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REPORT TO THE NATIONS

“Red tide” and global change:

Elements for the construction of an integrated governance of Harmful Algal Blooms (HABs)

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AGENCIA NACIONAL DE INVESTIGACIÓN Y DESARROLLO
FUNDING

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The electronic version of this document is available at the website www.cr2.cl/eng/habs/

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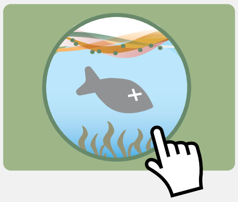

HABs Infography

Introduction

Introduction

Harmful algal blooms (HABs) are natural events that occur when certain species of phytoplankton* that inhabit aquatic ecosystems, lakes or oceans, rapidly increase their abundance, which can negatively impact human health, organisms where they inhabit, and multiple economic or social activities (for example, aquaculture and tourism), among others. This phenomenon is very recognizable to the naked eye, since the pigments of the microalgae turn the water into different colors, such as green, brown or red, among others. From these colors, the latter is the one most associated with HABs, which is why it is colloquially referred to as "red tide" and this concept is used as a synonym for HABs, although they are not exactly the same.

Some harmful algal blooms are caused by phytoplankton species producing toxins, which are assimilated by filter-feeding organisms, such as bivalve mollusks (mussels, clams, and oysters, among others), which, when consumed by humans or other species (birds and mammals), can cause serious poisoning and even death. According to their effects, these toxins or poisons have been grouped into three major categories: paralytic shellfish toxin (PST), diarrheal shellfish toxin (DST) and amnesic shellfish toxin (AST). Meanwhile, there are harmful blooms that are not necessarily toxic, but that also generate harmful effects on humans, other organisms or an ecosystem as a whole. For example, they can cause damage to the gills of fish farm, lowing oxygen by decomposing phytoplankton (causing suffocation in other organisms), ruining the landscape value of beaches due to the formation of foam and the bad odor associated with decomposition, or lead to large stranding and death of fish.

Thus, all types of HABs can become a highly relevant socio-environmental problem, especially for human communities that inhabit coastal areas. It is highly relevant to consider the previous, in the context of the multiple global environmental challenges that our planet faces, and especially, of climate change. In fact, there is evidence that the warming and acidification of the oceans could facilitate the proliferation and toxicity of some species that cause these blooms (IPCC, 2019; Trainer et al., 2020).

Chile is one of the four global hotspots tending to develop catastrophic blooms in view of the great magnitude of the impacts they can cause (Smayda, 2000). In our country, HABs have apparently increases in the last decades and have been concentrated mostly in the south-austral zone, in fjords and channels of the Los Lagos, Aysén and Magallanes regions. In order to approach these events, the government has strived both at the sanitary and socioeconomic level, mainly through monitoring programs to safeguard human lives and manage marine resources properly. Although these efforts have had positive results in preventing poisoning and associated deaths (Institute of Public Health of Chile 2010, 2012, 2022), it is important to maintain and improve vigilance continuously.

The foregoing reflects that the study of these phenomena has had important development in Chile, particularly from the natural sciences aspect. Nevertheless, there is still a knowledge gap around areas such as comprehensive risk management, impacts beyond health, local perceptions and responses to HABs, and the problem governance. In this sense, it is necessary to promote an inter and transdisciplinary research that facilitates the dialogue between scientific knowledge and local communities' knowledge and experience, advancing towards the development of a new governance of HABs that favors the decision-making process, focuses on the particularities involved in adaptation to climate change, has a more local orientation built on trust relationships and with effective coordination among diverse social sectors involved. The objective of this Report to the Nations is to contribute to a further understanding of the HABs by means of scientific evidence and from a transdisciplinary perspective, with a transformative climate governance approach that allows authorities as well as the private sector and local communities to develop more effective strategies for prevention, mitigation and adaptation, improving event responded way and advancing towards greater resilience of the coastal areas of Chilean Patagonia, which, for the purposes of this report, includes the regions of Los Lagos, Aysén and Magallanes, and more specifically its fjords and channels. To achieve this goal, we use the conceptual framework proposed by the Intergovernmental Panel on

** All words in blue and underlined are defined in the Glossary at the end of the Report*

Climate Change (IPCC), applying what was stated in its last report published in 2022. In this way, the concepts of risk, threat, exposure and vulnerability, along with transformation, are central to this dialog (see Box 1). Methodologically, we work with various databases and information associated with HABs events and analyze some specific events. Furthermore, we develop case studies in certain territories (see Figure 1).

The Report consists of nine chapters. The **first one** presents the coastal marine system-Chilean Patagonia- being studied in climatic, physicochemical, biological, socioenvironmental, and cultural terms. **Chapter two** describes and analyzes the main impacts of HABs on these socio-ecological systems. **Chapter three** presents one of elements composing HABs risk in a context of climate change and human activities pressure: threats. **Chapter four** introduces the other two elements of HABs risk: exposure and vulnerability. **Chapter five** characterizes and analyzes the current management of these events, highlighting the way in which decisions are made, the entities that participate and the coordination among them, as well as the main strengths and weaknesses of the model, and its characteristics. **Chapter six** describes and classifies the responses to HABs episodes that have taken place in some territories of Chilean Patagonia, also showing how they have been addressed internationally, while reflecting on the importance of building new responses from a transformational approach. **Chapter seven** details the results of the HABs perception survey that was carried out in Chilean Patagonia. **Chapter eight** synthesizes the main findings of the Report and reviews the adaptation gaps found. Finally, **chapter nine** proposes public policy recommendations to move towards transformative climate governance.

Although the Center for Climate and Resilience Research (CR)2 has led this Report, members of other research centers, scholars, the government, and social and private institutions also actively participated in its construction.

BOX 1 Concept map and basic definitions

In alignment to the latest IPCC report, published in the year 2022, which highlights an ecosystem approach to address climate change, risk is understood as the potential for adverse consequences on human and ecological systems, recognizing the dynamic interactions among: **threat** (as a potential occurrence of a natural or human-induced event that impacts the systems), **exposure** (such as the presence of people, livelihoods, ecosystems, environmental functions, services and resources, infrastructure, or economic, social or cultural assets that may be adversely affected), and **vulnerability** of the human or ecological system (that presents a propensity or predisposition to be affected). Each of these elements is understood systemically, by understanding its own complexity and integrating the existing interactions between human and natural systems.

More information

To address risk, there are three different types of social responses arising. The first one is of a **mitigation kind**, which aims at reducing the impacts or improving the conditions to confront them. A second one is **adaptive in nature**, which considers the potential damage of an event and responds to its consequences in advance or takes advantage of the opportunities that may be generated. The third one, has a **transformative inclination**, which means to change the fundamental attributes of a Socio-ecological system.

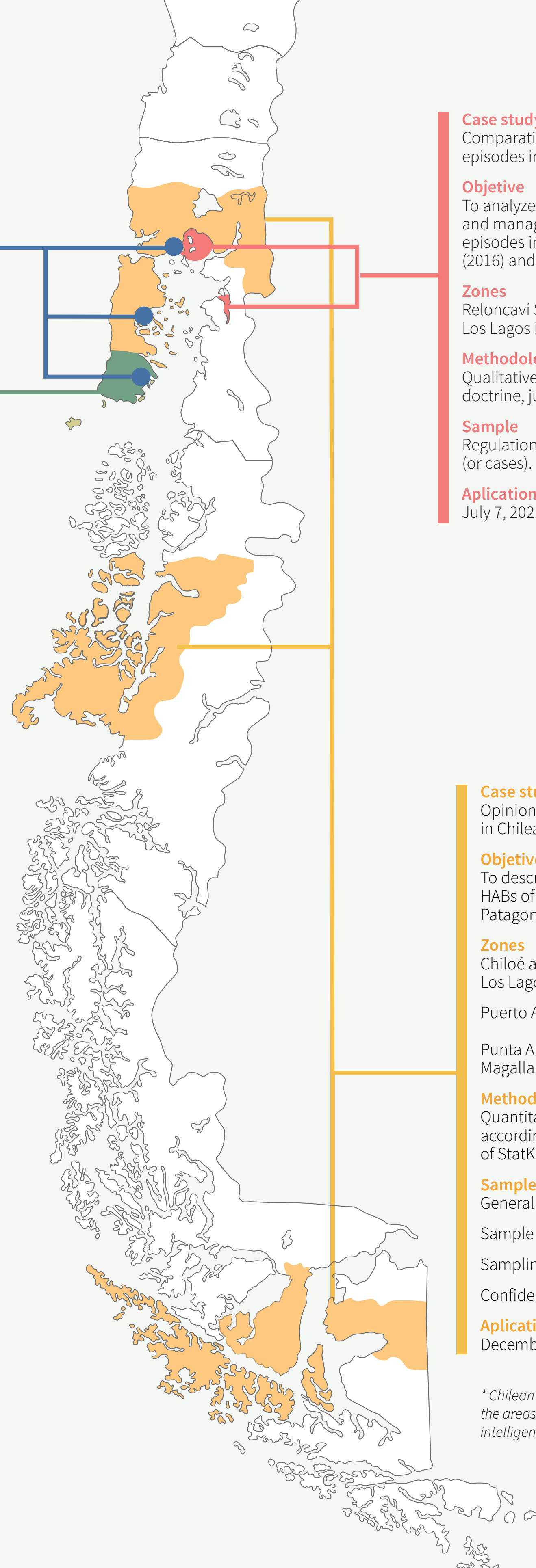
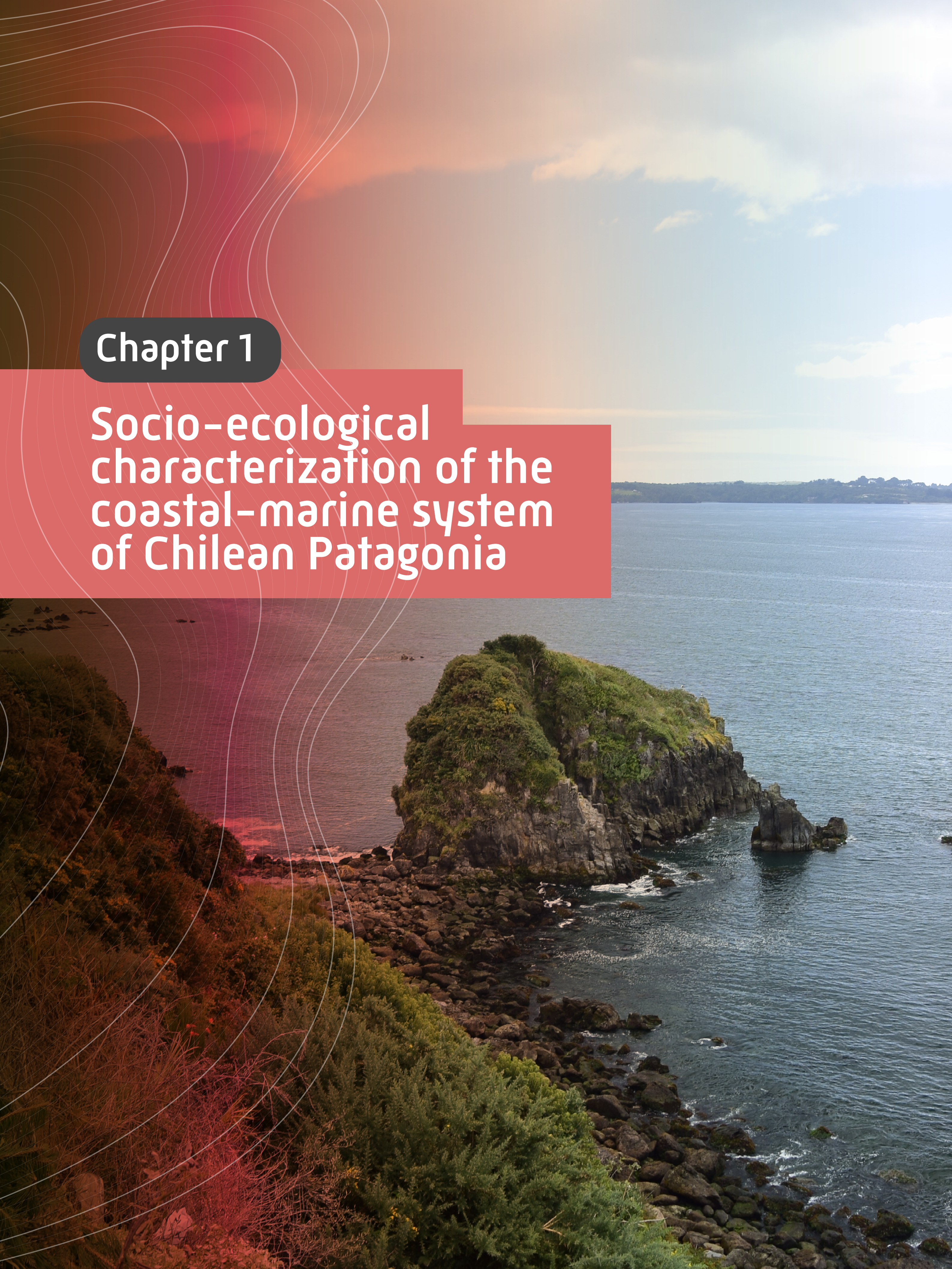


Figure 1: Case studies. Report to the Nations, HABs. Source: Self-Made



Chapter 1

Socio-ecological characterization of the coastal-marine system of Chilean Patagonia

Socio-ecological characterization of the coastal-marine system of Chilean Patagonia

The area of fjords and channels comprising Chilean Patagonia covers more than a third of the country's coasts and constitutes a unique and diverse enclave under marked impacts derived from both climate change and other socio-environmental forces. Subsequently, we briefly present the main characteristics of the coastal-marine system, that ranges from its ecosystem richness to the sociocultural diversity of the coastal communities that have inhabited this vast region throughout history.

Chilean Patagonia, considered one of the most pristine ecosystems in the world, represents one of the main freshwater reservoirs on the planet. There are wetlands, peat bogs, glaciers, fjords, rivers, lakes and forests capable of storing three times more carbon per hectare than the Amazon.

With a linear extension of approximately more than 1,500 km from north to south, and an intricate coastal zone located less than 300 km from the southern Andes, this territory is characterized by great landscape, cultural and ecosystemic wealth throughout the regions of Los Lagos, Aysén and Magallanes. From a biogeographical point of view, this extensive territory hosts great biodiversity and biological productivity, where three large ecoregions can be distinguished: Chiloé-Taitao, Kawésqar and Magallanes, which provide ecosystem services to the inhabitants of the area. Despite its large territorial extension, Chilean Patagonia only houses 6.25% of the total national population and 13% of the indigenous one, with a density of 3.79 inhabitants per square kilometer (INE, 2018). However, it holds a substantial anthropic footprint, mainly due to the expansion of aquaculture in recent decades (Buschmann et al., 2021).

The incessant influence of the westerly winds crossing Patagonia results in copious rainfall (between 3,000 and 7,000 mm/year) (Garreaud et al., 2013), which, together with the supply of fresh water of glacial origin, produce a high runoff and discharge from rivers, which provide silicates and sediments to the coastal zone (Iriarte, et al., 2014; González et al., 2019).

The interaction between continental freshwater and oceanic saltwater, which enters mainly through the entrance of Guafo, the Gulf of Penas, and the Concepción channel, creates an estuarine circulation system with distinguishable changes in temperature and salinity that control biological productivity and the biomass and structure of the phytoplankton that sustains regional fisheries and aquaculture (see Figure 2) (Iriarte et al., 2014; Cuevas et al., 2019; González et al., 2019; Pérez et al., 2021).

The complex geography, the hyper-humid climate, and the access to resources have been determining factors for the settlement and expansion of human beings in the area. Throughout history, the main demographic changes recorded in Patagonia have been associated with the exploitation of available natural resources. After the arrival of the first European explorations in the 16th century and Spanish colonization, the development of economic activities such as logging and the hunting of sea lions, otters and whales (17th to 19th centuries), followed by large-scale livestock farming (19th century), represented an economic boost for the area, with a consequent increase in the population. However, these activities greatly impacted the indigenous peoples, who were subject to genocide and persecution in the mid-19th century, causing them to be slaves and isolated, and forcing them to abandon their nomadic lifestyle. Despite this, the indigenous peoples have been a fundamental part in the construction of society and the territory as we currently understand.

