Ecosystem's Pollution and Health

Summary

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The Humboldt Current Large Marine Ecosystem (hereafter HCLME) is characterized by its high productivity, which is based on an upwelling system. This system, in turn, supports both an elevated phytoplankton productiveness, and an augmented production related to its trophic chain.

In Chile, the HCLME's boundaries are set from North to South in front of Antofagasta (23º S), Coquimbo (around 30ºS) and Talcahuano (around 37º S). These last two upwelling are seasonal ones.

This system's productivity presents seasonal fluctuations. One of the most important fluctuations is the one connected to El Niño/La Niña-Southern Oscillation (ENSO).

Together with these characteristics, one of the main features of the HCLME is related to the presence of a minima, sub-surface oxygen layer (<0.5 ml/L). This layer broadens and thickens from North to South in front of Peru and the Chilean North. Its influence decreases as it goes deeper toward the South-Center of the country.

In Chile, around 3.7 million out of the whole of the population (which corresponds to 22% of the population in 2012) live in cities and other settlements located on the coast, at a least under 10 kms from the ocean.

Geographically speaking, Chilean coasts are known to be narrow and flanked by two coastal mountain ranges, which reach heights of 800 and 1,200 meters above sea level (MASL). Such features remain fairly constant until the Reloncaví Sound, where the coastlines disintegrate and become a cluster of islands.

A central plateau ranging between 700 and 900 mts is found inland. A set of mountain ranges interrupt the plateau in the center of the country.

The Chilean Central Valley borders Los Andes mountain range, which decreases in height from North to South. Its highest peaks can reach 4000 to 6000 MASL.

Chile's economic activities put a great deal of pressure on its marine ecosystems, thus affecting its well-being and equilibrium.

The production of copper stands out in the mining industry. Copper is followed by a small production of molybdenum and zinc. Copper represents 82% of the GDP (Gross Domestic Product).

Geographically speaking, the North of the country concentrates the greatest mining development. In general, copper extraction takes place from Los Andes mountain range, and its products are transported to the coast line, from which they are exported to foreign countries.

Regarding the fishing industry, Chile is among the top 10 fish-exporting countries, with a growth which varied from 1,794 million USD in 2000 to 3,394 million USD in 2012.

The total offloading in 2011, as gathered until December corresponded to 4,435,373 tons, which constitutes an 18% increase, in respect to 2010.

In the area of aquaculture, 3,142 centers operated in Chile during 2011(with or without harvest), incrementing its production by 3% in relation to the previous year.

The majority of the harvest centers are located in the southern area of the country, particularly in Los Lagos Region (63,8%) and Aysen del General Carlos Ibáñez del Campo (20,6%) Region.

As for hydrocarbons, Chile possesses 40 oil terminals, 2 oil refineries, and 2 oil platforms. According to DIRECTEMAR, petrochemistry-related activity makes use of Valparaiso Region coastline, whereas the oil refinery does so in Magallanes and Antartica Region.

Marine pollution caused by hydrocarbons usually takes place in routine ship and vessel operations, whether intentional or not.

Concerning the forest industry, it represents the area with the highest levels of impact on the GDP after copper, corresponding to 31% of 2008 GDP.

Wood-pulp industries are located in the South of Chile. There are approximately 6 industries that are in direct relation with the coastal border.

One of the regions that bear a considerable impact is the BioBio Region, which originates from the intensive use of PCF-Na[1]-based products that were in use up until 1999, when these products were banned by the Ministry of Agriculture. Some records suggest that crab's death rates in 1996 were due to PCF contamination.

The alterative to such product is mainly sodium tribomophenate (TBF-Na). However, there is little information available regarding the consequences on biota or on its persistence and/or accumulation on the sediment matrix.

Agricultural and livestock encompass a vast section of the territory. In the North, from Arica to Copiapo, agricultural activities are related to specific valley points that resemble near-by oases located near the coastline. These valleys mainly assemble sheep farming and fruit and cereal growing industries.

