New seasonal closures for anchoveta and sardine began in 1980. Between 1982-1984 closures during spawning period, no-catch zones, fish size limits and gear restrictions were all introduced in addition to the traditional TAC limits to better protect anchoveta resource sustainability (Agüero 1996, Olazo 2000). In spite of these restrictions, anchoveta abundance dropped to its lowest point during the strong El Niño event of 1982/83, with a harvest of only 0.024MMT (Olazo 2000). An excellent recruitment year followed, however, leading to a predicted resurgence of anchoveta stocks (Alheit and Ñiquen 2004). But consistently low biomass estimates led IMARPE to become involved in attempting to better understand the ecology of the fishery.

To such purpose, international conferences were held regarding anchoveta ecology and management in 1987 and 1989, centered on anchoveta biology and ecosystem dynamics. These conferences produced two highly valuable reports written by experts from around the world (Pauly and Tsukayama 1987, Pauly *et al.*1989). Additionally, new sanctions for ignoring quota limits were set in 1988 (Supreme Decree 018-88-PE), and fishery access became more limited by requiring permits in 1989 (Supreme Decree 018-89-PE; Table 2).

3.6 Anchoveta during Peru's Recovery: 1990-1996

In 1990 Alberto Fujimori was elected, promising social and political change. He successfully initiated sweeping changes throughout Peru, successfully putting an end to domestic terrorism and implementing neo-liberal economic policies that included extensive privatization (Aguilar Ibarra *et al.* 2000). Fisheries regulations were implemented and enforced. The anchoveta fishery transitioned to a closed access fishery in 1991 (Ministerial Resolution 329-91-PE; Table 2), only approving permits in substitution of existing fleet capacity. While industry still controlled the supply chain fed by harvesting, management of the fishery was guided by both biological knowledge and best available management information.

Anchoveta stocks experienced a great recovery in the early 1990's, possibly related to a PDO induced regime shift, and aided by recent years of relatively low harvesting pressure. By 1994, harvest levels reached heights not seen since the late 1960's and, with the exception of the 97-98 El Niño event, anchoveta catches remained high (Figure 5). Of interest, the government never established a global quota for anchoveta at all for the year 1994 (Sueiro 2008, p.46). Then, in 1995, Peru became a signatory to the Rome Consensus on World Fisheries (FAO 1995), agreeing to manage its fisheries according to the Code of Conduct for Responsible Fisheries (CCRF, FAO 1995). Following the signing of the Consensus, Peru enacted legislation to improve fisheries sustainability. These included a series of Ministerial Resolutions that require (1) closing the entry for new vessels into the fishery completely, (2) monitoring vessels and their harvests using both GPS systems and live observers, and (3) setting new targets for the reduction of pollutants discharged to water by fishmeal plants (Olazo 2000). In its consultations with international fishery management experts, and in accordance with the CCRF, the state expanded its information and expertise role, more fully incorporating IMARPE into fisheries governance.

Fisheries governance under the Fujimori government was also refocused to diversify fisheries activities beyond anchoveta. Commercial exploitation was extended for other species such as Giant Squid (*Dossidicus gigas*), Yellowfin tuna (*Thunnus albacares*), and Chilean seabass (*Dissostichus eleginoides*). Efforts were also made during this time to aid in the enhancement of the artisanal fishing fleet, consisting of the subsistence fishing within 5 miles of the coastline, where extraction by the commercial fleet is generally not permitted as per the 2001 General Fisheries Law regulations (Table 2). The *Fondo Nacional de Desarrollo Pesquero* (FONDEPES), and the *Centro de Entrenamiento Pesquero de Paita* (CEP Paita) give technical support and training to artisanal fishers. In addition to these efforts, the Peruvian Institute of Fishery Technology (*Instituto Tecnologico Pesquero*, ITP) focused on developing anchoveta products for direct human consumption.

3.7 El Niño 1997-1998

An especially strong El Niño occurred in 1997-1998 which was anticipated, monitored and its impacts forecasted (Carr and Broad 2000, Broad *et al.* 2002, Colas *et al.* 2008). The Peruvian government devised task force to minimize damage from heavy rains and floods but its impact on the Peruvian economy was estimated around US $ 3 billion or about 5.3% of GDP (Glantz 2001). The Ministry of Fisheries, following IMARPE's recommendations, applied more extensive anchoveta bans with smaller quotas in a conservative policy attempting to protect the sustainability of anchoveta stocks, but these regulations were implemented after early landings had already overexploited the ever-vulnerable, shoaling anchoveta stocks (Zapata Velasco and Sueiro 1999).

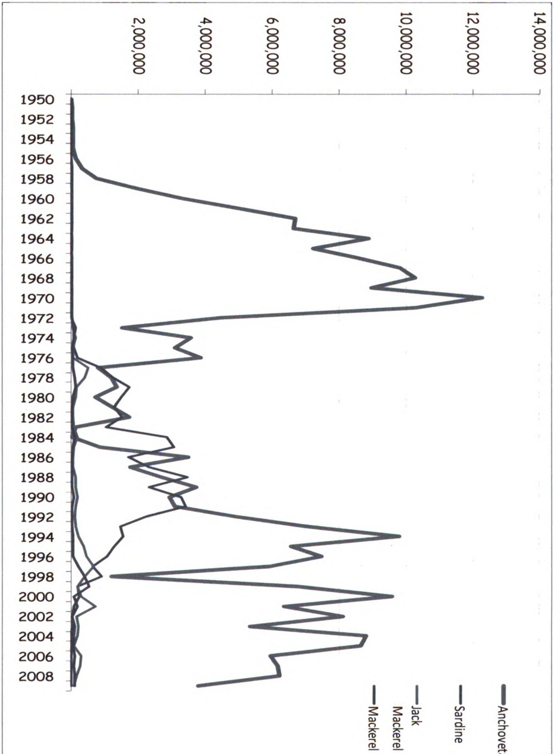

Figure 6: Fisheries landings of Anchoveta (blue, thick line), Sardine (green), Mackerel (yellow) and Jack Mackerel (red)

A financially vulnerable fishing industry, weakened by the Asian economic crisis which diminished credit availability, and already carrying massive debt from overcapitalization investments, was devastated by the 1998 El Niño. Depleted anchoveta stocks left the industry with insufficient cash flows, a financial deficit (close to US$ 80 million), accumulating debt (reaching US$ 1800 million or 11.2% of local bank debt while representing only 2% of GDP) and widespread bankruptcy (30% of debt was defaulted by early 2001), which threatened the solvency of some of the local banks which had invested in the fishery (Bayly 2000, Broad 2003, SBS 1998, Zapata Velasco and Sueiro 1999).

Another PDO phase shift in 1998-1999 returned the oceans to the cooler temperatures and stronger currents which characterized the boom period of the anchoveta fishery (Alheit and Ñiquen 2004, Chavez *et al.* 2003, Mantua and Hare 2002). With the fishery recovered, the industry consolidated debt and began a new growth cycle.

Code	Year	Type	Policy	Description	Implication and Notes
DL 18810 PE	1971	Legislation	General Fisheries Law introduced	Fishery development and sustainable exploitation established as objectives	Integrated into National Development plan 1971-1975
	1972		Anchoveta Fishery Nationalized	Expropriation of private sector holdings; integrated into public corporation	PESCAPERU controlled over 1200 vessels and 106 factories
	1975	Government	New military administration takes over	Privatization of the anchoveta fleet begins	
	1980	Government	Return to Democracy in Peru	Privatization of fleet continues, and factories begins	
DL 24790 PE	1988	Legislation	New General Fisheries Law replaces orginal from 1971	Jurisdictional regulation of the anchoveta fishery established	
DS 018-88-PE	1988	Legislation	Quota Violation Sanctions	High penalty fees were assessed for surpassing quota limits	
DS 018-89-PE	1989	Legislation	Anchoveta Fishing Permits Requirement	Permits required for anchoveta fishing	Overcapacity control
RM 329-91-PE	1991	Legislation	Anchoveta Fishery Access Closed	No new industrial permits issued, anchoveta fleet size capped	Emphasis on resource sustainability
RM 463-91-PE	1991	Legislation	Mandate establishes Biological year for sardine and anvhoveta	Two closed seasons established for anchoveta; juvenile landings regulated	Emphasis on resource sustainability
DL 25977 PE	1992	Legislation	New General Fisheries Law replaces that from 1988	Introduced new regulation, promotes resource and industry sustainability, conservation	Seasonal closures, juvenile protection, closed protected areas, gear
DS 01-94-PE	1994	Legislation	Ammendments to General Fisheries Law introduced	Artisanal anchoveta fleet licensing required; New environmental regulations	Artisanal fisher integration; stickwater plants mandated

Table 2: Anchoveta Fishery Legislation 1971-2009

Code	Year	Type	Policy	Description	Implication and Notes
RM 781-97-PE	1997	Legislation	Resolution establishes Sardine and Anchoveta as Fully Exploited Resources	Unlicensed vessels built 1961-1986 mandated to obtain licenses; fleet capped again	This time artisanal vessels are included
DS 012-2001-PE	2001	Legislation	Revised regulation and management for General Fisheries Law	Updates 1994 regulations	Emphasis on sustainability, conservation and socio-economic development
RM 218-2001-PE	2001	Legislation	Fishmeal Plant Construction Ban	Cap on installed processing capacity	Both FAQ and high protein production lines capped
DS 027-2003-PE	2003	Legislation	Fish Landings Control and Supervision Program	Mandates electronic weighing and automatic recording of landings upon unloading	Periodic inspectors; fines for tampering
RM 047-2004-PE	2004	Legislation	Fishmeal Plant Relocation Ban	Stops relocation of installed capacity to major fishing ports	
RM 205-2006-PE	2006	Legislation	Direct Consumption Fisheries Residual Meal Provision	Mandates the use of residual tissues from direct consumption fisheries for fishmeal	Residual meals are produced by anchoveta fishmeal plants
DS 006-2006-PE	2008	Legislation	Satellite Positioning System Provision	Mandates the instalation and use of satellite positioning systems and database integration	Real-time individual vessel position database created
DS 003-2008-PE	2008	Legislation	Special Fishing Zones for Indutrial Fleet within 5 miles	Ammends the 2001 regulation; allows industrial extraction within 5 miles of the coast in special zones	Must contribute to an artisanal fishers fund to gain access
RM 621-2008-PE DS 010-2008-PE	2008	Legislation	Fishmeal Plant Bay Effluent Regulation	Maximum legal water pollutant levels established for fishmeal factories	Four year grace period until mandatory compliance
DL 1084-08 PE	2008	Legislation	Individual Vessel Quota System introduced	Transition to Rights based management: Each vessel assigned a percentage of annual quota	No more competition for quota; overcapitalization incentive removed
RM 100-2009-PE	2009	Legislation	Artisanal Fisher Regulatory Framework	Regulates anchoveta artisanal fisher fleet	Promotes direct human consumption market

Table 2 (cont'd): Anchoveta Fishery Legislation 1971-2009

4. Anchoveta Management 2000-2008

Current fisheries management legislation was mostly enacted during the Fujimori administration, and governance has largely continued on a similar trajectory under succeeding presidents (Toledo 2001-2006, Alan Garcia 2006-2011), except for the recent change to a rights-based quota system (Section 5). Historically, anchoveta governance involved unsustainable interactions, first with private sector's political pressure for unlimited harvesting, and then with the state ownership and inefficient industrial management. Following the return to democratic leadership and private ownership of the fishery, governance evolved into a complex series of interactions between policymakers and IMARPE, while retaining the information sharing and exchange with industry. The focus remained on commercial exploitation of the resource, but with a new emphasis on sustainable use and diversification of the fishery. Peru had already declared both the sardine and anchovy fisheries as fully exploited resources in 1997, restricting access to both fisheries (Table 2). In 2002, the Integrated Management of the Humboldt Current large Marine Ecosystem project was born, seeking to develop effective governance measures for the entire ecosystem, based on scientific findings and predictions, as well as consensus between governance actors (industry, managers, policy makers, etc; IMARPE 2002).

At the state level IMARPE provides biological and management expertise such that decision-making is more closely informed by both management for maximum sustainable yield and ecosystem conservation and resource sustainability considerations. IMARPE recommends season quotas based on systematic biomass assessment and plankton community composition surveys together with a daily verification of industry landings data . There are two annual closed seasons instituted during anchoveta spawning (in May-July, and August-September). Short-term closures are also issued adaptively, in response to continuous monitoring of landings for percentage of juvenile catch, adult condition (lipid content), or evidence that spawning season has begun early or is still ongoing. The fishery is closed access, with new vessels only being allowed as replacements with the same licensed hold capacity. In addition, all commercial vessels, which must operate outside the 5nmi limit reserved for artisanal boats, are fitted with an industry-financed satellite vessel monitoring system, which allows the government to monitor their real time movements and position. Construction of fishmeal processing plants is also regulated by permits from both the Ministry of Production and the Ministry of Health, ensuring compliance with safety regulations and controlling capacity growth and distribution to manage environmental impact (FIN 2006, PRODUCE 2006). Today the Peru's total fishmeal plant capacity has been capped, and licenses are only issued to move/merge or replace previously existing plants.

Anchoveta management in Peru has become more robust over time, producing informed and enforced regulations, which industry now largely conforms to. In addition, FONDEPES, ITP, and CEP-Paita provide expertise regarding technology and sanitation, aiding in the management of the artisanal fishery and the development of products for human consumption. Decision-making authority now rests with the Vice-Ministry of Fisheries, a sub-division of the Ministry of Production, after the abolishment of the Ministry of Fisheries in August of 2002 under President Toledo.

However, regional management interactions are limited. While the bulk of the biological production and 85% of anchoveta harvest comes from the northern stock off Peru (6° to 15° south latitude), the southern anchoveta stock (15° to 24° south latitude) is shared with Chile (Agüero and Zuleta 1992). Within this shared stock, fishing by one country impacts the other, and a concern is that without a shared management plan the stock will be overfished as the two countries compete for landings. Ideas such as a shared fisheries management zone and overarching quotas across the region have been proposed in the literature as beneficial to both countries, both ecologically and economically (Agüero and Zuleta 1992, Agüero 1996). However, Peru and Chile have so far failed to incorporate joint management of the southern anchoveta stock into legislation.

5. Current Challenges

Sustainable development can only be accomplished through looking at the entire of a complex social ecological system (SES). Solutions directed at only selected parts of this integrated system will likely miss interactions that influence the future sustainability of the resource (Walker *et al.* 2006). In the case of the Peruvian anchoveta fishery and its future sustainability, this will mean addressing its governance at both the national and international scale, in addition to addressing the changing climate with concurrent changes in fisheries policy, and optimizing interactions between industry, society and the global marketplace. Today's challenges for the anchoveta fishery are complex, diverse and will affect all scales of governance.

