Status of and trends in the use of small pelagic fish species for reduction fisheries and for human consumption in Chile

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SUMMARY

The main aim of this report is to review the status of and future trends in Chilean small pelagic fisheries. The report discusses the implication of using small pelagic fish species for direct human consumption and as the main protein ingredient in aquafeeds for the sustainable development of the Chilean fisheries and aquaculture industries.

The fisheries sector represents an important industry in Chile, and its contribution to both the national economy and global supplies is significant. However, future development will require an increased emphasis on the sustainable use of natural resources. Chile is making concerted efforts to regulate all fishing activity and has given special priority to ensuring the sustainable development of this industry.

The total Chilean fishery landing in 2006 was around 4.9 million tonnes, which represents a significant decrease in comparison with the previous year and a volume that is 5 percent lower than the average for the period 2001–2005. This volume originates from two main sources: the capture fisheries sector, with 4.08 million tonnes and the aquaculture sector, with an estimated production of around 822.7 thousand tonnes. In 2006, 61 percent of the capture fisheries sector was contributed by pelagic resources, a figure that is slightly less than the value reported for the previous year. Trends in Chilean fishery and aquaculture production over the last ten years reveal the increasing importance of the aquaculture sector. With the increase in aquaculture production, the use of fishmeal and fish oil in aquafeeds has increased significantly in Chile.

The main pelagic species used for the production of fishmeal and fish oil, and the most important pelagic resources in Chile, are the Inca scad or Chilean jack mackerel (*Trachurus murphyi*), the anchoveta (*Engraulis ringens*) and two sardines (the South American pilchard, *Sardinops sagax,* and the Araucarian herring or common sardine, *Strangomera bentincki*), which contributed 45, 30 and 13 percent of the total accumulated landings for 2006, respectively. However, marked reduction in the captures of these species has been constant. The main species destined for the production of fishmeal and fish oil come from the industrial and artisanal pelagic fisheries. Anchoveta contributes 41 percent of the total fishmeal production, followed by jack mackerel with 27 percent; trash fish/low-value fish represent 15 percent, while other species contribute only 3.3 percent. In the last decade, the fishmeal production declined by almost 50 percent because of the substantial decrease in landings from these fisheries.

In 2005, 1.78 million tonnes of processed fishery products were produced. Fishmeal and fish oil represented around half of the products processed, followed by frozen products, with a 27 percent share, while fresh chilled and canned products together comprised 17 percent. From the second half of the decade 1995–2005, the production of fishmeal from overall pelagic fish landings was more or less constant, averaging 21 percent; however, canned product production from the same species increased slightly, rising from 2.1 to 2.8 percent. This means that the increased production of canned products from pelagic fish is directly correlated with the reduction in fishmeal production.

Of the total fishmeal produced in Chile, approximately 40 percent (340 thousand tonnes) is used for domestic consumption. Given that Chilean aquafeed production is on the order of 850 thousand tonnes, the inclusion of fishmeal in these feeds is around 240 thousand tonnes. The limited availability of fishmeal, unstable prices and a principle of economic and environmental sustainability has driven the aquaculture industry to look for alternative protein sources. Consequently, the reduction in fishmeal inclusion levels seen over the last few years has been substantial, a great portion of the fishmeal component in aquafeeds having been replaced by different plant and animal protein substitutes. Fishmeal substitution in the Chilean aquafeed industry was initiated around ten years ago as a direct result of the reduction in capture volumes of small pelagic species.

During the last decade, the capture fisheries sector has been characterized by a remarkable reduction in the labour force. Two of the main causes of this diminution are a reduction in the fishing fleet and an increased efficiency of processing plants. A sustained

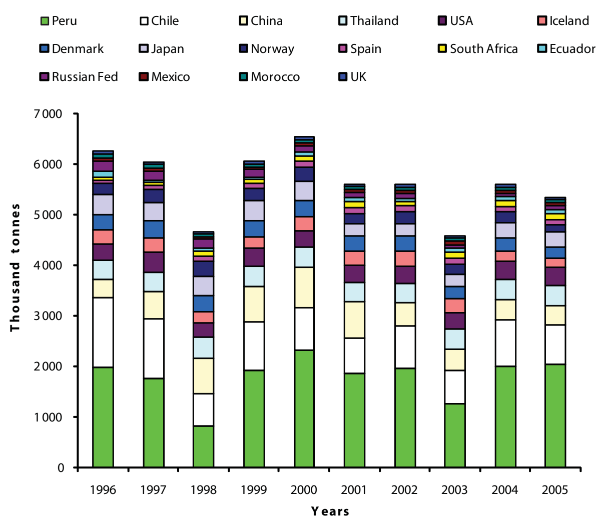
increase in the labour force in the aquaculture sector might compensate for the reduced employment in the capture fisheries sector. The salmon aquaculture industry is one of the most important employment generators in many areas of Chile, where poverty levels are much lower than the national average. The employment generated by this rising industry has a positive impact on poverty indicators for rural communities.

The hypothetical scenario of redirecting the use of jack mackerel from fishmeal production to the production of food for direct human consumption might have a positive effect. However, from the point of view of increased food security and poverty alleviation, the impact of the alternative use of this resource for human consumption might not be very significant, given that its products are not in high demand and would be mainly destined for export. Lowering the production of fishmeal will not have a negative impact on national salmon aquaculture, considering that at the present levels of fishmeal inclusion in salmonid aquafeeds there is still a surplus of fishmeal that is generally destined for export. Still, there could be a socio-economic benefit resulting from increased employment though greater processing opportunities.

1. INTRODUCTION

Global fishmeal production is principally utilized for animal feeding (livestock, poultry and aquaculture) and fish oil production is utilized for aquaculture and human consumption (Tacon, Hasan and Subasinghe, 2006). Fishmeal and fish oil are mainly produced from pelagic fisheries operating at an industrial level. Pelagic fishing is conducted all around the world, but the main fisheries are located along the Peruvian and Chilean coasts where the cold Humboldt current generates wide oceanic upwelling and consequently, high primary productivity (Bertrand *et al.*, 2004). Global fishmeal production during the last decade is shown in Figure 1. As described in this figure, global fishmeal production is concentrated in ten main countries. The two largest producers and fishmeal exporting countries are Peru and Chile, which produce 31 and 15 percent of the global total, respectively. In 2004, the estimated global fishmeal production was around 6.33 million tonnes, valued at over US$3 billion. Global fish oil production for the same year was estimated at around 930 000 tonnes, worth approximately US$0.56 billion (IFFO, 2005). These values are a clear indication of the importance of fishmeal and fish oil to the global economy and particularly to the Peruvian and Chilean economies.

FIGURE 1
World fishmeal production trends among the major producers during the decade 1996–2005



Source: IFFO (2005)

During the last 40 years, Chile has made significant strides in increasing both volume and value of capture fisheries and aquaculture production. From the mid-1960s to the present, the value of fisheries exports has increased from US$50 million to US$3 billion. Table 1 summarizes the value of total Chilean fish exports during the period 1995–2005 (SalmonChile, 2006).

Chilean total export values have doubled since 1995 and the production of farmed salmonids contributed around 60 percent of exports in 2006. Recent investments in new technologies, fishing vessels, processing plants and skilled human resources have made the Chilean fishing and aquaculture industries highly competitive in a global context. Chile is making concerted efforts to manage its fisheries in a sustainable and appropriate manner. However, future fisheries and aquaculture developments will require an increased emphasis on sustainability. For this reason, the Chilean Government is giving special priority to ensuring the achievement of this objective.

The contribution of the Chilean fishing sector to the national economy and global supplies of fishmeal and fish oil is significant (FAO, 2004). Hence, the responsible use of this finite commodity, principally by the animal feeds industry but also as human food and for pharmaceuticals, is very important. With the increase in aquaculture production, the use of fishmeal and fish oil in aquafeeds has increased significantly in Chile. However, because of fluctuating and lower pelagic catches, considerable cuts have been made in the inclusion rates of fishmeal in salmonid feeds over the last decade (Visión acuícola, 2006).

The price of fishmeal is determined by supply and demand, both of which are subject to a multitude of external factors. Probably the most important factors to have a

TABLE 1

Total Chilean export values, during the period 1995–2005 (values are given in million USD (FOB))

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006*
Fishmeal	633	612	552	349	282	235	257	320	373	362	487	466
Salmon and trout	489	538	668	714	818	973	964	973	1 147	1 439	1 721	2 010
Other products	660	621	652	611	684	667	639	666	726	777	869	831
Total	**1 782**	**1 772**	**1 873**	**1 674**	**1 784**	**1 875**	**1 861**	**1 959**	**2 246**	**2 579**	**3 077**	**3 307**

*Estimated values.

Source: SalmonChile (2006)

strong impact are those related to environmental changes, such as the El Niño Southern Oscillation event. However, it is possible that the fishmeal price would be high and over US$1 000 per tonne if there is an associated reduction in the stocks and catches (Mitrano, 2007). For this and many other reasons, most of them related to the negative environmental implications and concerns about the use of fishmeal in fish diets, there is a tendency to lessen or eliminate the fishmeal portion included in aquafeeds. In fact, for some species, including salmonids, fishmeal has been almost completely replaced as main protein source by other alternative ingredients (plant-derived proteins), not only in experimental diets but also in commercial feeds (Watanabe *et al.*, 1993; Storebakken, Shearer and Roem, 2000; Tacon, Hasan and Subasinghe, 2006; Visión acuícola, 2007).

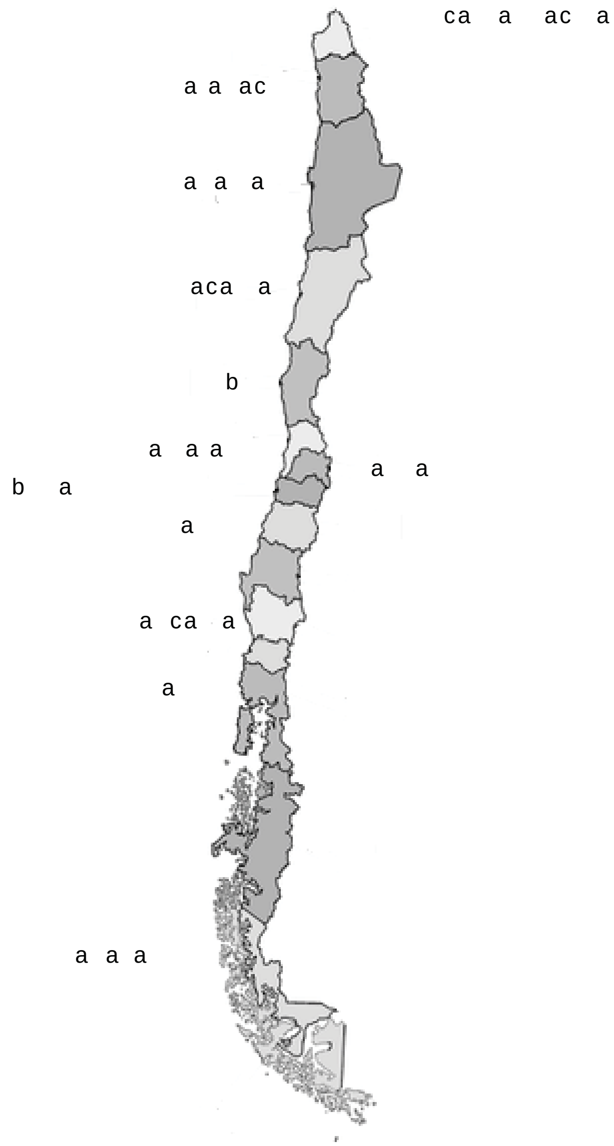
Fisheries and aquaculture are complementary activities and represent important industrial sectors of the Chilean economy. The development and implementation of a particular fishery or aquaculture management system has important repercussions in terms of environmental, economic and social outcomes. Consequently, the Chilean fishery industry needs to have important modifications in the different stages of its productive practice, including extraction and processing, as well as in the development and expansion of aquaculture. In this sense, the low accessibility and availability of resources together with the increasing demand to address the environmental problems posed by this activity and the concerns about its sustainability will have a huge impact on national fisheries management and future development.

In view of the magnitude and importance of Chilean fisheries in both national and international contexts, the purpose of the present report is to discuss and review the current status and trends of pelagic species and the implications of their use as aquafeed ingredients for the sustainable development of Chilean fisheries and aquaculture industries. This review examines the present situation of the Chilean small pelagic fisheries and identifies the future trends and activities. The data used in preparing this report come mainly from the updated database, registers and statistical yearbooks of the Government of Chile's Subsecretary of Fisheries and the National Fishing Service. In addition, some collected information was obtained from key sources like the industrial fishery associations, fishmeal and fish oil exporters, and National Fishing Zone Counsels.