Starting on Valparaiso Region until Maule, most of the agricultural activity is found, with a vast variety of products of great national prominence. Pollution associated to this area is mainly due to nonpoint sources that originate from the use of pesticides, fertilizers and the replacement of the soil's ground cover.

Climate change

In relation to the effects related to climate change regarding the sea level, some forecast indicate that for the case of Chile by the year 2100, the average sea will have increased by 20 cms, between 30º and 60º S, and between 20º and 30ºS (Fuenzalida *et al*., 2007; Gregory et al., 2001).

In spite of the importance of the fishing and the aquaculture within national economy, activity, Chile does not possess an acceptable level of research on the effects of the climate a set of international and national studies, it is possible to infer that the frequency of occurrence of El Niño/La Niña Southern Oscillation will experience modifications that may in turn affect in a negative way Chile's primary production.

Another predictable effect is related to the distribution and the abundance of mammals, which are highly sensitive to temperature variations, especially when considering its

[1] Sodium pentachlorophenate

restricted geographical distribution. In connection to this, there are few opportunities of widening their distribution ranges, in reaction to this climate change (Learmonth,2006).

Protected areas

Considering the various Chilean protected areas, consist of 15,080,538.25 ha (58,226.29 square miles), out of which 7,615.25 ha (29.4 square miles) can be found in the area covered by the Humboldt Current.

Although advancements have been made (10 new protected areas since 2002), there is still a deficit concerning the funding of the system is.

In Chile there are entities connected with preservation of marine biodiversity, such as Marine Parks and Reserves and the Marine and Coastal Protected Areas. Marine Parks are specific delimited, marine areas. Their purpose is to preserve ecologic units that represent areas of interest for science, and to care for the existence of areas that guarantee the protection and diversity of hydrobiological species, as well as those associated with their habitats.

Marine Reserves constitute areas for sheltering hydrobiological resources, in order to protect reproductive areas, appropriate sites for fishing, and those areas that have been restocked through management.

These areas are currently under the tuition of the National Fisheries Service (SERNAPESCA). Exploitation activities can only be carried out in a transitory manner, having such resolution been previously expressed by the Subsecretariat of Fisheries (Sierralta *et al*., 2011).

On the other hand, the Marine and Coastal Protected Areas are a particular case in which the main difficulty lies in the fact that such category has not been systematically regimented in a general set of regulations in which its definition, competencies, management or administrative tools, supervision, and penalties in non-compliance cases, etc.

Concerning the budget allocated by the National Fisheries Service and the Subsecretariat of Fisheries for the management of the protected areas for 2010, it corresponded to

$102,644,341 millions. However, it was cut by 31% for the year 2011, thus having a budget of $ 71,061,044, which are only destined for running cost. Human resources have been practically null; only two people, whose responsibilities are not only devoted to Protected Areas management (GEF-SNAP, 2010).

Legal and Institutional Aspects

In Chile, the main organism in charge of regulating the management of marine ecosystems is the General Law on Fisheries and Aquaculture (Law Nº 18.892/1998, modified in 2013 through Law Nº 20.657). Inside this legislative body, there are several policy guidelines and regulations that regiment the different ecosystemic management issues.

The management of marine ecosystems has traditionally been linked to the Ministry of Economy and to the Ministry of Defense through the Chilean Navy. Both organisms have given origin to different institutions that are meant to deal with the different institutional changes that have appeared since the Fishing Law was put into use.

At the beginning of 2013, the New Fishing and Aquaculture Law (Law Nº20.657) was published in the official journal of Chile. This law enforces changes on matters related to the sustainability of hydrobiological resources, the access to industrial and inshore fishery, apart from the creation of new regulations in connection to supervision and research.

The main objective of this piece of legislation the preservation and sustainable management of fishing resources via the application of a cautious approach and a ecosystemic approach. According to this legislative body, both the implementation and the efficiency of the protective measures regarding the fishing management.

In 2010, Chilean environmental institutionalism was redesigned as the following entities were created: the Ministry of Environment, the Council of Ministers of Sustainability and the Superintendency for the Environment.