5.1 Climate Predictions and El Niño Mitigation

One of the main challenges for Peru is monitoring and predicting the variability and frequency of the El Niño Southern Oscillation (ENSO), its effects within the Humboldt Current Large Marine Ecosystem, and preparing the industry to withstand the resulting pressures. Originally attributing the 1972-73 collapse of fishery primarily due to overfishing temporarily disguised the impact of climate processes on the anchoveta stocks (independently of fishing effort). The quick recovery of anchoveta stocks following the 1997/98 El Niño event, on the other hand, was recognized as being catalyzed by the strong La Niña event that followed it (Bertrand *et al.* 2004). Climate and ocean monitoring was greatly improved through the Tropical Ocean Global Atmosphere (TOGA) initiative in 1985, an effort by the World Climate Research Programme (WCRP) to monitor oceanographic conditions in the equatorial Pacific (Broad 2003, Glantz 2001). Though these monitoring networks allow adequate observation of ENSO cycle development, accurate forecasts do not guarantee useful management decisions (Glantz 1979, Broad 2003, Broad *et al.* 2002). Both bottom-up (e.g. food availability) and top-down (e.g. predation) controls on the dynamics of pelagic resources must be acknowledged and accounted for in management programs (Wolff *et al.* 2003). Still, uncertainty remains as to the relative strength of linkages between anchoveta and multi-decadal climate variability, partially because the catch data and biomass estimates only represent about the last 60 years (only about two PDO cycles). Further uncertainty about the impact of climate change compounds these challenges, as discrepancies between model predictions exist (Bakun 1990, Bakun and Weeks 2008), making it more difficult to enact effective long-term fisheries policy.

Ensuring sustainability depends on the continuation of adaptive management strategies that consider climate cycles, the improvement in predicting the variability and frequency of relevant climate variables, and the political expediency to base management decision on best available science, setting quota levels in accordance to climate-driven fish stock expectations. The creation of an industry stabilization fund might help mitigate the economic impact on the industry of extended closed seasons during future El Niño events. This would alleviate the incentive for illegal fishing during such seasons, thus protecting the anchoveta resource during its most vulnerable times.

5.2 Governance and Regulatory Framework

There is still much progress to be made in the development of effective fisheries governance in Peru. The continuation of independent management of the shared stock with Chile is indicative of Peru's state-centric focus of fisheries governance, although the development of a shared scientific program (IMARPE 2002) is a definite step forward. Moreover, since anchoveta stocks in southern Peru migrate further south into Chile during El Niño (Colas *et al.* 2008), shared management would represent a further tool to mitigate climate-driven financial damage to the Peruvian industry by allowing some catch in Chilean waters (Ñiquen and Bouchon 2004), while allowing Chilean fishers to access Peruvian waters in other years in exchange. As pressures on the fishery increase, either due to climate change or to increasing market pressures from fishmeal demand, holistic governance of the anchoveta fishery will continue to be more essential (Orlic and Berngartt 2007).

A failure of adequate governance structures embedded in the "Olympic Race" global quota management system has led to overcapacity in the anchoveta fishing industry. This has continued to worsen in spite of the 1992 General Fisheries Law, which sets limits on fleet and processing plant expansion, and mandates adherence to biological as well as social and economic considerations for management. Failure is largely the result of inadequate enforcement and regulatory loopholes. A clear example was the exploitation of measures to legitimatize "Viking Class" ships (wooden vessels of 30-110 MT hull capacity, classed as artisanal and exempt from most regulations imposed on the industrial fleet). The artisanal "Viking" fleet had been originally given duty-free access to direct human consumption fisheries as a government measure to provide local communities with legal, local livelihoods while accessing cheap, improved nutrition. However, in addition to fishing for direct human consumption species (e.g. mackerel and jack mackerel), these artisanal fishers found fishing for anchoveta and selling to fishmeal factories more profitable. To legitimatize these artisanal fishers' participation in the anchoveta fishery, the government granted them legitimate access through a licensing program from 1997 to 1998. The measure was exploited, where fleets of small commercial vessels applied for permits for large artisanal vessels, worsening the overcapacity problem and, in fact, during the legitimization process, six times as many "Viking" vessels were registered as were historically known to operate (Aguilar *et al.* 2000, Hidalgo 2002).

5.3 Overcapacity

A further challenge involves the problem of overcapitalization. Aided by international organizations such as the FAO and the Inter-American Development Bank (IADB), Peru had been heavily investing in fisheries infrastructure development for years (Lemay 1998). Open access to the fishery combined with funding and loan opportunities led to the overcapitalization of the industry, in the form of excess fleet and processing plants (Lemay 1998, Gréboval and Munro 1999), a situation that was recognized as a problem early on (IMARPE 1970). Overcapacity was worsened by the establishment of closed seasons for the fishery, which created incentives for businesses to invest in larger more efficient fleets, trying to outcompete each other for increasingly greater shares of the total quota before the next closure (Clark 1976, Gréboval and Munro 1999). Technological innovations including new vessels ensued (Section 8.2), which continuously increased fishing effort (Paulik 1971). This overcapacity had two important impacts on the anchoveta fishery. First, it promoted political pressure leading to high and increasing quotas (Deligiannis 2000). Second, while high capacity remained profitable when anchoveta were abundant, the excess capacity became a detriment to the industry after the collapse of the fishery, as accumulating debt could not be consolidated and paid for and resulted in widespread bankruptcies (Clark 1976, Hammergren 1981).

Although the increase in both fleet size and hold capacity was limited through access regulations, industry-wide competition generated by a global quota system, commonly referred to in Peru as the "Olympic Race", resulted in increased fishing effort through the use of better technology, know-how, and efficiency (Section 8.2). Part of the move towards greater efficiency included a large increase in the number of fishmeal plants (Figure 16), distributed along the coast, allowing fleets to make shorter trips between harvest and processing sites. Adding to the overcapacity problem of the industrial fleet, the "Viking Class" fleet has effectively doubled over the past decade (Figure 7). The Peruvian industry currently consists of 140 fishmeal processing plants, in addition to a fleet of 608 steel industrial and 592 wooden vessels (with a combined fish hold capacity of over 0.2 MMT (Aranda 2009, Figure 7). Given that Maximum Sustainable Yield (MSY) of the fishery is estimated to be about 8 MMT, the length of an average season and 2007 fleet hold capacity would lead to a calculated overcapacity of 70% for the fleet and 89% for the factories (Freón 2008). Other reports, have found that estimated overcapacity fluctuates with annual quota assignments, and ranges from about 60-78% for the fleet, and 65-80% for fishmeal factory processing capacity (Paredes and Gutierrez 2008). This level of overcapacity, combined with efficiency improvements, has resulted in increasingly short anchoveta fishing seasons, as quotas are being reached increasingly faster, as short as 54 days in 2006 (PRODUCE 2006, Figure 8). In addition to accelerated depletion of the anchoveta resource, overcapacity dissipates economic benefits to the fishery industry (Section 5.4), and thus to society (Section 5.6).

An international symposium on future anchoveta fishery management was held in Lima in 1992 (Loayza, 1994), which focused heavily on individually transferable quotas (ITQ's) as a way to both control the potential for overharvesting and discourage overcapitalization by improving economic efficiency and removing the need to compete for a share of the global quota (Aguilar Ibarra *et al.* 2000, Hidalgo 2002). Although the

ITQ system had been successful and profitably implemented in other countries (Section 6), it was not established in Peru due to the reservations by the politically powerful and overcapitalized fishmeal industry, fearing decommissioned asset devaluation under the new scheme (Hidalgo 2002, Morón and Sandborn 2005). Therefore, the 1992 General Fisheries Law (DL 25977, 1992) remained unchanged as the guiding legislation, which bases management upon seasons, quotas and gear restrictions, with a shared total allowable catch set for the year. As discussed in section 6, this global quota scheme was replaced by a new rights-based management approach and the institution of individual vessels quotas (IVQ) in 2008 (Section 6.1).

Other, perhaps complementary, strategies to aid with the overcapacity problem would include a government sponsored vessel buy-back and decommissioning program and a freeze on "Viking" fleet capacity expansion and possible reduction. In addition, incorporating environmental impact mitigation costs into licensing or operating fees would raise the entry barrier for large artisanal anchoveta fishers, while promoting more environmentally friendly practices by those in the fishery industry.

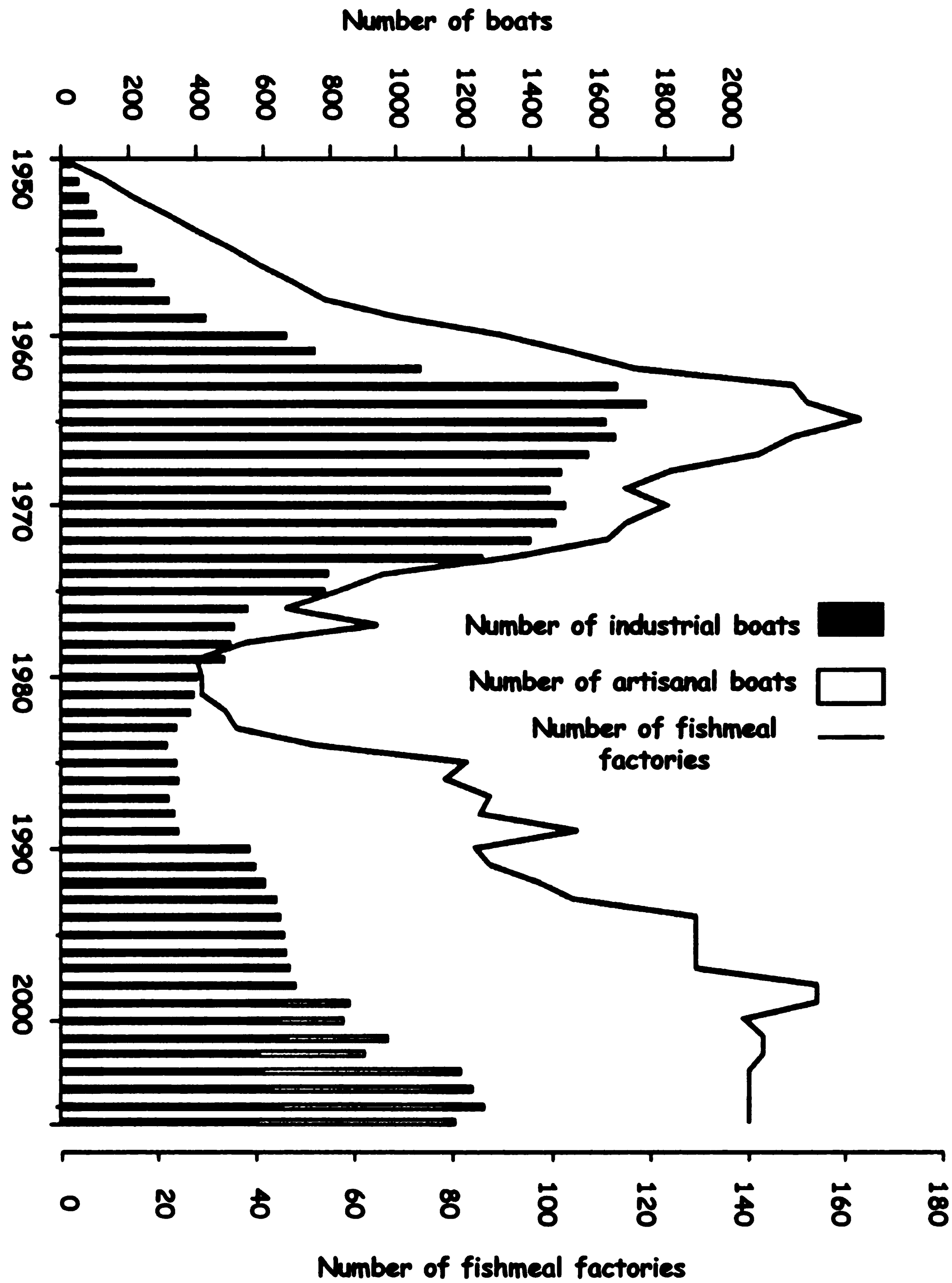

Figure 7: Fleet size and number of fishmeal factories. Top chart (adapted from Freon *et al.* 2008, p 405) is from 1950-2006. Bottom chart (self-elaborated) is from 1997-2009.

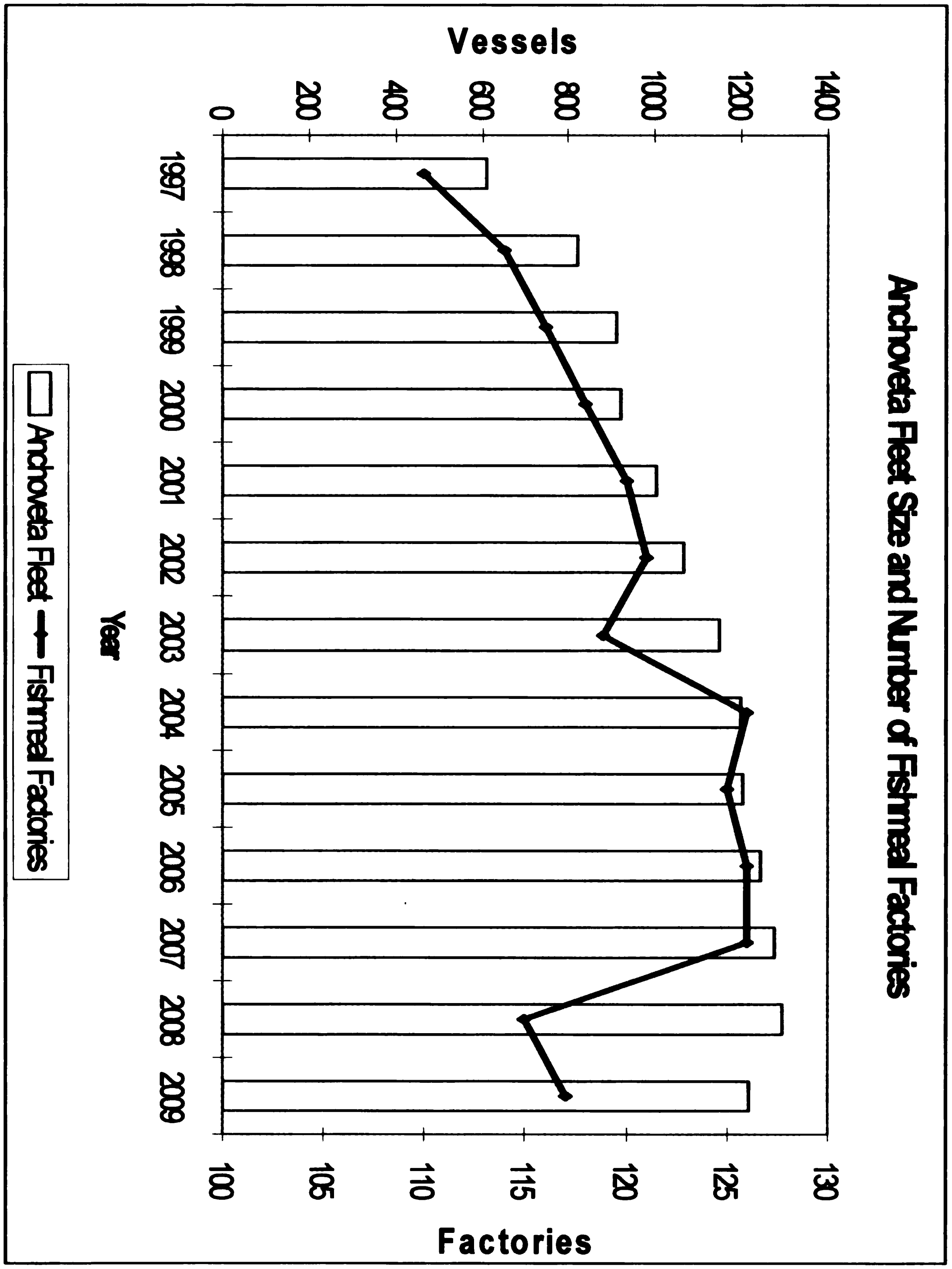

Figure 7 (cont'd): Fleet size and number of fishmeal factories. Top chart (adapted from Freon *et al.* 2008, p 405) is from 1950-2006. Bottom chart (self-elaborated) is from 1997-2009.