The report is structured in five main sections. This first part provides a brief and basic introduction to the document. The second section illustrates the Chilean fisheries sector and its organization, considering the types of fisheries and regulations, as well as the historical trends in and present production of the main pelagic species. The third section analyes the present situation with regard to fishmeal and fish oil production in Chile: the trends, prices and interrelation with direct human consumption or processed products. The fourth section deals with the use of fishmeal and fish oil in Chilean aquaculture and includes a brief description of the novel use of alternative protein sources as fishmeal substitutes in the national aquafeed industry. The final section discusses the social and economic impacts of the fishery and aquaculture industries in

Chile, offering a hypothetical study of the particular case of the jack mackerel resource in Region VIII (Bio-Bio), which represents around 45 percent of the total pelagic fish landings in Chile.

FIGURE 2
Map of Chile showing the country administrative divisions



Each region is designated by a name and a Roman numeral (I, Tarapaca; II, Antofagasta; III, Atacama; IV, Coquimbo; V, Valparaiso; VI, Libertador Bernando O'Higgins; VII, Maule; VIII, Bio-Bio; IX, Araucania; X, De Los Lagos; XI, Aisen; XII, Magallanes y Antártica; RM, Metropolitan Region, Santiago; and the new recently created regions: XIV, Los Rios; XV, Arica-Parinacota)

2. CHILEAN PELAGIC FISH PRODUCTION

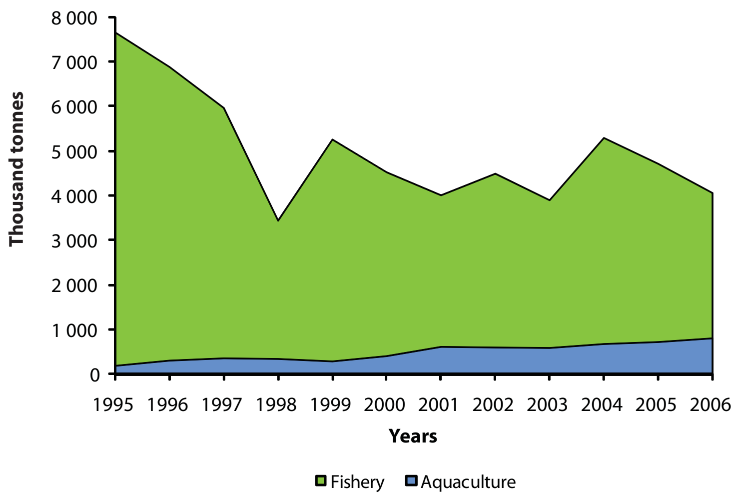
2.1 Chilean fisheries: the context

Chile possesses a unique geography, and the importance of its fishing industry is determined by its long seaboard, which extends approximately 4 300 km from its boundary with Peru at latitude 17°30´S, to the tip of South America at Cape Horn, latitude 56°S, a point only about 667 km north of Antarctica (Figure 2). The country is divided into 15 administrative regions (each region is designated by a name and a Roman numeral), including the Metropolitan Region of Santiago where 38 percent of the total population is concentrated (INE, 2005).

The extremely high biological productivity of Chilean coastal waters represents a source of fishery resources of great commercial value. Chile is one of the biggest producers and exporters of fish in the world, just behind countries like China, Peru, India, Japan, the United States of America and Indonesia. The Chilean fisheries industry is one of the main industrial sectors of the country, together with mining, agriculture and forestry. The fishery industry plays a major role in Chile's export-led economy. Chile's fisheries exports reached US$1.24 billion during the first ten months of 2006, which represents a 7.9 percent increase over the same period a year ago according to the Sociedad Nacional de Pesca (SONAPESCA, 2007).

FIGURE 3

Fishery and aquaculture production trends in Chile, 1995–2006



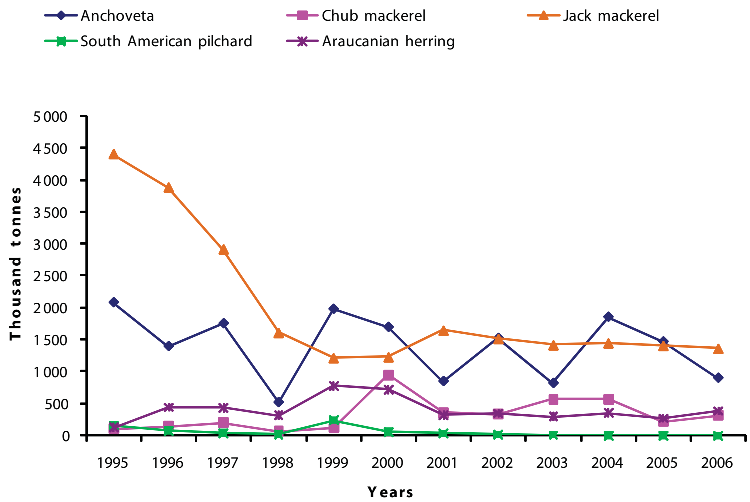
Source: SERNAPESCA (2006)

During the last half of the 1990s, the Chilean fishery industry went through a continuous decline in production volumes and in 1998 reached its lowest historical level as a direct result of the unfavourable environmental conditions induced by the El Niño over the period 1997–1998 (Arcos, Cubillos and Núñez, 2004; Pinochet and Villagrán, 2004). This drastic reduction is clearly evident in Figure 3, the total fishery production reached in 1998 is represented by the lowest point (only 3.9 million tonnes). The overall fishery production decrease was strongly influenced by the low availability of small pelagic species (jack mackerel, anchoveta and sardines) that sustain most of the reduction fisheries. These species contribute an important fraction of the national total landings but are very sensitive to environmental changes (Figure 4).

The Chilean fishing sector has made important changes in its productive structure, mainly with regard to the supplying of raw materials, a situation consistent with trends observed elsewhere. Aquaculture represents an important driver of these changes (Figure 3). The Chilean aquaculture industry supplied a major portion of the salmonids, molluscs and other cultivated aquatic resources.

Many of the world's fisheries are approaching full exploitation. As a result, aquaculture production is an important alternative to increase the raw materials supplying seafood processors. The Government of Chile is very concerned about this fact and based on the stabilization of traditional fisheries through capture quotas, has oriented its efforts to wards towards:

FIGURE 4
Variation in the main pelagic fish landings in Chile, 1995–2006



Source: SERNAPESCA (2006)

- establishing responsible management for the most important Chilean fisheries – in order to maintain sustainability, Chilean fisheries are well regulated, with restricted access to main fisheries zones; and
- developing a sustainable aquaculture industry – aquaculture represents the best alternative to increasing production and developing a sustainable national fishing industry. For this reason government policies aim to generate and promote the best conditions to support the aquaculture industry's sustainable development, on the basis of diversification, production of high-value species for international markets, and the development of environmentally sound methods and high sanitary standards.

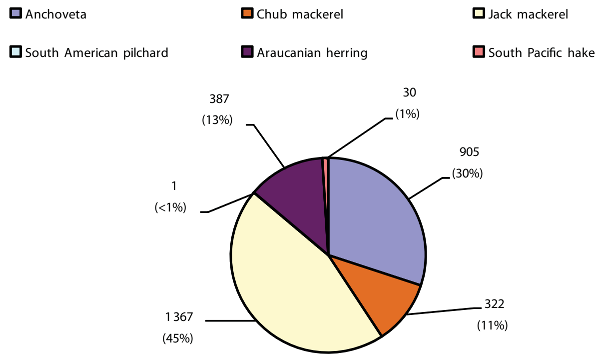
In this way, Chile has been aiming to strengthen its position as an important fish producer. The total Chilean fishery landing in 2006 was 4.91 million tonnes, which represents a decrease of 10.4 percent from the previous year and a volume that is 5.0 percent lower than the average for the period 2001–2005. This volume is provided by the productions of two main sources: the capture fisheries, with 4.08 million tonnes, and the aquaculture sector, with an estimated production of 822.7 thousand tonnes (Figure 3). Trends in Chilean fishery and aquaculture production over the last ten years reveal the increasing importance of the aquaculture sector. The 61.4 percent of capture fishery production represented by pelagic resources in 2006 is slightly less than the 62.4 percent registered for the previous year (Figure 3).

2.2 Main pelagic species

The upwelling of subsuperficial colder water towards shallower depths is induced by the action of the persistent winds that blow parallel to the coast, which in combination with the earth's rotation (the Coriolis effect), cause a displacement of the surface waters and their movement away from the coast. When this movement takes place, the superficial water displaced towards the open sea is replaced by deep waters, causing a reduction in the superficial temperature of the sea. This water, which is usually abundant in nutrients, enriches the superficial layer, allowing a high primary production (CONA, 2006).

This upwelling phenomenon occurs along a great part of the Chilean coastline as a result of the north-south shore orientation and the wind direction (Strub *et al.*, 1998). However, it is usual that these processes are specially localized in specific coastal areas, for example those areas associated with mountainous peaks and capes where there is a

FIGURE 5
Total accumulated landings by main pelagic species captured in Chile, 2006 (thousand tonnes)



Source: SERNAPESCA (2006)

high incidence of strong winds. Along the Chilean coast, the main areas of upwelling are located south of Arica, from south of Iquique to Punta Lobos, south of Coquimbo, south of Valparaiso, San Antonio and the zone between Talcahuano and the Gulf of Arauco (CONA, 2006). As a consequence of the upwelling process, these regions are some of the most productive on the planet, and they provide an abundant source of the main pelagic species that form an important part of the Chilean and global fisheries. In 1996, 20 percent of the world landings were caught in the area of the Chile-Peru Current System, which that represents only 0.09 percent of the ocean surface (Yañez *et al.*, 2001).

These areas support a significant industrial fishery for jack mackerel (*Trachurus murphyi*), anchoveta (*Engraulis ringens*) and sardines (South American pilchard, *Sardinops sagax* and Araucarian herring or common sardine, *Strangomera bentincki*) (Cubillos, Núñez and Arcos, 1998; Atkinson *et al.*, 2002; Escribano *et al.*, 2004), which are the main pelagic species used for the manufacture of fishmeal and fish oil. However, these zones are also directly affected by the El Niño Southern Oscillation (ENSO), which is characterized by an increase in the surface temperature of the ocean (Escribano *et al.*, 2004). Small pelagic fish such as sardines, anchoveta and herring respond dramatically and quickly to changes in ocean climate (Cubillos, Bucarey and Canales, 2002). Most are highly mobile and have short, plankton-based food chains, some even feeding directly on phytoplankton. They are short-lived (3–7 years) and highly fecund, some even being capable of spawning all year round. These biological characteristics make them highly sensitive to environmental changes and thus extremely variable in their abundance (Alheit and Niquen, 2004). The change in the normal conditions of the water induced by the ENSO causes the migration of pelagic species and the disappearance or replacement of some species, as happens, for example, with the anchoveta and sardine, and can produce, in addition, a diminution of the upwelling processes and intense precipitation in coastal zones (Yañez *et al.*, 2001).

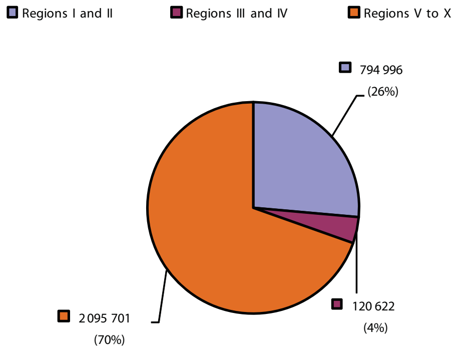
As mentioned previously, the most remarkable among the important pelagic resources in Chile are the jack mackerel, the Peruvian anchoveta and the Araucarian herring

TABLE 2
Pelagic fish landings in Chile by year for the main captured species (thousand tonnes)

Species	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Anchoveta	2 086	1 401	1 757	523	1 983	1 701	853	1 527	823	1 860	1 473	905
Chub mackerel	110	147	212	72	120	958	365	343	572	577	223	322
Jack mackerel	4 404	3 883	2 917	1 613	1 220	1 234	1 650	1 519	1 421	1 452	1 412	1 367
South American pilchard	162	81	40	28	246	60	33	19	11	5	2	1
Araucarian herring	127	447	441	318	782	723	325	347	304	356	275	387
South Pacific hake	207	375	71	354	310	91	162	133	86	71	33	30
Total	**7 096**	**6 334**	**5 439**	**2 907**	**4 661**	**4 767**	**3 388**	**3 889**	**3 217**	**4 321**	**3 417**	**3 011**

Source: SERNAPESCA (2007)

FIGURE 6
Distribution of pelagic fish landings by fishing zone for the year 2006 (tonnes)



Source: SERNAPESCA (2006)

or common sardine, which contributed, respectively, about 45.4, 30.0 and 12.9 percent of the total accumulated landings for 2006 (Figure 5).

Jack mackerel is the main fishery resource that sustains the industrial activity from Atacama (Region III) to Los Lagos (Region X). Along the Chilean coast, jack mackerel has been considered a key target species for national fisheries. This species represents, in terms of volume, one of the most important fishery resources in Chile and the world (Arcos, Cubillos and Núñez, 2001). In Chile, the maximum historical total landing for this species was 4.4 million tonnes in 1995. From 1996, a marked reduction in the captures of this species was observed, and catches have been constant during the last five years, with an average close to 1.4 million tonnes (Table 2).