In 2012, this redesign was supplemented with the creation of the Environmental Courts. In addition, a legislative project is currently in the process of formulation, project which intends to give origin to the Biodiversity and Protected Areas Service (2013), organism

which will take on functions related to the administration of marine areas and protected coastal areas in the country.

Together with the new environmental institutionalism, a set of new regulations have emerged during this period, with the objective of granting those activities that are developed in the context of marine ecosystem a greater degree of sustainability. Among such regulations the following ones can be mentioned:

(1) Primary Quality Standard for the protection of seawater and estuary water for recreational activities involving direct contact (D1 Nº 144/2009, MINSEGPRES);

(2) Law Nº 20.256 on Recreational Fishing in 2008, establishes various protective dispositions of the ecosystems in which these activities are carried out.

The legal framework that lays down the rules for the use of the Chilean coastline is composed of a series of participant Ministries: Ministry of National Assets, Ministry of Public Works, Ministry of National Defense, Ministry of Economy, Ministry of Development and Reconstruction, Ministry of Agriculture, and the General Secretariat of the Presidency. These entities are, in turn, constituted by organisms and/or public services which work in administration and management (zone division processes, aquaculture, conservation) which constitute the use of the coastline.

In connection with the arrangement of the Coastline has had a policy to resort to for such matters, namely, the National Coastline Use Policy (DS[2] Nº 475/94, Ministry of Defense), in which the National Commission for the Use of the Coastal Border and the corresponding Regional Commissions for the Use of the Coastal Border. This National Commission set the basic common guidelines for the operation of organisms all along the country.

In the context of this policy, during the 2004-2005 period, an agreement was signed in order to initiate the zoning process at a macro level, in the coastline area, process which came to an end in the year 2010.

The aforementioned zone division process takes into account the Preferential Use Zones for Preservation or Conservation, which contains sites of first importance that have been

[2] Supreme Decree

identified in the Regional Biodiversity Strategies as well as Marine and Coastal Protected Areas for Multiple Uses and the Marine Parks and Reserves.

In 2010, a modification on Law Nº 19.300 was introduced, regarding the obligatory nature of conducting a Strategic Environmental Assessment in the coastline zone division.

Industrial effluents that go into seawaters are regulated by means of the MINSEGPRESS DS 90º/2000. In 2006 an assessment on this regulation began. In February, 2010 the proposals made by public organisms in relation to these changes were published.

Such changes, currently being processed for further promulgation, deal with the inclusion of new parameters (trihalomethanes and free residual chlorine), maximum limits (Cadmium, Manganese, Nickel, Lead, and Zinc) the modification of "zones with protected coastal areas", the incorporation of estuaries in the regulations, and the modification of the processes for monitoring and control.

As far as monitoring is concerned, among the functions established by the Superintendency of the Environment, the following ones can be mentioned: (i) supervision or inspection of law compliance, rules and other standards referring to industrial liquid waste discharges.

Sectoral organisms in charge of conducting environmental inspections will continue to be in possession of their competencies and legal authority in all those matters and instruments that bear no connection with the Superintendy's set of competencies.

Regarding international agreements signed by Chile, in 2005 the agreement on Conservation of Albatrosses and Petrels was ratified. In 2007, the National Action Plan was ratified as well, in order to reduce the Incidental Catch of Seabirds in Longline Fisheries. Along a similar line, in 2006 the National Action Plan on Illegal Fishing was made official, in 2007 the National Strategy for Integrated River Basin Management and the National Plan of Action for the Conservation and Management of Sharks were also settled, and in 2008 a set of regulations related to recreational fishing (Law Nº 20.256), as well as other rules connected to the banning of cetacean species catch and protection; in 2010 the Inter- American Convention for the Protection and Conservation of Sea Turtles was also made official.