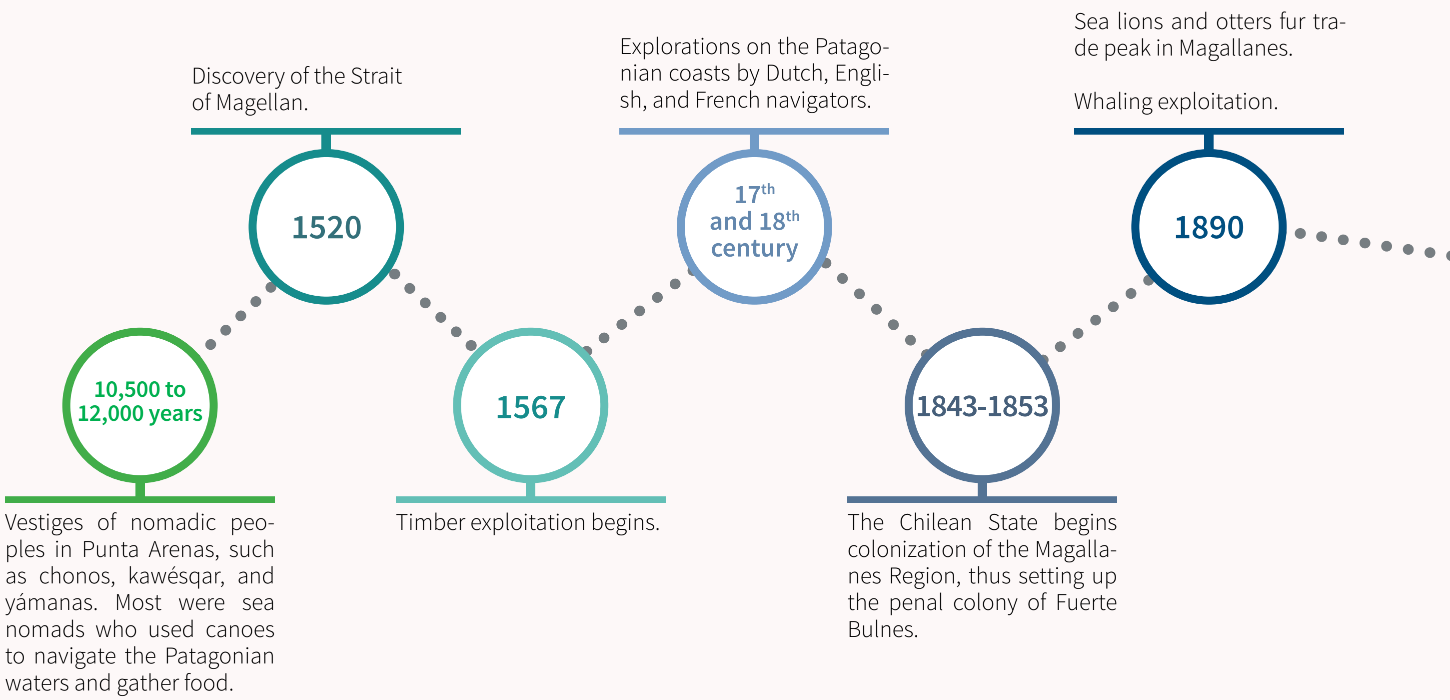


Figure 1: History timeline of Patagonia, containing main historical, economic, and environmental events. Source: Self-Made.

The arrival of industrial aquaculture in the 1980s and its exponential growth played a determining role in the Chilean fjords and canals, causing massive migration to coastal towns, as well as change in the lifestyle of the communities. Self-employed workers who previously engaged in artisanal fishing, local shellfish and algae harvesting, or small-scale agriculture, went on to work for large aquaculture industries (WWF Chile, 2011; Sepúlveda & Lara, 2021).

Although activities such as agriculture and logging continue to develop, fishing together with the collection of algae, and mollusks and salmonids farming constitute the main economic activities of the coastal communities of this territory, which depend on the sea and available resources to a great extent. Moreover, from a cultural point of view, the link between human beings and the sea, which has characterized the coastal communities of Patagonia throughout history is undeniable. "The sea", as it is colloquially called, is considered a space to protect and preserve, and not a mere reservoir for these communities, but an intrinsic and irreplaceable part of their identity; a scene of memories rooted in the collective memory.

However, the change in the economic model caused by the arrival and expansion of industrial aquaculture, along with it, brought about both cultural-alterations in some traditions and knowledge-impacts and socio-ecological ones , deteriorating natural habitats and triggering socio-environmental crises. This scenario has been associated with a potential increase in HABs occurrence, duration, and expansion, from Magallanes to Los Lagos (Buschmann et al., 2006; Crawford, et al., 2021; Soto et al., 2021). In recent years, the impacts associated with these events, jointly with the motivation to strengthen traditions and knowledge on the part of coastal communities, have led to the creation of socio-environmental movements that aim at the preservation of ecosystems through sustainable development of the area, which is reflected on the increase of protected areas throughout Patagonia (Sepúlveda & Lara, 2021).

1920-1950

Fire generation clear forests, devastating millions of hectares in Aysén. Consequently, soils are exposed to date.

1930-1940

Commercial and industrial fishing production begins in Aysén.

1960

CORFO acquires a mining company in Aysén.

Chiloé's earthquake causes migration to Puerto Natales.

1970

Decline of the sheep wool market in Aysén.

Livestock economic crisis.

1980

Development of industrial fishing (early 80's).

Installation of industrial aquaculture in Chiloé.

Extraction increases of Chilean abalone and hake in Puerto Cisnes and the Guaitecas archipelago.

Chilean abalone fever generates wave of migrants and fishing crisis due to overexploitation.

Start of salmon farming (late 80's).

1990

Salmon farms setup in Llanquihue, Chiloé and the northern area of Aysén.

First salmon farming centers in Puyuhuapi.

1996

Estero Quiltraco becomes the first coastal marine protected area in Patagonia.

2000

Tourism consolidates as an economic activity in Patagonia.

2004

Creation of the first Patagonian marine park in Magallanes.

Creation of the first marine reservoirs in Chiloé, Pullinque and Putemun.

2007-2009

Sanitary crisis in salmon farming due to the ISA virus in Los Lagos, causing the closing of centers and high loss of employment.

2012

Social protests over fishing quotas that paralyzed the Aysén region for over a month.

2016

Red tide crisis with strandings of fish, mollusks and death of birds that generates social mobilizations in Chiloé.

HABs in the context of climate variability

HABs, along the coastal-marine system of fjords and channels in Chilean Patagonia, are caused by different native species of phytoplankton, mainly diatoms and dinoflagellates. Including *Alexandrium catenella*, *Pseudo-nitzschia* sp. and *Dinophysis* sp., among others (Alves de Souza et al., 2019; Crawford et al., 2021; Díaz et al., 2021), they have harmful effects on the human population and local fauna.

Historically, the HABs occurrence in Patagonia can be traced back to the end of the 16th century (1584-1599), when the first explorers described intoxications after shellfish ingestion (Kerr, 1824; Henry, 1875; cited in Crawford et al., 2021). Meanwhile, the first scientific records of HABs, with effects on human health, date as early as the 1970s, and are associated with *Dinophysis* sp. and *Alexandrium catenella* blooms in Los Lagos and Magallanes, respectively. In recent decades, HABs events recorded throughout Patagonia show high variability and diversity. The events were caused by both toxic and non-toxic species (for example: *Pseudochattonella* sp., *Heterosigma akashiwo*, *Karenia* cf. *mikimotoi*), with socioeconomic or health repercussions. From the 1990s to date, it seems that these events have increased in northern Patagonia, especially in the Aysén and Los Lagos regions (see Figure 2).

These blooms constitute a natural process, whose occurrence, distribution, and duration are variable depending on the species involved and multiple factors, including the physicochemical conditions changes of the waters related to natural climate variability, climate change, and human influence (León - Muñoz et al., 2018; Alves de Souza et al., 2019; Crawford et al., 2021).

It should be noted that global-scale climatic phenomena such as the El Niño Southern Oscillation (ENSO) and the Southern Annular Mode (SAM), which produce climatic variations including droughts in the summer and autumn months in northern Patagonia, have been associated with the occurrence of HABs, such as the event that took place in the Chiloé-Taitao ecoregion in 2016. This event gave rise to one of the greatest socio-environmental crises in the pertaining territory history, bringing about serious ecological (mass mortality of birds, fish and cetaceans) and socioeconomic (loss of jobs, decrease in income, citizen protests) (León-Muñoz et al., 2018; Mardones et al., 2021) consequences.

Both ENSO and SAM occur naturally in the climate system, alternating between their positive and negative phases. In recent decades, the SAM shows a clear trend towards its positive phase, giving rise to a weakening of the westerly winds, an increase in air temperature associated with greater solar radiation, and precipitation changes presenting drought in the Northern Patagonia and rainfall increase in Magallanes (Garreaud, 2018; Aguayo et al., 2021). This trend is caused by stratospheric ozone depletion and greenhouse gases increase, both induced by human actions. The drought in northern Patagonia, where more than 75% of the total population of the territory resides (INE, 2018), is one of the clearest signs of climate change in Chile, which would continue throughout the rest of the 21st century (Aguayo et al. al., 2021; IPCC 2021), warning of a potential increase in phytoplanktonic species that cause HABs and which thrive under the above scenario.

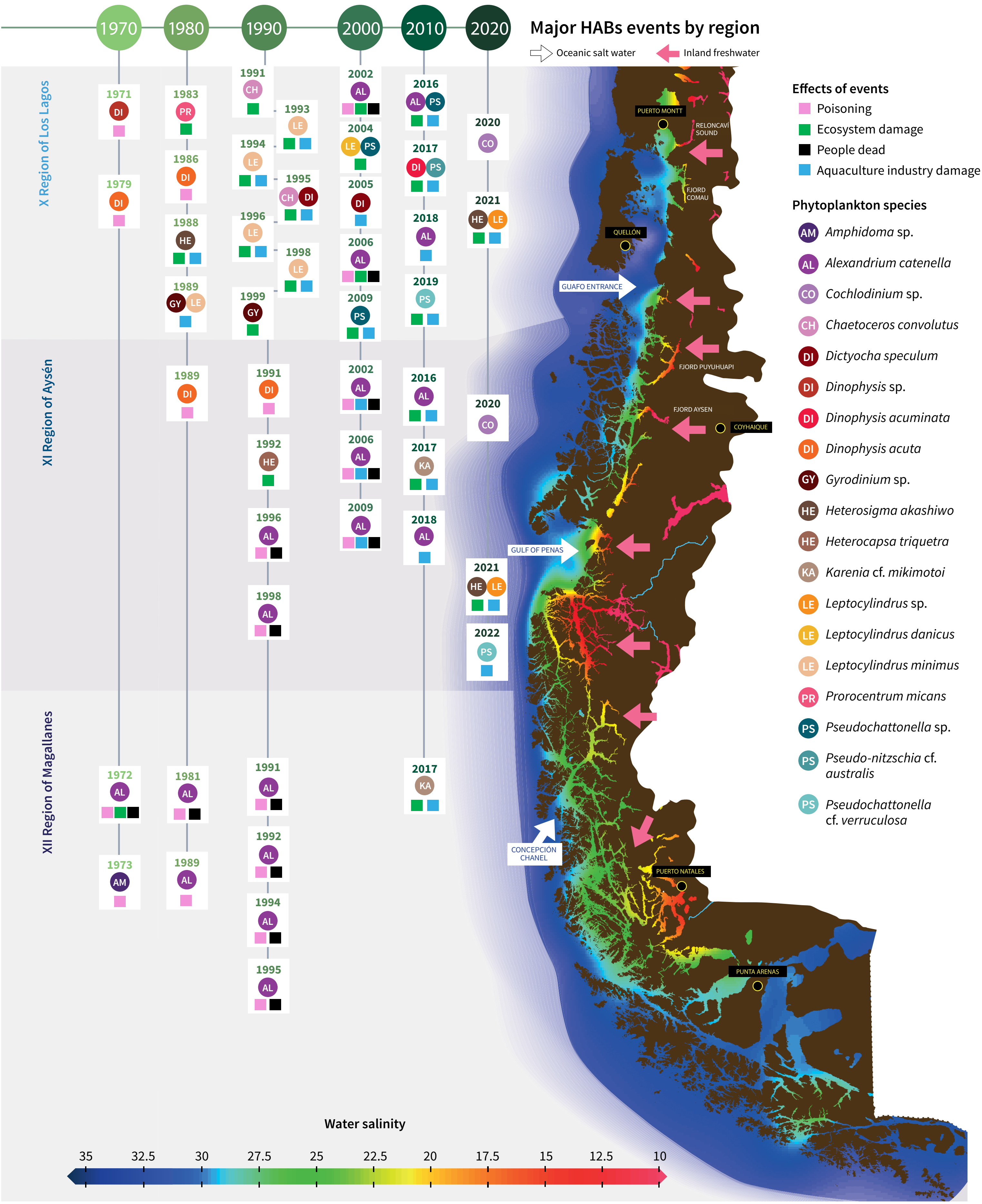
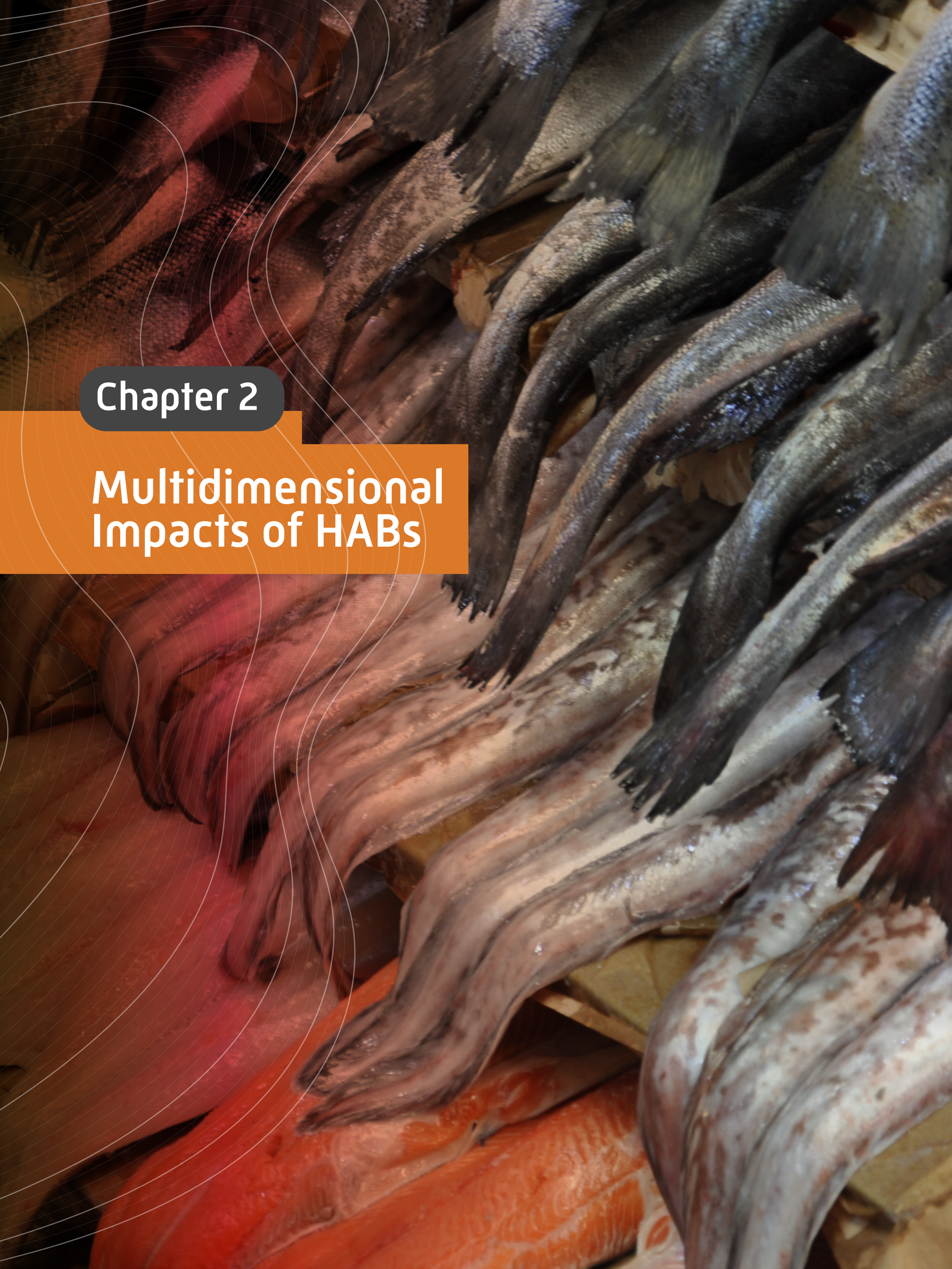


Figure 2: Major HABs events by region from 1970 to 2020 with the respective responsible phytoplankton species and their impacts at the socio-ecosystem level. The below bar represents whether the waters seen on the map are of higher salinity (blue) or lower salinity (red). Source: Self-Made

Chapter 2

Multidimensional Impacts of HABs



Multidimensional Impacts of HABs

Thanks to the constant prevention and education work carried out by institutions and public services, the number of people who are affected annually in Chile by poisoning, associated with HABs contaminated shellfish consumption is relatively low. However, HABs continue to be a phenomenon that claims fatalities and constantly exerts pressure on the health system. In addition, the scope of HABs can extend far beyond the health area, by significantly affecting the life of coastal communities. The economic, social and psychological impacts observed in various critical HABs episodes in the last decade show the importance of understanding these phenomena from an inter and transdisciplinary perspective.

HABs have historically been recognized because of their impact on human health, predominantly in the shape of poisoning, caused by contaminated shellfish ingestion during these events (see BOX 1).

Although the statistics in our country show a low mortality rate associated with this phenomenon, crises such as the one generated by HABs in the summer of 2016 (see BOX 2 and BOX 3) have shown that the impact is not limited to human health, but also multiple aspects of the life of coastal communities can suffer.

For example, depending on the magnitude of HABs event and the responses implemented, severe economic losses can be triggered, especially in activities such as artisanal fishing, shore harvesting, industrial fishing, aquaculture, tourism, and any other sea-related (Díaz et al., 2019; Araos et al., 2019; Mascareño et al., 2018).

Thus, the prevention and monitoring work remains essential, both to continue poisoning risk reduction efforts and to avoid deaths -which is still an occurrence related to this phenomenon-, as well as to better face the multiple economic and social problems that HABs can generate.