Fresh fish stall at the fish market in the port city of Coquimbo, Chile

Fresh fish stall at the main artisanal fish market in the port city of Coquimbo, northern Chile. In spite of the abundant fish stocks, annual consumption of fish is low in Chile, at about 7 kg per person. It may look like smoked fish but in fact is an optical effect of the picture.

Courtesy of Adrian Hernandez

Common sardine or Araucarian herring (*Strangomera bentincki*) together with anchoveta (*Engraulis ringens*) represent the second most important resource for the fishery activity in the center-south of Chile. Sardine is largely distributed along the Chilean coast from Coquimbo to Chiloe, while anchoveta occurs from Peru to Chiloe. In Chile, the fishery activity for these species is mainly localized in Bio-Bio (Region VIII). There has been a reduction in the landings for these two species as a result of increased regulation and reduced effort by the industrial fleet for these resources.

The major proportion of pelagic fish landings in Chile is principally concentrated in the area between Regions V and X, with landings of almost 2.1 millions tonnes (70 percent), while in Regions I and II, the total landings reached around 795 thousand tonnes (26 percent). Regions III and IV, with 120.6 thousand tonnes, represent only the 4 percent of the national landings (Figure 6).

2.3 Fishing zones

For administrative purposes, until 2006 Chile was divided into five fishing zones, each of which was headed and regulated by a Fishing Zone Council that was integrated with the Chilean Fisheries Subsecretary. The Fishing Zone Councils contribute to the decentralization of the administrative measures adopted by the national authority and promote the participation of regional agents in activities related to fisheries and aquaculture. The five zones are as follows:

Zone 1 Regions I and II (Tarapacá and Antofagasta)

Zone 2 Regions III and IV (Atacama and Coquimbo)

Zone 3 Formed by a wide area extending from Regions V to IX (Valparaiso to Araucania) and oceanic islands

Zone 4 Regions X and XI (Los Lagos and Aysen)

Zone 5 XII Region (Magallanes) and Chilean Antarctica

From the point of view of the fishing industry and the types of fishing activity conducted, Chile is divided into three main zones: North Chile, South Chile and Austral Chile.

- **North Chile.** This zone is located from Regions I to IV (from Tarapacá to Coquimbo), where the main pelagic reduction fisheries are conducted. This zone is essentially a fishmeal producing area, with an annual production of around 220 thousand tonnes.
- **South Chile.** This is the main fishing zone of Chile and extends from Region V to X (Valparaiso to Los Lagos). In this zone, most products are produced in large-scale processing plants. The main processed products are frozen jack mackerel and South Pacific hake (*Merluccius gayi gayi*), with annual volumes surpassing 250 thousand tonnes. Around 550 thousand tonnes of fishmeal are produced annually in this zone.

Medium-size boats, used for seine fishing in Bio-Bio, Chile

Medium-size boats, 80 to 100 tonnes, used for seine fishing of pelagic species in Region VIII (Bio-Bio, Chile). This fishing method is known in Chile as "pesca de boliche".

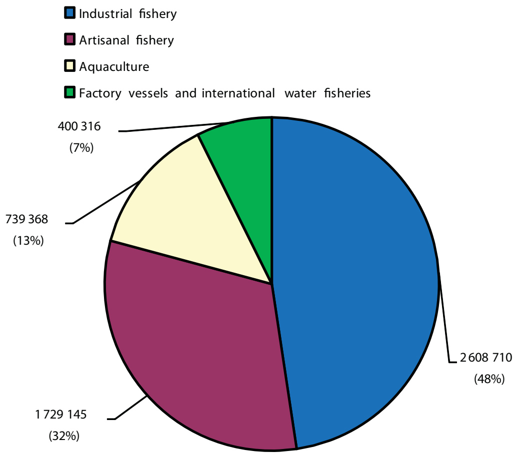
Courtesy of Adrian Hernandez

Fishmeal and fish oil processing factory in Talcahuano, Chile

Fishmeal and fish oil processing factory in the city of Talcahuano, Region VIII, (Bio-Bio, Chile). The major fishing industries are located in this region and process 70 percent of the pelagic species caught in Chile.

Courtesy of Adrian Hernandez

FIGURE 7
Fish production in Chile by type of source (tonnes)



Source: SERNAPESCA (2006)

- **Austral Chile.** This zone is basically dedicated to deep-water demersal fisheries and aquaculture production. The capture fisheries have a high artisanal component and depend principally on South Pacific hake. Aquaculture is the most significant activity in this zone, with the greatest development in Aysen and minor activity in the southern regions.

2.4 The structure of Chilean fisheries

Chilean fisheries can be divided into four main groups according to the source and method of production: artisanal fisheries, industrial fisheries, international-waters fisheries and aquaculture. In the year 2005, these four production groups reached a total volume of 5.48 million tonnes. The industrial fishery represents 48 percent of the total landings, the artisanal fishery 32 percent and aquaculture 13 percent, whereas the fishery in international waters and factory vessels represent only 7 percent (Figure 7).

The industrial fishery produced 2.6 million tonnes based on the operation of a total of 224 vessels. Ninety-five percent of the industrial landings were represented by the pelagic resources, with anchoveta and sardines contributing 1.14 million tonnes (43.6 percent) and chub mackerel (*Scomber japonicus*) and jack mackerel contributing 1.34 million tonnes (51.4 percent). The zone where the bulk of landings of these species is concentrated is the Bio-Bio (Region VIII), with a total of 1.3 million tonnes, which represents 49.9 percent of the national industrial fishery. During 2005, industrial landings of pelagic fish decreased by 18 percent from the previous year.

The artisanal fishery captured 1.73 million tonnes and operated with a total of 1 439 boats. Pelagic resources represented 44 percent of the artisanal landings. Anchoveta and sardines contributed 704 thousand tonnes (41 percent), while chub mackerel and jack mackerel accounted for 50 thousand tonnes (3 percent). Again, Region VIII accounted for the largest landings of pelagic species, with a total volume of 414 thousand tonnes (23.9 percent). Other species used for human consumption accounted for the remaining 56.3 percent (974 thousand tonnes) of the production.

In 2005, factory vessels operating in national waters captured a total of 76 thousand tonnes, with 100 percent of the catch being fish (as opposed to molluscs), while vessels operating in international waters captured a total of 3.14 thousand tonnes (1.97 thousand tonnes of fish and 1.17 thousand tonnes of molluscs). The volume captured by international industrial vessels was 320 thousand tonnes.

During 2005, a total of 1 020 aquaculture operations was registered in Chile, and the subsector produced approximately 739 thousand tonnes. Fish represented 82 percent (614 thousand tonnes) of production, molluscs 15 percent (109 thousand tonnes) and seaweed 3 percent (15 thousand tonnes). Eighty-three percent of the aquaculture centres were located in Region X (Los Lagos), where 28 percent of the centres corresponded to fish farming (mainly salmon and trout), 39 percent of the centres to mollusc culture and 33 percent to seaweed farming.

2.5 Fishing regulation and restrictions

Given its significant contribution to global fisheries production, Chile recognizes the importance of regulating all fishing activity in the country. The Government of

Chile undertakes and promotes regular monitoring surveys to establish the state of the national fishery resources, using the results of these surveys to set the control measures required to protect and manage the fishery stocks. In Chile, the exploitation, use and conservation of the living marine resources have been based on the concept of maximum sustainable yields, the application of seasonal and geographical closures, the definition of catch areas, and regulations on the use of fishing gear and minimum size limits. The General Law on Fisheries and Aquaculture was promulgated in 1991 to establish the legal framework that currently prevails in the Chilean fisheries (Gobierno de la Republica de Chile. Ley No. 18.892, 1991). This law was created with the objective of preserving the marine resources and to set up a series of national rules that maintain a general regime of free access to fisheries resources, with the exception of those considered endangered or in recovery. For this reason, the national fishing authority, represented by the Chilean Subsecretary of Fisheries, has strengthened the application of regulatory measures aimed at restricting the entry of new vessels or fishing methods in order to avoid increased pressure on current fisheries and to establish limits or capture quotas with the objective of maintaining the sustainability of these resources. In addition, all fishing boats in Chile are fitted with a Vessel Monitoring System (VMS) to ensure that they do not operate inside prohibited areas (such as designated areas of recovery) or the zone reserved for small artisanal fisheries (first five miles offshore).

To protect the spawning stocks, closed seasons for anchoveta and sardine appropriate to their spawning cycles are set on an annual basis, usually between August and September of each year in the northern part of the country. Closed seasons are also imposed during December to mid-January to protect the recruitment process of anchoveta. In the central-southern part of the country, closed seasons are set for anchovy and sardine to protect the spawning period (usually July and August) and also from mid-December to mid-February (SERNAPESCA, 2007).

The Government of Chile has introduced legislation to establish an annual total allowable catch (TAC) for each species declared in full exploitation for each owner of a boat or group of boat owners. The capture quotas approved for 2007 by the Chilean Subsecretary of Fisheries were published in December 2006. The quotas established by the national authority have not varied significantly and have been kept at almost the same levels during the last years in order to preserve the fisheries resources within acceptable limits of exploitation. These measures aim to relieve the pressure on the resources and to sustain an activity that has demonstrated to be very vulnerable during recent times. The main pelagic species for which capture quotas for the year 2007 were increased are anchoveta, sardines and jack mackerel. Although minimum landing sizes are applied for jack mackerel, there is the possibility that several fishing bans can be imposed during the year to protect small-sized fish. These measures reinforce controls to protect stock recruitment. The approved capture quota for jack mackerel during 2007 was 1.6 million tonnes, an increase of around 14 percent from the previous year. In the case of anchoveta and sardines, the official quotas during 2007 for Regions V to IX presented an increase of 44 percent for anchoveta and 29 percent for sardine (288 and 280 thousand tonnes, respectively). Total capture quotas permitted by the Chilean

TABLE 3

Official capture quotas established by the Chilean Subsecretary of Fisheries, 2007

Fishery	Anchoveta	Sardine	Jack mackerel	South Pacific hake	Total
Industrial	1 272 314	73 400	1 444 000	154 000	2 943 714
Artisanal	341 766	203 700	76 000		621 466
Research	49 920	8 400	80 000	4 000	142 320
Total	**1 664 000**	**285 500**	**1 600 000**	**158 000**	**3 707 500**

Source: SUBPESCA (2006a)

Talcahuano Port, Chile

Talcahuano Port, Talcahuano, Region VIII (Bio-Bio, Chile)

fisheries authority for anchoveta and sardine are 1.66 million tonnes and 285 thousand tonnes, respectively (Table 3).

3. PROCESSING AND PRESERVATION OF PELAGIC FISH AND FISH-BASED PRODUCTS IN CHILE

3.1 Fishmeal and fish oil production

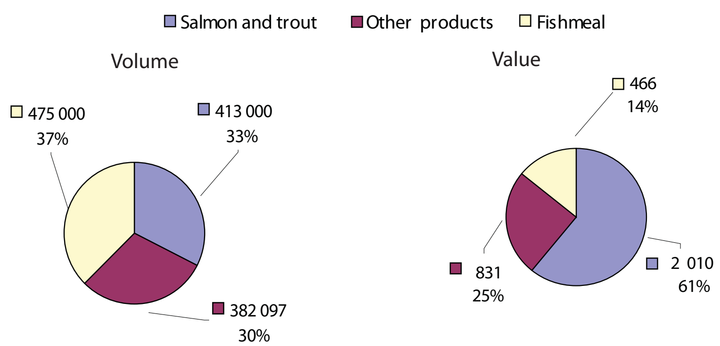
3.1.1 Present fishmeal and fish oil production and values

Nowadays the Chilean production of fishmeal and fish oil is around 900 and 170 thousand tonnes, respectively. Preliminary values for November 2006 indicate that the accumulated volume of fishmeal exported represents 37 percent (475 thousand tonnes) of fishery product exports, with an estimated value of approximately US$466 million, representing about 14 percent of the total value of fishery products exported by Chile (Figure 8).