5.4 Economic Inefficiency

Overcapacity is inherently inefficient, and has led to crew employment reduction to under 100 days a year to be become common as larger, better equipped fleets reach harvesting quotas faster (Freón *et al.*2008). Businesses have been continually investing in their fleet size capability and processing capacities, and are being left with an increasing numbers of idle capital assets for increasingly longer periods of time as the fishery season is shortened by an overcapitalized fleet fulfilling the quota faster. At the same time, these investments have been made by diverting capital resources which could have been used to invest in improving harvesting efficiency (e.g. cost reduction) and processing practices (e.g. processing yield maximization; quality maximization); very important opportunity costs. As such investments have been show to boost profitability while reducing the firms' environmental impact (Section 8.2).

In addition, overcapitalization combined with anchoveta stock fluctuations, led to a major financial debt load in the industry (e.g. reaching US$ 1800 million), absorbing capital at a high opportunity cost to both business development and resilience (e.g. susceptibility to bankruptcies due to El Niño, Section 3.7). Without investment capital, firms are left with capacity surpluses of outdated and inefficient technologies, such as fishmeal plants that can neither meet high-end international market demands (for high quality, high protein meals), nor modern environmental standards.

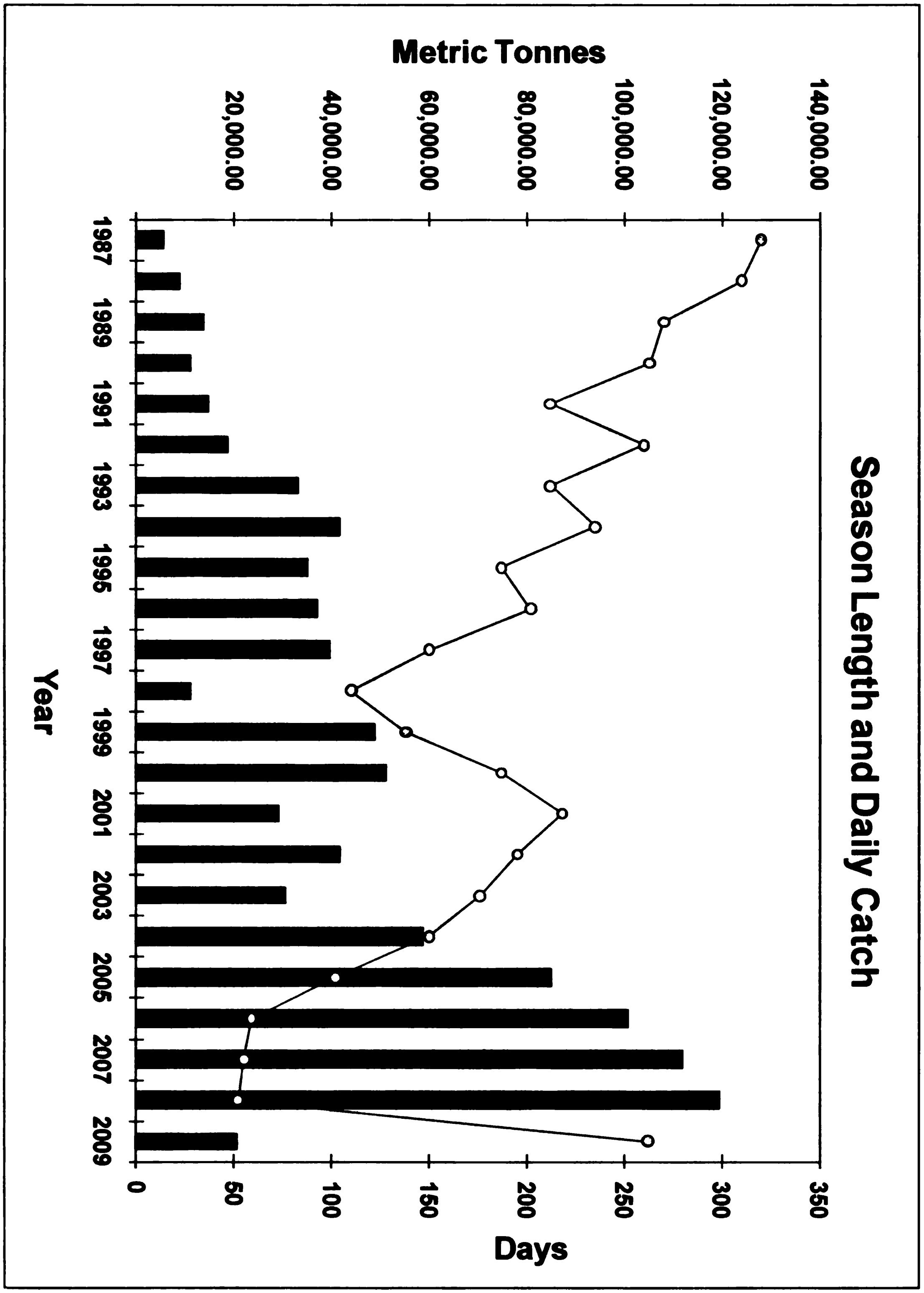

Figure 8: Anchoveta fishing season length and average daily catch 1987-2009 (data updated Jan 2010).

While industry consolidation, driven by legislation to create incentives for fleet and processing capacity reduction (e.g. ITQ system), has had success in aiding with fishery overcapacity (Section 6), a longer term view of business, with dedicated investments towards the improved future sustainability of the industry and the fishery resource is still needed. For example, although higher quality fishmeal improves feed conversion ratios (Figure 14), making aquaculture more sustainable (Naylor and Burke 2005), only 40 of 145 fishmeal plants were equipped to produce high quality, high protein content fishmeal by the end of 2008. Market pressure from consumer demand should encourage this to further improve in the future.

5.5 Pollution and Environmental Degradation

While excess fishing effort is clearly linked to periodic collapses in the anchoveta fishery, the issue is compounded heavily by the effects of El Niño and the relative importance of each is still debated. But overfishing is also an issue in other species such as sardine, hake and jack mackerel.

Direct impacts of fishery exploitation include the ecosystem impacts of by-catch of non-target species and trophic linkage degradation, and these have been shown to impact ecosystem productivity, stability, and resilience (Brunner *et al.* 2009). To minimize these impacts Peru has established a maximum 10% by-catch regulation, and has started the process to delineate Marine Protected Areas (MPAs) for future implementation. Independently of harvesting, there are also environmental impacts related to air and water pollution incurred from processing anchoveta. These impact could be mitigated through the use of technology that has already been introduced to the industry to both recover waste from fishmeal plant water discharge, and reduce air emissions by replacing conventional meal dryers with steam dryers, the latter of which result in the production of higher quality (and higher priced) fishmeal (Section 8.2). In recognition of the potential for accessible and reliable environmental impact mitigation, Peru passed legislation to regulate both fishmeal plant water discharge (pH, solid and lipid content, PRODUCE 2008b), and atmospheric emission (sulfides and particulates, PRODUCE 2009). In addition, a combined effluent treatment scheme for all fishmeal factories in the bay of Pisco was introduced in 2004, with plans for a similar scheme to begin construction for Chimbote in 2010 (PRODUCE 2005, PRODUCE 2008a). But further regulation is required to internalize environmental costs and other negative externalities, thus creating the incentive for industry-wide implementation of such improvements (reducing the profitability of unsustainable operations).

5.6 Unrealized contribution to Peruvian society

Besides ecological and economic viability, sustainability should further be measured by the extent to which an activity accrues benefits to society. Inefficiency and high debt loads mentioned earlier for the Peruvian anchoveta fishery have high social opportunity costs including creating a lack of financing for anti-poverty or food security agendas, job opportunities from diversified and value added industries related to anchoveta, and investment capital to reduce pollution of air, water and food through technology (Personal Communication 2009c). In the past, industry tax-relief to aid with indebtedness during unprofitable seasons has meant that industry contribution to national welfare has been disproportionately low (annual contributions as low as only 40% of what could be expected from another similar size industry; Personal Communication 2009c).

Furthermore, the potential for fisheries to aid with widespread malnourishment has been apparent for some time, but only 6% of fish landings go towards the domestic direct consumption market (Freón *et al.* 2008, Figure 9). Anchoveta represents a highly nutritious food resource, containing several essential amino acids, vitamins (*e.g.* A and D) and minerals (*e.g.* K, Fe, Ca, I) in addition to essential fatty acids (*e.g.*Omega-3, IFFO 2009). In light of this value, many advances have been made to bring innovative anchoveta products to the direct consumption market, especially through collaborations between the Peruvian Vice Ministry of Fisheries and the Peruvian Institute of Fishery Technology (ITP).

Several Peruvian administrations have passed legislation attempting to increase direct human consumption of fish, but without significant results. This failure can be largely attributed to a shortage of distribution and storage capacity, unable to absorb available supply from harvests. For example, legislation banning the use of jack mackerel for fishmeal production will not significantly increase its direct human consumption if there is no adequate infrastructure to maintain its freshness long enough to process and distribute it to the public. Similarly, though recent efforts to divert more anchoveta harvest towards direct human consumption have achieved some progress with increasing popular acceptance of anchoveta as a food fish (Figure 9), their success is limited however, due to shortcomings in the proportion of refrigerated anchoveta fleet, cold storage facilities and distribution outlets. Developing these output channels and storage infrastructures to increase human consumption may contribute to solving the problem of malnourishment.

Fishmeal and fish oil production remain the only economically and logistically viable alternatives for the bulk of anchoveta harvest in the foreseeable future, as directing a fishery with such voluminous landings towards human consumption would require currently unattainable infrastructure and supply chain investments. This point is illustrated by the current volume of the total domestic market for Peru's direct human consumption all fish species, which is around 0.75MMT per year (PRODUCE 2008a) , or 12% of 2008 anchoveta catch.

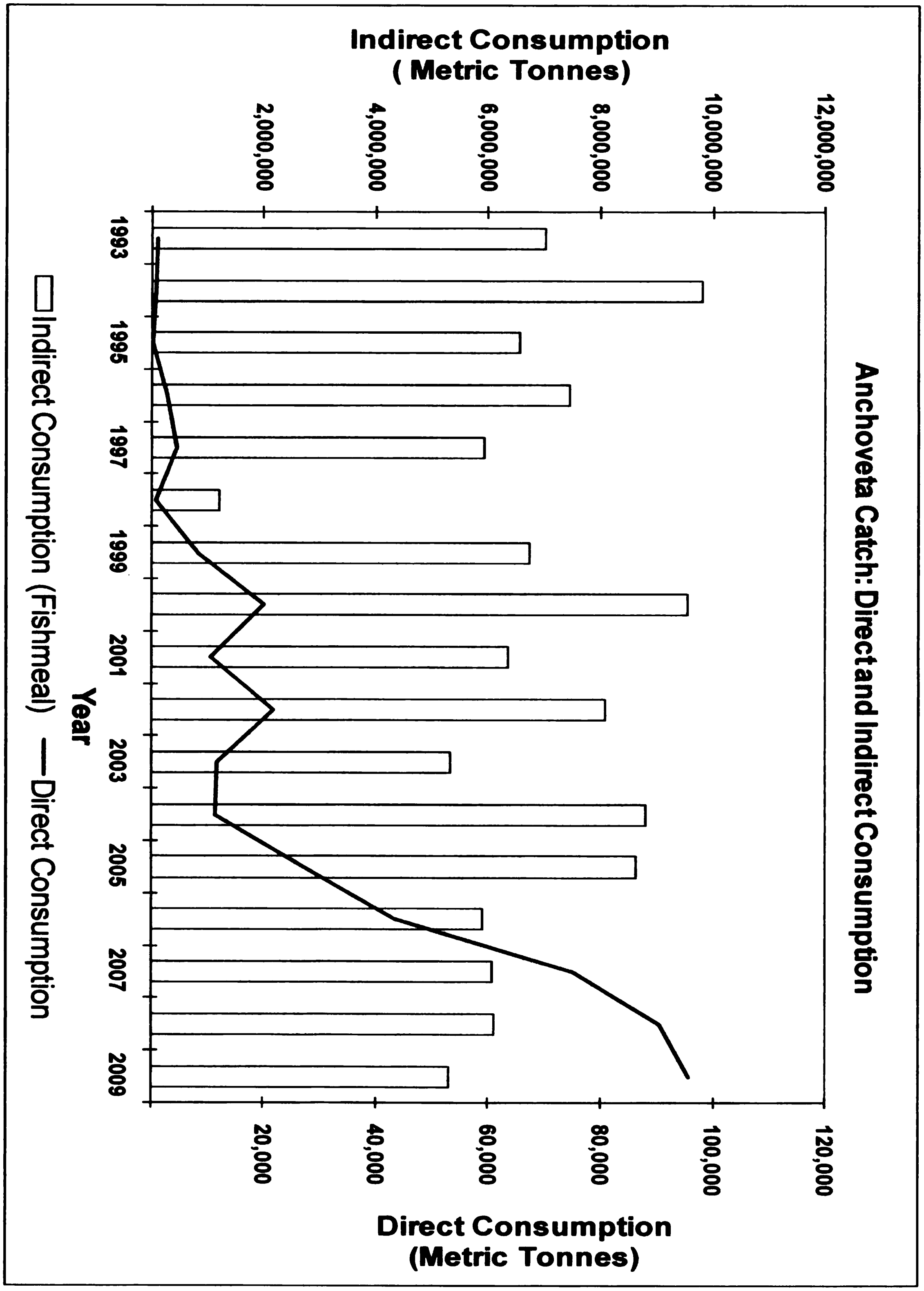

Figure 9: Direct and indirect anchoveta consumption 1993-2009 (updated Dec 2009)

6. Regulatory Innovation – Individual Vessel Quotas (IVQs)

An IVQ system allocates a share of the year's Total Allowable Catch (TAC) to each fishing unit (i.e. each vessel in the anchoveta fishing fleet), essentially assigning property rights to the resource (Gréboval and Munro 1999, Perman *et al.* 2003). The details of individual quota systems vary in accordance with policy and management objectives, and include initial quota allocation, degree of transferability, resource rentals, aggregation limits, and setting the TAC (Grafton 1996). In general, individual quota assignment removes the possibility of competing for increasingly larger shares of the TAC, and allows effort to be distributed over longer fishing seasons, maximizing efficiency as operators preferentially choose to harvest on favorable days when anchoveta are near fishing ports and in high numbers. This would be expected to increase fishing effort efficiency through selective fishing trip scheduling, adjusting trip allocation towards times when fish are both relatively abundant and in close proximity to shore. Shorter and more successful fishing trips would allow a much greater portion of the fleet to arrive with fresh catch, which always yields higher quality fishmeal and ultimately increases industry profit margins. Moreover, shorter fishing trips (without the need to race for fish) requires less fuel, thus reducing both the industry's cost of production and their atmospheric emissions.

Optimizing performance under an IVQ system no longer requires overcapitalized operators to compete with one another. This is achieved, instead, by smaller fleets (with consolidated quotas) and a smaller number of strategically located fishmeal plants. With the incentive for overcapitalization and overfishing removed from the system, fishers now have a stake in the future health and sustainability of the resource. In addition, transferability creates the incentive for operators to maximize the market value of individual quotas, favoring a more conservative and precautionary management of the fishery. But controversies regarding the suitability of ITQs in developing nations remain, especially as rigorous enforcement is essential to their success, and unemployment is a consequence of reducing industry capitalization (Aguilar Ibarra *et al.* 2000).