BOX 1 HABs impacts on health

Some microalgae species can synthesize powerful toxins. A variety of them have been detected in our country, of which, the best known are paralytic, diarrheal and amnesic toxins.

The **paralytic toxin** acts at the cellular level, with initial symptoms of numbness in the mouth, neck, lips, and extremities (arms and legs). In the case of intermediate intoxications, the individual feels a sensation of lightness and in serious cases, it produces respiratory paralysis, causing death. There have been 37 fatal cases and hundreds poisoned since its first detection in 1972.

The **diarrheal toxin** causes acute gastrointestinal upset, including nausea, vomiting, diarrhea, and abdominal pain, but does not cause death.

Finally, the **amnesic toxin** produces gastrointestinal symptoms, and if the concentration is higher, it can have unusual neurological effects, such as short-term memory loss. There is no record of intoxications in humans associated with the latter in our country.

It is essential to acknowledge that marine toxins are not removed by cooking, adding lemon or vinegar, nor does the shellfish change color, smell, or flavor when the toxins are present. Additionally, to date, there are no antidotes for any of the mentioned toxins.

BOX 2 Impacts in Quellón

The Study carried out in Quellón addressed the perception of HABs impacts from inhabitants especially in the coastal zone of this commune.

The events that have affected this area in recent years, especially the one that occurred in 2016, allow us to illustrate the complexity and concatenation of impacts that these phenomena can generate. The necessary ban on extracting and consuming marine resources to prevent poisoning has a systemic impact on this town, since it paralyzes industries and affects jobs and economic incomes of many families that engage in artisanal fishing, shore harvesting, and many other sea-related activities:

> *"But obviously the red tide issue brings about a huge economic problem, not only in terms of the individuality of the fisherman, as far as I know, but also other actors, such as small companies that operate and in which many people are currently working, so they would also lose their jobs"*
> (Civil Society member interview).

It can even lead to changes in the conditions or ways of life, customs and practices in coastal communities:

> *"To stop shellfish fishing, which is a typical activity of the territory...the curanto, for instance... many times the curanto is not prepared because of the red tide. So, you can't do".*
> (State sector member interview).

Thus, the impacts extend beyond the risk of poisoning and mental health effects. They may also associate with the insecurity or fear of eating contaminated food, psychosocial exhaustion, and the uncertainty that changing habitual practices and customs carries during a HABs episode, whose extent cannot be predicted:

> *"I think it is pretty much the same throughout the island. The tide hits us and you feel unsure, because the toxin may be lower today, but maybe tomorrow, the temperature rises and the toxin goes up"*
> (Private sector member interview).

In this way, what begins as a health problem can end up as a deep crisis with economic, social, cultural and psychological impacts that need to be addressed by public policies.

BOX 3 Social impacts of HABs in fishing coves from Chacao to the north: misinformation, mistrust and uncertainty

Until 2016, the northern boundary of HABs associated with paralytic toxins was the Chacao channel. But in that year the phenomenon advanced for more than 230 kilometers to the Los Ríos Region, affecting for the first time about 15,000 fishermen and divers who live mostly in small, rural and isolated coves, and who are dedicated to a great extent to the managing and extraction of abalones. In some cases, the prohibition of extraction and sale because of toxin levels above the allowed limit, lasted up to 18 months. Field studies have revealed that beyond the economic consequences associated with the closing of fishery activities, relevant social impacts rise. The unexpected HABs phenomenon evidenced associated misinformation in coastal communities, as well as the shortcomings in communication and coordination with the regional health and fisheries authorities:

> *"We didn't know anything. It was never discussed that there was a red tide here. We knew that it was present down south. When I was working in the south there were channels and things like that, but not here"*
>
> (Fisherman Interview).

In addition, the mortality and discharge of rotting salmon into the sea by the salmon industry and other latent conflicts with local industries fueled suspicions about the nature and causes of the HABs event. The beliefs against artisanal fishing proliferated and an atmosphere of mistrust was generated towards the private sector and public institutions.

Finally, the unexpected HABs of 2016 exacerbated the perception of uncertainty, regarding the sustainability and viability of lifeways of the fishing-artisanal communities:

> *"We are worried, especially about what will happen to us as artisanal fishermen. If this red tide thing gets worse, what will happen to us? (...) our work source is in jeopardy and any error or improper handling of the process to determine if there is a red tide or not will cost us our jobs, our food, and our own health, as well as the general population's"*
>
> (Fisherman Interview).

In this sense, it is important to recognize and address HABs impacts in advance, especially in isolated localities, highly dependent on benthic resources and where there is no previous experience with HABs, since the relationships among people, organizations and institutions can deteriorate and trigger greater social conflict. Learning lessons from the observed impacts is an essential step to learn to live in a collaborative way with HABs.

Quotes from interviews and workshops carried out in five coves between Chacao and Mehuín during 2017 and 2018. Source: Project FONDE- CYT 11171068 Post-disaster livelihood recovery and adaptations in natural resource-dependent communities in Chile. Andrés Marín, University of Los Lagos.

In the year 2019, the annual cost of monitoring phytoplankton and toxins in Chile was as much as 6,400 million pesos (Mardones et al., 2020). This monitoring is the one that activates the HABs program of the Ministry of Health (Minsal), determining the closing of coastal areas and the inspection of potentially contaminated products. If such action was not taken, the number of poisonings could increase dramatically, with an estimated cost of up to $30 billion. In fact, our country has the highest rate of poisoning and deaths in Latin America (Sunesen et al., 2021). It should be noted that in 2018 Chile registered the highest concentration of paralytic shellfish toxin (PST), specifically in mussels extracted from the Aysén region (Guzmán et al., 2018; Rivera Belmar & Tocornal Ríos, 2018; Díaz et al., 2019), presenting toxicities that exceed the permissible limit for human consumption by almost 1,800 times. It must be considered that the cost of hospitalizations in 2018 was approximately $65,000,000 for the care of 26 cases (Minsal, 2018), in general, it is estimated that the social cost related to deaths from preventable poisoning is $7,300,000 per person (Eichenbaum et al., 2020).

Although how much it is known about the impacts of HABs, beyond the health field, is still quite limited, the impact that these events have on the productive activities of the fishing sector, especially in aquaculture, has favored greater studies of these phenomena. The latter also considers that the production costs associated with HABs can increased greatly, if losses in terms of income sources are contemplated, which would equal an amount of 32.7% of the fishing sector production, with an estimated cost of almost $700,000,000 (Eichenbaum et al., 2020).

However, very little is still known about the systemic crises that HABs can trigger and the multiple impacts in pertaining areas, such as the mental health of coastal communities, food sovereignty and the culture of these localities. The above is particularly relevant when these events become chronic phenomena that prevent the development of certain activities and even force many people to seek new income sources or new places to live in.

Impact indicators

HABs manifest abundantly and continuously, particularly in southern Chile. For this reason, there is a permanent surveillance and response protocols on the part of the health, fisheries, and aquaculture authorities to protect people's health and avoid poisoning or deaths associated with the contamination of seafood. This surveillance and response, together with the self-care actions of the population has made it possible to keep the cases of morbidity and mortality quite controlled. However, both HABs and the measures deployed to deal with them -such as the closure of extraction areas- alter or prevent the normal development of activities in the territory, thus generating economic and social impacts.

The multidimensionality of HABs Impacts

Based on the documented experience in Chile and at an international level, as well as on interviews and surveys carried out in the Los Lagos Region, eight areas that may be affected by HABs events have been identified: four related to social impacts, three economic ones, and one related to health and well-being. Within these eight areas, twenty-two sub-areas are recognized, in the latter there may be one or more impacts, so that the total number of identified social, economic and health impacts reach sixty.

Although all these impacts are not necessarily manifested throughout each HABs event, it is important to keep them in mind when planning the best strategies to deal with these phenomena.

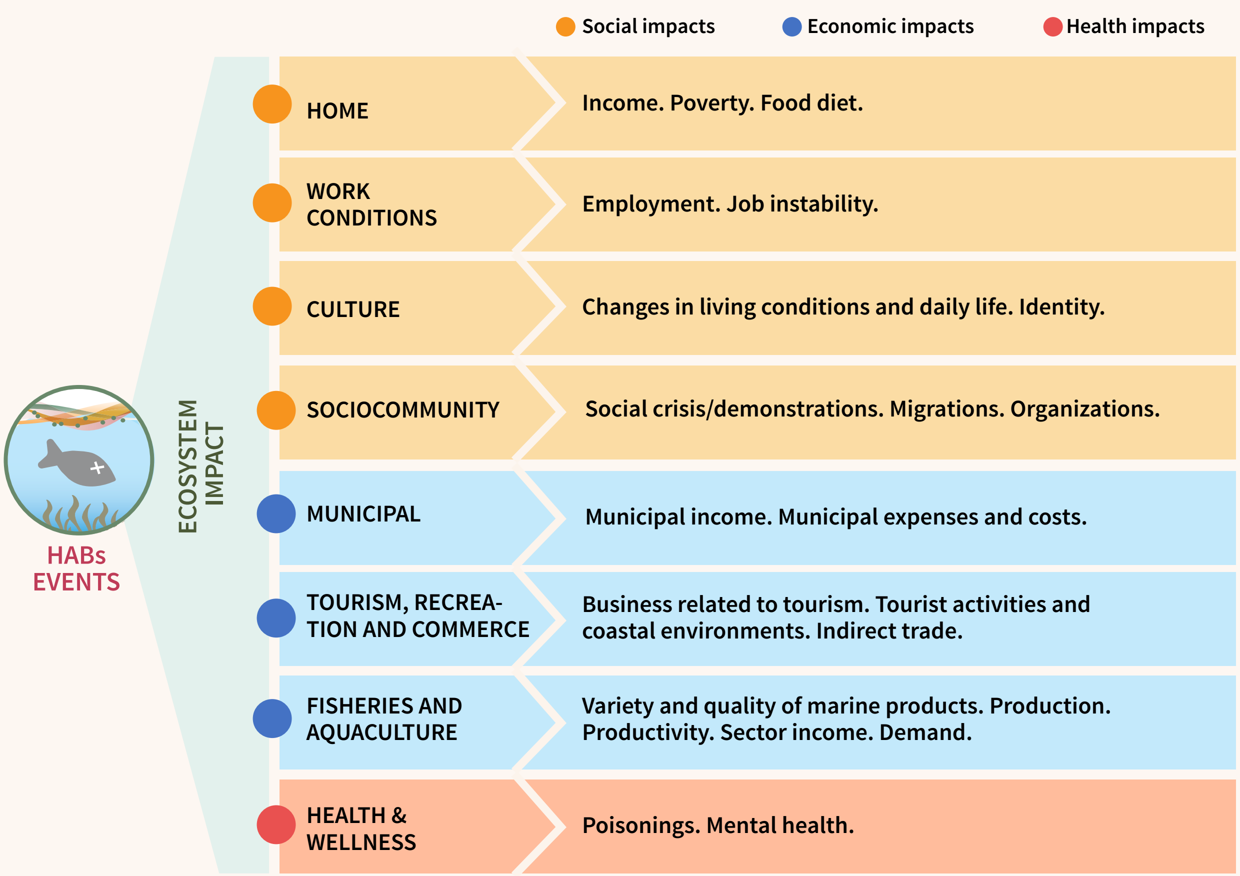


Figure 1. Scopes and sub-scopes of impacts caused by HABs events.
Source: Self-Made.

To assess the presence and magnitude of these impacts, indicators at the community level became necessary. For the period between the years 2013 and 2020, eleven indicators were detected (see Table 1) in three communes: Calbuco, Quellón and Castro, which show a variation after the HABs event in 2016 (see Figure 2). Despite the previous, it cannot be concluded that there is a causal relationship with the event, but it is a starting point for a more in-depth analysis of HABs impacts in each commune, and of factors, practices that can amplify or mitigate the impacts thereof.

SCOPE	SUBSCOPE	IMPACT	INDICATORS
FISHERIES AND AQUACULTURE	Production	Production affectation	**Fish aquaculture:** Landing of fish aquaculture in tons
			Shellfish aquaculture: Landing of shellfish aquaculture in tons
			Artisanal mollusks: Landing of artisanal mollusks fishing in tons
MUNICIPAL MANAGEMENT	Municipal income	Change in municipal income	**Aquaculture patents:** Municipal income for payment of aquaculture patents
TOURISM, RECREATION AND COMMERCE	Tourism related businesses	Decrease in sales of tourism characteristics activities (TCA	**TCA sales:** Net sales on the tourism characteristics activities: "Passenger transport by road"
			Visitors to Parks: Number of visitors to recreational parks
HOMES	Income	Affectation of the household economy, decreasing family income	**Income:** Average household work income
			Subsidies: Average household monetary subsidy
	Poverty	Change in poverty levels	**Poverty:** % of people living in poverty
WORK CONDITIONS	Employment	Increase in severance or unemployment	**Unemployed:** % of unemployed
			Job seekers: People registered in the municipality looking for a job

Table 1: Economic indicators to measure HABs impacts. Source: Self-Made.

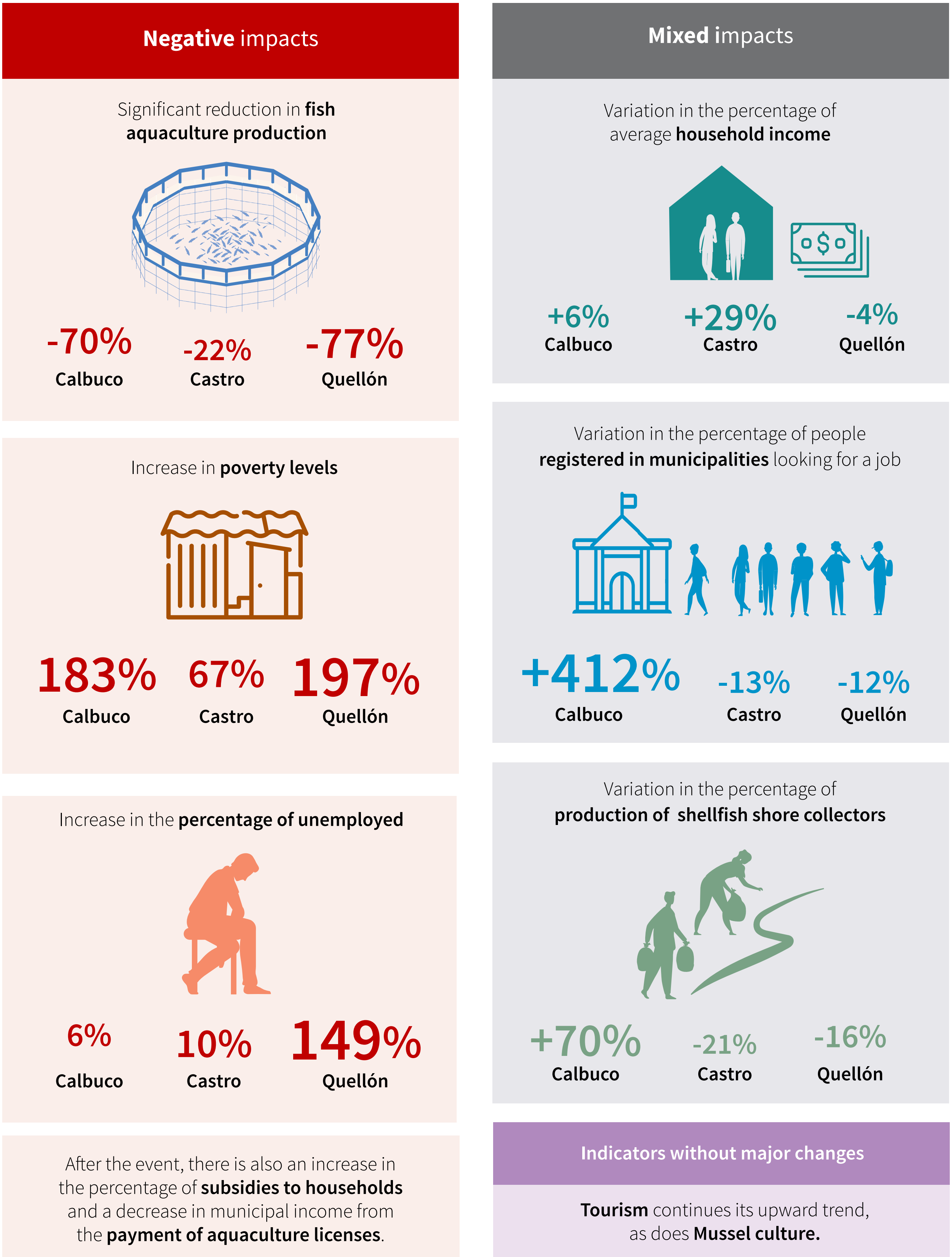
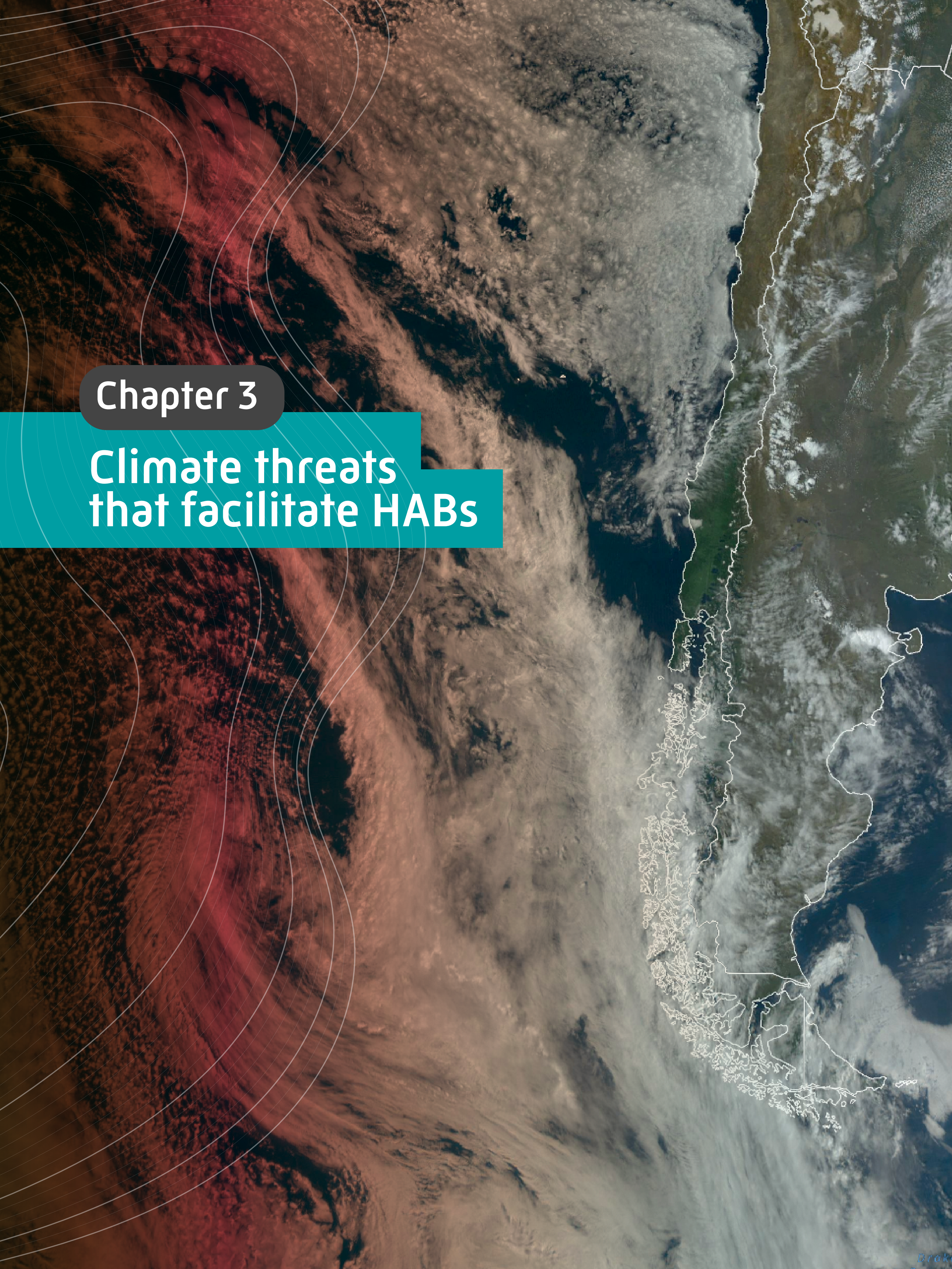