The capture of the main pelagic species in 2005 was close to 3.5 million tonnes, while for November 2006 alone, the accumulated landings totaled 3.1 million tonnes (Table 2). The main species destined for the production of fishmeal and fish oil come from

FIGURE 8

Preliminary volumes and values of exports for the main Chilean fish products (tonnes and millon US$)



Source: SERNAPESCA (2006)

the industrial and artisanal pelagic fisheries. In 2005, 49.7 percent of total fishmeal production was contributed by anchoveta, 7.2 percent by chub mackerel, 29.4 percent by jack mackerel, 9.2 percent by sardine and 0.4 percent by South Pacific hake (Table 4). In 2005, these species combined represented 95.9 percent of all the pelagic fisheries landings used for the production of fishmeal and fish oil. The fishmeal production are presented in Table 4. It can be observed that 41 percent of the total fishmeal produced was made

TABLE 4
Capture volume of the main pelagic species used for fishmeal production and fishmeal production by species used, 2005, (thousand tonnes)

Species	Capture volume	% of total contributing to fishmeal production	Fishmeal production	% of total fishmeal production
Anchoveta	1 531	49.7	341	41
Chub mackerel	221	7.2	53	6
Jack mackerel	906	29.4	221	27
Sardines	284	9.2	58	7
South Pacific hake	14	0.4	2	0
Others	127	4.1	27	3
Trash fish/low-value fish	-	-	125	15
Total	**3 082**	**100**	**827**	**100**

Source: SERNAPESCA (2006)

TABLE 5
Production of fishmeal by species, 1995–2005 (thousand tonnes)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Anchoveta	439	306	392	117	424	387	194	333	183	417	341
Chub mackerel	25	34	49	14	26	2	77	69	123	115	53
Jack mackerel	956	834	594	260	204	216	302	243	227	233	221
Sardines	50	103	99	73	214	153	72	71	60	74	58
South Pacific hake	36	70	12	69	58	16	28	15	2	0	2
Other fish	1	3	6	3	2	3	4	1	11	17	27
Trash fish	45	49	72	106	72	81	100	104	99	128	125
Total	**1 553**	**1 399**	**1 225**	**643**	**1 000**	**858**	**778**	**836**	**705**	**984**	**827**

Source: SERNAPESCA (2006)

FIGURE 9
Fishmeal production trends by species, 1995–2005

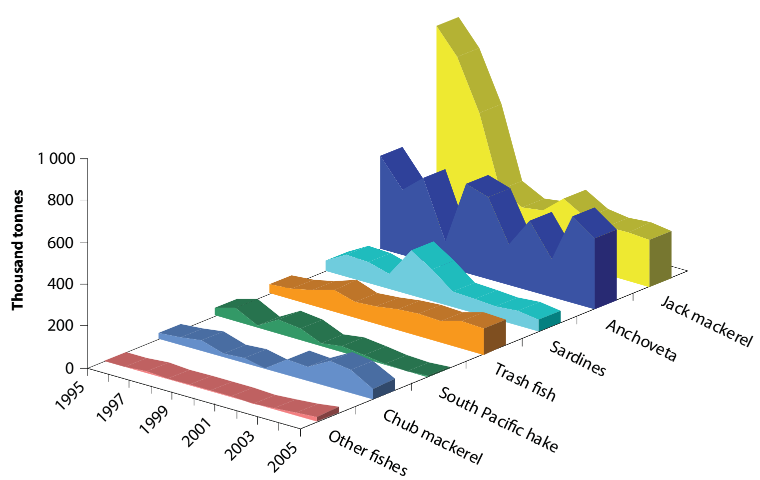
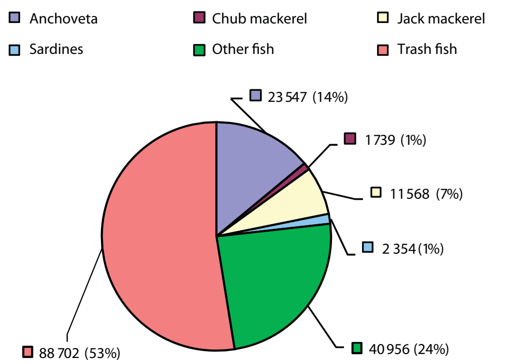


FIGURE 10
Fish oil production by species in Chile, 2005 (tonnes)



Source: SERNAPESCA (2006)

from anchoveta, 27 percent was made from jack mackerel and 15 percent was made from trash fish and only 3 percent was made from other species.

3.1.2 Fishmeal and fish oil production trends during the last decade

Table 5 and Figure 9 present the trends in fishmeal production in Chile over the period 1995–2005. During this period, fishmeal production declined by almost 50 percent because of a substantial decrease in landings. The species with a noticeable reduction in capture volume and as a consequence, a reduction in contribution to fishmeal production, is jack mackerel. The capture volume of this species in 1998 was only a quarter of that taken in 1995, and since 1999, annual landing volumes have stagnated at around 235 thousand tonnes, with authorized capture quotas on the order of 1.5 million tonnes. The contribution of anchoveta to fishmeal production remained broadly stable over the last decade with an annual average of 321 thousand tones, varying between 183 and 439 thousand tonnes, not considering the landing of 117 thousand tonnes in 1998 (a year in which the El Niño phenomenon had a high impact on Chilean fisheries).

An important increase in fishmeal production using species not traditionally destined for fishmeal occurred during the last three years; annual average production reached 27 thousand tonnes, which corresponds to a capture of around 127 thousand tonnes in 2005 (Table 4). In the same way, the production of fishmeal from chub mackerel and trash fish shows an increase that began in 2001 and maintained an annual average of 87 and 111 thousand tonnes, respectively. In the case of production from trash fish, during the first half of the decade 1995–2005, the annual average production did not exceed 71 thousand tonnes.

At present, more than 53 percent of the fish oil is produced from trash fish and 24 percent is produced from species other than the main pelagic species usually destined for fishmeal production. Only 22 percent of fish oil was derived from anchoveta, sardine and mackerel (Figure 10). Of the most abundant pelagic species, anchoveta shows the largest fish oil contribution of 23 547 tonnes or 14 percent of the total fish oil produced in 2005.

The trend in fish oil production over the period 1995–2005 is shown in Table 6 and Figure 11. In the first half of the decade, the annual average production was around 219 thousand tonnes, while the annual average during the period 2001–2005 was on the order of 153 thousand tonnes of fish oil, which represents a decrease of around 40 percent. With regard to fish oil production, the item "other fishes" includes not only the main pelagic species (anchoveta, jack mackerel, chub mackerel and sardines), which only contributed 23 percent of the total fish oil produced during 2005, but also other smaller species like king gar or agujilla (*Scomberesox saurus scombroides*), starry butterfish

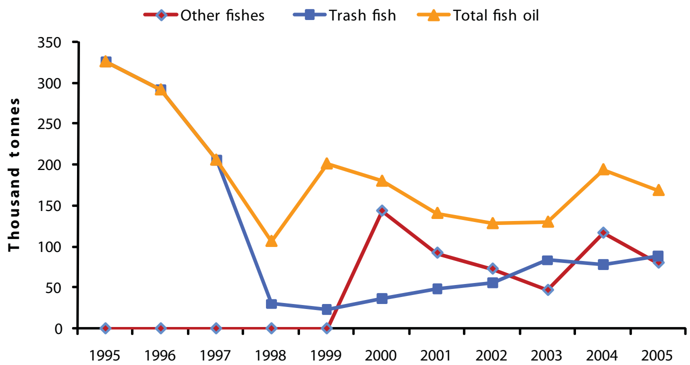
TABLE 6
Annual fish oil production in Chile, 1995–2005 (thousand tonnes)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Other fishes	0	0	0	77	178	144	92	73	47	117	80
Trash fish	326	292	206	30	23	37	49	56	83	78	89
Total fish oil	**326**	**292**	**206**	**107**	**201**	**181**	**141**	**129**	**130**	**195**	**169**

Source: SERNAPESCA (2006)

or pampanito (*Stromateus stellatus*), cabinza grunt (*Isacia conceptionis*) and other fish that as a whole contributed approximately 24 percent of the oil. By contrast, trash fish contribute around 47 percent of the total fish oil produced in Chile. These trash fish originate mainly from the canning and fish processing industry.

FIGURE 11
Annual production of fish oil, 1995–2005



Source: SERNAPESCA (2006)

3.1.3 Fishmeal and fish oil prices and markets

In 2005, approximately 40 percent (340 thousand tonnes) of the total fishmeal produced in Chile was used for domestic consumption. Given that the Chilean aquafeed production was on the order of 850 thousand tonnes, the volume of fishmeal included in these feeds was around 240 thousand tonnes. The remaining amount was devoted to other uses in animal production. Between 1991 and 1994, domestic use of fishmeal was more or less 70 percent of the total national production. In 1995, the domestic use was reduced to 60 percent of total production, and by 1998 only 45 percent of the total production. During 1998, national fishmeal production was at its lowest at any time the last decade (643 thousand tonnes), and coincided with one of the most devastating El Niño events ever to affect the coasts of the South Pacific (Avaria *et al*., 2004). In 1999, the production of fishmeal increased significantly (1 million tonnes), with domestic consumption accounting for around 70 percent of the total fishmeal production.

FIGURE 12
Fishmeal use in Chile, 1991–2005

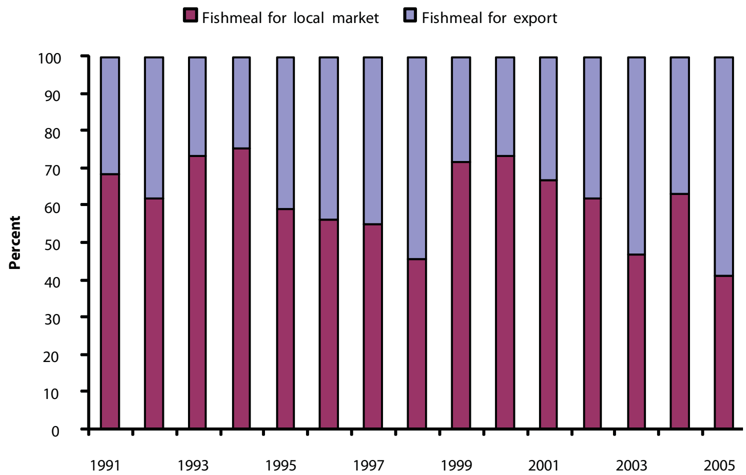


TABLE 7
Annual production of fishmeal and volumes for domestic use and export (thousand tonnes)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Fishmeal production	1 471	1 423	1 383	1 841	1 553	1 399	1 225	643	1 000	877	778	843	705	988	827
Fishmeal for export	465	540	366	453	633	612	552	349	282	235	257	320	373	362	487
Fishmeal for domestic market	1 006	883	1 017	1 388	919	786	672	294	718	642	520	523	332	626	340

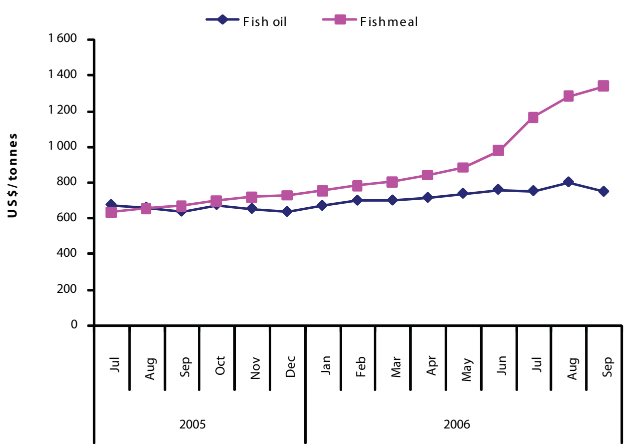
Source: SUBPESCA (2006b)

TABLE 8
Main importers of Chilean fishmeal

Country	Value (US$ thousand)		Volume (tonnes)	
	2005	2006	2005	2006
China	165 841	152 853	260 234	151 545
Japan	61 213	78 399	95 914	78 081
Taiwan POC	43 991	42 788	68 952	45 909
Germany	14 554	29 114	19 983	26 448
Republic of Korea	20 604	28 538	31 443	27 780
Viet Nam	19 320	24 329	30 625	26 656
Italy	16 949	23 465	27 502	24 672
Spain	19 440	22 520	29 968	22 893
Indonesia	14 492	13 807	23 372	14 966
Other countries	60 065	49 385	91 277	55 882
Total	**436 470**	**465 198**	**679 269**	**474 832**

Source: SUBPESCA (2006b)

FIGURE 13
Variation in fishmeal and fish oil prices, 2005–2006



Source: SERNAPESCA (2007)

From 2000 until 2005, there was a sustained decline in the domestic use of fishmeal, even though the annual average fishmeal production stabilized around 836 thousand tonnes (Table 7 and Figure 12). Table 8 shows the main destinations for Chilean fishmeal. To November 2006, the main markets were China with 153 thousand tonnes, followed by Japan with 61 thousand tonnes and together accounting for 52 percent of the fishmeal exported from Chile. As regards the use of fish oil, 100 percent was for internal consumption, mainly for the salmon aquafeed industry.

Figure 13 shows that the price of fishmeal (US$636/tonne) reached a peak in September 2006 (US$1 340/tonne). The average price during 2006 was US$983/tonne (Table 9). The price of fish oil during the period from July 2005 to September 2006 varied between US$637 and US$803/tonne (Figure 13). The average price in 2006 was US$733/tonne (Figure 13). Estimations of the Asociación de Industriales Pesqueros (ASIPES) from the Bio-Bio Region forecasted that the price of fishmeal would be over US$1 000/tonne during the year 2007.

Exapesca S.A. is a Chilean company founded in October 1994 and dedicated to the commercial development of fish oil. At present, it has nine large Chilean fishery subsidiaries located throughout southern Chile and represents 90 percent of the total fishery production in Regions V to X and 64 percent of the total national pelagic fishery production. In terms of national production for 2006, it produced 74 percent of the fishmeal and fish oil.

