



Harmful algal blooms (HABs), marine ecosystems and human health in the Chilean Patagonia*

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Florecimiento de algas nocivas (FANs), ecosistemas marinos y la salud humana en la Patagonia chilena

The Los Lagos Region in Chile is located in Chilean Patagonia between latitudes 40°13' - 44°30' S and longitudes 74°49' - 71°34' W. This region comprises a territory from the Pacific Ocean to the Andes. It contains two interior seas, the Reloncavi Gulf and the Chiloe Interior Sea, and multiple archipelagos, estuaries and fjords. Its climate is rainy and temperate, with year-round precipitation and average temperatures (depending on elevation) of approximately 15°C. The geographical characteristics of the region with innumerable bays, fjords and channels and its rich marine biodiversity have for many years spurred the development of intensive industrial aquaculture of salmonids and mussels and extractive fisheries to prepare fish meal for these activities. Chile is the second largest world producer of salmon after Norway. The Los Lagos Region produces more than half of the approximately 800,000 metric tons of salmonids that Chile exports each year. Moreover, the region generates approximately 80-90% of the fish and shellfish consumed internally in the country, and also provides important amounts of algae harvested for human consumption and for export. This area is thus one of great industrial and economic activity related to the marine environment and its resources.

This year the marine environment of Los Lagos Region experienced a series of biological phenomena that may undermine its vibrant economic activities, including both aquaculture and commercial fishing, in the future^{1,2,3}. In January and February of 2016, salmon farms in the northern part of the Chiloe Interior Sea and the Reloncavi Gulf experienced massive fish kills produced by a harmful algal bloom (HAB) of *Pseudochattonella marina*^{1,2}. This HAB killed approximately 50,000 metric tons of fish and produced important economic losses for the industry and significant unemployment^{1,2}. In April and May, an HAB of *Alexandria catenella*, an organism producing a paralytic neurotoxin, extended from the southernmost part of the Chiloe Interior Sea to cover it almost totally and into the Reloncavi Gulf to the north. Unexpectedly, this HAB expanded into the open Pacific west of Chiloe Island, and advanced 300 to 400 km to the north³. In the open ocean, this HAB was accompanied by massive

mortalities of shellfish and birds as evidenced by their stranded shells and corpses on the coastline. As a result, the government curtailed harvesting and consumption of wild and cultured shellfish for many weeks, creating still more unemployment, economic disruptions and massive political protests. This in turn led the authorities to declare a state of emergency in the affected areas and to implement a program of subsidies for the large number of unemployed and their families.

The Los Lagos Region had experienced HAB in the past, but the extension, intensity and levels of toxicity of these latest HAB appear to be new to the region⁴⁻⁷. Their potential reappearance and permanence, and their negative effects on the main industries and economic engines of the Los Lagos Region have raised great uncertainty. The sea in the region has also seen HAB producing diarrhetic and amnesic toxins. In the past, this same region experienced the largest epidemics of diarrhea of *Vibrio parahaemolyticus* in the world, emerging infections of novel fish pathogens (both antimicrobial-susceptible and resistant)^{6,7}, and more recently, repeated summer jellyfish blooms that negatively affected recreation and fishing. Whales indigenous to the area also seem to have been affected by these developments as hundreds of their corpses have been beached at least twice in the last months.

The sum of these occurrences indicates major instability and degradation of this large marine ecosystem (LME). Climate change coupled with a vigorous El Niño phenomenon and warming of the sea has been implicated in their occurrence. Other stressor playing a role in these processes may be nutrient overload (eutrophication) and overfishing generated by many years of intensive salmonid and mussel aquaculture in the area characterized by passage of large amounts of organic matter into the marine environment and essentially permanent use of considerable amounts of antimicrobials, antiparasitic drugs and chemicals to prevent and treat disease and avoid biofouling of structures⁴⁻⁸. These industries have also generated habitat loss and decreases in biodiversity with salmon escapees as contributing factor. All these are important stressors of LME and they undermine marine

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ecosystem services such as their ability to be food sources as well as their resilience.

As a result of these developments, the LME of Los Lagos Region and Chilean Patagonia has become a landscape where anthropogenic degradation of local marine ecosystems on a background of global warming is generating further ecological degradation of the marine environment⁹⁻¹². These dynamic interactions are fostering the emergence of diseases that affect fauna and flora in the sea with the potential to negatively affect human health and economic activities that sustain the economic and social framework of the area's population. These developments linking LME ecosystem degradation and vulnerability with adverse effects on

human health were forecast more than 20 years ago by the Emergent Infections Group at the Harvard T. H. Chan School of Public Health⁹⁻¹². The group also called for an integrated and holistic approach to investigate, prevent and forestall the emergence of such problems in order to avoid their potentially negative societal impacts. The developments described here in Chilean Patagonia indicate that it is now time to heed their call with some urgency⁹⁻¹².

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