An IVQ system can be highly profitable, increasing the efficiency of companies that remain. However, introducing IVQs into an overcapitalized fishery, individual quotas will be insufficient for all operators to continue fishing profitably in an overcapitalized fishery, most companies cannot be assigned a large enough quota to balance return on investment, resulting in low or negative profits, and the social and political cost of bankruptcy and unemployment. Those who are able to continue operating profitably will do so more efficiently and will likely buy quotas from the rest, resulting in industry consolidation. This has been observed in many of the over 200 fisheries around the world where individually assigned quotas have been implemented (Figure 10), with clear environmental advantages and positive economic results, especially for single-species fisheries (Grafton 1996, Branch 2009, Chu 2009).

A few examples are from (1) Iceland, where Individual Transferable Quotas (ITQs) were instituted in response to crises in different pelagic and demersal stocks (Arnasson 1993), and have proven successful at preventing their collapse their while providing positive economic rents from the pelagic fisheries; however, much controversy remains about rent contribution to national welfare (Eggertson 2004); (2) Namibia, where ITQs were assigned by the Marine Resources Act of 2000, characterized by non-transferability and fee assessments, have proven successful for both their environmental management and economic objectives (Sumaila et al. 2004); and (3) the groundfish trawl fishery off the coast of British Columbia has been managed with individual quotas since 1997, with very successful results including increased catch data reliability, decreased fleet capacity, increased economic rent, and a positive shift in fisher behavior towards resource conservation and economic efficiency (Grafton 2004).

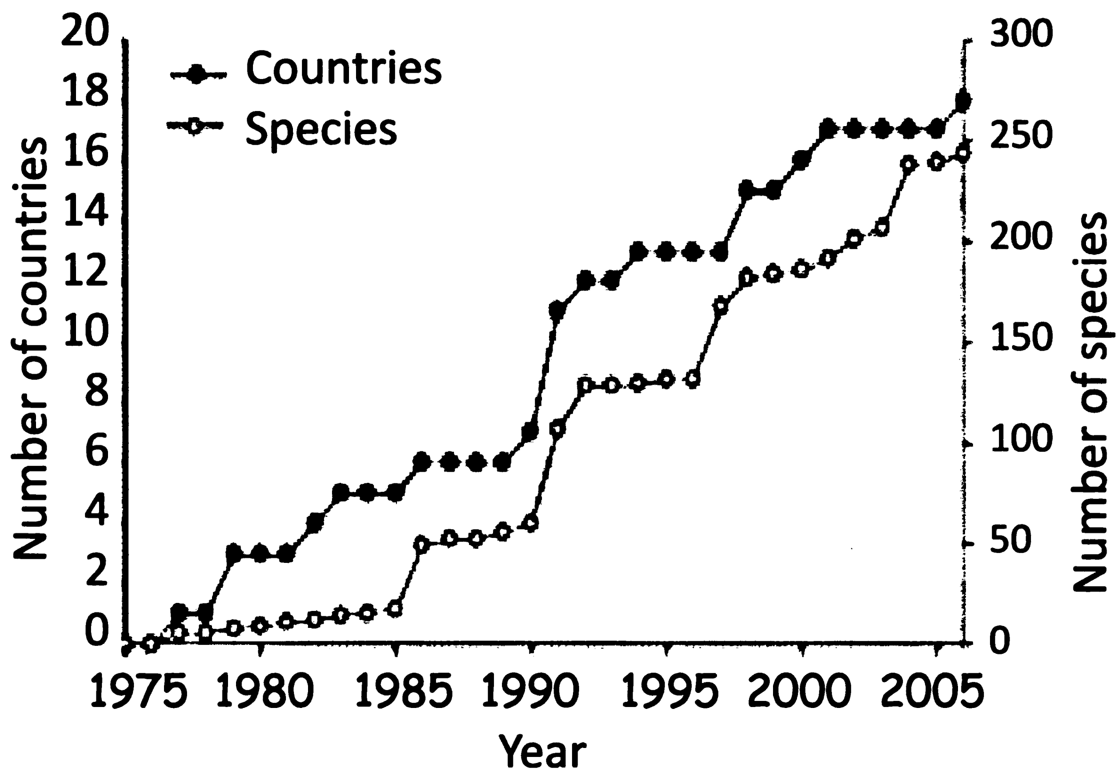

Figure 10: Global assessment of the number of countries and species managed suing ITQ systems (adapted from Chu 2009, p220)

6.1 Transition to Rights-Based Management in Peru

A transition to individually assigned quotas in Peru has long been delayed by a lack of consensus, with political capital tied to the issue of fairness to smaller operators that would become uncompetitive, and larger industrial players lobbying for different quota assignment methodologies that would better benefit individual companies. After being rejected outright by both government authorities and stakeholders in 1992, the government proposed a gradual transition to Individual Vessel Quotas in 2002. This was withdrawn in 2004 due to political opposition, arguing an inherent implementation asymmetry which had a bias towards larger, industrial businesses (Hidalgo 2002). Industry consolidation over the past few years (Figures 7 and 8) however, has allowed for consensus to be built around a strategy based on IVQs which could reduce overcapitalization and increase commercial efficiency, while protecting the artisanal sustenance fishery and mitigating the social costs (i.e. unemployment) of the transition (Costello *et al.* 2008). The implementation of the IVQ's was in no small part due to a positive experience that Peru has had with the recently instituted IVQ system for the *merluza* or hake (*Merluccius gayi*) fishery since 2003 (DS-016-2003, RM-492-2008; PRODUCE 2008a).

In June 2008, legislation was passed in Peru that mandated that anchoveta fishery transition to an IVQ system, under the 'Maximum Capture Limits per Vessel' act (DL-1084-08-PE), fundamentally restructuring its management. The new IVQ system aims at ending the "Olympic Race" for fish, and represents a step towards resource sustainability through capitalization reduction and reduction of fishing pressure over a longer season .

Both industrial and "Viking" fleets are allocated their share of the TAC. Quota allocation is based on both vessel hold capacity and historical catch, but using distinct criteria for each fleet. Whereas "Viking" vessel quota allocation is determined exclusively on the basis of its best performance year since 2004, only 60% of industrial vessels' quota is determined this way, the remaining 40% is determined by their licensed fish-hold capacity. Specific season quotas are determined by multiplying these coefficients by that year's TAC (set by IMARPE). All vessels are required to install satellite tracking devices (already installed in the majority of the industrial fleet) to ensure enforcement of seasonal closures and non-harvesting after reaching individual quotas.

Allocated quotas are valid for 10 year and are attached to the vessel they are awarded to: they are not transferable between owners. However, quotas accumulation by active vessels from both decommissioned and temporarily inactive vessels within a company is allowed. Economic efficiency to maximize industry profits under the IVP system requires overall industrial capacity reduction (Section 6.0), but stronger incentives for decommissioning may be required to reach sustainable levels of industry capitalization. Additionally, complementary mechanisms to incorporate transferability are expected to evolve gradually (Aranda 2009).

Capacity reduction will reduce industry employment, and thus worsen unemployment in Peru. Even though this is a significant social cost, it is lessened by the alternate employment that many in the fishery have found to complement their increasingly brief, seasonal involvement in the shortened seasons of the historically overcapitalized anchoveta fishery. In response to unemployment concerns, the Fishers Compensation Fund has been created, funded by mandatory contributions from all fleet owners (*Fondo de Cooperación para el Desarollo Social*, FONCOPES). The fund, which is part of a socio-economic development government program, will contribute financing for early and voluntary worker retirement, and upgraded pension and severance packages, in addition to re-education funds towards worker relocation into new industries.

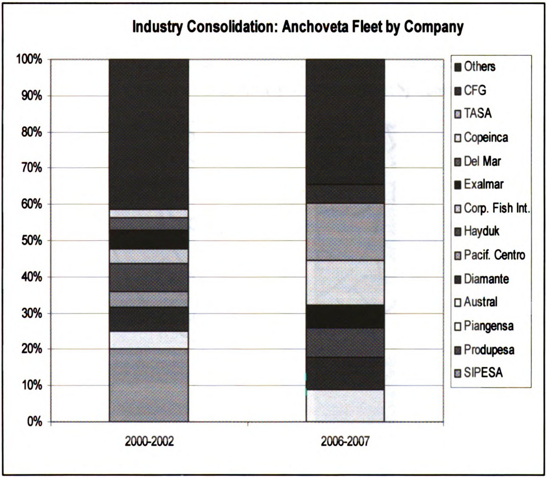

Figure 11. Fishmeal plant ownership distribution by company (%): 2000-2002, 2007-2008. Data obtained from PRODUCE 2008a.

6.3 First Season Early Results

In anticipation of the new IVQ regime, an unprecedented number of mergers and acquisitions occurred in the period of 2006-2008, as industry participants were aware that added profitability of operating under the new scheme would be dependent largely on the amount assigned quota accumulated. This led to the formation of conglomerate firms Tecnológica de Alimentos (TASA) and Corporación Pesquera Inca (COPEINCA) with combined assets exceeding 150 vessels (40,000 MT hull capacity) and 29 fishmeal plants along the Peruvian coast (Figure 11 and Figure 12).

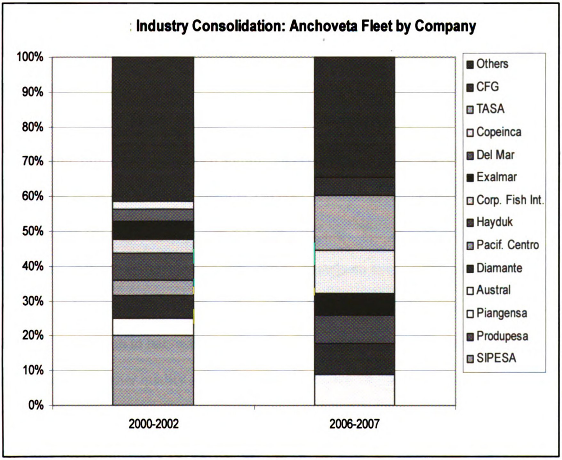

Figure 12. Anchoveta fleet ownership distribution by company (%): 2000-2002, 2007-2008. Data obtained from PRODUCE 2008a.

The first season of IVQ implementation began in April 2009 with promising results towards achieving sustainability for the fishery. No longer in competition for increasingly larger portions of the TAC, the anchoveta fleet only utilized about 60% of the licensed anchoveta fleet for the season, which lengthened to over 100 days from an average that had been dropping below 55 days (Figure 8). The reduction of fishing pressure on anchoveta stocks is exemplified by the average daily catch, which decreased from an average of over 100,000MT per day to about 35,000MT per day (Figure 8). Additionally, the unused 40% of the anchoveta fleet is being scrapped, sold, or redirected towards a different target species, thus alleviating the anchoveta overcapacity problem, while also potentially increasing the supply of fresh direct consumption fish to both domestic and export markets as the proportion of catch by vessels with refrigerated fish holds increases.

At the same time, there have been significant economic savings: fleet fuel consumption is about 60% of recent historical average and cost of fishmeal production is down about 30%, though the exact figure varies for each company. The savings are largely from only using part of the fleet, but also, of importance, vessels no longer navigate at full speed, or are sent on long voyages to fishing sites are far from the coast (Personal Communication 2009a). In addition to harvesting cost savings, a greater proportion of the fishmeal produced is of higher quality grades (Figure 13, Figure 14), as raw material reaches factories faster and in fresher states (Zugarramurdi *et. al* 2004). The increase in quality provides approximately a 10% price premium in the export market, making the current anchoveta fishery even more profitable. Fishmeal conversion efficiency also improves with fresh raw material as well as with factory operations beings constrained to their intended mechanical processing capacity (Figure 14).

Under the new IVQ regime, the average daily catch has been diminished to optimize harvesting efficiency, lengthening of the fishing season (Figure 8). The decrease in daily anchoveta supply to fishmeal factories, together with worldwide demand remaining strong, has resulted in an increase in anchoveta prices. Higher prices have worsened the revenue incentive for illegal harvesting, and the seemingly excessively low fish conversion factor (Figure 14) reported in some cases suggests that this has probably indeed been occurring. Further, intensive supervision by government officials may be required to investigate this possible issue and enforce proper quota compliance.

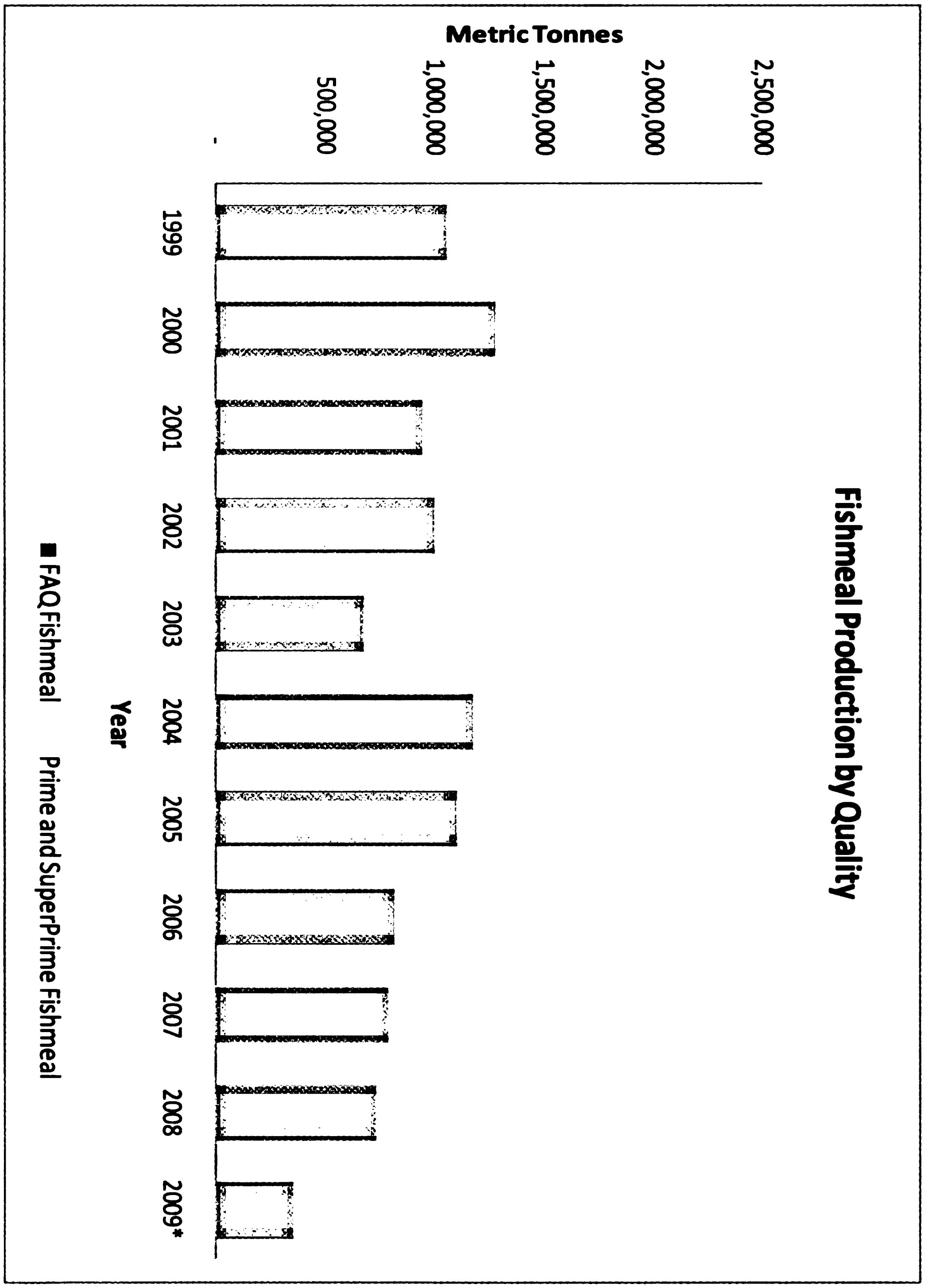

Figure 13: Fishmeal Production by Quality 1999-2009: FAQ and Prime, Super Prime (data updated until August 2009)