3.2 Fish-preserving industry

The most important fishery products produced in Chile are fishmeal, fish oil, and frozen, fresh chilled and canned products. In Chile, there are a total of 760 plants for the processing and preserving of fishery products. Around 41 percent of the plants are dedicated to frozen products, and only 5 percent of the plants to the manufacture of fishmeal and fish oil. Figure 14a shows the distribution of these plants by type of process line, whereas Figure 14b indicates the distribution of plants by region. Sixty-eight percent of the plants are concentrated in the south-Austral zone. Regions VIII, X and XII contain a total of 457 processing plants, representing 18, 33 and 10 percent of all the plants in Chile, respectively. Table 10 shows the number of processing plants by region and by type of process line.

In 2005, 1.78 million tonnes of processed fish products were produced, which represents 39.4 percent of the total landings in Chile (4.53 million tonnes). Fishmeal and fish oil represent around 56 percent of the products processed, followed by frozen products with 27 percent, while fresh chilled and canned (preserved) products together represent 17 percent (Figure 15).

During the period 1995–2005, the production of fishery-processed products declined in line with the decline in total landings, which decreased by 39 percent, while the production of processed products dropped by 22 percent (Table 11 and Figure 16). However, if the development of processed products for human consumption is compared (adding frozen, fresh chilled and canned products) with fishmeal and fish oil production (Figure 17), we can observe that while fishmeal has maintained a constant reduction of 47 percent during the period 1995–2005, development of products for human consumption shows a sustained growth of 166 percent during this period.

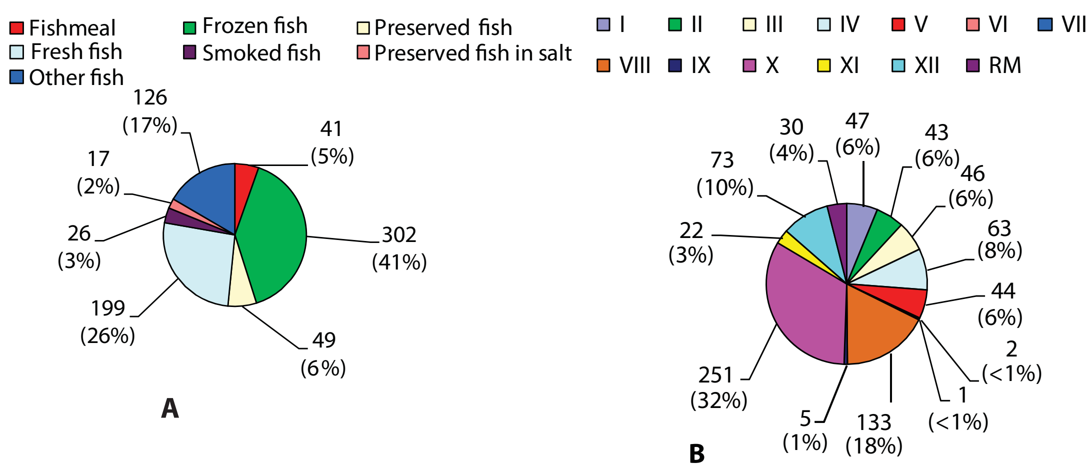
TABLE 9
Monthly variation of fishmeal and fish oil prices, July 2006 - September 2006

Year	Month	Fish oil	Fishmeal
2005	Jul	676	636
	Aug	661	657
	Sep	639	672
	Oct	676	700
	Nov	654	723
	Dec	637	731
Mean		657	687
2006	Jan	671	757
	Feb	700	786
	Mar	701	807
	Apr	716	844
	May	739	886
	Jun	761	980
	Jul	754	1 166
	Aug	803	1 283
	Sep	750	1 340
Mean		733	983

Source: Aqua (2006)

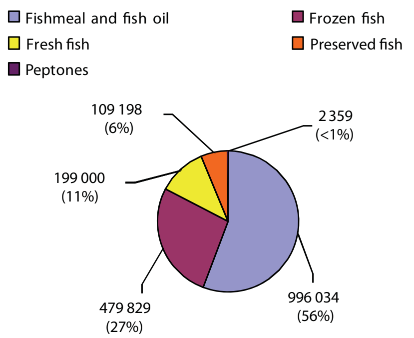
When the production of processed products for human consumption is divided into frozen, canned and fresh chilled, we can observe that the frozen products maintain a significantly greater production than the other products. The frozen and fresh chilled products have maintained a continuous growth during the period 1995–2005,

FIGURE 14
Percent distribution of all the processing plants in Chile by type of product and region



Source: SERNAPESCA (2006)

FIGURE 15
Production (tonnes) and percent distribution of main fishery processed products, 2005



Source: SERNAPESCA (2006)

with an increase of around 176 percent and 411 percent, respectively. The total production of frozen products has increased from 174 to 480 thousand tonnes, whereas that of fresh chilled products grew from 39 to 199 thousand tonnes. Production of canned fish products has stagnated during the same period, the average annual growth being -3.3 percent (Figure 18).

3.2.1 Frozen products

In 2005, the total production of frozen products was 480 thousand tonnes, of which 90 percent correspond to fish (432 thousand tonnes), 8.7 percent to molluscs (42 thousand tonnes), 1 percent to crustaceans (4.6 thousand tonnes) and 0.3 percent to other species (1.5 thousand tonnes). Of the production of frozen fish, 55 percent corresponds to

TABLE 10
Number of processing plants in Chile by product line and region, 2006

	Chilean region													
Product line	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**RM**	**Total**
Fishmeal	5	2	3	4	2	0	0	20	0	4	1	0	0	41
Frozen fish	4	10	6	30	28	2	1	44	1	115	12	36	13	302
Preserved fish	1	0	1	6	0	0	0	14	0	22	0	5	0	49
Fresh fish	14	17	12	14	11	0	0	15	2	70	8	27	9	199
Smoked fish	0	0	0	1	0	0	0	2	2	20	0	0	1	26
Fish preserved in salt	10	3	0	0	0	0	0	0	0	3	0	1	0	17
Other fish	13	11	24	8	3	0	0	38	0	17	1	4	7	126
Total	**47**	**43**	**46**	**63**	**44**	**2**	**1**	**133**	**5**	**251**	**22**	**73**	**30**	**760**

Source: SERNAPESCA (2006)

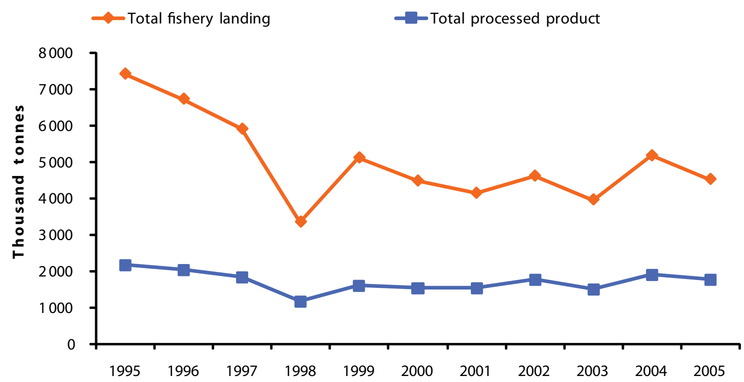
TABLE 11
Production of main processed fish products, 1995–2005 (thousand tonnes)

	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Total fishery landing	7 411	6 726	5 905	3 362	5 118	4 486	4 151	4 621	3 971	5 176	4 531
Fishmeal	1 553	1 399	1 225	643	1 000	877	778	843	705	988	827
Fish oil	326	292	206	107	201	180	141	128	130	194	169
Frozen fish	174	179	216	226	223	288	390	380	378	447	480
Fresh fish	39	77	74	78	73	99	135	128	164	164	199
Preserved fish	84	79	118	117	110	110	108	286	115	116	109
Peptones*	0	0	0	0	0	0	0	2	3	2	2
Total processed products	**2 176**	**2 025**	**1 839**	**1 170**	**1 608**	**1 555**	**1 551**	**1 767**	**1 494**	**1 912**	**1 786**

* Peptones are protein hydrolysates that are soluble in water and not heat coagulable. These products may have significant value for the fisheries industries because their market prices are somewhat higher than those of the usual by-products such as fish silage and fishmeal.

Source: SERNAPESCA (2006)

FIGURE 16
Fishery landing trends compared with processed production



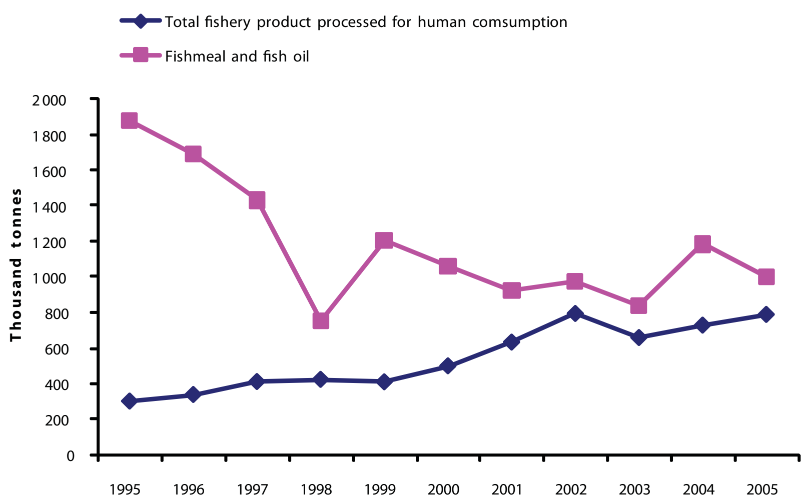
Source: SERNAPESCA (2006)

cultivated fish (mainly Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*)), 35 percent corresponds to pelagic fish (anchoveta, jack mackerel, South Pacific hake and sardine) and the remaining 10 percent is comprised of other fish (Figure 19).

In 2005, 78 percent (116 000 tonnes) of frozen pelagic fish products was made from jack mackerel, 16 percent South Pacific hake (23 000 tonnes) and 5 percent chub mackerel (7.6 thousand tonnes), with anchoveta and sardines together contributing only 1 percent (Table 12 and Figure 20).

Pelagic fish that are traditionally destined to the reduction industry have made a significant contribution to the growth in the production of frozen products. Over the period 1995–2005, their contribution has increased by around 700 percent, rising from a total of 21 thousand tonnes in 1995 to 147 thousand tonnes in 2005. The greatest

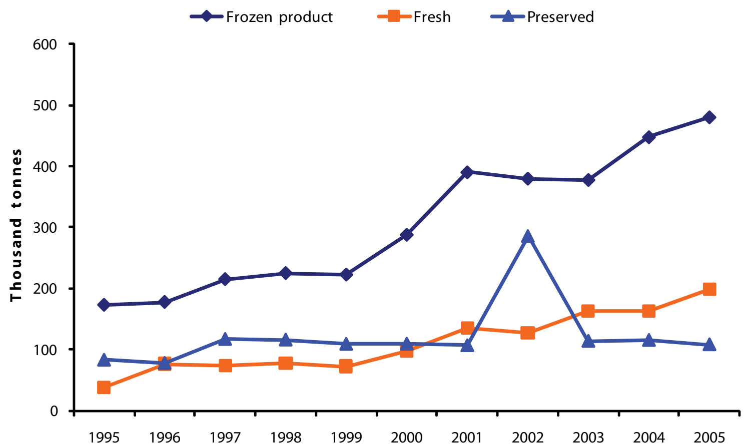
FIGURE 17
Fishmeal and fish oil production trends compared only with trends in production of processed fishery products for direct human consumption, 1995–2005



Source: SERNAPESCA (2006)

contribution to growth is provided by jack mackerel, chub mackerel and South Pacific hake, with an average increase during this period of almost 1 157 percent. Nevertheless, the production of frozen product from smaller pelagic fish (anchoveta and sardines) has decreased by an average of around 87 percent (Table 12 and Figure 21).

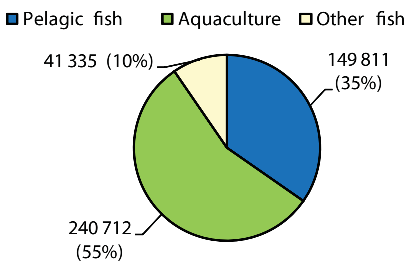
FIGURE 18
Annual production trends of the main processed fishery products for direct human consumption during the period 1995–2005
Source: SERNAPESCA (2006)



Source: SERNAPESCA (2006)

Figure 22 and Table 13 show the total pelagic fish landings and the production of frozen fish and fishmeal. It can be observed that from the first half of the decade 1995–2005 the production of fishmeal from the pelagic fish landings has stayed more or less constant, with an average of 21 percent; however, the production of frozen fish has shown an increase from 0.7 to 4.1 percent, which means that the growth in frozen fish production has not affected fishmeal production, a fact that could be explained by the reduction of other types of processed products.