Figure 2: Negative, mixed and unchanged impacts in the municipalities of Calbuco, Castro and Quellón after the HABs event in 2016. These indicators are a starting point for a more in-depth analysis of HABs impacts on each commune, and of factors and practices that can amplify or mitigate the impacts thereof. Source: Self-Made.

Chapter 3

Climate threats that facilitate HABs



Climate threats that facilitate HABs

As indicated in the Introduction of this report, the concept of risk represents possible negative impacts for humans and ecosystems and consists of the following interactions: a threat, community exposure and its vulnerability, which is related to a greater predisposition to the impact of threat. In this context, the next chapter will focus on the climatic variables posing a threat to facilitate HABs.

A climate threat is understood as any climate variable or a set of variables that can affect human and natural systems negatively. In the case of HABs, there are meteorological and oceanographic variables having impact on the abundance and diversity of phytoplankton, which may become a threat to socio-ecosystems. Some of these variables are the precipitation, the volume of freshwater discharged into the sea and the intensity of the wind (Garreaud, 2018; León-Muñoz et al., 2018; Díaz et al., 2021). In particular, the precipitation and freshwater discharge cause seawater to separate into different layers of density (stratification), while wind causes vertical mixing of the waters. Both the changes in the stratification and in the mixing can cause a lower or greater entry of nutrients to the superficial layer of the sea, where phytoplankton mainly inhabit, thus impacting on its growth and blooms occurrence (Paredes-Mella et al., 2020).

At the same time, there are climatic oscillations at a global level that modify the meteorological and oceanographic conditions, affecting the temperature, solar radiation, precipitation, and wind in Patagonia. Some of them are the Madden-Julian Oscillation (MJO), the Southern Annular Mode (SAM), the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). Due to their interactions, the conditions associated with each of these oscillations can amplify or buffer each other, making it very complex to attribute and accurately forecast changes in climate variables.

In the case of the channels and fjords systems in the Aysén region, the precipitation variations between the years 2007 and 2019 coincide with changes in the abundance of *Alexandrium catenella* (a species known to cause catastrophic HABs events in the area) as well as in the concentration of saxitoxins (toxins that this species produces). For example, in rainy years (2010 and 2011) there was a decrease in *Alexandrium catenella* and saxitoxins, as well as in the total phytoplankton biomass. On the contrary, throughout dry years (2014 to 2016), the relative abundance of *Alexandrium catenella* shows a clear increase (see Figure 1). This fact has been associated to climatic oscillations such as the ENSO and the SAM, since during El Niño (warm phase of the ENSO) or under the positive phase of the SAM, lower rainfall is recorded in northern Patagonia, thus altering the abundance of *Alexandrium catenella*.

The reason why dry years favor the presence of this species is not completely known, but it is speculated that it is due to the rivers freshwater discharge and runoff decrease, generating less stratification. It causes the nutrients from the deeper waters to reach the surface and favor the growth of phytoplankton, increasing the probability of HABs occurrence. On the other hand, a lower freshwater discharge causes a decrease in estuarine circulation and an increase residence time in water, especially in semi-closed aquatic systems such as channels and fjords (Pinilla et al., 2020), which can favor the permanence of nutrients, organic matter and pollutants, generating favorable conditions for the occurrence of HABs events. In fact, it was evidenced in northern Patagonia during 2016 (Figure 2), one of the driest years in recent decades with the longest permanence of water, which caused less renewal thereof.

In addition to the facts previously described, it was evidenced that, on the time scale of days to a few weeks (intraseasonal scale), the presence of a migratory anticyclone (synoptic system of high atmospheric pressure), located in the extreme south of South America also affects the phytoplankton biomass. In fact, between the summers of 2003 to 2019, 16 high phytoplankton biomass events influenced by this phenomenon were identified in the inland sea of Chiloé. This responds to the fact that anticyclone favors conditions of high solar radiation, a sea surface temperature increase, and a reduction in the depth of the photic layer, which favors phytoplankton photosynthesis its growth, and consequently, the HABs occurrence probability. However, it should be noted that the occurrence frequency of this particular meteorological situation depends partially on the Madden-Julian Oscillation (MJO), a phenomenon of tropical origin that can determine the intraseasonal atmospheric circulation to a certain degree, in mid-latitudes of the southern hemisphere.

Despite the facts stated, it is relevant to clarify that the atmospheric conditions favoring phytoplankton blooms may vary according to coastal geography and season of the year. For example, contrary to what happens in the inland sea of Chiloé, oceanographic data in situ (recorded in summer in the Puyuhuapi fjord) show that a greater phytoplankton biomass is favored by frontal systems (low atmospheric pressure synoptic systems) passing, since the associated intense winds cause strong vertical mixing of the water column, weakening stratification, and causing greater nutrients availability near the surface, a necessary factor for optimal phytoplankton growth.

In summary, there are different atmospheric and oceanographic mechanisms that determine optimal combination to favor phytoplankton presence and abundance and eventually, potential HABs occurrence. Therefore, when the aim is to gather evidence on climate threats that currently affect and will affect the growth of phytoplankton produced by HABs, the different local and remote variables mentioned must be analyzed, as well as the combination thereof, especially in a context of climate change.

What has changed and what does the future hold? Climate trends and projections for Patagonia

In recent decades, the atmospheric and oceanographic variables have undergone shifts, and due to climate change, it is forecasted that these shifts will continue (Boisier et al., 2018; Garreaud, 2018; León-Muñoz et al., 2018; Aguirre et al., 2019; Diaz et al., 2021). In this context, trends between 2000 and 2020, particularly in the summer season, indicate that **clear days** have increased in the Los Lagos and Aysén regions, by approximate six days in total, in the latter two decades (approx. 3 days per decade).

Time series of variables between the years 2007 and 2020

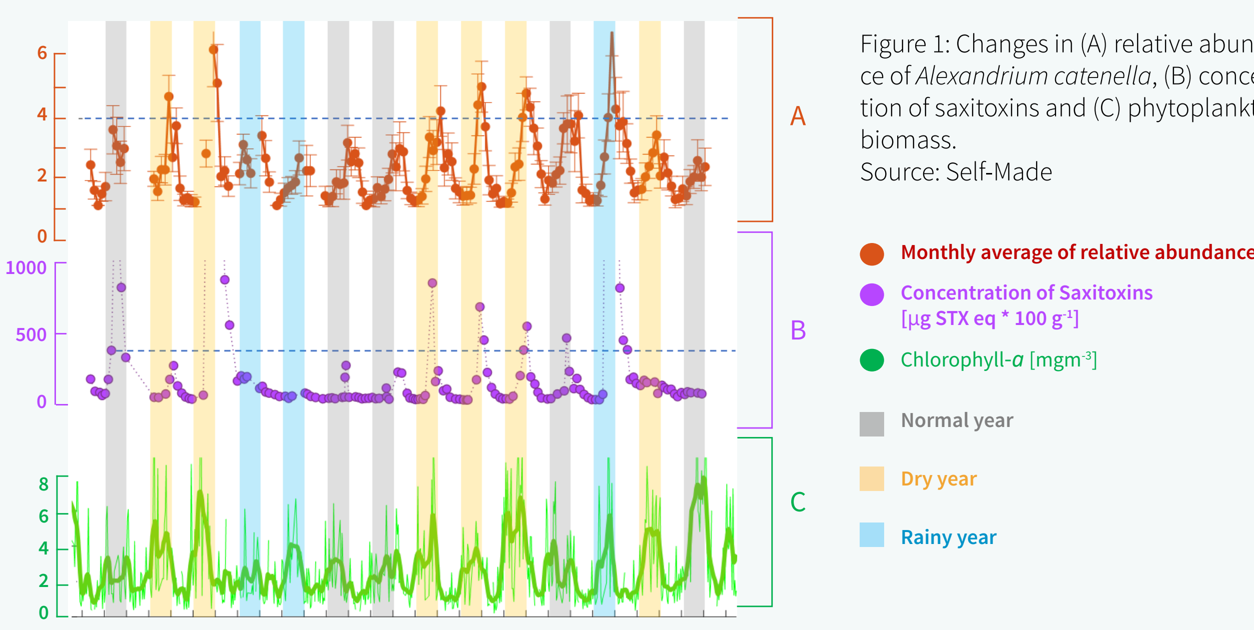
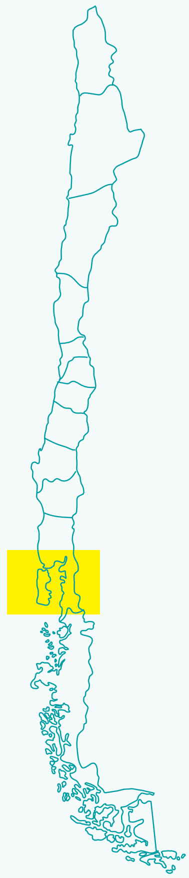


Figure 1: Changes in (A) relative abundance of *Alexandrium catenella*, (B) concentration of saxitoxins and (C) phytoplankton biomass.
Source: Self-Made



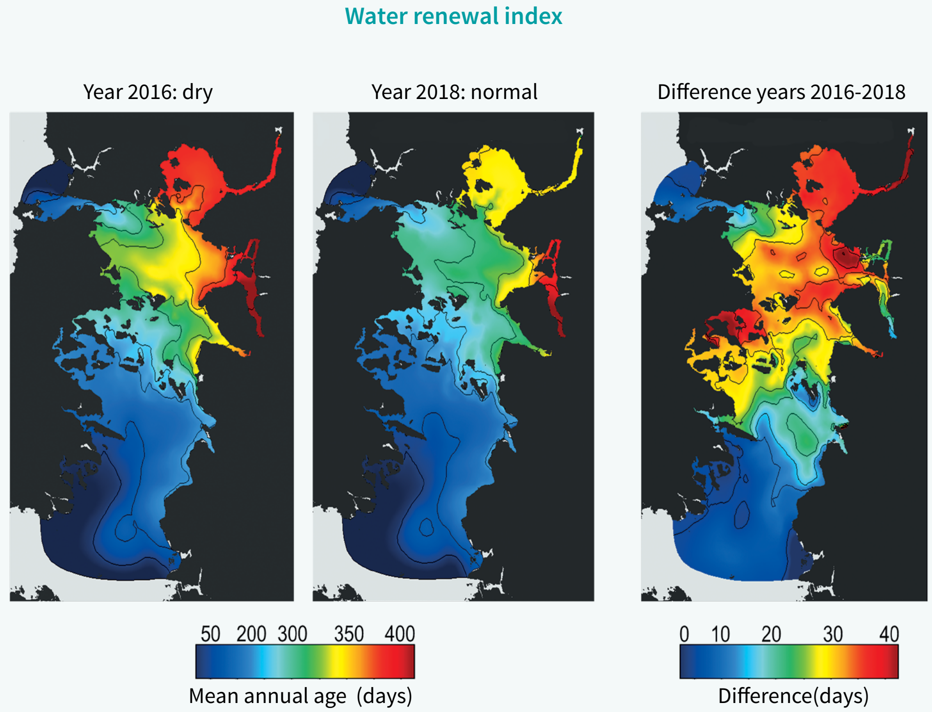


Figure 2. Water renewal index measured as residence time for a dry year (2016), a year slightly above normal (2018) and the differences between both years. Source: Elías Pinilla, Fisheries Development Institute.

Global climate models and projections indicate that this trend will continue by the end of the century, therefore, solar radiation is expected to increase (see Figure 3), a factor that could favor the development of HABs.

Meanwhile, in recent decades, the sea **surface temperature,** a key variable for the occurrence of HABs, shows a sustained increase of about 0.5 °C per decade, in the Los Lagos and Aysén regions. However, the trend shows opposite behavior in the Magallanes Region, with a decrease of -0.1 ºC per decade. As expected, the end of the century projections show that the increase will continue for all Chilean Patagonia, with an increase of 3 °C with when compared to current climate, which will even include Magallanes (see Figure 4).

Regarding **rainfall** during the summer season, in the last 20 years (2000 - 2020) a decreasing trend has been observed in northern and central Patagonia. For this reason, a robust decrease is projected in the Los Lagos and Aysén regions (-20 %) by 2100, which would favor species HABs such as *Alexandrium catenella*. Nevertheless, a slight increase in the amount of rainfall (5%) in the Magallanes region is projected towards the end of the century (see Figure 5).

In relation to the **wind,** an increase is projected that would favor coastal upwelling off northern Patagonia, a pattern that would continue by the end of the century (2100). On the other hand, the observations indicate a trend of the westerlies moving southward in recent decades (2000-2020), which leads to decrease of the wind that blows from West to East, up to approximately latitude 53°S, with an intensity increase in more polar areas. These trends are consistent with the patterns projected under a climate change scenario, which show that by the end of the century, a robust decrease in the westerly wind is expected in the Los Lagos and Aysén regions, and a robust increase in Magallanes (see Figure 6).

The changes observed in the last decades (2000-2020), as well as the changes projected for the end of the century (2100), modify the environmental conditions of the canal and fjord ecosystems of Chilean Patagonia, and make them more favorable for the development of some types of HABs.

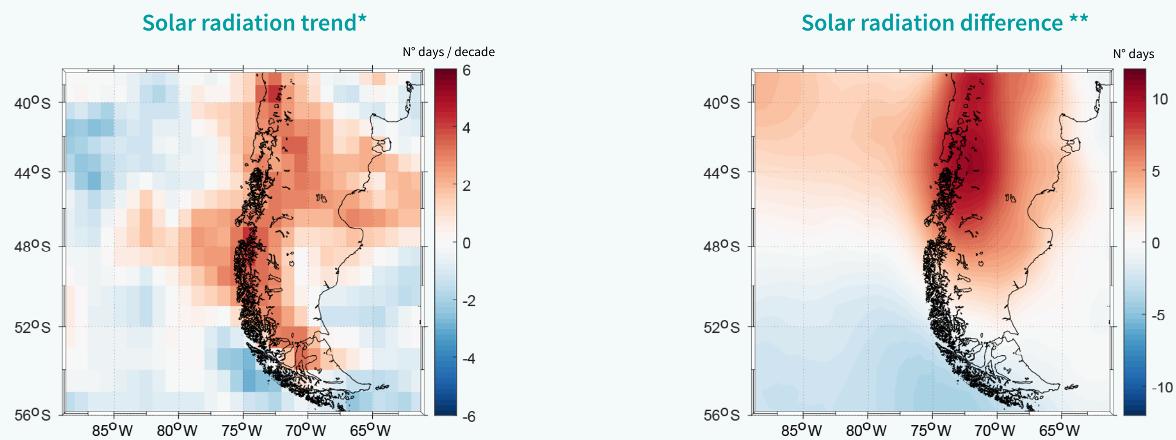


Figure 3. Recent trends (left) and expected changes (right) in solar radiation towards the end of the 21st century (2100) in the Southern Cone of South America. Source: Self-Made.