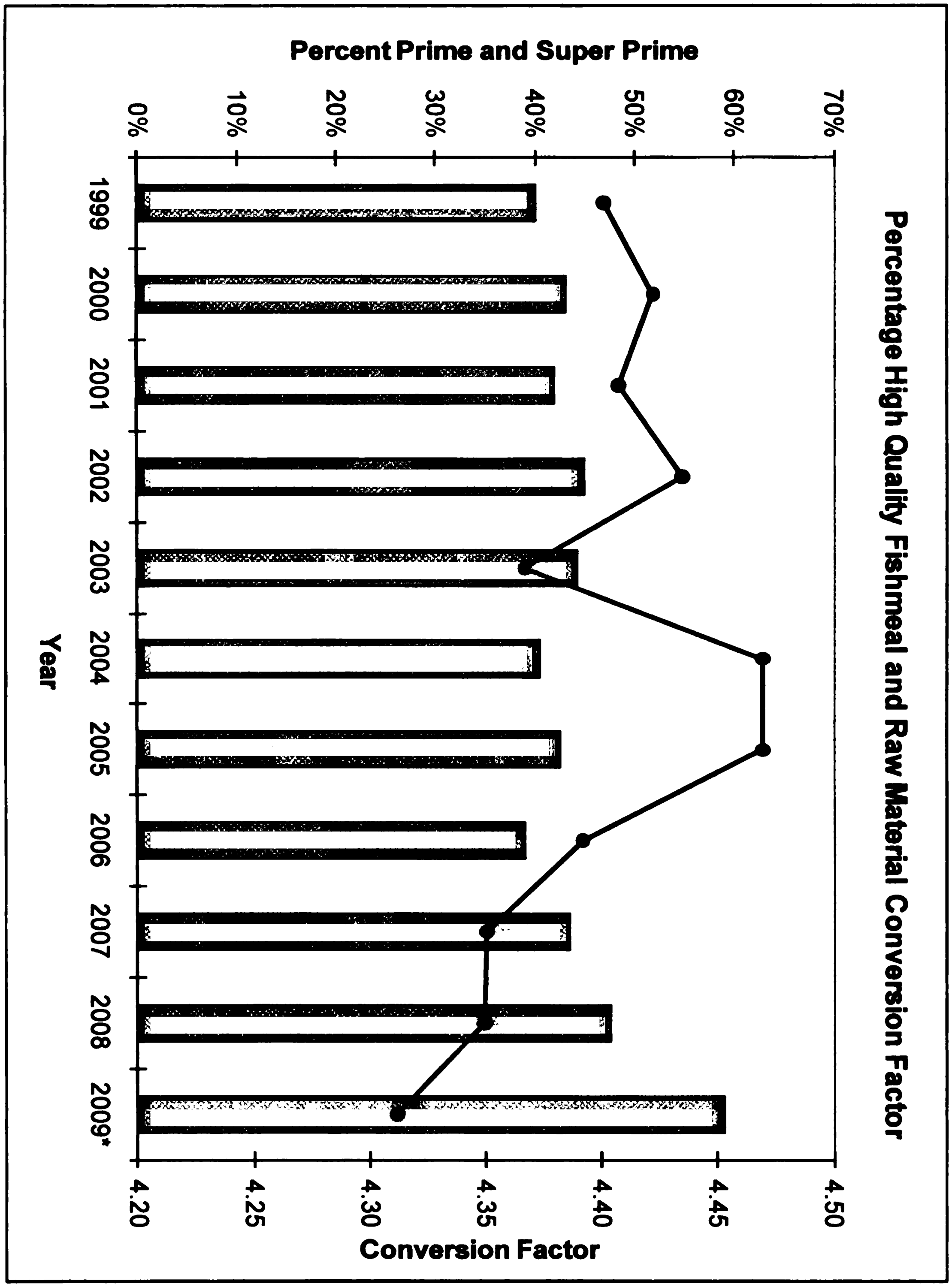

Figure 14: Percentage of fishmeal production that is Prime or Super Prime quality(*green bars*), and Raw Material Conversion Factor (tonnes of fish per tonne of fishmeal produced, *blue line*)

7. Anchoveta Industry: Fishmeal and Fish Oil Production

The vast majority of anchoveta landings in Peru are destined for reduction plants, where fishmeal and fish oil are produced. As of December 2008, the Peruvian anchoveta fishing fleet consisted of over 1100 ships (with about 60% being large industrial vessels, which represent about 84% or fish hold capacity), and over 140 operational fishmeal plants, with a capacity to process over 8,900 metric tons of raw material per hour, employing over 11,000 workers (IFFO 2009). These figures have changed significantly since the introduction of the new Individual Vessel Quota system in 2009 (Section 6.3). Only a fraction of their production is absorbed by the domestic market (less than 0.1%, Figure 15). Though Peru's growing livestock industry continues to use fishmeal as part of its feed, anchoveta fishmeal production has always exceeded domestic demand many fold. Fishmeal and fish oil are thus primarily exported, and formulated into specialized feedstuffs for use in livestock and, increasingly, aquaculture operations which increase the supply of high quality protein for the global marketplace.

Although Peruvian fishmeal accounts for roughly 30-40% of world fishmeal production (Tacon 2009), the industry has only represented about 0.8-1.4% of Peru's Gross Domestic Product (GDP), or about 10% of the country's exports (though these figure vary; PRODUCE 2008a, Figure 16). The primary market for fishmeal are manufacturers of feedstuffs for aquaculture, with China being the largest consumer, importing over 50% of Peruvian fishmeal for 2008-2009 season, while fish oil is primarily exported to Europe and Chile for their aquaculture feed markets (PRODUCE 2008a, IFFO 2009). With increasing demand from growing industries worldwide, and the inability to increase total fishmeal or fish oil production due to fully exploited or overexploited fish stocks, prices are likely to continue to increase. As a result, we can expect that operating margins for the Peruvian anchoveta industry will increase as well, as will end-user consumer prices for formulated feedstuffs. The International Fishmeal and Fish Oil Organization (IFFO) promotes fishmeal and oil consumption and is an industry venue for international collaboration and exchange.

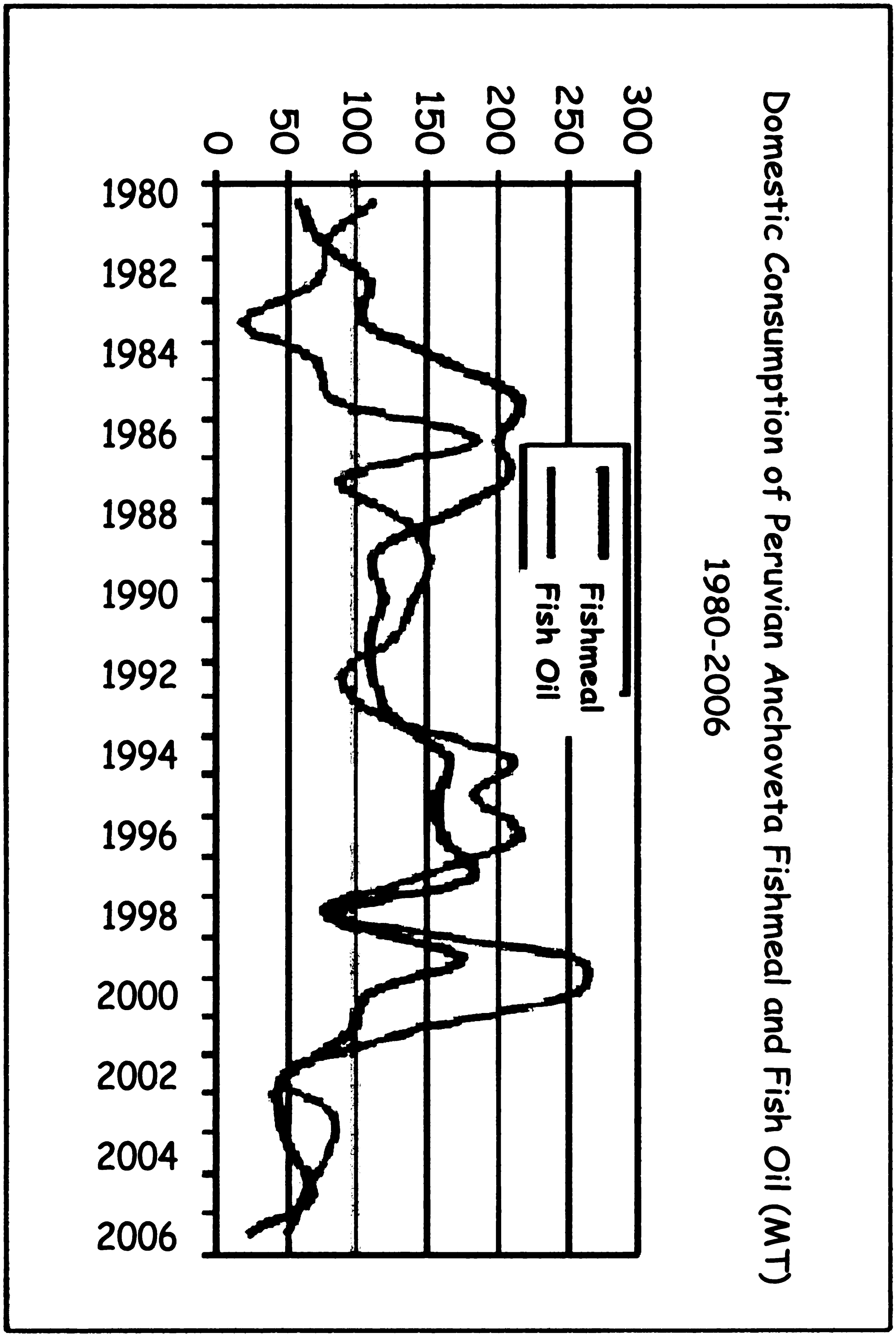

Figure 15: Domestic fishmeal and fish oil demand (MT)

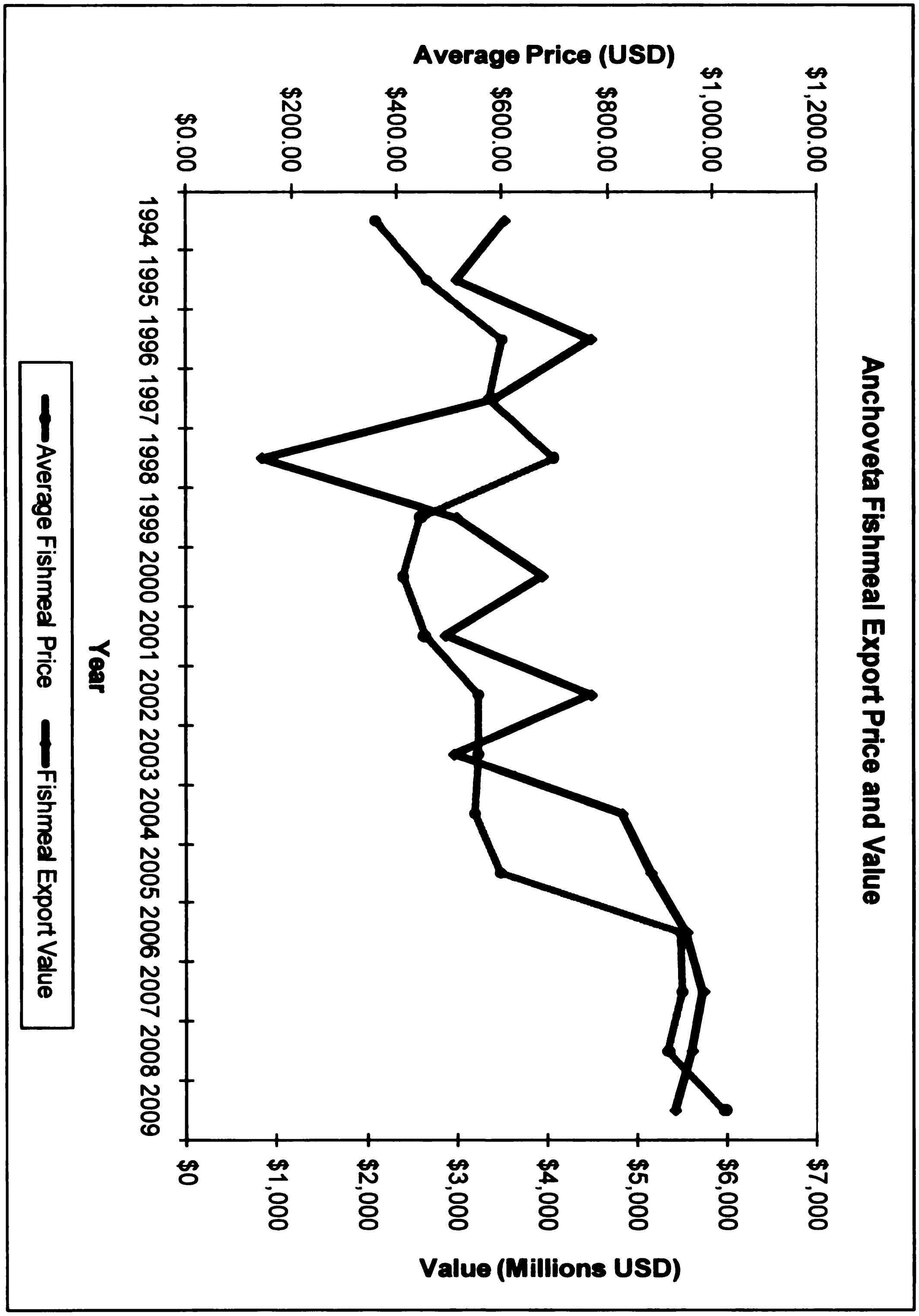

Figure 16: Average annual fishmeal price (USD), and value of Peru's fishmeal exports (millions of USD) 1994-2009

Anchoveta fishmeal is highly digestible, high in protein and other nutrients (Glencross *et al.* 2002, Shepherd et al. 2005), and has been found to be largely free of chemical contaminants and diseases such as prion-based pathogens (ACAF 2001). In addition, fishmeal has the highest digestibility among potential substitute feeds (e.g. soymeal, Glencross *et al.* 2002, and references therein). Although it is still possible to increase supply towards aquaculture, concerns have been raised about both the sustainability of this sector growth's and its continued reliance on fishmeal coupled with the climate driven unreliability of fishmeal supply chains (Alder *et al.* 2008, Brunner *et al.* 2009, Naylor *et al.* 2000). These concerns are being addressed by the aquaculture industry through diet protein source diversification efforts, towards both alternative animal and vegetable sources, but with limited success thus far (Deutsch *et al.* 2007, Naylor and Burke 2005).

There is also a growing direct consumption industry for anchoveta in Peru, in both fresh and canned forms. In fact, although the bulk of landings are processed in fishmeal factories, labor intensive canneries employ more workers and are higher value added producers that tend to purchase fish from artisanal fishers, thus contributing to local communities' economy and welfare.