FIGURE 19
Production (tonnes) and percent distribution of frozen fish, 2005

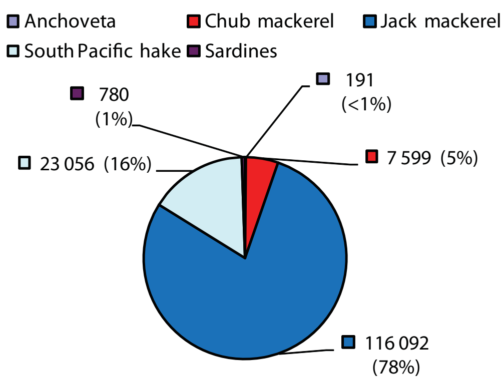


Source: SERNAPESCA (2006)

3.2.2 *Chilled fresh products*

The total chilled fresh fish production is around 199 thousand tonnes, of which 98.5 percent corresponds to fish (196 thousand tonnes), 0.84 percent to molluscs (1.7 thousand tonnes), 0.01 percent to crustaceans (29 tonnes) and 0.7 percent to other species (1.3 thousand tonnes). Of the total production of fresh chilled fish, 93 percent corresponds to cultivated fish, mainly Atlantic salmon, coho salmon (*Oncorhynchus kisutch*), rainbow trout and turbot (*Psetta maxima*), 7 percent to pelagic fish (anchoveta, jack mackerel, South Pacific hake and sardine) and a very small percentage to other fish (Figure 23).

FIGURE 20
Production (tonnes) of pelagic fish processed as frozen products, 2005



Source: SERNAPESCA (2006)

3.2.3 *Canned products*

The total production of canned fishery products in 2005 was 109 thousand tonnes, of which 91 percent corresponded to fish (99 thousand tonnes), 8.8 percent to molluscs (9.6 thousand tonnes) and 0.2 percent to crustaceans

TABLE 12

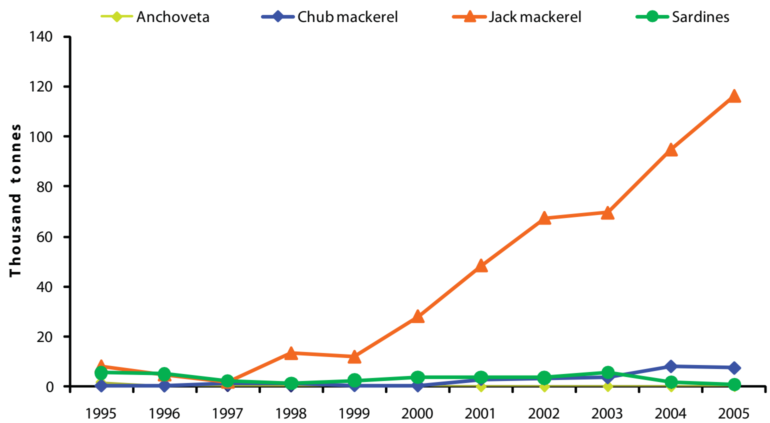
Production of frozen products from small pelagic species, 1995–2005 (thousand tonnes)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Anchoveta	1.66	0.04	0.16	0.02	0.36	0.05	0.09	0.07	0.17	0.09	0.19
Chub mackerel	0.39	0.45	1.14	1.18	0.53	0.50	3.06	3.25	3.74	8.26	7.60
Jack mackerel	8.15	4.83	1.92	13.37	11.97	28.15	48.41	67.42	69.43	94.66	116.09
South Pacific hake	5.64	1.94	4.05	4.98	4.92	3.08	9.96	16.58	22.68	21.34	23.06
Sardines	5.31	4.89	2.15	1.16	2.34	3.75	3.74	3.40	5.47	1.75	0.78
Total	**21.15**	**12.15**	**9.41**	**20.70**	**20.13**	**35.53**	**65.26**	**90.72**	**101.48**	**126.09**	**147.72**

Source: SERNAPESCA (2006)

FIGURE 21

Production of frozen products from the main pelagic species, 1995–2005



Source: SERNAPESCA (2006)

TABLE 13

Production of fishmeal and frozen products from the main pelagic fish species in Chile (thousand tonnes)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Total pelagic fish landing	7 096	6 414	5 560	3 041	4 576	4 868	3 516	4 032	3 368	4 477	3 577
Fishmeal	1 553	1 399	1 225	643	1 000	877	778	843	705	988	827
Frozen products	21	12	9	21	20	36	65	91	101	126	148
% fishmeal	22	22	22	21	22	18	22	21	21	22	23
% frozen products	0	0	0	1	0	1	2	2	3	3	4

Source: SERNAPESCA (2006)

TABLE 14

Production of fresh chilled fish from pelagic species, 1995–2005 (thousand tonnes)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Anchoveta	0	0	0	134	5	0	0	3	87	129	5
Chub mackerel	0	0	0	0	0	3	28	44	15	0	0
Jack mackerel	285	8 444	9	79	499	3 272	11 281	3 301	757	321	256
Sardines	10	8 512	0	0	0	256	33	138	94	0	0

Source: SERNAPESCA (2006)

TABLE 15

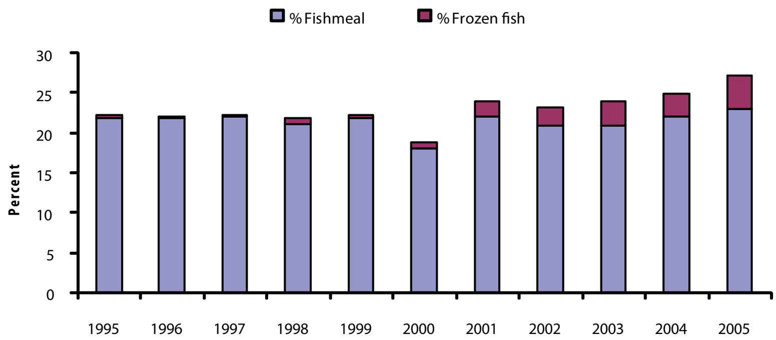
Production of canned fish from pelagic species, 1995–2005 (thousand tonnes)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Anchoveta	0	0	0	0	0	1	0	0	0	0	0
Chub mackerel	1	0	1	1	1	1	5	3	5	12	5
Jack mackerel	60	63	99	103	95	99	92	273	100	94	94
Sardines	11	2	4	1	0	1	0	0	0	0	0
Total	**73**	**66**	**104**	**105**	**97**	**101**	**98**	**276**	**105**	**105**	**99**

Source: SERNAPESCA (2006)

FIGURE 22

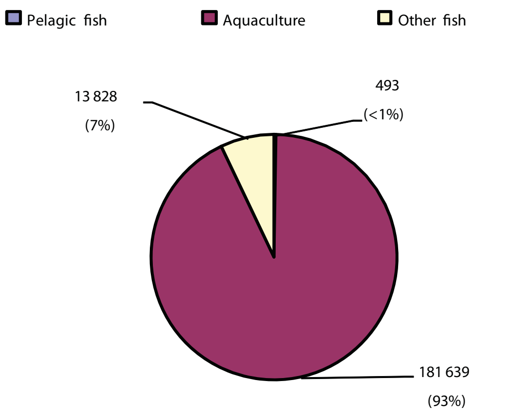
Relative proportion of fishmeal and frozen fish produced from the total landing, 1995–2005



Source: SERNAPESCA (2006)

FIGURE 23

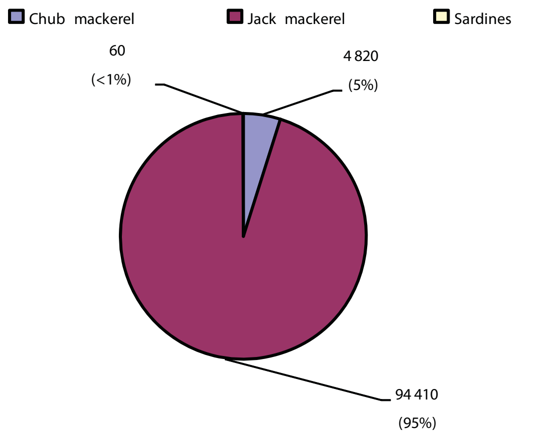
Production (tonnes) of fresh chilled fish, 2005



Source: SERNAPESCA (2006)

FIGURE 24

Production (tonnes) of canned pelagic fish processed from main species, 2005



Source: SERNAPESCA (2006)

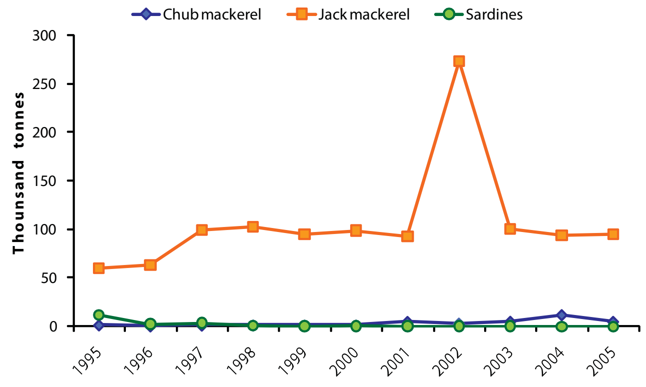
TABLE 16

Production of fishmeal and canned fish from pelagic species in Chile (thousand tonnes)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Total pelagic fish landing	7 096	6 414	5 560	3 041	4 576	4 868	3 516	4 032	3 368	4 477	3 577
Fishmeal	1 553	1 399	1 225	643	1 000	877	778	843	705	988	827
Canned fish	73	66	104	105	97	101	98	276	105	105	99
Percent fishmeal	22	22	22	21	22	18	22	21	21	22	23
Percent canned fish	1.0	1.0	1.9	3.4	2.1	2.1	2.8	6.9	3.1	2.4	2.8

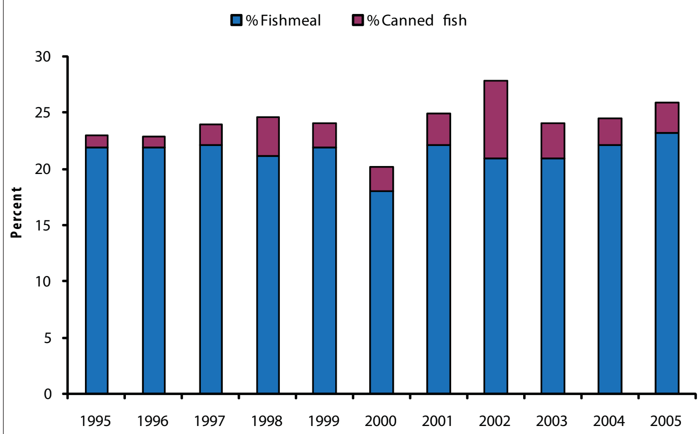
Source: SERNAPESCA (2006)

FIGURE 25
Production of canned products from the main pelagic species, 1995–2005



Source: SERNAPESCA (2006)

FIGURE 26
Fishmeal and canned fish production from pelagic fish species, 1995–2005



Source: SERNAPESCA (2006)

(214 tonnes). The total production of canned fish was entirely derived from pelagic species (anchoveta, jack mackerel and sardines) (Table 15).

In 2005, 95 percent (94 thousand tonnes) of the production of canned pelagic fish was from jack mackerel, 5 percent from chub mackerel (4.8 thousand tonnes) and less than 1 percent from anchoveta and sardines (Table 15 and Figure 24).

During the period 1995–2005, the production of canned products from pelagic fish increased by 36 percent, rising from a total of 73 thousand tonnes in 1995 to 99 thousand tonnes in 2005. This growth was due to the increased use of jack mackerel (whose contribution rose by 58 percent), while the use of other pelagic fish did not have a significant impact on the production of canned products (Table 15 and Figure 25).

Table 16 and Figure 26 and show a comparison of total landings of and fishmeal and canned products produced from the main pelagic species. It can be observed that from the second half of the decade 1995–2005, the production of fishmeal from overall pelagic fish landings was more or less constant, with an average of 21 percent. However, production of canned products from the same species presented a slight increase, rising from 2.1 to 2.8 percent. The increasing production of canned products from pelagic fish did not impact fishmeal production.

3.2.4 Destination of main processed products

From January to March 2007, the Chilean export of fish products showed an increase of 34.6 percent over the same period in 2006 (SERNAPESCA, 2007). Almost 46 percent of exports was frozen products and 33.5 percent was fishmeal, followed by exports of chilled fresh and canned fish products. The majority of these exports were derived from salmonids produced by the aquaculture industry. Besides fishmeal that is produced from pelagic fisheries, the remainders of the processed and preserved products that are derived from non-salmonid aquatic species do not contribute significantly to the total export values. As of February 2006, 88 countries were destinations for fishery exports. Nine countries account for 81.6 percent of the total value exported, the most important being Japan (32.7 percent), the United States of America (23.4 percent), China (6.3 percent) and Spain (5.2 percent).