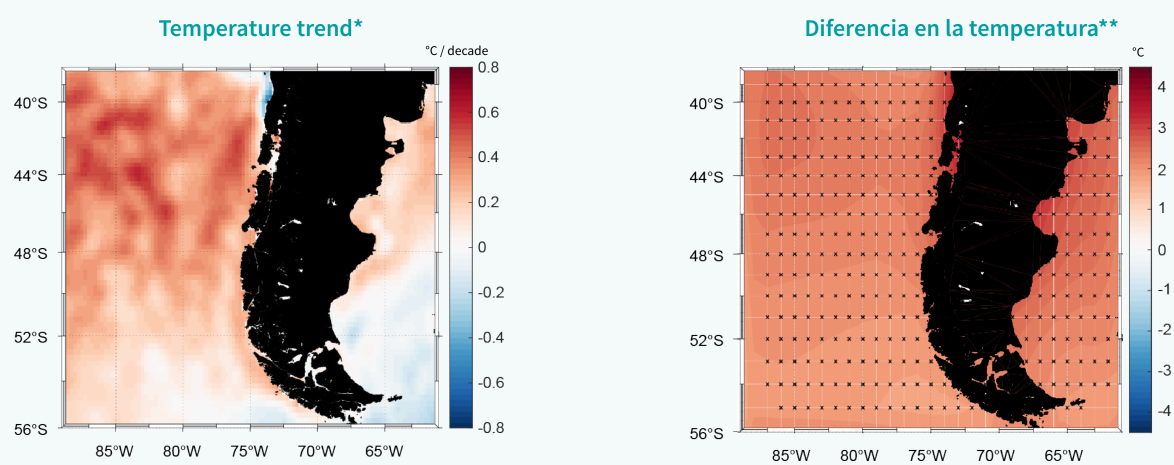


Figure 4. Recent trends (left) and expected changes (right) in temperature towards the end of the 21st century (2100) in the Southern Cone of South America. Source: Self-Made

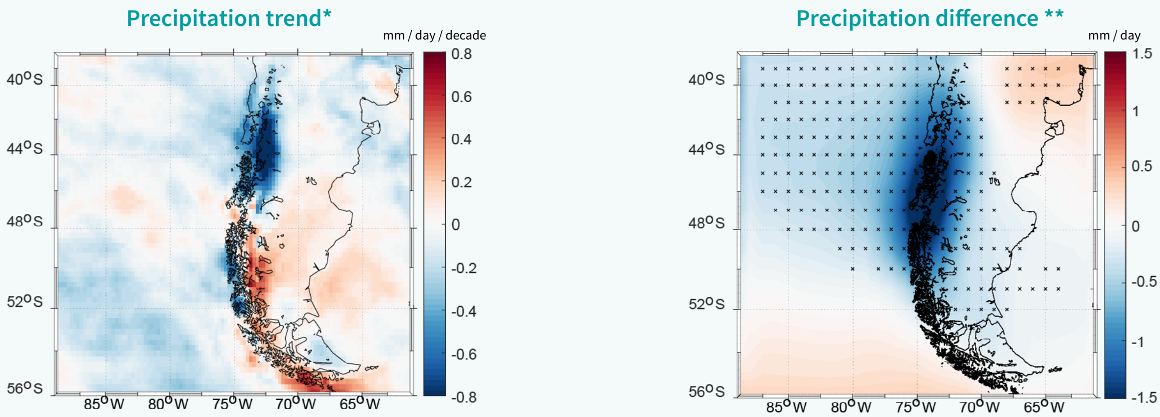


Figure 5. Recent trends (left) and expected changes (right) in precipitation towards the end of the 21st century (2100) in the Southern Cone of South America. Source: Self-Made

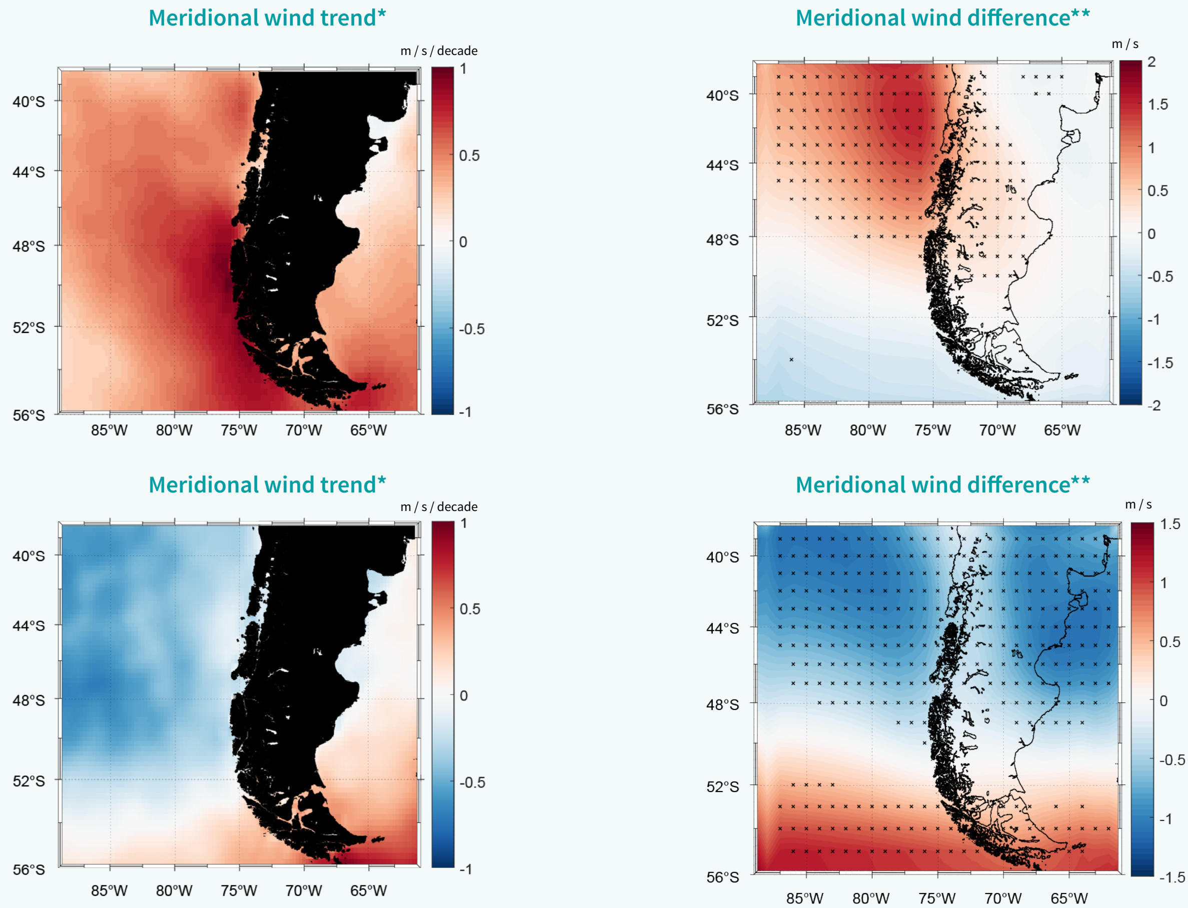


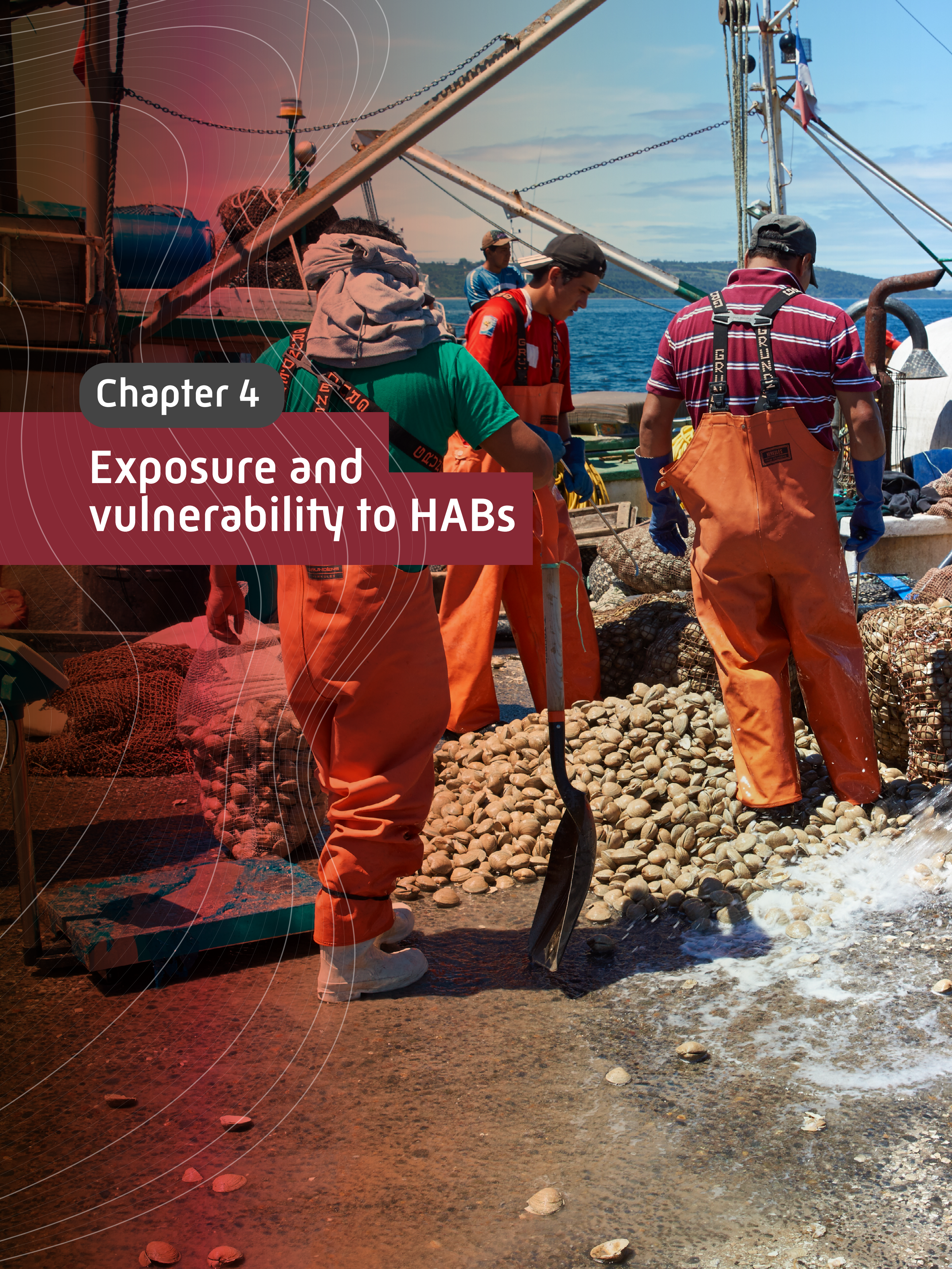
Figure 6. Recent trends (left) and expected changes (right) in surface wind towards the end of the 21st century (2100) in the Southern Cone of South America. Source: Self-Made.

*Left: Recent trends of the summer season, calculated for the period 2000-2020. Source: Clouds and Earth's Radiant Energy Systems (CERES) Energy Balanced and Filled (EBAF), for radiation; reanalysis ERA5, for precipitation; Optimum Interpolation Sea Surface Temperature (OISST), for sea surface temperature; and Cross-Calibrated Multi-Platform (CCMP) wind vector analysis, for wind.

**Right: Differences calculated as the record of climate projections considering the RCP 8.5 scenario for the end of the century (2070-2100) and those corresponding to the historical period (1970-2000) considering 25 models of the Coupled Model Intercomparison Project (CMIP5). The areas where a robust change is observed are highlighted, that is, where more than 80% of the models show the same trend of change.

Chapter 4

Exposure and vulnerability to HABs



Exposure and vulnerability to HABs

The previous chapter focuses on the risk component of climate hazards that could potentially cause an increase in the probability of HABs occurrence.

This chapter addresses the other two risk components: exposure and vulnerability to HABs.

Exposure to HABs, what is in danger of being lost in Chilean Patagonia?

Exposure refers to those elements potentially susceptible to being affected by a certain climatic hazard, and in this particular case, the climatic hazards that may favor HABs increase. Such elements include human life (health and well-being), livelihoods, ecosystems and species, economic, social and cultural assets, and services and infrastructure, among others (IPCC, 2022). The more existing elements in a certain territory that can potentially be affected or negatively impacted by HABs, the greater the exposure to HABs; therefore, the greater the risk.

It should be noted that the current and potential impacts of HABs are unevenly distributed when comparing different geographical areas (see details in chapters 2 and 7). In the case of the Los Lagos, Aysén and Magallanes regions, there are important differences in the type and quantity of natural systems (coastal ecosystems) that would be exposed to HABs. For example, if we focus on the number and surface of Marine Protected Areas (AMP), the Los Lagos region stands out for having the highest number (4), as compared to Aysén (2) and Magallanes (3). However, the area varies, since the Magallanes region has 145,000 km^2 of protected areas, compared to Los Lagos and Aysén, which have 63,000 and 7,000 km2 respectively. Along with this, there is a large number of species susceptible to HABs. The Magallanes region has nearly 2,000 described species, that occupy its coastal-marine territories, while Los Lagos has 593, and Aysén, 458.

Regarding the exposure of socio-ecological systems to a HABs, important differences are also observed when comparing the three regions (see Figure 1). For example, the Los Lagos region stands out as the region of Patagonia with the highest exposure levels to HABs due to its high dependence on sea-related activities, specifically fisheries and aquaculture. Today, fisheries and aquaculture provide this region with a significant amount of direct and indirect employment, as well as permanent and temporary labor. The region has a high number of artisanal fishermen, centers registered in the National Aquaculture Registry, and a high volume of overall algae and mollusk landing. This dependence on the fisheries and aquaculture sector is associated to the large number and variety of species of interest to the aquaculture sector (gracilaria seaweed, atlantic salmon, coho salmon, rainbow trout, cholga mussels, chorito mussels and Chilean oyster), artisanal fishing (giant kelp, cochayuyo, mazzaella laminarioides, sarcothalia crispata, gigartina skottsbergii, anchovy, southern hake, Pacific pomfret, cholga mussels, chorito mussels, Tawera gayi clam, abalone, culengue Pacific clam, sea asparagus, king crab and sea urchin) and industrial fishing (Chilean seabass).

Administratively, the Los Lagos region also has a large number and area of Management and Exploitation Areas for Benthic Resources (MEABRs) and and Coastal Marine Areas of Indigenous Peoples ((ECMPO in Spanish), which shows how intensive the extraction of resources is and accounts for the importance and dependence of this region on the activities revolving around the sea and its coasts.