7.1 Production Process

Fishmeal production consists mainly of cooking, pressing, and drying raw fish material. Oil and water released during such processing is pumped to decanters to remove suspended solids, then separated by centrifuge, with the oil pumped into storage tanks

(Figure 17). In general, production yield increases with raw material freshness and lipid content. In addition, modern fishmeal plants include additional stickwater plants, a suspended-solid recovery stage that increases yield while decreasing plant effluent pollution to the bay (Zugarramurdi *et al.* 2002).

The production process is elucidated by the mass balance diagram in Figure 17. Fish are loaded directly from the factory storage hold into the cooker system (A) at a constant rate. The coagulated mass that results is pre-strained in a strainer conveyor (B). Strained solids then enter the screw press (C) and yield press cake (solids) and press liquor (liquids). Press liquor (from C) join strained liquids (from B) at the decanter (D). Decanted liquids are centrifuged (E) to obtain fish oil, kept in large tanks. Remaining water (still containing some suspended material) goes to the stickwater plant evaporators (F) for additional yield recovery. Press cake (from C) joins decanted cake (from D), and stickwater concentrate (from F) in a solids mix that is ground up and entered into driers (G), to finally yield fishmeal. Meal is automatically weighed out in bags, cooled, and stored for shipping. An antioxidant is usually added in the screw press conveyor to stabilize the fishmeal for storage.

Figure 17: Mass balance for an anchoveta fishmeal factory. Values are averages for observed production at a Chimbote plant (corresponds to company in case study Section 8). Solid lines follow fishmeal, dashed lines follow fish oil.

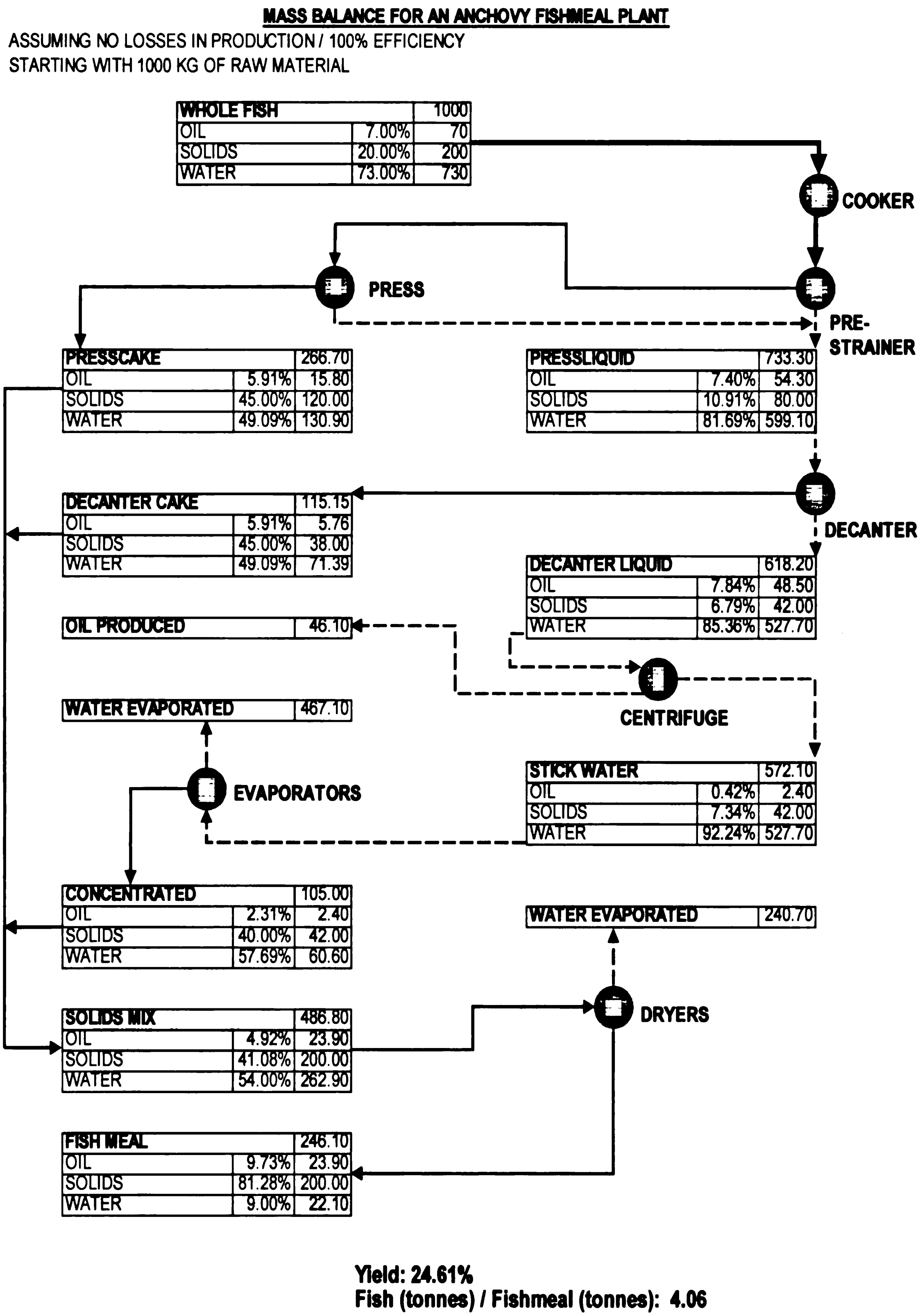

Figure 17: Mass balance for an anchoveta fishmeal factory

7.2 Fishmeal and Fish Oil Quality

Fish oil quality is assessed on the basis of visual appearance, free fatty acid content, and maximum allowance iodine, peroxide, sulphur, phosphorus, and trace metal content. Fish oil is largely sold as a commodity, though recently market trends have attributed a price premium to especially high concentration of omega-3 fatty acids (Personal Communication 2009a). Fishmeal quality is determined by protein content, amino acid profile, and digestibility. International markets classify fishmeal based on these parameters as either Fair Average Quality (FAQ), Prime or Super Prime. Standard, or FAQ, fishmeal typically has 64-68% protein content, while special (Prime and SuperPrime) fishmeal has 68-72% protein content (IFFO 2009). The two most critical variables that contribute to fishmeal quality have been found to be raw material freshness and proper processing, specifically at the drying stage (Zugarramurdi *et al.* 2004).

Fish spoilage, which begins during landing and continues on until processing, is not significant for short fishing trips (several hours), but can be minimized for any trip duration with on-board refrigerated storage. Raw material freshness can be assessed using the presence and concentration of biogenic amines (producing during spoilage) as indicators (IFFO 2009).

On the processing side, the best fishmeal drying method to preserve quality has been found to be indirect hot air dryers, minimizing thermal exposure while drying homogenously (Section 8.2). Another alternative is to combine steam and hot air drying in series, also reducing the thermal stress that can denature valuable protein content

(Zugarramurdi *et al.* 2002). In this way, maintaining temperatures ideally below 90°C during both cooking and drying processes has been found to increase quality. Higher fishmeal quality commands increasingly greater demand (from aquaculture) and hence a valuable price premium which provides the return on investment needed to make the transition to higher quality meals profitable. This can also allow for industry profit targets to be reached while reducing harvest levels. In addition, higher quality fishmeal is used to feed farmed fish rather than livestock, increasing the global marketplace supply of high quality protein.

Fishmeal bacterial contamination is non-existent due to high temperature cooking and drying stages in the process, but appropriate hygiene in handling and storage is necessary to avoid risk of re-contamination. Currently, fishmeal plants must possess a working license from the Ministry of Production and a health certification from the Peruvian Institute of Fishery Technology (ITP), in addition to having Hazard Analysis and Critical Control Points (HACCP) systems in place. Many factories are working towards implementing quality control systems such as Feed Materials Assurance Scheme (FEMAS) and some have already gained International Organization for Standardization (ISO) certification. Many of these advances have been made possible due to the greater incentive to invest in production quality and added value provided by the new quota system (Section 6.3).

Furthermore, recent regulations from the European Union are demanding higher harvesting and operating standards for fish intended to produce direct human consumption oil (IFFO 2009). With increasing demand for omega-3 supplement sources, investors and entrepreneurs are in the planning stages of constructing new fish oil refineries in Peru (Personal communication 2009c). In accordance to aforementioned regulations, these would have to limit their supply to those vessels in compliance with high international market standards, and this creates the incentive for firms to invest in technology to reach such compliance (*e.g.* refrigerated fish holds).

7.3 Investment Costs

Assessing the actual investment cost for a plant involves a detailed calculation, incorporating harbor and unloading facilities and equipment, buildings, fishmeal and fish oil storage tanks, sewage outfitting, power generators and a transformer station, in addition to the direct processing equipment and the cost of land. But it can be estimated by the cost of installed process equipment, a relationship first empirically stated by Lang (1948) as a constant (Lang factor), such that smaller plant size are not comparatively less expensive than large-scale plants, even under different conditions (Zugarramurdi *et al.* (2002). The exception being small, overcapitalized plants, which incur costs of equipment for capacity beyond their future production. Investment costs can also vary depending on the inclusion of additional or more expensive equipment, and the optimal investment would become situation and goal specific. Of course, this additional equipment also represents a step towards sustainability of the fishery by improving production cost and efficiency, and reducing environmental impact (Section 8.2).

Fishmeal plant capacity has usually been over-built, overestimating actual predicted processing volume. This acts as a safety measure, allowing plants to deal with higher than expected landings, while usually obtaining the higher protein and lower fat meals that reduced operational capacity yields. In fact, it is almost impossible for a factory to operate at full nominal capacity for an extended period of time due mainly to raw material freshness and availability, technical issues and maintenance schedules. However, overestimating capacity can also lead to decreased efficiency and represents a higher investment costs than necessary. Thus, both labor productivity and processing technology need to be considered (Zugarramurdi *et al.* 2002). Under the new IVQ regulation, the incentive for building overcapacity into fishmeal plants has been removed, as they no longer need to be process raw material in a hurry, or be prepared to face the uncertainty of possible excessive supply of raw material.

7.4 Production Costs

Fixed production costs include insurance, capital costs (depreciation and interest on investments), lease of land, routine maintenance, and management and supervision wages. Common operational variable costs include direct labor wages, harbor charges, packaging, freights, water, power and fuel. But the main cost driver for fishmeal and oil production is the cost raw material, either caught by a proprietary fleet or purchased from a third party operator. Total production cost is observed to decline in accordance to economies of scale, while, in addition, technology plays a key role distinguishing average production costs across plants of similar capacity (Montaner *et al.* 1995). But most importantly, raw material quality has been found to increase productivity of fishmeal yield and its quality, while lowering production costs (Zugarramurdi *et al.* 2004). This is because fresh raw material minimizes organic material loss (fish parts, oil) to unloading water, and using a closed circuit for unloading water allows accumulation of recoverable yield (Section 8.2). Spoiling raw material doesn't allow for water recirculation because accumulation is too rapid and clogs the system. Fresh raw material also lowers production cost further as it requires less heat for the cooking stage, while also improving the return on investment by yielding higher quality meals (Personal Communication 2009a).

8. Innovation and Leadership in the Industry: A Company Case Study

In order to evaluate the role of entrepreneurial innovation in the Peruvian anchoveta fishery, a specific company was selected for this case study as the innovation leader, measured by having consistently outperformed the rest of the industry. This was measured by both relative landings to relative fleet hold capacity ratios, and proportion of higher quality meals produced, while also observing production efficiency, pioneering technological implementation, social responsibility and environmental stewardship. For the purpose of this study the selected company has chosen anonymity, and will henceforth be referred to as "Peru Fishing", its fleet consisting of vessels named PF 1-12 (numbered chronologically by construction date) which unload at their factory in the fishing port of Chimbote.

Innovative from the beginning of their inception, in stark contrast to the usual 1960's era anchoveta purse seiner, the company we are studying built its first vessel in 1982, PF1, designed and equipped to catch anchovy for the fishmeal industry in addition to sardines for the direct human consumption (canneries). Equipped with a Recirculating Seawater System (RSW), PF1 was the first vessel to be able to refrigerate its full 200 tonne fish hold. Using a larger and deeper net (1 ½ inch mesh) for sardine fishing, it would become the first vessel to provide canneries with refrigerated fish (around 0° C), unloading fresh fish year round in Chimbote, where the Peruvian canning industry was concentrated. With this technological innovation, PF 1 reliably provided the canning industry with unprecedented quantities, allowing them to reduce their production costs by producing everyday rather than seasonally. No longer solely dependent on the irregular performance of artisanal boats (limited by sardine spoilage on long fishing trips when stocks were distant from the coast), gave them the ability to sell to international markets since they could comply with the shipment schedule that clients require, at an improved quality. In response, over 40 canning plants were able to expand their operations, to PF 1's commercial success. Because RSW technology was new to Peru, with significant monetary and time investments needed to implement, it was many years until other companies followed suit in using this system.

Over the next decade, Peru Fishing would build on the initial success of PF1, and build 8 additional refrigerated vessels in the next decade, allowing them to expand their reliable supply of fresh sardine to the cannery industry, and produce higher quality fishmeal at lower production costs (Section 7.4). Over the years Peru Fishing would also diversify its target catches beyond refrigerated anchoveta and sardines, to include, Chilean sea bass, mackerel and jack mackerel for direct human consumption (rather than for fishmeal production). In fact, the company would continue to lead and outperform the industry through continuous innovations (Section 8.2). This case study focuses on the key innovations that led to the Peru Fishing's success: Corporate Culture, Fishing Effort technology, Fishmeal and Fish oil production technology, and Corporate Social Responsibility.

8.1 Corporate Culture and Business Model

The success of the Peru Fishing strategic venture would depend on effective and efficient equipment utilization. In order to establish and maintain its competitive edge through the application of new technologies, the Company hired and trained people with a desire for change and self improvement. From the beginning fishing vessel crew and other personnel were invited into an innovative agreement with management, forging a bond of bilateral commitment, above and beyond support provided by laws and regulations. A different paradigm from the fixed model written by authorities, this new model allowed for continuous change and growth in labor relationships. Specifically, higher performance and loyalty to employee partnership were developed through a bonus and financial incentive program to compensate vessel skippers and other personnel for higher fish catches and returns in addition to cost control and efficiency.

Traditionally crew wages had been assigned by a factor of catch and international fishmeal prices. Peru Fishing decided to encourage catch performance by paying 50% and 100% pay premiums for seasonal catch tonnage beyond specific targets (set higher than the national average catch across comparably sized vessels). As a result, the company was more profitable, since these additional, incentivized catches came at a low marginal cost (Personal Communication 2009a). As a complement, a 15% pay per ton premium was paid for good quality, well refrigerated catch. This measure ensured that crew had no incentive to increase catch beyond what could be efficiently refrigerated (RSW system water takes up volume fish hold). This is important because appropriate refrigeration (using enough water) cools fish holds to a lower temperature, keeping catch more fresh, and fresh raw material increases its fishmeal yield and quality at a lower production cost (Section 7.4). In addition, bonuses were also awarded to the crew on the best performing vessel for each year (measured by landing efficiency - tonnage, quality, and harvesting cost), introducing friendly competition within the company.

There were also bonuses for those who followed a professional code of conduct (subject to Peru Fishing management's opinion). Those who performed well without breaching this code of conduct for 4 years were given additional medical and life insurance benefits (Section 8.3). In this way, specific bonuses were agreed upon for the different types of work and specific responsibilities performed, while also promoting professionalism, labor relationships, and work ethic.