4. USE OF FISHMEAL AND FISH OIL IN AQUAFEED

The fishmeal that is used in the manufacture of aquafeeds in Chile is all produced domestically. Most of the aquafeed manufacturing companies make use of high-quality fishmeal with low biotoxic residues (minimum toxic biogenic amines content) made from fresh raw ingredients. The average price of fishmeal during 2006 was approximately US$1 200/tonne, which together with the vitamin premix and carotenoids pigments, represents more than 60 percent of the total costs of aquafeed ingredients.

4.1 Chilean aquaculture production

The aquaculture of salmon and trout has a special importance in Chile. The enabling environmental conditions and abundant water resources, together with the availability of advanced scientific and technological know-how, have made Chile to become the second largest producer of salmon after Norway. The Chilean aquaculture industry is now one of the main sources of income and employment in the country. It is also one of the most important export sectors in Chile, contributing 22.2 percent of the total food products exported.

There are around 65 Chilean companies dedicated to fish culture, with 1 400 authorized salmon farming centres. Most of the Chilean salmon producers are members of the Chilean Salmon and Trout Producers Association, which is known as SalmonChile. This association was founded in 1986 by 16 of the main companies and has the main objective of ensuring the quality standards of produced and processed salmon.

During 2005, the total aquaculture production in Chile reached a volume of around 739 thousand tonnes, with salmonids contributing about 83 percent of the total, followed by molluscs (14 percent) and seaweeds (3 percent).

There are also some preliminary projects that aim to enhance the development of new species aquaculture in different regions of the country. These initiatives are promoted by the central government through the Chilean Economic Development Agency (Corporación de Fomento de la Producción, CORFO).

4.2 The aquafeed industry

Nowadays, in Chilean salmon aquaculture, the feed constitutes about 60–70 percent of the costs at the farm level and about 30–35 percent of the total cost of the final product once it is processed and packaged. In the beginning years of the Chilean salmon aquaculture industry, feed production was the exclusive responsibility of the aquaculture farms, and the diet formulation was essentially a mix of cattle entrails (predominantly liver), wheat by-products, fishmeal and occasionally, vitamins or special additives. Entrails were crushed in small mills and manually mixed with the rest of the ingredients. Intensive commercial aquaculture operations and industrial aquafeed companies started up in 1984 when the high demand for aquafeeds made it necessary to produce diets in the form of pellets whose formulation was based almost exclusively on the use of fishmeal and fish oil as main ingredients (Bórquez *et al.*, 1996). Since then, new feed production technologies and feed formulations have been incorporated into aquafeed industry operations, and the quality control of ingredients employed has become more rigorous.

Initially most of the aquafeeds employed in the Chilean aquaculture industry (fundamentally, in salmonid culture) was of a very simple formulation based on a high percentage (around 60 percent) of fishmeal as the main protein source, together with wheat flour, mineral premix and vitamins (Bórquez *et al*., 1996). The average concentrations of fishmeal and fish oil used in aquafeeds by Chilean salmon aquaculture operations during 2006 were around 25–30 percent and 15 percent, respectively. These values represent a significant reduction in the use of these ingredients in salmonid feeds when compared with the levels used during the mid-1980s.

It is important to stress that fishmeal is considered the best protein source for salmonid aquafeeds mainly because of its high protein content and suitable amino acid profile. Salmonids are carnivorous species that are able to make use of this kind of protein source in an efficient manner. However, the limited availability of fishmeal, unstable prices and a principle of economic and environmental sustainability have driven the national aquaculture industry to look for fishmeal substitutes. Consequently, the reduction of fishmeal inclusion levels during the last five years has been both accelerated and substantial. This reduction has been the result of sustained and joint research between aquafeed companies and universities in Chile. The average feed conversion ratio with these innovative low-fishmeal diet formulations in the Chilean aquaculture industry is around 1.35, meaning that the amount of aquafeed required to produce a tonne of fish is around 1 350 kg and that the amount of fishmeal incorporated in these diets is approximately 405 kg.

4.3 Aquafeed-producing factories in Chile and installed production capacity

During the 1990s, in Chile there were around 23 salmon feed factories that produced approximately 100 thousand tones of feed; however, the feed production subsector has consolidated and specialized, generating diverse types of diet that optimize nutritional content and create pellets which are resistant to crumbling (Bórquez and Zuñiga, 1995). Since 2000, there are seven major aquafeed manufacturing plants belong (Skretting Chile, Ewos Chile S.A., BioMar Chile S.A., Alitec S.A., Salmofood S.A., Salmones Antartica S.A. and Cultivos Marinos Chiloé Ltda) that all together produce nearly 700 thousand tonnes of feed per year. The installed production capacity of Chilean salmon feed plants was around 1.2 million tonnes in 2003 (SalmonChile, 2003).

4.4 Innovative use of alternative protein ingredients in Chilean aquafeeds

Most diets for carnivorous fish are heavily dependent on fishmeal as the main protein source. Fishmeal is prepared from dried, ground tissue of whole marine fish, mainly pelagic species such as jack mackerel, anchovy and sardines, or from the waste of processed fish products. Feed is the highest recurrent cost in aquaculture and represents more than 60 percent of the variable operating costs, depending on the intensity of the operation. In general, fishmeal is considered a conventional and important ingredient of aquaculture diets. Fishmeal contains from 55 to 75 percent protein, depending on the species of fish used. Li *et al.* (2000) reported that fishmeal contains from 5 to 10 percent oil, making it rich in energy and essential fatty acids, together with bones and other sources of essential minerals. Currently, an important proportion of the world's supply of fishmeal is used by aquaculture, followed by poultry raising, swine production and other applications. The worldwide production of feed for aquaculture currently consumes around 46 percent of the available fishmeal. According to the projections, the demand in 2010 will double. Traditionally, fishmeal is the most important protein source in formulated diets of carnivorous fishes (Hardy, 1989; Pike, Andorsdottir and Mundheim, 1990; Donaldson, 1997).

Salmonid aquaculture depends on fishmeal, which constitutes a substantial part of the concentrated feeds that are used for these species, because of its essential amino acid content (Cowey, 1994), the high bioavailability of amino acids (IAFMM, 1970) and also its high palatability (Pike, Andorsdottir and Mundheim, 1990). But fishmeal is an expensive ingredient, and global supplies are becoming insufficient to sustain aquaculture production that uses fishmeal-based feeds. In addition, further increases in fishmeal prices are expected due to the anticipated increase in the amount of marine raw materials used by aquaculture (Hardy, 1995), which will result in increased demand for this finite resource (Rumsey, 1993; Hardy, 1996).

Therefore, rational use of fishmeal is a priority if further development of aquaculture is to be sustainable (Bardach, 1997). The need for alternative protein sources to replace fishmeal has been recognized, alternatives are needed also because the rich phosphorus content of fishmeal leads to increased pollution of receiving waters through aquaculture effluents. In response to environmental concerns, fishmeal production sustainability issues and increased costs, efforts are focused on research aiming to reduce or eliminate phosphorus from fish feeds employed in aquaculture. The resultant efforts have led to the development of many plant feedstuffs that have already been tested in the diets of freshwater and marine fish. Total or partial substitutes for fishmeal by the inclusion of alternative protein sources having low phosphorus content has been used in freshwater and marine species with varying success (Pongmaneerat *et al*., 1993; Viyakarn *et al*., 1992; Watanabe *et al*., 1993, 1997, 1998; Ketola and Richmond, 1994; Akiyama *et al*., 1995; Luzier, Summerfelt and Ketola, 1995; Riche and Brown, 1999; Storebakken, Shearer and Roem, 2000; Satoh *et al*., 2003; Hernandez *et al*., 2004). If Chile intends to maintain its international position as a leading salmonid producer, it is imperative that it evaluates the use of new vegetable protein sources produced in the country as alternatives to fishmeal.

The main factors in the selection and use of alternative protein ingredients for commercial aquaculture diets are that the ingredients contain a sufficient amount of essential nutrients for optimal growth of fish and that the nutrients are digestible, bioavailable and commercially available at a reasonable cost, and do not contain antinutritional factors and toxic substances. Enhancement of the nutritional quality of alternative ingredients is one of the main strategies in the sustainable development of national aquaculture. Efficiency of alternative plant raw materials could be maximized by means of biotechnological processes that aim to enhance the abovementioned factors. In this sense, biotechnological innovations aimed at concentrating the protein content, improving the essential amino acids profile (sulfured amino acids), reducing the level of carbohydrates and fiber, and increasing nutrient digestibility and energy availability will make possible the optimal use of plant raw materials. Among the biotechnological processes, bioconversion has emerged as a potential technology for the production and use of agro-industrial products and by-products, and provides an alternative for the improved utilization of alternative protein sources that in another form would be limited or simply would not be available.

In Chile, a great portion of the fishmeal component in aquafeeds has been progressively replaced by plant and animal protein substitutes. Among the main ingredients that have been recently used to replace fishmeal and those that will gain more relevance in the near future are: corn gluten meal, lupine, peas, sunflower, feather meal, canola meal, soybean meal and bio-proteins. Plant protein concentrates with high nutritional value and digestibility, as well as some animal protein meals, will acquire great importance in the coming years.

Use of fishmeal substitutes by the Chilean aquafeed industry was initiated around ten years ago as a direct result of the reduction in capture volumes of small pelagic species. These substitutes have been used considerably and are effective and viable. Nowadays, a greater percentage of the protein fraction in aquafeed is of plant origin, and these plant protein resources are expected to substitute, for around 50 and 50–80 percent of the fishmeal and fish oil respectively, currently being used.

Fishmeal substitution by other protein alternatives is a primary objective for Chilean aquafeed companies. The replacement must be done in a way that does not affect productive performance, health and the sanitary quality of fish. This replacement still requires intensive and advanced research, as well as a great economic effort. The Government of Chile has identified aquaculture research as a priority and one of the most strategic sectors for national development. Considerable resources are invested in this area, and there are numerous projects aimed to increase the inclusion of alternative protein sources in aquafeed through research in nutrition, genomics, proteomics, biotechnology and new feed technology processes.

When considering fish oil replacement, numerous researchers have concluded that this aquafeed ingredient can be exchanged at a level of 50 percent with alternative vegetal oils without affecting the productive performance, normal growth, health or nutritional quality of fish. Nowadays, the Chilean aquafeed industry incorporates in the diets around 30–50 percent of vegetable oils and between 50 and 65 percent of fish oils. Fish oil is very important in salmon diets, mainly because it can supply the essential omega-3 fatty acids (eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)) that are necessary for the normal metabolic functions and well-being of the fish. These essential fatty acids that deposit in salmon muscle can also have important nutritional functions for human health, including reduction of cardiovascular diseases, cancer and diabetes. Additionally, these fatty acids have an important role in the development of the nervous system and in the normal metabolic functions of the body. Some vegetal oils that are rich in omega-3 fatty acids can substitute a portion but not all of the fish oil in the aquafeed formulations.

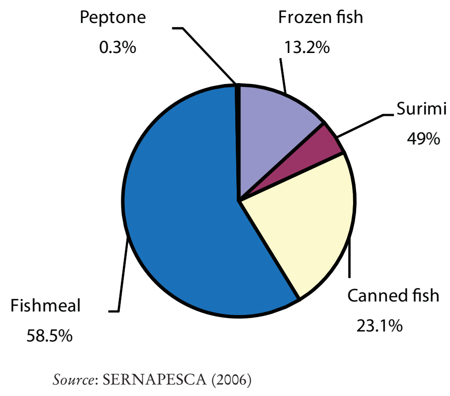
Currently, the main limitation is that there are not enough commercially available sources for these fatty acids except fish oil. However, there have been important scientific advances with promising results for the development of new sources of fatty acids with the capacity to generate or convert into EPA and DHA. These advances will reduce the high dependence of the salmon aquafeed industry on fish oil as the main source of essential fatty acids.

5. CASE STUDY: THE JACK MACKEREL RESOURCE IN REGION VIII, BIO-BIO, CHILE

The national fishery sector has been affected by a strong contraction of the labour force during the last decade. Some of the main causes for this reduction are related to the decline of the industrial fishing fleet and the optimization of production processes in processing plants.

Market demand and the intention to increase productivity require increased specialization and training of the labour force. Increasing the skill levels of the labour force in the Chilean aquaculture industry could compensate for a possible high reduction of employment in fishing fleets and processing plants. However, it is unlikely that the employment levels previously enjoyed by the fishing sector would be achieved, at least over the short- and medium-term. Even though the salmon aquaculture industry is a major and reliable employment generator in many areas of Chile, the skill levels in communities where salmon aquaculture takes place are much lower than the national average. Changing demands for labour

FIGURE 27
Destination of jack mackerel captures in Region VIII, Bio-Bio, Chile



Source: SERNAPESCA (2006)

Coquimbo Port, Coquimbo, northern Chile

in the sector represent both a challenge and an opportunity for the unqualified workers that characterize the poorest groups of the country. Therefore, the employment that is generated by this expanding industry has a positive and direct impact on the poverty indicators of communities where aquaculture is developed.