Problems related to the ecosystem's pollution and health

In 2000, the Permanent Commission for the South Pacific (CPPS) pointed out that the highest amounts of cadmium found in water had been registered in Iquique, Tocopilla y Coquimbo; in the case of lead, in San Vicente, Antofagasta and San Antonioo, zinc in Talcahuano, Playa Ancha (Valparaíso) and Chañaral; chromium in Arica; mercury in Coquimbo, Concón and Puerto Montt, Castro, San Vicente and Talcahuano. As for , the highest amounts were registered in Concón, San Antonio y San Vicente; chromium in Iquique, Antofagasta, Talcahuano and San Vicente; copper in Antofagasta, Charañal, Coquimbo, Caldera and Valparaíso; mercury in San Vicente; and zinc in Arica, Antofagasta, Chañaral and San Vicente. Similar results were shown by the analyses of heavy metals in the tissues of mollusks (CPPS, 2000).

On the other hand, OCDE (CEPAL) (2005) proposes that the majority of the waters in the country present an acceptable quality. Nevertheless, it is worthwhile noting that there is still bad quality of water found in some lakes, rivers and coastal waters, mainly due to urban and industrial discharges of unprocessed liquid waste. Likewise, there are important amounts of pressure imposed by heavy metals in the North of the country, salmon aquaculture supplies in the South, and the agricultural supplies in rural areas of the country. In particular, in the North the main sources of contamination can be equated with the mining activities, which have, during decades, discharged waste onto the ocean whether directly or indirectly.

In this sense, Velázquez (2005) points out that the levels for the cases of copper, nickel, arsenic and silver found in the northern coast of Chile are unusually high, as compared with other locations in the world, and also comparatively speaking in relation to other places in Chile as well.

Concerning the Chilean central zone, the main sources of contamination come from the agricultural area, by means of pesticides and fertilizers, which arrive to the marine zone through the rivers (Figueroa and Calfucura, 2006). There are also sewage discharges even though an important percentage is represented by treated water . On the other hand, solid domestic waste that have not been collected accumulate mainly in the bay areas of the central zone.

Further South, there is a relevant amount of fishing industries which discharge onto the ocean industrial liquids from their fishing exploitation, reductive, processing and manufacturing activities. All of these started being regulated by the SD Nº9.

Aquaculture must also be considered as it constitutes a major activity related to seawaters and lake systems. Aquaculture causes important impacts ecologically speaking (Figueroa and Calfucura, 2006). Some of these effects can be seen in the following areas: (i) the consumption of dissolved oxygen; (ii) the interaction between indigenous farmed species and those that have left their original habitats, and (iii) the integration of bioactive components, such as antibiotics and pesticides.

Further South, (Aysen and Magallanes and the Chilean Antarctic Regions) threats posed on the environment are represented by spillages that have occurred as a result of oil exploitation activities together with the intense vessel transit, which in turn entails a high amount of garbage and plastics dumping, in spite of the existence of standards and regulations on this matter (Decree Nº1, 1992, Ministry of Defense).

According to the information made available by DIRECTEMAR, in 2011, a vast amount of the marine pollution present coincides with the zone being included by the Humboldt Current. Filtrations and spillages constitute the main causes for such contamination. The highest amounts were due to the crack on an inland tank located in San Vicente bay, Calbuco area, containing 30,000 liters of diesel.

Historically, between the years 2000-2011 there have been 149 pollution episodes, with an average of 12 a year. Taking into consideration the Humboldt Current zone, the episodes correspond to approximately 122 and the average, 10 a year.

Another source for marine contamination is represented by the sewage outlet pipes – the final disposal of sea wastewaters system. Even though at an international level a sewage outlet pipe is a channeling that runs under the ocean, this is far from being applied in Chile, given that these systems correspond to any kind of duct that discharges its waste onto canals, rivers, lakes, lagoons, sewers and the sea (DIRECTEMAR, 2007).

The types of polluting agents can be classified as follows: organic matter, heavy metals, organic compounds, persistent organic pollutants, and hydrocarbons, depending on their emitting source.

Taking into consideration the total amount of ducts – whether installed or fully functional, that the Maritime Authority recorded in 2007 as emitting sources, 37 correspond to sewage outlet pipes belonging to water companies.