Employment and Economic Resources

Permanent jobs (fisheries, aquaculture and processing sectors)
Source: SERNAPESCA Chile - Year 2020

Casual jobs (fisheries, aquaculture and processing sectors)
Source: SERNAPESCA Chile - Year 2020

Regional GDP percentage of the fishing sector
Source: Banco Central Chile - Year 2019

Regional GDP percentage of the commerce, restaurants and hotels sector - Source: Banco Central Chile - Year 2019

Biodiversity and Protected Areas

Marine Protected Areas
Source: Undersecretariat for Fisheries (SUBPESCA Chile)

Diversidad de especies
Ocean Biodiversity Information System (OBIS) SERNAPESCA, Chile

Fisheries and Aquaculture

Tons of fish harvested
Source: SERNAPESCA Chile - Year 2020

Tons of shellfish harvested
Source: SERNAPESCA Chile - Year 2020

Algae landing
Source: SERNAPESCA Chile - Year 2020

Fish landing
Source: SERNAPESCA Chile - Year 2020

Shellfish landing
Source: SERNAPESCA Chile - Year 2020

Crustacean landing
Source: SERNAPESCA Chile - Year 2020

Existing fishing plants by the year 2020
Source: SERNAPESCA Chile

Centers registered in the National Aquaculture Registry between 2015 and 2020
Source: SERNAPESCA Chile

Management and Exploitation Areas for Benthic Resources (MEABRs)
Source: SUBPESCA Chile

Areas Appropriate for Aquaculture (AAAs)
Source: SUBPESCA Chile

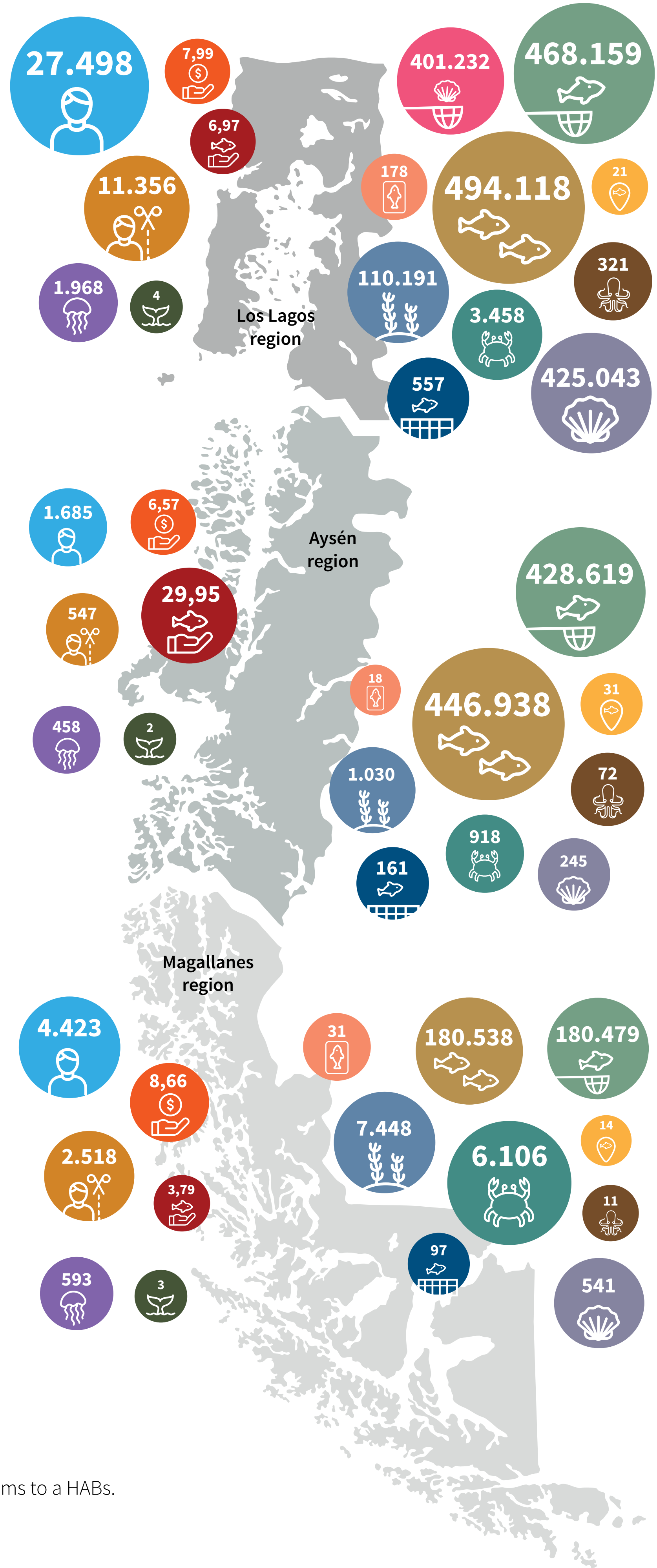


Figure 1. Exposure of socio-ecological systems to a HABs.
Source: Self-Made.

In economic terms, the fisheries and aquaculture sector has a high impact on the Gross Domestic Product (GDP) of the Los Lagos and Aysén regions, showing sustained growth in the last five years, with values of around 335 M$ and 269 M$ in 2019. It is here that the Aysén region, compared to the other regions, stands out for its high economic exposure to climatic events that could generate HABs events. In fact, according to data from the National Municipal Information System (Sinim), the fisheries sector contributes to almost 30% of Aysén's regional GDP, compared to a much inferior 7% and 4% in the Los Lagos and Magallanes regions, respectively. In addition, there are important shellfish landings in Aysén, but these activities are declared in the Los Lagos region.

Tourism is another important sector exposed to negative impacts of the potential increase in HABs due to changes in weather conditions. The Los Lagos region, followed by Magallanes, stands out for having a large number of companies of the service sector (hotels and restaurants). Other relevant categories for this region, in terms of quantity are: number of workers, annual sales, companies related to cultural activities, number of tourists, and passengers transported by water and visitors to Wilderness Protected Areas. The contribution of the tourism sector to the regional GDP (commerce, hotels, restaurants) is quite similar in the three regions, varying from 7% to 9%.

What is the level of vulnerability to HABs in Chilean Patagonia?

Vulnerability is defined as the degree of susceptibility or inability of a system to face an adverse impact, produced by a phenomenon or a process. Vulnerability will also depend on the relationship between the sensitivity of the system and its adaptive capacity, thus, sensitivity is defined as the predisposition to be negatively affected by the presence of a phenomenon (IPCC, 2022), while adaptive capacity refers to the planning and formulation of strategies that reduce the impacts and/or vulnerability to a given threat. It should be added that, in many cases, the difference in terms of the level of vulnerability between territories, is a consequence of multidimensional inequalities, often produced by the socioeconomic development processes of each region.

Areas with greater sensitivity to HABs in Chilean Patagonia

The presence of certain phytoplankton species (endemic or exotic) that cause HABs events in a water body could be considered as a sensitivity factor. Taking this into consideration, there is evidence that between 2006 and 2020, certain areas throughout Chilean Patagonia showed greater sensitivity or predisposition to present phytoplankton HABs events, such as *Alexandrium catenella*, *Dinophysis acuta* and *Pseudo-nitzschia australis*. The first two are mainly concentrated in the north-central area of the Aysén region, while *Pseudo-nitzschia australis* was detected from the Los Lagos region to Magallanes, an area which also concentrates *Alexandrium catenella*.

It should be noted that, although *Pseudo-nitzschia australis* and *Alexandrium catenella* are found in the north of the Magallanes region, both declined progressively towards the south, where *Dinophysis acuta* acuta is practically absent. On a subregional scale, the data show that *Pseudo-nitzschia australis* y *Alexandrium catenella* are mostly located in the area of channels and islands that are open to circulation. Meanwhile, *Dinophysis acuta* sis located in more semi-enclosed fjords, such as the Jacaf channel and the Puyuhuapi fjord, which are under the direct influence of freshwater discharge (see Figure 2).

In addition, there are other processes and factors, both natural and anthropogenic, that can increase the sensitivity of an ecosystem, such as the incorporation of pollutants (fertilizers, antibiotics, fungicides, etc.), organic matter or nutrients (eutrophication), and the existence of low-oxygen areas (hypoxia) (Silva & Vargas, 2014; Peréz Santos, 2017; Quiñones et al., 2019; Soto, Barthey, et al., 2019; Urbina et al., 2019). In addition to these factors, massive mortality and exodus of exotic fish species and loss of biodiversity have also occurred in aquatic systems in Chilean Patagonia (Gomez-Uchida et al., 2018; Haussermann et al., 2021).

Currently, salmonicultura is recognized as an anthropic activity providing organic matter and nutrients to water bodies. These inputs of organic matter and nutrients can make aquatic systems in Chilean Patagonia more sensitive to the impacts of HABs events. In fact, in inland areas and semi-enclosed fjords (Puyuhuapi and Aysén), there is evidence of a significant increase in the concentration of nitrogenous nutrients (nitrate) between the years 2008-2018, compared to the period between 1995-2007 (see Figure 3), which could have a correlation to the exponential growth of the salmon industry (see BOX 1).

Another relevant impact, probably due to the feeding, growth and fattening of salmon (see BOX 2), has been the increase in the ratio between nitrogenous (N) and phosphate (P) nutrients. This nutrient concentration of N (nitrate, nitrite and ammonium) to P (phosphate) ratio, known as the N:P ratio or Redfield ratio, which in the marine environment is close to 15, is an indicator of the nutrients ratio required for optimal growth of phytoplankton. A higher-than-expected ratio (15) indicates that there is an excess of N, which could potentially favor certain phytoplankton blooms.

Data and observation show an increase in the N:P ratio (greater than 15) in Patagonian channels and fjords. This increase is more pronounced in areas intervened by salmon farming. Finally, when analyzing the nutrient load in these aquatic systems and its relationship with the growth of certain phytoplankton species, it is also necessary to consider the ratio. This is because silicate (Si) concentration decrease, due to the lower discharge of fresh water and runoff, affects the growth of diatoms.

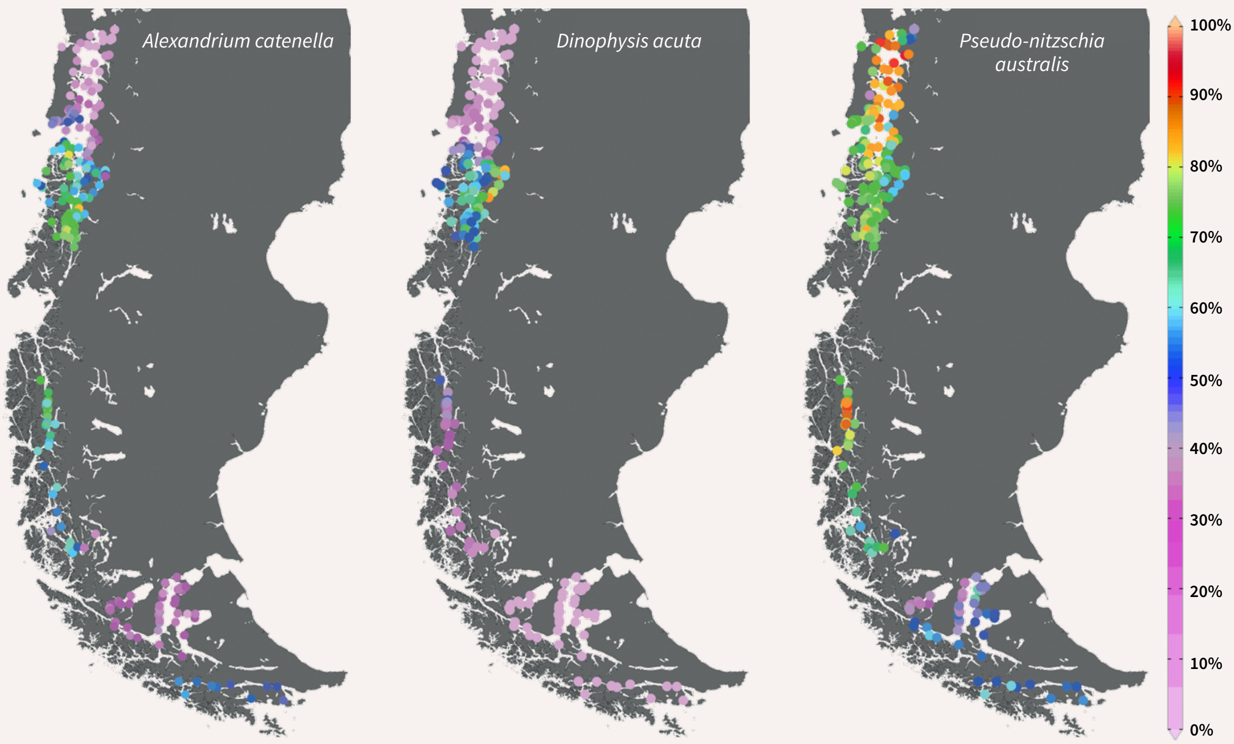


Figure 2. Presence maps of phytoplankton species causing HABs (expressed in %): a) Alexandrium catenella, b) Dinophysis acuta, and c) Pseudo-nitzschia australis, throughout Chilean Patagonia. The right-side bar indicates the presence ranges in colors: orange-red presents very high (greater than 80%), green presents high (between 80 and 60%), blue presents medium (between 60 and 45%) and lilac presents low (less than 30%). Source: Self-Made.

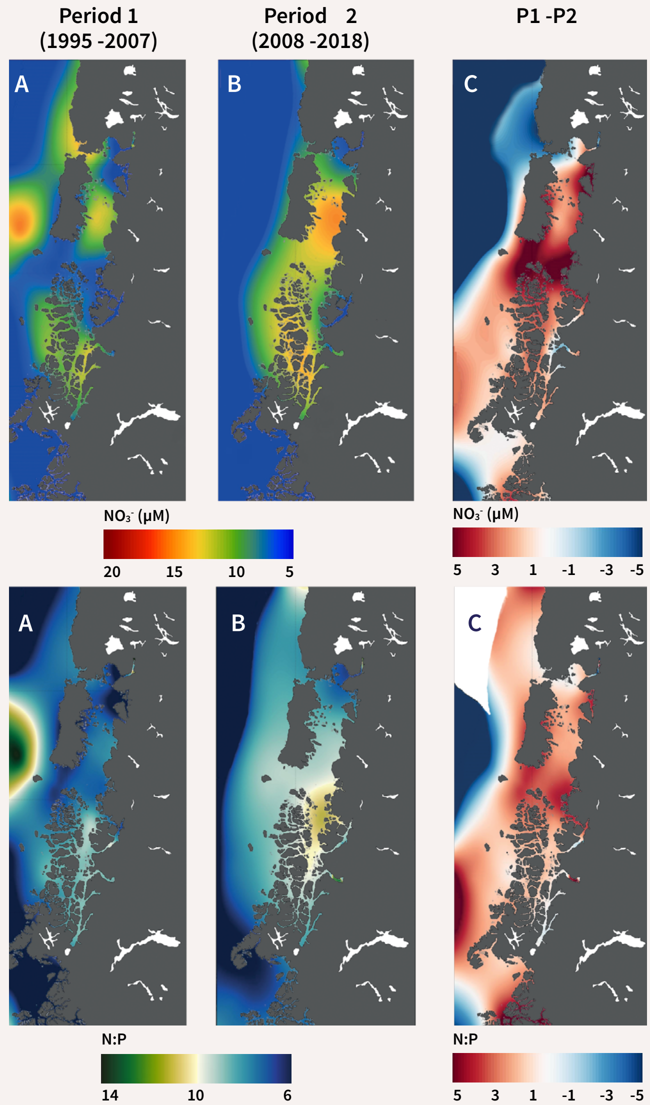


Figure 3. Distribution of the concentration of nitrates (NO_3^-) and N:P ratio in surface water (0-10 m) of northern Patagonia based on an average of the period 1995-2007 (column A) with respect to the period 2008-2018 (column B). The differences in the concentrations of both periods (column C) indicate an increase (positive value in red) or decrease (negative value in blue). The dominance of red shades, particularly in some closed fjords, shows an increase in the N:P ratio, that is, an excess of N over P.
Source: Self-Made

BOX 1 The development of salmon farming in Chilean Patagonia

Salmon farming is one of the most important and fastest growing industries in Chile, with **salmon** being the second most traded product abroad after copper, with exports of more than US$5 billion in 2021. However, when determining the locations and density of farming centers, an environmental criterion or the carrying capacity of the aquatic systems has not prevailed, which has generated to date that certain areas are currently more exposed and sensitive to climate change and other environmental stressors (Soto, León-Muñoz, et al., 2019).

The salmon industry operates logistically through the permit application from marine concessions. Each fattening center is grouped into neighborhoods or concession groups for salmon farming (ACS), and each ACS is run separately, having its own management plans to improve the environmental and health performance, and comply with the measures set by current regulations. Since 1983, the salmon industry has exponentially increased the number of centers per ACS, but in a heterogeneous way and concentrated in small fjords, such as Reloncaví, Puyuhuapi and Aysén (see Figure 4). As of 2007, almost 85% of the production was concentrated in the Los Lagos region, which later moved to the Aysén region, and in recent years to the Magallanes region. As of 2019, Patagonia showed around 1,400 concessions granted, with 135 centers concentrated in a small area that encompasses the three fjords mentioned, presenting an average increase rate of 157% in centers for the period between 1983 and 2018 (Undersecretariat of Fisheries and Aquaculture, 2020).

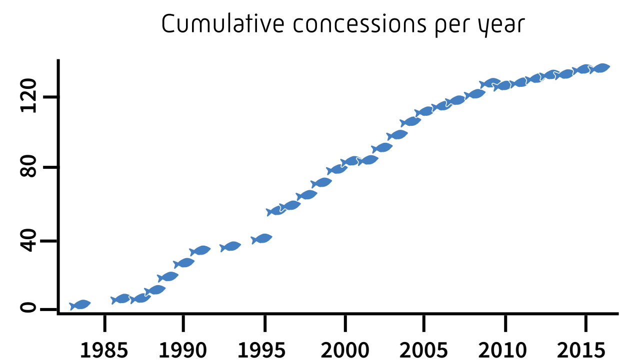


Figure 4: Concessions increase rate per year for the fjords of Reloncaví, Puyuhuapi and Aysén since the beginning of salmon farming. Data of Subpesca 2020.
Source: Self-Made.

BOX 2 Salmon farming as an additional source of nutrients to aquatic systems

One of the main contributions of salmon farming is nitrogen input into water bodies due to the protein pellets feeding the fish. 40% of these pellets are not consumed and settle on the seabed, while the 60% ingested is partially eliminated into the water through urine, as dissolved organic nitrogen and/or mucus and feces, which is particulate organic nitrogen.

These forms of nitrogen break down into organic and inorganic compounds (nitrogenous nutrients such as urea, ammonium or nitrates), and affect or stimulate the microbiota (Fernández et al., 2020; Molina & Fernández, 2020; Montero et al., 2021). In the Reloncaví, Puyuhuapi and Aysén estuaries, the amount of nutrients produced by salmon farming is one hundred times higher than the one naturally received by runoff or discharge from the rivers that flow into the respective systems.

If these nutrients are not assimilated by phytoplankton and macro algae, or in the case that they are not exchanged with adjacent waters at the same rate at which they are being regenerated, they accumulate in the fjords waters, and may favor or stimulate the growth of certain microalgae, which makes the systems more prone to HABs events. Therefore, before installing a salmon farming center, the carrying capacity of the aquatic ecosystem must be considered (Soto, 2022).