Technological innovation allowed Peru Fishing's fleet to harvest almost continuously during the anchoveta open season, and greatly reduce the time for each fishing trip (Section 8.2). As a result, second crews here hired to alternate in regular rotations with original crews for each vessel, since no crew could work the full time that each vessel would operate on consecutive days. This also avoided direct dependence of a particular vessel on a specific crew, and made personnel changes or relocation to different vessels easier. Additionally, the best performing skippers were rewarded by being promoted to the newest and best equipped vessels as they became operational. This was taken as a recognition of merit, as well as giving selected skippers an advantage in the following season's competition for new bonuses (Personal Communication 2009a).

A multi-level feedback system between the work force and the managers of the corporation was also instituted. Performance reports of each vessel (monitored weekly) were made available to and discussed with skippers, sharing results and asking for ways to enhance future improvements. The latter, in conjunction with a technology communication task force within the Company, helped narrow the gap between technology design and application, taking crew personnel ideas to technology suppliers and working together with them to provide the most modern and efficient available tools for each job. For example, upon crew suggestion, Peru Fishing's sonar manufacturer designed a special monitor to superimpose the information of additional equipment on the sonar screen. Similarly, advances in fishing net design and improvements in choosing on-board hydraulic equipment were achieved through interaction with crew members (Personal Communication 2009b).

Furthermore, Peru Fishing made special arrangements with equipment suppliers that allowed them to field test their new ideas and technology, trying out new pre-production prototypes on operating vessels and providing important feedback. Linking the industrial hierarchy together was an important innovation with effective teamwork being rewarded via a bonus system that for instance links the on-shore fishing logistics group with on-board crew members, with bonuses for both groups being a function of catch efficiency.

Meticulous records were kept of the final fishmeal and fish oil production quality, and evaluated against the quality of fish caught and any variables on a vessel and production line that could influence finished product quality. Changes were not only focused on improving fleet performance, but to improve the whole operation and optimize the quality and performance of the production line utilizing that fish. Due to these innovations, Peru Fishing was able to consistently outperform the industry with regards to conversion ratios (Figure 17).

Where the increased vessel efficiency from use of new technologies would provide for higher returns (Section 8.2), management would not only use them to pursue growth, but also established a commitment to providing the best possible maintenance, logistics and facilities on the boats, focusing on personnel safety. To maintain and continue to build on personnel performance, professional and technical training courses have been periodically required and provided, in many different areas including safety, navigation, fish detection, maintenance, all vessel systems, fish quality, emergency procedures, vessel performance and operational efficiency. In addition, international trips were arranged for specific personnel to gain valuable experience from participating in fishing trips in fisheries abroad, where they could have access to and learn to use the latest technology. Furthermore, since Peru's anchoveta fishery is characterized by exceptionally high catch per unit effort, international trips were an opportunity for workers to gain experience in a more challenging fishery. This level and diversity of workforce training has led to reducing harvesting, unloading, processing and production time as well as maintenance and production costs (beyond what hiring lower wage employees could accomplish, Personal Communication 2009a).

8.2 Technological Innovation

The short sighted concept of maximizing profits by keeping investments low was never accepted by Peru Fishing (Personal Communication 2009a). The alternative chosen was to invest in the best available technologies that, while requiring higher investments, maximized long-term return on those investments. Higher quality products at a lower operational cost resulted in a positive outcome for the company. Similarly, the Company's environmental policy has been to invest on impact prevention rather than in clean-up technologies, and has continuously exceeded Peruvian regulatory standards. The innovative application of technologies, after many years of fishing, proved to increase catch efficiency and fleet and processing plant productivity, while being environmentally friendly.

When Peru Fishing was founded, the Peruvian fishing fleet (mainly anchovy purse seiners) was dependant on magnetic compasses for navigation, requiring vessels to travel parallel to the coastline for guidance. Vessel PF1's first generation Global Positioning System (GPS) was truly revolutionary for the Peruvian anchoveta fishery. Modern GPS not only allowed direct navigation to fishing grounds and back (for the first time), but also to record the position of every catch, along with the speed and heading of fish schools, and a prediction of probable fishing grounds positions for the next day.

Combined, these advantages allowed for much shorter, more fuel efficient and more successful fishing trips.

The ability to catch fish used to be dependent on the skipper's ability to physically see the fish schools, limiting catch times to dawn, in order to distinguish the reflection of dawn's twilight off the scales of schooling fish. More recently, most vessels were equipped with primitive mechanical echo sounders for fish detection. Fishing effort was thus fundamentally changed when PF 1 started using a first generation color sonar, and for the first time was able to observe the location of fish schools independently of time of day. These modern echo sounders send signals at an angle, thus detecting schools at a distance, allowing vessels to "see" fish schools before being directly over them. The result was that most of PF1's catches were actually made during the day and with great effectiveness: a full load per day. Before, vessels relying on however much (or as little) catch as they could land during the hours of dawn, most often to return to port with partial loads. Peru Fishing's employment of the modern sonar proved highly profitable, effectively doubling the catch per unit without significantly increasing harvesting cost.

As new vessels were built in the following years, more powerful and alternative deck equipment together with different net designs were brought into play, making it possible to continue to improve efficiency and operate even in the most diverse ocean conditions. Importantly all these vessel innovations were not only designed and implemented to increase efficiency and increase fishing effort, but also to provide deck and crew personnel with a safer working environment that required less physical effort. For example, company ship design focused on vessel navigation and operational safety, but also on more comfortable, larger living and working quarters, to which the crew responded in generally high spirit (Personal Communication 2009a).

Innovative net designs allowed them to sink faster and make better catches while expenditures for repairs were reduced from 22% to 12% of the net value per year. The first change was to use a higher quality of nylon for net threading which, while being thinner, has more tensile strength. This means that the net was now more resistant, lasting longer without repairs. Seine nets are conventionally weaved with a knotted design to increase their resistance, but nets made of higher quality nylon were resistant enough that knotted weaving became unnecessary. This not only meant that less material was needed per unit area of net, lowering the relative weight (kg/m^2), but also created faster sinking nets which are better at catching moving schools of fish. Seine net costs were therefore significantly reduced by Peru Fishing, since less material (though more expensive) was required, and replacements were needed less frequently (Personal Communication 2009a).

As the size and hold capacity of vessels increased (in response to the "Olympic race" competition between operators that the shared quota incentivized, Section 5.3), seine net size was also increased, to allow full vessel catches in a single set. At the same time, more powerful hydraulic deck equipment was installed in order to handle these larger nets, and to do so in increasingly shorter time. New, larger underwater fish pumps were also installed to load fish from the purse seine into the fish hold much faster, and were also redesigned to avoid fish breakage during the loading process. A longer pump discharge hose (40m) was designed, its intake directed via a newly added crane (Personal Communication 2009b). This was especially important for reducing damage to catch consisting of larger, direct human consumption species, and reduced the proportion of discarded food fish (which were diverted for fishmeal production) from about 25% to under 10% of the average total catch. Additionally, the time for making a full set (fully loaded vessel) was reduced from about three hours, to less than one hour, as the use of new nets, hydraulics, and pumps was optimized (Personal Communication 2009a).

Peru Fishing also developed its own vessel design department, and its contributions would prove valuable in the construction of new additions to the fleet. Many of the traditional ways of shipbuilding were changed by new designs which, together with the use of lighter materials made new vessels more fuel efficient. Fuel being the largest cost of the fishing process, fuel efficiency proved to be critical to reducing production costs, especially as fuel prices increased. The company's latest design is 40% lighter in hull weight than their first vessels, saving up to 30% in fuel consumption, or about 7.5% of total extraction cost. Better designs also permitted the construction of inherently faster vessels with the ability to catch more fish in a single set with better fish hold distribution, less down time for maintenance, and a safer vessel operation (Personal Communication 2009b).

Much time and effort were devoted by the company to design a new Recirculating Seawater (RSW) system that allowed refrigeration of anchoveta to 4°C, a rather difficult task that has still not been achieved by any other company. Keeping anchoveta refrigerated meant increasing the range from which vessels could catch fish and return to port with fresh raw material for fishmeal factories. Raw material freshness positively affects output product quality (Section 7.1) while lowering production costs (Section 7.4). As a result, Peru Fishing has been able to consistently produce high quality (Prime and Super Prime) fishmeal, increasing its profits from the price premium that markets award for such quality. In addition, since consumer acceptance has developed in the domestic market for direct human consumption of anchoveta (Figure 9), Peru Fishing became (and remains) the only large scale supplier in Peru.

Progressive fleet innovations were followed by new investment in the best available technologies for the company's fishmeal plant facilities. Once vessels bring their landings to port, the first step is to unload catch into holding compartments, headed for processing. Water need for unloading is commonly taken directly from the harbor to pump catches that are often already degrading (due to the lack of an on-board cooling system). In contrast, Peru Fishing minimizes waste during unloading by starting with refrigerated fish, using potable water and a vacuum pump in a closed water circuit, thereby minimizing the volume of unloading water required for the unloading process. Vacuum pumps are now able to unload fish efficiently, reducing the amount of water required for the process (1:1, water:fish ratio, older pumps had a 3:1), thus making a closed system that used potable water feasible. Where a typical unloading system uses about 12,000 tonnes of water to unload 4,000 tonnes of fish (not an unusual day for a large fishmeal factory in Peru), Peru Fishing's closed system only works with about 1,500 tonnes of water. As such, Peru Fishing does not pollute because there is no water discharge to the harbor, and reusing water in this closed recirculation system builds its emulsion content until it is high enough to recover additional production, which is feasible to handle because of the relatively small amount of water used. Peru Fishing's large vacuum pump also unloads fish rapidly (over 500 tonnes per hour) and with only minimal damage, and using potable water, instead of continuously using a flow through system that depended on contaminated water from the same harbor site where it discharged. In addition to minimizing loaded effluents into the bay, this method provides fresher, cleaner fish to the factory on land, where low temperature fish storage maintains the fish high quality until they are transferred to a canning factory (direct human consumption) or processed through the fishmeal plant (indirect human consumption).

Another phase of the fishmeal process where Peru fishing has innovated is the drying stage. Conventional, direct flame, fishmeal drying systems burn fuel and apply heat directly (450-650 °C) to dry fishmeal as it is heated to over 100 °C. Above 90 °C , the protein structure in fishmeal begins to break down (or denature), and fishmeal quality suffers. In fact, all fishmeal produced with direct flame dryers is considered FAQ (Fair Average Quality, Section 7.2). More recently indirect steam dryers (where fishmeal comes into contact with steam heated elements along inner lining of meal chamber) have been designed to protect fishmeal protein, where the 90 °C critical temperature is not exceeded. Though this drying method can produce Prime and Super Prime quality meals, it does not dry product homogenously. In contrast, Peru Fishing's innovative dryer applies both steam and heated air (280 °C) directly to fishmeal particles (keeping them below 85 °C). This design allows production of Super Prime quality meal and with an unusually high digestibility (over 90 %), allowing this company the opportunity to sell to the most demanding markets around the world, especially the aquaculture industry which has seen the most rapid growth in the last years.

Environmental impact from the Peruvian anchoveta industry is minimized through technological innovations that have reduced pollution while at the same time have increased yield, efficiency and profitability. Atmospheric emissions from the drying process are virtually eliminated by reusing the vapor and steam produced by the aforementioned Peru Fishing direct steam drying system (the only one installed in Peru), in the company's stickwater plants instead of having additional steam boilers, and thus lowering their fuel usage per tonne by about 30%. Harbor pollution by fishmeal plants occurs both at loading and post-production waste water discharge, which historically was released directly to the harbor. Such harbor pollution has been widely addressed by the now industry-wide (and legislatively mandated) implementation of stickwater plants at every fish processing location in the country. This additional recovery system for suspended solids and lipid emulsions in liquid effluents has proven not only to reduce a plants impact on the environment, but also to increase productivity (yield) by adding fat content back into the fishmeal production line that would have otherwise been discarded, making the final product of higher value to the consumers. In general however, producers have not introduced closed systems for unloading water to address harbor pollution from this stage (as described above), as the return on investment apparently is not sufficient substantial to incentivize this implementation.

Applying clean technology from the start removes cost of retrofitting plants in the future to comply with increasing complex and restrictive environmental regulation and has proven, thus far, to provide a return on investment that most business plans that function on immediate returns have failed to implement. The lack of early adoption to environmental pollution control measures has been costly for the industry, as most have had to try to engineer retrofits to existing facilities as Peru passed regulation of fishmeal plant water discharge pH, solid and lipid content (DS 010-2008-PRODUCE), as well as atmospheric emission of sulfides and particulates (DS 011-2009-PRODUCE). In the last decade most newly built vessels and renovated factories are implementing the technological innovations first introduced by Peru Fishing.

8.3 Corporate Social Responsibility

Peru Fishing was founded with the strong beliefs that (1) their profit-making was not at odds with, but complementary to making a contribution to Peruvian society, and (2) people, united by a common purpose that improves all livelihoods, collectively accomplish more than they could accomplish separately. To build a successful team, the company realized that the need to create a system that would take care of the needs of its members beyond the requirements of the existing laws and regulations. Beyond a high work ethic and healthy corporate culture, specific additional policies were adopted for fishing personnel engaged in the business of Peru Fishing. Where workers in the Peruvian fishing industry may have felt abused by their companies, due to social injustice and inadequate labor law issues, in Peru Fishing, workers understood and appreciated the company's social responsibility agenda, and held a sentiment of respect and common purpose (Personal Communication 2009a).

A database was created in order to keep records of each individual history and family situation, including a relationship of relatives and dependents. This database allowed the company to tailor benefits to specific employees. A special human resources service office was instituted to provide counseling to all workers, dealing with education of children, family health, legal advice, managing personal income, savings and investments. For example, a merit and need based assistantship program was created to provide financial aid for employee's children education and, as a result, the percentage of company employees' children graduating from high school increased significantly, from about 50% (average for the industry) to over 80% (Personal Communication 2009a). Also, the company's database was used to determine worker's specific insurance needs. Because government provided health services and insurance were insufficient for most workers and their family (only covers accidents of the primary holder), the company absorbed the cost of increasing insurance coverage to include every family for sickness and urgent care.

Additionally, in order to have their workers avoid expensive short term debt, the company created a fund which gave zero interest worker loans. The fund was finite and a three salary maximum loan limit was placed. A loan selection process used urgency and necessity as criteria to ensure the fund was making a positive difference in employee's lives and the future of their families. Loans were to be repaid in installments deducted from the worker pay, helping to develop fiscal responsibility while eliminating the potential problem of late payments (which were allowed if a reasonable explanation was given, Personal Communication 2009a). A worker controlled investment fund was also offered, with continuous company supervision and professional staff advice. The fund was very successful at protecting the value of employee savings in spite currency devaluation, high inflation (e.g. Section 3.5) and other difficult circumstances that Peru's emerging economy has experienced over the years that Peru Fishing operated.

Thus, Peru Fishing evolved to become a trustee for their workers forming binding social networks by making sure their employees basic needs were met, and giving them the opportunity to prosper. The commitment of people in the company and the realization that their effort to make the company strong was their best investment for the future resulted in a high productivity and profit, further enabling Peru Fishing to productively and economically outperform the rest of the industry.

8.4. Industry Outperformance

Peru Fishing's innovations and corporate leadership have allowed them to outperform their industry peers. Anchoveta vessels are ranked by performance (total landings) at the end of every season, and vessels have consistently been ranked amongst the top 5% of the country's fleet, outperforming similar sized vessels by up to 40% in landings (Personal Communication 2009a).