Common problems connected with ecosystem's pollution and health

Thermal power plants installations constitute a main issue in relation to the pollution and health of the marine ecosystems of the Humboldt Current.

Such thermal power plants correspond to industries that produce electricity out of coal, petroleum derivatives or biomass. These plants have a huge boiler which takes water to its boiling point by using a turbine, thus generating electricity (Sampedro, 2000).

These projects have been preferably located on the coastline of Chile, mainly due to need for huge amounts of water volumes for the refrigeration processes, and, to a lesser extent, in order to dilute the Liquid Industrial Waste (LIW), process in which sea water constitutes the biggest source of supply, taking into consideration, on the one hand, its appropriate levels of availability and conflict with other users in the case of fresh water resources. (Contreras, 2010). As for refrigeration, power plants extract sea water and pump it toward the condensers, in which temperatures vary from 8º-12ºC above the initial temperature. After this, the water is sent back to the sea (Rovira, 2006).

In accordance with Oceana (2011), the impacts caused by coal-based thermal power plants are, among others, CO2 emissions, mercury emissions, seawater suction, high-temperature water discharge, coal-based particulate. Similarly, the construction and management of these thermal power plants may have a wide range of impacts on the marine environment. These include changes in the sediments and substrata, the quality of water and habitats, and in hydrology.

Regarding the unfavorable effects on marine resources, some of these are as follows: (i) fish and invertebrates suction and trawling; (ii) altered levels of natural water flow; (iii) deterioration of the coastline and waterside habitats (NOAA, 2008).

Generally speaking, the focus of the assessments of the projects and impacts regarding this type of industries has been placed on public health, mainly concerning atmospheric emissions. Such focus underestimates these effects on the marine environment, in the context of the oceans' alleged unchanging nature or high capacity for dilution (Contreras, 2010).

Quintero bay, is undoubtedly the most emblematic case on pollution on this matter. This bay comprises the district of Quintero and Puchuncaví, an industrial park of around 14 polluting factories. These include: the state copper and gold foundry and refinery, Codelco, 2 thermal power plants, natural gas storage facilities, 3 oil companies (Shell, Copec and Enap), and entry harbors for coal, oil, gas and a variety of chemical products belonging to Oxiquimin industry. Therefore, during these years, the impacts on the marine and terrestrial biodiversity of Quintero bay have not only been caused by thermal power plants, but have also come from other sources of contamination from different industries.

In relation to research on the pollution levels, there have been studies regarding spillages and their effects on hydrocarbon concentration in bivalves (Andrade, 1986 and 1987; Romorino, 1989), as well as on the levels of concentration of metals on shellfish and crustaceans[3].

Governance analysis in respect to the ecosystem's pollution and health

In Chile, governance issues and HCLME's pollution and health monitoring systems are linked to several problems.

Some of these problems are in connection with a lack of balance between the levels of encouragement regarding the following areas:

(i) On the one hand, the development of the fishing sector, and

[3] For further information check Oceana 2012 study in collaboration with Fundacion Chile regarding shellfish and crustacean samples in the areas of Bajo la Boca, La Virgen, La Churra and El Tebo.

(ii) On the other hand, the development of research and its related elements, such as the capabilities of national technologies, and researchers available. The focus for such research is not linked exclusively to inshore or industrial fishery.

The main aspect of public policies is the lack of a secondary, quality regulation for marine sea waters. Such policies should focus on protection and environmental or nature preservation. Along a similar line, the current lack of funding for managing Parks and Marine Reserves plays a key role as far as the policies for the preservation of marine ecosystems are concerned.

As for the economic agreements, Chile has signed a series of these that are in connection with the management of marine ecosystems. In 2006, Chile, Australia and New Zealand raised multilateral processes of enquiry in order to establish a South Pacific Regional Fisheries Management Organization. Chile's main concern in such process is to guarantee the preservation of scads. This species exists both in its Economic Exclusive Zone as in its adjacent offshore areas. Such agreement might have considerable effects on the HCLME's health system. Nevertheless, and similarly to what has been stated in relation to the state of research, it is compulsory for Chile and Peru to engage in joint efforts.