Adaptive Capacity and identification of adaptation measures that respond to vulnerabilities.

The concept of adaptive capacity related to HABs refers to several aspects, such as the legal and regulatory framework, monitoring and warning systems, resources, risk perception, and the institutions and administrative structures that allow generating effective adaptation processes, aimed at vulnerability reduction. Two sources of adaptive capacity are addressed in this section: monitoring and risk perception. The rest are developed in the next chapter, which analyzes HABs governance in terms of regulatory framework, articulation of actions, resources and planning, as well as the cooperation and coordination networks among various actors. All these capacities must have territorial coherence, based on the social and cultural characteristics of the systems considered.

Monitoring as part of the HABs surveillance system

The monitoring programs are systematic activities, in space and time, that provide information on natural and human-induced trends of certain variables, which are used as environmental change and impact indicators of public health and productive activities. Having monitoring or alert systems helps to plan and respond to potential events that could produce negative impacts.

Currently, in the fjords and channels of southern Chile there are four main monitoring programs related to HABs:

1. SUBPESCA/IFOP Monitoring System (Fiordos Red Tide Program and Pacific Program) (see BOX 3)

2. Surveillance and Control of Poisoning by Harmful Algal Blooms Program, run by the Ministry of Health

3. Bivalve Mollusk Health Program (PSMB in Spanish), run by Sernapesca

4. Phytoplankton Monitoring Program (Promofi), run by the Salmon Technical Institute

In addition, there is a Cimar-Fiordos program, aimed at generating knowledge and establishing baselines of different variables and oceanographic processes in the fjords and channels of Chile. All these programs are financed by the State, except for Promofi, which belongs to the private sector (see Figure 5). Until now, the analysis of HABs monitoring systems shows adequate spatial coverage and density for the entire area potentially exposed to these events. The sampling frequency varies from two to five years (Cimar) and monthly/weekly (Fiordos-IFOP, Promofi) and increases when HABs events occur (reactive or contingency monitoring).

However, the diagnosis shows little spatiotemporal integration and coordination among the different monitoring systems and the institutions that carry them out. For example, the IFOP sampling stations are not in the areas covered by the PSMB, nor in the salmonid fattening centers. The lack of integration prevents a proper validation of different information sources and does not strengthen decision-making when raising environmental attributions to HABs events. In addition, it is observed that fundamental environmental variables measurement does not follow the same protocol (they are not measured in the same way or with similar precision), nor are the same variables included in the different monitoring schemes. One example is the category of nutrients, which has been added by IFOP programs only in recent years.

Despite these weaknesses, it is considered that the surveillance and follow-up of the sanitary and productive status of HABs events in Chile is pioneering in Latin America. These programs are effective in terms of preventing mass poisoning, in addition, they comply with international export certification.

BOX 3 Monitoring system of the Fisheries Development Institute IFOP

The IFOP runs the Program for the management and monitoring of HABs and marine toxins (Red Tide), which is deployed in fjords and in the Pacific Ocean of central-southern Chile. This scheme registers environmental and oceanographic information of the waters, phytoplankton, and the nutrients contained thereof, as well as shellfish samples for the quantification of different toxins (paralytic, amnesic and lipophilic). The Red Tide program in fjords was created in 2006 and covers virtually the entire system of fjords and channels from Reloncaví to the Beagle Channel, in the far south. Currently, it considers 228 sites with a monthly sampling frequency, and includes 23 sites in the south of Chiloé and north of Aysén that are visited every ten days. In 2018, Pacific Ocean Program was added, which includes a total of 67 sampling stations, in the geographical area between the Biobío and Aysén regions.

In the same year, IFOP launched the i-HABs(i-FAN) mobile application, which allows users to access the alert status, according to the relative abundance of the main toxin-producing phytoplankton species through a color scale (white, green, yellow, orange and red).

In addition to these efforts, the "Chonos" oceanographic and atmospheric information system has come into existence. This system is generated through numerical modelling in Chilean Patagonia, supporting the management and planning of territory with timely information, as well as the management of environmental or health contingencies.

Download the app here:

HABs monitoring

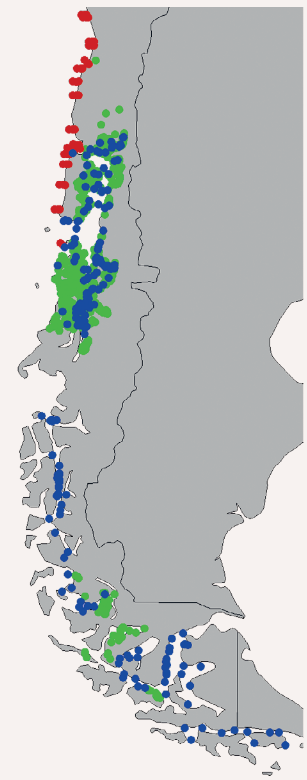


Figure 5. Map with the location of the sampling stations of the IFOP Pacific Coast, Red Tide in Fjords (IFOP Fjords) and PROMOFI programs. The three programs measure environmental variables, as well as phytoplankton composition. The highest concentration of monitoring stations is in northern Patagonia. Source: Self-Made.

Risk perceptions of coastal communities to HABs in Chilean Patagonia

The risk perception by the different communities and actors cohabiting coastal zones, contributes to the vulnerability or adaptive capacity of a socio-ecosystem. Acknowledging the problem, as well as the perception thereof, allows us to be more or less prepared to face a certain crisis, and such is the case of HABs. The perception of the phenomenon causes or the ways to deal with it are decisive in the planning, and above all, in the implementation of the most appropriate strategies, to reduce both the impact and the vulnerability of natural and human systems.

As people become more aware of the problem and perceive that their knowledge and skills are adequate to face a certain risk, the chances of adequately addressing a crisis -such as those generated by HABs- are greater. In this sense, to acknowledge the problem is necessary but not enough to build more effective responses and thus, increase the adaptive capacity of the population. In this way, the access to scientific evidence on the causes of HABs, and the existence of knowledge networks that allow a dialogue among the different social actors especially with local communities, can facilitate a better understanding of the problem and the implementation of strategies with greater territorial impact. In this context, the local perceptions of HABs are key to assessing the relationship between public entities and coastal areas inhabitants, as well as the impact on the local communities of the initiatives deployed by the institutions, in order to reduce, based on the knowledge and adequate plans, the uncertainty and concern generated by HABs.

According to the results of the Patagonia Survey (see Chapter 7), the population of the southern zone considers that HABs are mainly caused by water pollution, the salmon industry, and the lack of rain. These perceptions vary according to the territories. For instance, in Puerto Aysén and Punta Arenas/Porvenir, the perception that the main cause is the salmon industry is stronger, while for the inhabitants of Chiloé and Llanquihue, water pollution is perceived as the main cause of HABs. Among the findings, it is surprising that people who have a medium or high-level dependence on the sea, seldom mention the salmon industry as the cause of HABs.

The perceptions of people and communities indicates the coexistence of different beliefs, associated with this phenomenon, that can influence the way in which the actors respond to HABs events or their willingness to support certain actions aimed at facing them. For this reason, it is necessary to intensify the local awareness and perceptions of different groups of society about the causes of HABs, which are generated from existing official and unofficial information about these events (see BOX 4).

BOX 4 Perceptions about HABs causes in Quellón

The Quellón Study's aim was to understand risk perception from the experience of people, their beliefs, opinions and ideas related to HABs.

Those who carry out sea-related activities, such as artisanal fishermen, shore collectors, and mussel farmers, among others, consider water warming as an element to observe and link it to the causes of HABs:

> *"The red tide is something that takes place worldwide, it is not only present here and it is something that pertains to the sea. This event will happen no matter what; even if the world had not become polluted, it would have still warmed up. If a month has ten or fifteen hot days, you know that the red tide is coming, because of how the blooms behave and how the sun makes the microalgae bloom".*
>
> (Private sector member interview).

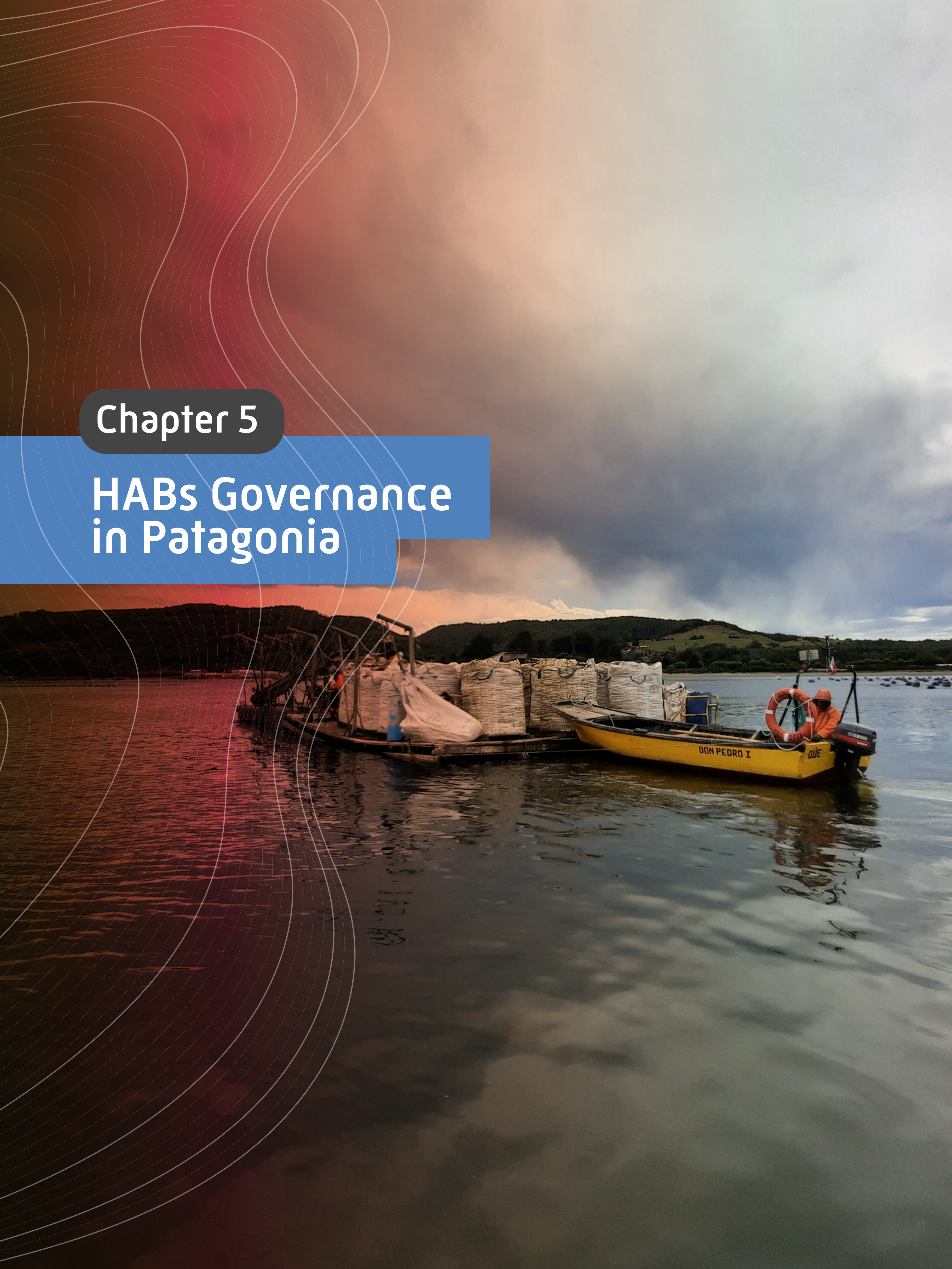
On the other hand, some members of civil society and the private world link the HABs with the salmon industry and with the activity of boats that transport live fish (*wellboat*). They suggest that these vessels transport HABs around the places they navigate, which makes them the real vectors. Nevertheless, even if the linkage between HABs and well-boats waters (a matter that is under study) is real or not, it signifies a great concern for the public, who demand greater supervision of these vessels:

> *"The fear is real. We know that the temperature has risen, the sea temperature has risen as well, we cannot do anything against salmon farms. Boats will keep bringing fish from the eleventh region, with water, because the fish must be alive, so the risk that they will bring us the red tide or the brown tide or the whatever tide, will remain"*
>
> (Civil Society member interview).

The general public is not very knowledgeable about other influential factors to HABs.

Chapter 5

HABs Governance in Patagonia



HABs Governance in Patagonia

If we consider governance as the economic and political coordination of social life, the government-society interactions in decision-making, the definition of values and objectives of coexistence, and the establishment of collective goals (Perreault, 2016; Cruz-Sánchez, 2017), it is reasonable to state that, at present, we do not have a comprehensive governance model for HABs. The existing version has demonstrated to be rather precarious and disorganized, falling mainly under the wing of the State and supported by other sectors, such as the scientific and private one, while the civil portion of society has been much more absent. The existing efforts are incipient, isolated, and mostly reactive, making it difficult to address the events

HABs Management in Patagonia

In Chile, the management of HABs events is characterized by a highly complex and fragmented participation of the different institutions involved. While the State, the private sector, the scientific sector, and the civil society all fulfil their roles, the main character is the State. Thus, on behalf of the public sector, the entities that participate are: The Undersecretariat for the Armed Forces of the Ministry of National Defense, the National Fisheries and Aquaculture Service, the Undersecretariat for Fisheries and Aquaculture of the Ministry of Economy, Development and Tourism. However, since HABs have serious health impacts, the Ministry of Health (Minsal), by means of its Seremis and the Institute of Public Health (ISP), also takes a leading role. These institutions create all main regulations, **particular** or **occasional**, that regulate HABs, which are oriented by the framework that governs the Chilean coastline (such as the National Policy for the Use of the Coastal Edge and the Regulation of Aquaculture Concessions, the Regulation for the Control of Aquatic Pollution, among others). Although this framework does not rule over areas directly related to HABs, it does regulate the entities who interfere or may affect HABs management, thus establishing the limits and regulatory guidelines for the design of policies, plans or programs, or in the implementation of actions for HABs management.

Particular regulations establish policies, plans, programs or actions of a permanent nature. Regarding HABs, such is the case of the Regulation of Protection Measures, Control and Eradication of High-Risk Diseases for Hydrobiological Species, and the Regulation on Hydrobiological Pests. As well as there are the National Plan on Harmful Algas Blooms (1999) and other important measures such as the *Alexandrium Catenella* Monitoring and Surveillance Program (2009), the Bivalve Mollusk Health Program (1990), or the Red Tide Monitoring Program in the regions of Los Lagos, Aysén, and Magallanes (2007). All these measures have made it possible to maintain a timely and reliable information system for early decision-making, constituting a great advance in the management of HABs in Patagonia.

On the other hand, **occasional regulations** are actions and measures that allow and delimit exceptional actions by the institutions and services involved in the occurrence of an event, such as the declaration of affected areas, the establishment of a health emergency and the prohibition of extraction of marine resources, among others. These measures are established mainly through Decrees and Resolutions. From 1941 to the date (May 2022), 26 decrees associated with HABs have been established in Patagonia, most of which emanated from Minsal. However, when HABs episodes reach greater socio-environmental dimensions, the Ministry of the Interior and Public Security intercedes, as was the case of the 2016 mega-event in Aysén and Los Lagos. Regarding the Resolutions, the total is 326 from 1996 to the date (May 2022), with the Los Lagos region being the one concentrating the majority (296), then Magallanes (21), and the Aysén region in the last place (9), with an increase in the number of resolutions during 2016.

Other state-level institutions also participate in the process of designing and implementing these regulations, such as the National Oceanographic Committee (CONA in Spanish), the National Aquaculture Commission, and the Chilean Navy. Figure 1 shows how these institutions are part of the process, highlighting the intervention of some institutions in all axes. Additionally, two institutions from other sectors were incorporated, given their role and relevance in the design and implementation of regulations and actions by HABs. These entities are the Fisheries Development Institute (IFOP, private sector that supports the State) and the National Aquaculture Commission (public/private sector), both differentiated in red.

Another relevant group is the scientific sector, made up of various research centers, universities, laboratories, and natural persons who have systematically addressed the study HABs in itsvarious dimensions. Science has contributed to the acknowledgement of HABs by means of research, teaching and technology transfer actions, generally from a multidisciplinary approach. Its main products are databases, scientific articles, reports, monitoring, and writings, that are used as dissemination means. In some cases, international collaborations are generated, which allow us to delve into the subject and compare research results.