In fact, they landed about 2.7% of the country's annual quota, with just under 2% of the fleet capacity in their last 5 yrs of independent operation (Figure 18). Moreover, their fishing boats are the only vessels that have on-board RSW systems capable of evenly cooling anchoveta to 4°C while in their holds, providing their fishmeal factory with the freshest raw material possible and consistently producing almost exclusively Prime and Super Prime fishmeal.

Furthermore, their fishmeal plant operates with minimal environmental impact and extremely high efficiency, consistently outperforming its competitors. Peru Fishing's fishmeal plant operates so efficiently that they only require 4.2MT of anchoveta raw material per MT of fishmeal produced (where the industry average is about 4.6). Together with more efficient harvesting and higher quality raw material, factory regularly produces about 3.9% of Peru's fishmeal production using only 2.3% of the installed processing capacity. Moreover, Peru Fishing's production consisted almost exclusively of high quality fishmeal, which often exceeds Super Prime specifications (exhibiting >90% digestibility).

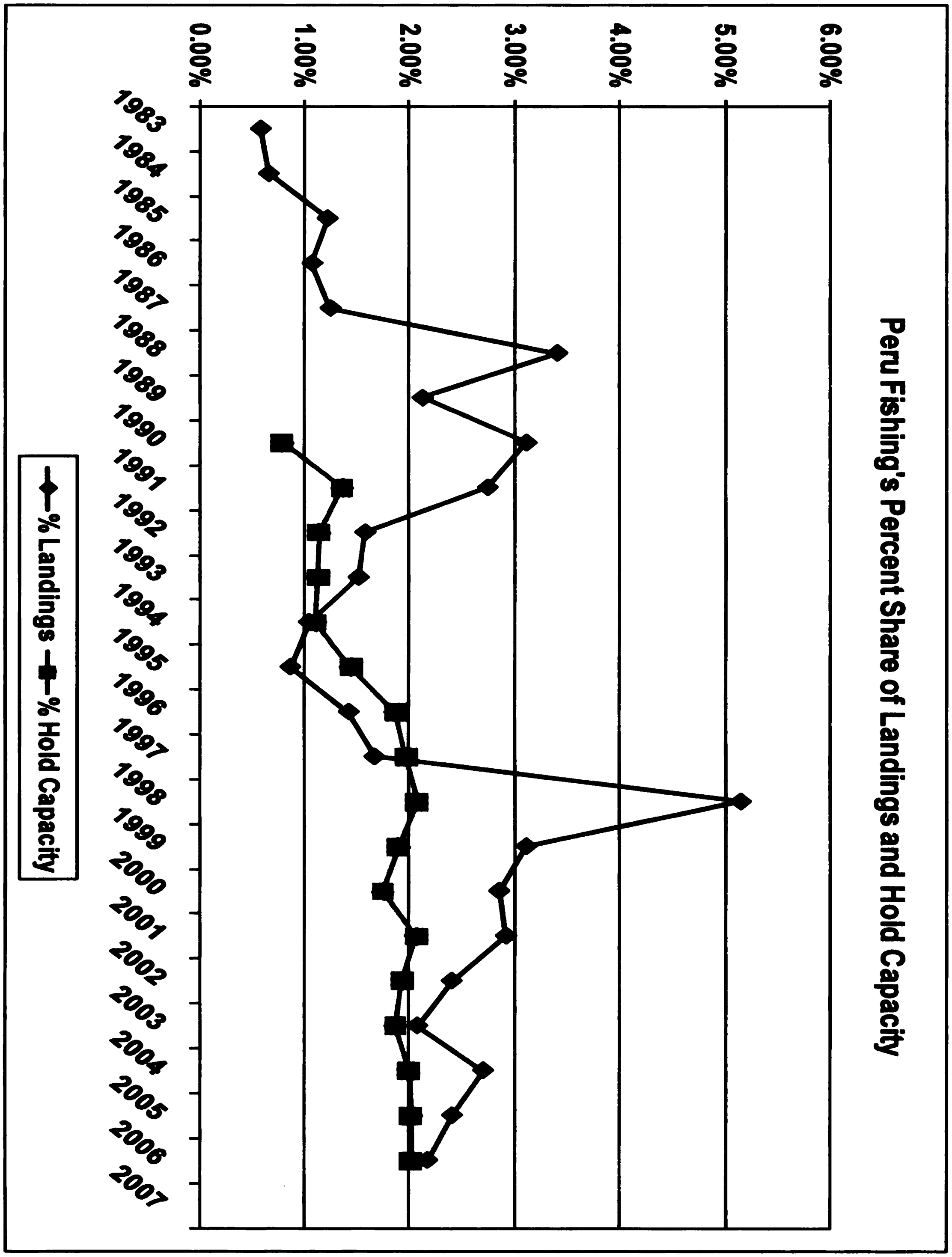

Figure 18: Peru Fising's share of Peru's annual anchoveta landings (blue line, diamonds), and total for anchoveta-licensed fleet (green line, crossed squares)

9. Conclusions

Sustainable fisheries require the adequate management of marine species and ecosystems, ensuring our ability to continue profitably harvest valuable resources in the future while protecting the welfare of stakeholders. Both the FAO Code for Responsible Fisheries (FAO 1995) and the U.S. based Marine Stewardship Council (MSC) have identified such components of sustainable fisheries management, including:

- Conserving and maintaining aquatic environments and fish habitat
- Maintaining biomass of both target and non-target species
- Apply precautionary approach to decisions based on best available science
- Use environmentally safe fishing gear and practices
- Integrate fisheries interests with coastal management
- Ensure fleet compliance with conservation and management measures

Much progress has been made towards achieving these sustainable fisheries management goals in Peru. The recent shift towards "rights based" management through the IVQ assignment has already proven successful at reducing overcapacity, increasing industry efficiency and this is expected to continue (Personal Communication 2009a). Reduced fishing pressure intensity on anchoveta stocks should contribute towards resource stock sustainability and resilience. Still, further steps towards sustainability must be taken. The case study (Section 8) included in this chapter illustrates how entrepreneurial innovation can lead to even further advances towards true sustainability: ecological, social and financial. The role of entrepreneurial leadership and innovation in the development of the anchoveta industry clearly emphasizes how not only technological and infrastructure innovations can benefit productivity and efficiency, but also the role of corporate culture and social responsibility in contributing to the triple bottom line sustainability of the anchoveta fishery. Broader implementation of the innovations discussed is seen as a roadmap for private sector contribution towards environmental stewardship, social awareness and responsibility, and a more efficient and productive fishmeal and fish oil industry, placing less pressure on marine resources while becoming more profitable and beneficial to society.

Reports by IFFO on the availability of marine resources used in fishmeal production state that worldwide production has leveled off near maximum production with the recovery of the Peruvian anchoveta stocks, and that the trend of increasing production is highly unlikely (Shepard *et al.* 2005). Publications by the Peruvian fishmeal industry indicate a similar belief (Trillo and Tord 2003). International trade in fishmeal has increased in recent decades, with export value recently increasing disproportionately more from increasing prices (Figure 16). High prices exacerbate the incentive for future administrations of Peru's government to choose the exploitation of market opportunities to improve its trade balance, rather than safeguarding the long term interests of both fishers and consumers. Short term economic interests must never prevail over the sustainability of anchoveta and its ecosystem, as this has historically been seen to lead to irreversible damage to fisheries resources and the Peruvian people.

Furthermore, the initiatives to increase the proportion of anchoveta for direct human consumption are to continue. Recent and expected improvements in fleet and processing technology provide the opportunity for these initiative to become more effective (with refrigeration most important among them). The Peruvian Institute of Fishery Technology (ITP) continues lead the way towards increasingly innovative processed solutions to provide anchoveta-derived nutrition to Peru's population.

Government focus should be on anchoveta biomass assessments, better understanding the linkages to climate and the mitigation of its effects on the industry, and establishing incentives to promote industry transition towards sustainability. Peru will then be better prepared to manage its fishing industry during times of low biomass, and perhaps support it through special programs to ensure solvency during times when harvest sales may not cover extraction costs. A fund similar to an emergency insurance fund, could secure employment and avoid industrial enterprise bankruptcies that would affect Peru's trade, in addition to their local community development and quality of life. In addition, an ecosystem management perspective is being considered, focusing not only on the productivity of the anchoveta and its supply chain., but also the underlying ecosystem influencing that productivity and its sustainability. Though there are improvements to be made, the overall picture of the current state of management is rather promising, and in fact, in 2008, a research report by Mondoux *et al.* from the Fisheries Center at the University of British Columbia ranked Peru's fisheries and marine ecosystem as the most sustainable in the world.

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SUMMARY AND CONCLUSIONS

Anchoveta stocks are sustained by the highly productive coastal upwelling Humboldt current system. Peru's coastal productivity is highly variable, however, and subject to fluctuations in climate, oceanographic and ecosystem conditions, dominated not only by seasonal but also by the interannual frequencies associated primarily with the El Niño Southern Oscillation (ENSO, Alheit and Ñiquen 2004, Bakun 1990, Chavez *et al.* 2003,Wolff *et al.* 2003). During El Niño, warm surface water from the western Pacific expands eastward, deepening thermocline off Peru (Wang and Fiedler 2006), limiting nutrient flux, and resulting in a decline in primary production (Barber and Chavez 1983), together with changes in plankton assemblage composition that lead to the disruption of the anchoveta food web (Chavez 2005). Combined with the reduction of habitat due to warmer temperatures, this leads to extensive anchoveta biomass losses and a redistribution of remaining stocks, tending to aggregate in small, shallow pockets of remaining favorable conditions (Bertrand *et al.* 2004). In contrast, during La Niña years, characterized by cold surface water and increased primary productivity anchoveta fishery yield has been observed to increase, aiding stock recovery when following an El Niño (Ordinola, 2002).

Interannual variability is embedded within lower frequency fluctuations of multi-decadal climate variability, the most relevant being the Pacific Decadal Oscillation (PDO) which alternates between warm and cool regimes lasting about 15 to 30 years (Mantua and Hare 2002 and references therein). These basin-wide multidecadal ecological changes associated with the PDO, or regime shifts, have been found to correlate well with climatic-oceanographic conditions (Chavez *et al.* 2003, Alheit and Ñiquen 2004, Bertrand *et al.* 2004, Cahuin *et al.* 2009). It seems clear that climatic phenomena of both long and short-term periodicity interact to influence oceanographic conditions and that these in turn control biological productivity, impacting fisheries. In fact, a shift to the warm PDO phase has been argued to have hindered the recovery of anchoveta stocks following the fishery collapse in the early 1970's (Chavez *et al.* 2003).

The development of the modern day anchoveta fishery was preceded by a climatic and ecological regime shift favorable for anchoveta, and harvests by a growing industry increased rapidly from the mid 1950's until 1971. Extreme abundance led to the fishery being treated as an open access resource, and early governance was shaped by the drive to manage for maximum exploitation. The industry was developed primarily to supply an export market and, in response to international demand, was soon dominated by fishmeal and fish oil production. As the anchoveta fishery became established, its management followed trends common to fisheries management throughout Latin America: (1) open access, (2) nationalization of industrial capacity by the government, followed by a (3) a return to private ownership (Agüero 1996).

The collapse of the anchoveta fishery in 1972 came as a shock to the Peruvian government. It was likely due to a combination of (1) overfishing, (2) an unfavorable, decadal-scale ecosystem regime shift, and (3) a strong El Niño event that year (Bakun and Broad 2003, Bertrand *et al.* 2004, Ñiquen and Bouchon 2004). The nationalization experiment that followed proved unsuccessful. Recognition of such unprofitability resulted in government led privatization, with the return to private ownership of the anchoveta fishing fleet starting in 1975, while that of the fishmeal processing facilities began in the 1980's (Hammergren 1981, Agüero 1996).

Key regulations were passed into legislation during the next decades, including new seasonal closures (1980), no-catch zones (1982), fish size limits and gear restrictions (1984). The anchoveta fishery transitioned to a closed access fishery in 1991, requiring (1) closing the entry for new vessels into the fishery completely, (2) monitoring vessels and their harvests using both GPS systems and live observers, and (3) setting new targets for the reduction of pollutants discharged to water by fishmeal plants (Olazo 2000). In addition to two annual closed seasons (in May-July, and August-September for spawning), short-term closures are also issued adaptively. Anchoveta management in Peru has become more robust over time, producing informed and enforced regulations, which industry now largely conforms to.

Regional management interactions are still limited. While the bulk of the biological production and 85% of anchoveta harvest comes from the northern stock off Peru (6° to 15° south latitude), the southern anchoveta stock (15° to 24° south latitude) is shared with Chile (Agüero and Zuleta 1992). However, Peru and Chile have so far failed to incorporate joint management of the southern anchoveta stock into legislation.

The major challenges identified in Chapter 2 are:

1) Climate predictions and El Niño mitigation
2) Governance regulatory framework: incentive structures and implementation controls
3) Overcapacity of the fishing fleet and fishmeal industry
4) Economic inefficiency of the industry
5) Pollution and environmental degradation which could be reduced
6) Unrealized contribution to Peruvian society beyond the *status quo*

These issues are the product of the fishery's past management and development. Since its beginnings and until 2008, the fishery operated under a global quota. This quota regime fostered an ongoing annual competition between firms to attempt to capture increasingly larger portions of the global quota for that season. Over-investment to outcompete other firms led to the overcapitalization of both fleet and factories, and a series of inefficiencies that stem from progressively larger amounts of capital assets remaining idle for increasingly longer periods of time (as the quota was reached in increasingly shorter seasons). These inefficiencies included lower fish quality landings, risk of overfishing, water pollution, and extraordinarily high operating costs for fishery operators. To address these issues the Peruvian government introduced regulatory reform in 2008, making anchoveta a rights-based fishery since 2009. This shift to Individual Vessel Quotas (IVQ), where every vessel was assigned a percentage share of a given annual quota, has had promising success in its first season, reducing industry utilized capacity (overcapacity) and costs, and improving upon the quality of landings and their processing (economic efficiency), while lessening environmental impact. A compensation fund was created and is being used to mitigate the social coast of capacity reduction (temporary unemployment). On the other hand, unrealistically high efficiency reporting from fishmeal plants suggests that landing underreporting has become an issue under the new system, and more intensive supervision may be required.

As mentioned in Chapter 2, much progress has been made towards achieving sustainable fisheries management goals in Peru, and in 2008, a research report by Mondoux *et al.* from the Fisheries Center at the University of British Columbia ranked Peru's fisheries and marine ecosystem as the most sustainable in the world. The case study included in this chapter illustrates how entrepreneurial innovation can lead to even further advances towards true sustainability: ecological, social and financial. Broader implementation of the innovations discussed is seen as a roadmap for private sector contribution towards environmental stewardship, social awareness and responsibility, and a more efficient and productive fishmeal and fish oil industry, placing less pressure on marine resources while becoming more profitable.

Government focus should be on anchoveta biomass assessments, better understanding the linkages to climate and the mitigation of its effects on the industry, and establishing incentives to promote industry transition towards sustainability. Peru will then be better prepared to manage its fishing industry during times of low biomass, and perhaps support it through special programs to ensure solvency during times when harvest sales may not even cover extraction costs. A fund similar to an emergency insurance fund, could secure employment and avoid industrial enterprise bankruptcies that would affect Peru's trade, in addition to their local community development and quality of life. In addition, an ecosystem management perspective is being considered, focusing not only on the productivity of the anchoveta and its supply chain., but also the underlying ecosystem influencing that productivity and its sustainability