On the other hand, one of the most valuable economic agreements for management is the one constituted by the Management and Exploitation Areas for Benthic Resources (AMERB). These have promoted a kind of cooperation between the public sector and the offline fishers for the exploitation and preservation of resources that have yet to fully develop in terms of their potential. Such process is essential for establishing a wider and more global scope regarding preservation through marine protected areas.

The National Confederation of Artisanal Fishers and the National Confederation of Artisanal Fishing Federations are the two most prominent civil society organizations. They comprise unions, cooperatives and fishers trade associations. Both associations have actively participated in the debate of the different points of the Fishing Law. They are also key factors when it comes to organizing the AMERB. Taking such situation into account, the joint work done by these organizations constitutes a crucial point for consideration in order to make progress in the elaboration of a preventive and ecosystemic approach of the HCLME.

Regarding international agreements, Chile recognizes the Convention on the Law of the Sea (CONVEMAR) as the legal framework that encompasses all the activities developed in the context of the marine environment.

Additionally, on the basis of a preventive and ecosystemic approach, Chile favors the incorporation of measures which tend to appropriately preserve offshore living marine resources. Chile also supports the following: putting a stop on trawling on the seabed, fighting illegal, unregulated and undeclared fishing, the establishment of protected marine and coastal areas, and the creation of regional fishing management organizations.

Besides, Chile proposes that ocean floor genetic resources located beyond territorial waters belong to the humanity's patrimony, thus an agreement must be elaborated regarding the CONVERMAR implementation regarding the management and sustainable exploitation of such resources.

Conclusions and recommendations

There are multiple factors likely to explain the various gaps and limitations existing in respect to the knowledge on health and pollution concerning the HCLME; encouragement and state funding, research centers capabilities, job openings, to name a few.

These limitations entail the current difficulties in elaborating an evaluation which would in turn allow to take specific decisions in relation with the management of the Humboldt Current.

As was mentioned before, one of the most relevant constraints relates to research. In this sense, diagnostic enquiries (Thiel et al., 2007) show that it is necessary to acquire knowledge in the following areas:

1) Interactions between ocean-atmosphere and offshore oceanography (climate change, ENOS, productivity);

2) Minimum amount of oxygen required (low oxygen ecosystems);

3) Research on near-shore coastal oceanography and benthic-pelagic coupling;

4) Fishing resources management approach (as related to the insertion of the bio-socio-ecosystemic approach proposed by fisheries in relation to the management of national fishery;

5) Implementation of a global net system for marine preservation (on the basis of the AMERB use);

6) Research on foreign marine species;

7) Molecular marine biology, particularly, genomic;

8) Creation of appropriate conditions that allow to increase the number of marine taxonomists;

In the long term, the following proposals are made:

1) To intensify the preventive and ecosystemic approach in the management of fisheries;

2) To implement an offshore preservation policy;

3) To strengthen continental slope, deep-sea and abyssal ecosystems research;

4) To develop scientific and technological research on deep-sea gas (methane) hydrates;

5) To evaluate the future effects resulting from climate change.

In relation to the strengthening of the marine protected areas, even though the AMERB was not originally designed as protected ones, there have been some cases in which these areas have demonstrated their ability to adequately preserve the resources under management (Castilla, 1996). This is the main cause for national research to consider these units as possibilities that can influence the development of a marine protected areas network.

Together with what was previously stated, a critical issue related to the ecosystem's preservation is the elaboration of an appropriate stage of management and funding for the Parks and Marine Reserves.

Finally, it is also imperative to accelerate the enforcement of the regulations established in the General Environmental Framework Law, fundamentally the Emission Standards, Secondary Environmental Quality Standards, and the Long-term Prevention and Decontamination Plans, all of which must be implemented especially in valuable areas that are particularly sensitive to become deteriorated as a result of pollution phenomena.

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