5.1 Introduction

Question: Could the Region VIII of Bio-Bio obtain more social and economic benefit and improved food security if the jack mackerel resource were used mainly for human consumption instead of for reduction?

Region VIII (Bio-Bio) contains the most important fisheries landing sites in Chile for the main pelagic species, including jack mackerel. The total fisheries landing in Chile during 2005 was 5.5 million tonnes, of which Bio-Bio contributed 1.91 million tonnes or 34.1 percent. Jack mackerel landings in Bio Bio represent around 50.3 percent (960 thousand tonnes) of the total fisheries landings for the Region and 67.1 percent of all the jack mackerel captured (1.43 million tonnes). The artisanal fishery sector contributes only 1.7 percent (16.72 thousand tonnes) of the total jack mackerel landed in Region VIII and has around 2 617 boats, of which 733 are dedicated to the jack mackerel resource (SERNAPESCA, 2006). The industrial fishing sector in Region VIII operates only 102 vessels.

The industrial fishing sector in Bio-Bio employs 14 771 people (63 percent men and 37 percent women); 7 891 workers are employed in processing plants (fishmeal, canning, frozen, etc.), 982 people are employed on vessels (on average, each vessel operates with a crew of 9.6 persons) and 5 580 are employed in aquaculture centers (SERNAPESCA, 2006). The artisanal fishing sector employs 12 434 people (91 percent men and 9 percent women) as follows: shipbuilding – 1 451 people, shellfish collectors – 2 304 people, seaweed harvesters – 1 949 people and artisanal fishermen – 10 139 people (Montoya, 2006).

Region VIII has 133 processing plants, with some of them dedicated to more than one line of production: 20 plants for fishmeal and fish oil, 44 plants for frozen fish, 14 for canned fish, 15 for fresh chilled fish, two for smoked fish and 38 for other fish products (SERNAPESCA, 2006). The total number of plants in the region represents 17.5 percent of the fish processing plants in the country.

5.2 Use of jack mackerel for reduction and human consumption

An analyse the destination of the jack mackerel captures, we can observe that 41.5 percent were destined to human consumption, as can be seen in Figure 27.

In the artisanal fishing sector the landed prices for chub mackerel and jack mackerel were as follows: monthly average price US$809 per tonne (minimum price US$56.9 per tonne and maximum price US$2 365 per tonne). The same resources in the industrial sector registered landing prices with a monthly average of US$110 per tonne (the minimum price was US$53.20 per tonne and the maximum was US$151.40 per tonne). Considering the monthly average price in 2006, the artisanal sector of Region VIII obtained gross revenues for the jack mackerel resource of around US$13 525 935; this value divided by the number of artisanal fishers results in an annual average per capita income of US$1 334. Based on the monthly average price of jack mackerel industrial landings, a gross income of about US$105 370 326 was generated, which represent an annual average income per boat of approximately US$1 033 042 or US$1 982 per crew member.

National fishmeal production is about 829 thousand tonnes, of which 221 thousand tonnes come specifically from the jack mackerel resource (SERNAPESCA, 2006). The fishmeal production in Region VIII is around 435 thousand tonnes (52.6 percent of the national production); of this, 176 thousand tonnes are from jack mackerel, which represents 40.4 percent of the total fishmeal production of the Region. According to the fishing industry, to produce 1 tonne of fishmeal requires around 4.1 tonnes of fresh fish, which means that in Region VIII, 712 thousand tonnes of fresh jack mackerel were used to produce 176 thousand tonnes of fishmeal (SERNAPESCA, 2006). Considering that the average sale price during 2005 was US$643 per tonne, the gross income from fishmeal produced in Region VIII was approximately US$113 200 000.

The export of jack mackerel during 2005 reached values of around US$164.8 million, ranking third in importance among total national exports of fish. During that year, canned jack mackerel represented 52 percent of the total exports for this species, followed by frozen jack mackerel with 35 percent and surimi with 12 percent. If the

TABLE 17

Volumes and FOB values of processed jack mackerel by product line in Region VIII

Product line	Raw material (tonnes)	Processed product (tonnes)	Relation RM/PP*	FOB value (US$/ tonne processed)	Total value (US$ million in 2005)
Fishmeal	712 311	175 985	4	643	113
Canned fish	281 885	93 707	3	1 059	99
Frozen fish	160 716	115 846	1	473	55
Surimi	59 948	17 277	3	1 130	20
Peptones	3 711	916	4	1 052	1
Fresh cooled fish	283	256	1	482	0
Smoked fish	28	17	2	4 000	0
Total	**1 218 882 ****	**404 004**	**3**		**288**

* RM/PP: relation between raw material and processed product.

** According to the national statistics service SERNAPESCA, the jack mackerel total landing in Region VIII is 969 thousand tonnes; however, the statistics of the SERNAPESCA affiliated institutions responsible for one specific product line give values that are greater than the registered landings for the region. Apparently, the fish processing industry in Region VIII receives raw material from others regions.

Source: SERNAPESCA (2006); BCC (2006)

TABLE 18

Adjusted volumes and FOB values of processed jack mackerel by product line in Region VIII*

Product line	Raw material (tonnes)	Processed product (tonnes)	Relation RM/PP**	FOB value (US$/ tonne processed)	Total value (US$ million in 2005)
Fishmeal	561 226	138 658	4	643	89
Canned fish	222 096	73 831	3	1 059	78
Frozen fish	126 627	91 274	1	473	43
Surimi	47 233	13 612	3	1 130	15
Peptones	2 924	722	4	1 052	1
Fresh chilled fish	223	202	1	482	0
Smoked fish	22	36	1	4 000	0
Total	**960 350**	**318 335**	**3**		**227**

*Adjusted volumes and values in relation to the true jack mackerel landing in Region VIII.

**RM/PP: relation between raw material and processed product.

Source: SERNAPESCA (2006); BCC (2006)

total value of the jack mackerel processed products for export was about US$164.8 million, the contribution from Region VIII was on the order of 78 percent (BCC, 2006).

5.3 Evaluation of alternative-use scenarios

Table 17 shows the volumes of processed jack mackerel by type of processing and the US$ freight on board (FOB) value, Table 18 describes the adjusted values in relation to the real jack mackerel landing in Region VIII and Table 19 presents a simulation that considers three different scenarios:

- the *first scenario* considers that the entire volume of jack mackerel that is currently destined for fishmeal production and be used in equal proportions for the production of frozen and canned products;
- the *second scenario* considers that the whole volume of jack mackerel that is currently used for fishmeal is destined for the production of canned products; and
- the *third scenario* allocates the jack mackerel used for fishmeal production to the preparation of frozen products.

TABLE 19

Simulation of volume and value of jack mackerel for human consumption that are destined for fishmeal production in Region VIII

	Fishmeal	Canned product	Frozen product	Surimi	Peptones, cooled fresh and smoked	Total
Present situation*						
Landing (tonnes)	561 226	222 096	126 627	47 233	3 169	960 350
Destination (%)	58	23	13	5	0	100
Processed product (tonnes)	138 658	73 831	91 274	13 612	0	317 376
Value of processed product (million US$)	89	78	43	15	1	227
Scenario 1						
Landing (tonnes)	0	502 708	407 240	47 233	3 169	960 350
Destination (%)	0	52	42	5	0	100
Processed product (tonnes)	0	167 569	290 886	13 612	0	472 068
Value of processed product (million US$)	0	177	138	15	1	331
Scenario 2						
Landing (tonnes)	0	783 321	126 627	47 233	3 169	960 350
Destination (%)	0	82	13	5	0	100
Processed product (tonnes)	0	261 107	91 274	13 612	0	365 994
Value of processed product (million US$)	0	277	138	15	1	431
Scenario 3						
Landing (tonnes)	0	222 096	687 853	47 233	3 169	960 350
Destination (%)	0	23	72	5	0	100
Processed product (tonnes)	0	74 032	491 324	13 612	0	578 968
Value of processed product (million US$)	0	78	232	15	1	327

**Source*: SERNAPESCA (2006); BCC (2006)

The sale price of jack mackerel that was destined for freezing and canning during 2005 was US$473.00/tonne and US$1 059.90/tonne, respectively (BCC, 2006). If the volume of jack mackerel intended for fishmeal production were used instead for frozen fish (with a yield of 0.71 tonne frozen per 1tonne fresh fish), 491 thousand tonnes of frozen jack mackerel with an approximate value of US$302 760 667 could be produced. Bearing in mind that Region VIII has around 44 processing plants with the capacity to process 161 thousand tonnes of frozen products, it can assumed that at least triple the number of plants would be needed and consequently, the demand for labour could grow in the same proportion (scenario 1).

In the same way, if the volume of jack mackerel destined for reduction were used for canned fish (scenario 2)., with a yield of 0.33 tonne of canned per tonne of fresh jack mackerel, around 235 thousand tonnes of canned products with a value of US$248 930 658 could be produced, and the waste residue (head, tail, entrails) could be used to produce 110 thousand tonnes of "standard fishmeal" with a value of US$87 756 715. At the moment, Region VIII has 14 processing plants producing 94 thousand tonnes of canned jack mackerel. To process all jack mackerel in canned form would require double the number of plants and labour force.

In the first scenario, the total income derived from jack mackerel processed products shows an increase of 46 percent in relation to the income currently derived from fishmeal production. In second scenario, the revenue earned by jack mackerel processed products increased by 89.6 percent, while in the third scenario, the increase is 44 percent. Regarding the volumes of processed products, the first, second and third scenarios show increases of 48.5 percent, 15 percent and 82 percent, respectively. Hence, the highest demand for labour for the production of processed jack mackerel would occur in the first and third scenarios.

Although Chile is a country with a long coastline, there is a limited tradition of seafood consumption. Per capita consumption in the country is not higher than 7 kg/year; therefore, an increase in jack mackerel production aimed for human consumption would have a limited impact on the per capita consumption. Changing the destination of jack mackerel from reduction to processing for human consumption could have a greater impact in the export sector of Chilean fishery products. Chile has a free-market economy that bases its development on the economic diversification of products for export; hence, the benefits from a change in production strategy will mainly accrue to this sector of economic activity. Indirectly, this would result in an increased demand for workers in the canning and frozen fish sectors, assuming that the demand for labour tripled in the processing plants (rising from 7 000 to 21 000 persons) and the level of unemployment declined by 1.9 percent in Region VIII (from 9.6 to 7.7 percent) (INE, 2005).

If jack mackerel landings in Region VIII were reserved exclusively for processed products (frozen and canned products, and surimi, etc.), the result would be a reduction in total Chilean fishmeal production of 176 thousand tonnes (21 percent). The impact on national salmon aquaculture would be limited, as nowadays fishmeal inclusion levels in salmon aquafeeds are around 30 percent, which generates a demand for little more than 30 percent of the national fishmeal production. However, in Chile, all the fish oil produced in the country is used domestically, so a reduction of 21 percent in fishmeal production would result in a reduction in fish oil production of 7.73 thousand tonnes.

At present, the average inclusion of fishmeal in the aquafeeds is around 30 percent, and the average conversion factor of the salmon aquaculture industry is 1.35, meaning that for each tonne of salmon produced, 1 350 kg of feed is consumed and implies that to produce this amount of feed, it is necessary to incorporate 405 kg of fishmeal. To produce 405 kg of fishmeal, 1 687 kg of jack mackerel are required; hence, if only the net weights are considered, only 1.7 kg of jack mackerel are needed to produce 1 kg of salmon.

One tonne of salmon yields approximately 850 kg of headed and gutted (H&G) salmon, while 1 687 kg of jack mackerel yield 843 kg of H&G jack mackerel. As explained in the foregoing paragraph that 1 687 kg of jack mackerel, when reduced to fishmeal, would produce about 1 tonne of salmon and hence, it can be deduced from these values that there is no difference whether salmon or jack mackerel are used for human consumption, because both would eventually yield the same amount of H&G fish. However, the price of salmon H&G is at least four times the price of jack mackerel. From this point of view, the salmon introduces an additional value relative to jack mackerel and benefits the entire country at a macro-economic level. Again, the impacts shown by this analysis relate mainly to the export sector – access to the salmon resource is limited, because it is an expensive product intended for a market with high purchasing power, while jack mackerel is accessible to populations with low buying power.

In summary, diverting jack mackerel from fishmeal production to food production for human consumption might have a positive impact. However, from the point of view of the role of jack mackerel in food security and poverty alleviation, using this resource for human consumption might not have a very significant impact, given that demand for it is not very high and it would be destined mainly for export. Reducing the production of fishmeal will not have a negative impact on national salmon aquaculture, given the present levels of inclusion in salmonid aquafeeds and the surplus of fishmeal, which is generally destined to export. However, there is a socio-economic impact when the production of fishmeal is reduced to increase the production of human food products, as this conversion is only translated into an increase in employment for Region VIII, basically as a result of an increase in the number of processing plants. If there is a high demand for new processing plants, this could result in a need for new investment for construction or if the present plants have unused processing capacity, it could lead to only a small increase in the demand for labour.

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