On the other hand, the private sector, made up mainly of companies whose activities may be affected by HABs, such as the salmon industry and mussel farming, does not have unified actions to deal with these phenomena. However, some members of this sector do develop contingency plans, preventive actions, research and development, and consulting strategies. Although, in most cases, the information about these actions is not public, studies performed enable the establishment of certain valuable information. One example is the salmon industry, which applies certain common measures, such as stopping fish feeding when bloom events

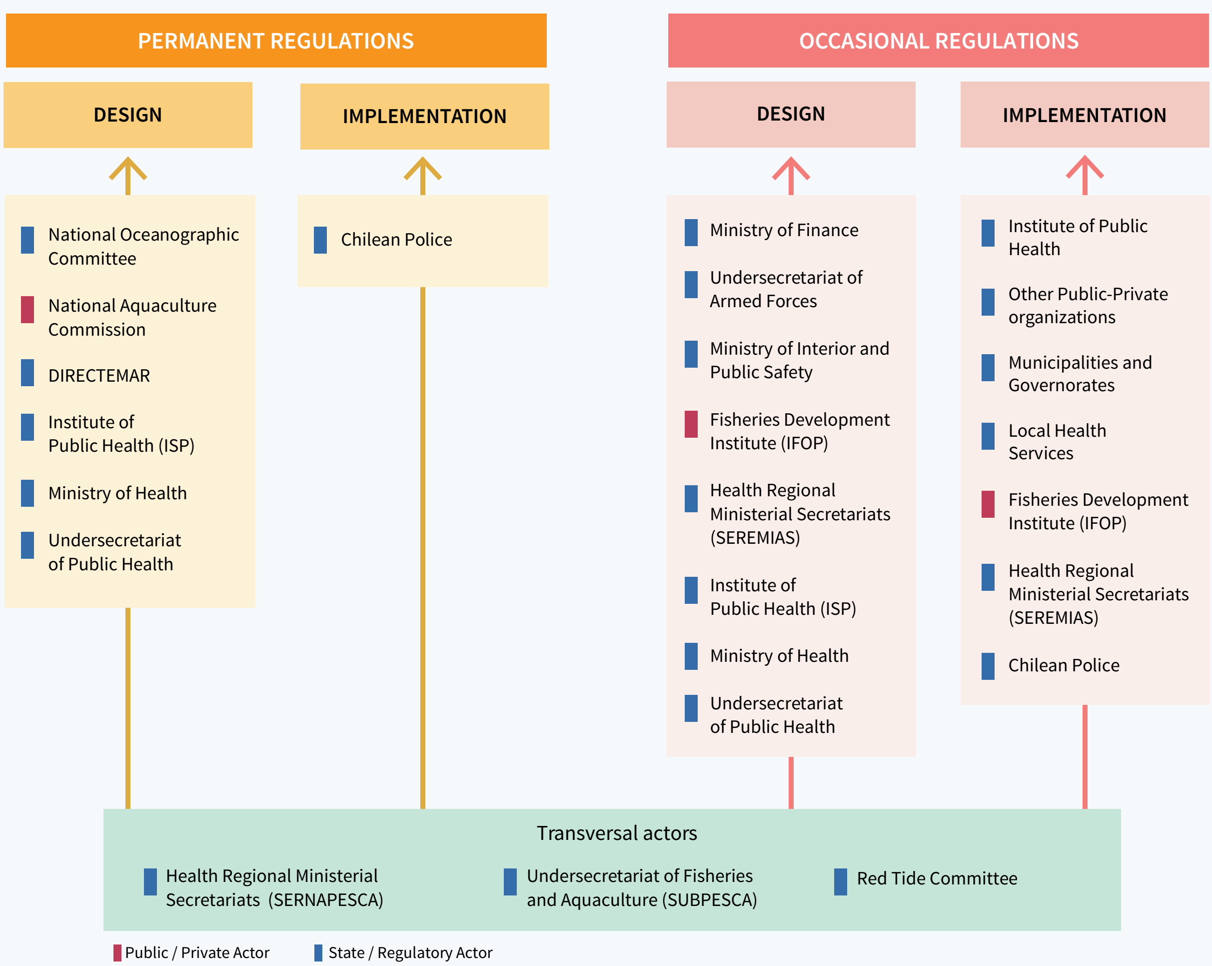


Figure 1. Institutional participation in the design and implementation of regulations in the face of HABs. Source: Self-Made.

arise, moving schools to areas without algae presence, advancing harvests if authorized by the relevant authority, and periodically analyzing water parameters. Most of these actions are more reactive than preventive; in fact, despite the enormous economic losses and serious environmental damage caused by these events in production areas, very few companies have a department or unit dedicated to HABs. In addition, these measures are self-regulated, like most of the actions carried out by this sector to face the different socio-environmental externalities (see BOX 1). It should be noted that the salmon industry generates important alliances among each other, such as SalmónChile, which can act as a facilitator to generate joint actions before HABs events.

Finally, the civil society is the sector that can be identified as the most complex and difficult to specify in the decision-making process, since currently, there is no civil association that is exclusively dedicated to working on the HABs issue at a national level. In general, this group is made up of guilds, unions, social movements, NGOs, and foundations that are engaged in activities associated to rivers, seas and oceans, or to the protection and conservation of the environment in general terms. The only public information available on the actions of these actors in the face of HABs episodes is found in press notes and records, statements, opinion columns and social networks. In general, their actions are reactive and are generated in the face of a certain event, depending on the level of affectation they perceive and the socio-environmental impact on the territories.

The different social sectors considered in this chapter establish links called "HABs management network" (see Figure 2), composed mainly of the scientific sector (51%), business agents (20%), state (18%), and the civil society (11%). Out of these, seven subgroups that organize this network were identified. Each subgroup, identified by colors, is made up of institutions from different sectors which have a deeper association to one another. The main alliances are the State-scientific sector, the scientific-private sector, and the scientific -civil society sector. These alliances generate collaboration networks that enable inter-sectorial progress, starting from the bases towards new forms of HABs management (see BOX 2). This network is a first approach to the subject, which may be updated and complemented with other information sources in future studies.

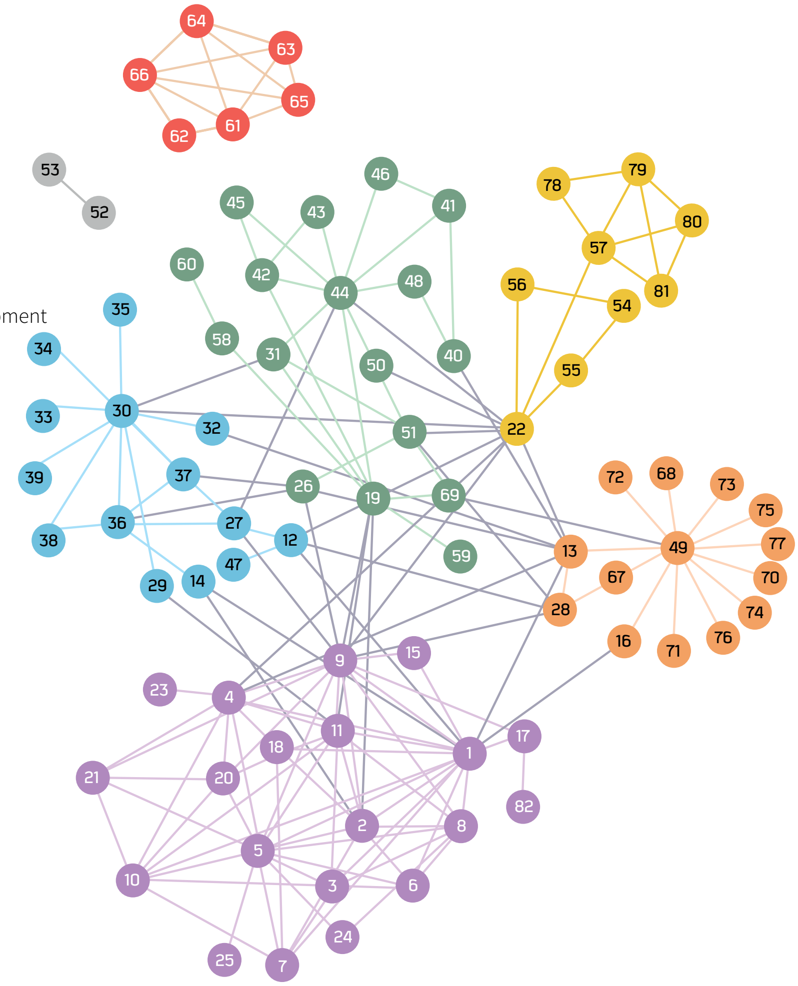
BOX 1 Business self-regulation of the Chilean aquaculture industry

The complexity, inefficiency and fragmentation of coastline governance, as well as productive activities, has led the private sector to develop its own self-regulation mechanisms to anticipate or respond to the pressures of the civil society, in the face of socio-environmental externalities associated with its activities..

Higher standards, certification schemes, ecolabels, traceability, environmental and social reporting, and other corporate social responsibility practices have proliferated in the Chilean aquaculture sector. This is especially true after the successive crises and scandals around it in the last two decades, including the 2016 socio-environmental crisis in Chiloé. Even though certifications have compliance standards higher than Chilean regulations, they tend to be preferred by private actors, as they are clearer and provide added value in international markets. However, the adoption of these mechanisms varies greatly from one company to another, which creates a scenario of inequality, meaning that some companies products are virtually all certified, while others only reach marginal figures in this regard.

On the other hand, the data freely provided by this sector frequently show discrepancies when compared to the one kept by the authorities. This, in turn, creates significant gaps and inconsistencies, making it difficult for the industry to monitor. The previous, jointly with factors such as the industry trend to move towards pristine regions, a limited consideration of ecosystem balances, and a little linkage with local communities and artisanal fishing, result in reduced learning capacities and stagnation in the way things are done. This approach seemed successful in the past although merely in economic terms, but it is unsustainable in the face of current climate and environmental changes.

More information



22 Center for Climate and Resilience Research (CR)2
54 Interdisciplinary Center for Aquaculture Research
55 Department of Oceanography, University of Concepción
56 Department of Botany, University of Concepción
57 Protected Chiloé
78 Let's Defend Chiloé Movement
79 Greenpeace Chile
80 Ecoceanos
81 WWF
52 Department of Geophysics, University of Concepción
53 Laboratory of Measurement, Innovation and Geophysical Development
12 Laboratory of Marine Toxins of Faculty of Medicine of University of Chile
14 Integrated Aquaculture Management System
27 Study Center of Harmful Algae
29 Chilean Antarctic Institute
30 Institute of Aquaculture and Dynamics Research Center of High Latitudes Marine Ecosystems (IDEAL)
32 University of Magallanes
33 Alfred Wegener Institute for Polar and Marine Research
34 Scripps Oceanographic Institute
35 Korea Polar Research Institute
36 CSIRO Ocean and Atmosphere, GPO
37 Biology Department, Woods Hole Oceanographic Institution, Woods Hole, MA, USA
38 tudy Center of Marine Systems, Argentina
39 Environmental Resources Analysis Center, Austral University of Chile (CERAM)
47 REMARCO
13 GAIA Antarctic Research Center, University of Magallanes
16 Australis SeaFoods
28 Miticulture Technological Institute
49 Chilean Salmon Industry Association
67 Camanchaca
68 Aquachile
70 Cermaq Chile
71 Cooke Aquaculture
72 Cultivos Yadran
73 Invermar S.A.
74 Mowi Chile S.A.
75 Salmones Austral
76 Salmones Multiexport S.A.
77 Ventisqueros
61 Environmental and Fisheries Sciences Division, Northwest Fisheries Science Center
62 Gustaaf Hallegraeff, Juan José Dorantes-Aranda
63 Ocean Sciences Department, University of California Santa Cruz
64 Plancton Andino SpA, Puerto Varas Laboratory
65 Estuary & Ocean Science Center, Romberg Tiburon Campus, San Francisco State University
66 Plancton Andino SpA, Castro's Laboratory
1 Sernapesca
2 Subpesca
3 Subsecretariat of Armed Forces
4 SEREMIS
5 General Comptroller of the Republic
6 General Directorate of Maritime Territory and Merchant Marine
7 Chilean Police
8 National Aquaculture Commission
9 Fisheries Development Institute
10 Red Tide Committee
11 National Oceanographic Committee
15 Chilean Mussel Farmers Association
17 National Confederation of Artisanal Fishermen
18 Quellón Red Tide Communal Work Group
20 Ministry of Public Health
21 Institute of Public Health
23 Quellón Health Social Work Group
24 Environment Superintendency
25 Ministry of Interior and Public Safety
82 National Council for the Defense of Artisanal Fishing
19 COPAS-South Austral Program
26 Salmon Technical Institute
31 Patagonia Ecosystem Research Center
40 Faculty of Marine Sciences of Catholic University of the North
41 Marine Research Center (Regional Government of Galicia)
42 Center for Research and Technological Development in Algae and Other Biological Resources
43 Center for Bioinformatics & Integrative Biology
44 Spanish Institute of Oceanography
45 Biotechnology and Bioengineering Center, University of Chile
46 Department of Aquaculture, Catholic University of the North
48 Department of Geophysics of University of Chile
50 Research and Development of Coastal Resources and Environments i-Mar
51 Marine and Rhinological Sciences Institute, Austral University of Chile
58 Catholic University of the Most Holy Conception
59 Caleta Bay
60 Biodiversity and Sustainable Environments Research Center
69 Blumar S.A.

Figure 2: Network Analysis. From the tracking of information on the web pages of these institutions in a previous study stage (2020), it was established that there was a link between them every time an entity explicitly appeared on the web page of another as a collaborator. Thus, seven subgroups were identified: two isolated (red and gray) and five linked to each other. The relevant actors among each other with high number of links are GAIA Centre, IFOP, Seremi de Salud, COPAS-South Austral Program, (CR)2 and Sernapesca. Other important actors are General Comptroller of the Republic, Chilean Salmon Industry Association, Subpesca, Spanish Institute of Oceanography, Institute of Aquaculture and Dynamics Research Center of High Latitudes Marine Ecosystems (IDEAL). It should be noted that the methodology used, therefore, omits other forms of linkages between entities such as informal, unreported, emerging, or newly created links. Source: Self-Made

Striving towards HABs climate governance

Based on all the above, jointly with a preliminary analysis of the regulations associated with the HABs phenomenon, and in light of the governance principles proposed in Report (CR)2 "Climate Governance of the Elements", it can be observed that some weaknesses and strengths present in the current management of HABs.

Regarding the weaknesses, there is a lack of instruments that specifically aim to address the phenomenon in an integrative manner, since the management is fragmented among institutions with relevance in very diverse fields, such as the Minsal, Subpesca, the Ministry of National Defense, or the Ministry of the Environment, which show a low degree of coordination and collaboration among each other. Additionally, this management is limited, in general, to the monitoring and prevention of poisoning, and does not address other types of impacts in depth. Likewise, there is little participation from other society sectors (eg, civil society, private actors), whose collaboration would be highly relevant to HABs management. There is also an insufficient inspection system, tolerating non-compliance could favor the phenomenon occurrence (eg, in relation to the treatment of aquaculture waste). Due to all the above, one cannot properly speak of a HABs governance model, but rather of isolated and incipient management efforts, with an eminently reactive approach, that makes it difficult to address the problem causes comprehensively (Farías, 2022).

BOX 2 Red tide response and adaptation network: contributions for a governance of HABs from the bases

In 2019, the Red Tide Response and Adaptation Network* (Rearmar) (Instagram: @re_ar_mar) was created as a space for meeting, exchanging knowledge, and generating learning and proposals for the co-construction of a new approach to HABs. Although the public policies to address HABs in Chile can be considered great achievement in the areas of health, regulations and scientific matters, this cluster presented three proposals to carry out governance from the bases: **1. Incorporate** greater emphasis on vulnerable natural resources management before the red tide. That is, to develop the knowledge and tools allowing fishermen to make timely decisions to sustain and diversify their productive activities. **2. Develop** education and involvement programs for fishermen to address HABs properly. In other words, introduce criteria "from the base up" so that coastal communities are part of the solutions and not only of the problem. **3. Implement** permanent, proactive, and adaptive actions against the threat of HABs at the local and regional level. In other words, in the face of more severe blooms and in larger areas, policies must be created to anticipate events and teach how to endure this disturbance.

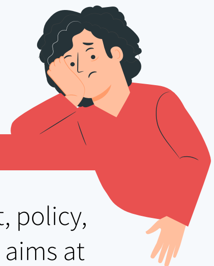
Holding this aim in mind, Rearmar has generated bridges among fishermen's organizations, the public sector, and the scientific sector (Marín et al., 2022). Workshops in which fishermen and collectors participate create a space to share local concerns, where scientific results of various studies were presented and discussed. In addition, the meetings called “red tide tour” have been held, which enable fishermen from remote sectors to visit the laboratory of the Los Lagos Health Seremi, where marine toxin are analyzed (Photo attached). A WhatsApp group was also created, with the participation of over fifteen fishing leaders from places as varied as Quellón and Mississippi, where the updated information is shared and anomalous situations along the coastline are channeled. Among the upcoming challenges for the network is the incorporation of more organizations, including small mussel farmers, and presenting their proposals to regional authorities.

**This work is part of the FONDECYT Project Nº11171068 Post-disaster livelihood recovery and adaptations in natural resource-dependent communities in Chile; ULAGOS Project RTI05/19 Platforms for the collaborative governance of red tide: articulation of efforts, experiences and knowledge for local and adaptive fisheries management responses.*

Current HABs management

Strengths

- There is technical-scientific knowledge about HABs, and although it is rather little currently, there is research available. There is also other ongoing research about the progress, which can be used to design better regulations, policies and public programs.
- Efforts to improve coordination and collaboration.
- Normative advances of regulations that affect HABs management, such as modifications to the General Law on Fisheries and Aquaculture, the coming into effect of the Framework Law on Climate Change, and the Long-Term Climate Strategy, among others.



Weaknesses

- There is no regulatory instrument, policy, plan, or program that specifically aims at addressing the occurrence of the phenomenon, its causes and consequences, in an integrative way.
- Insufficient inspection system, particularly regarding regulatory obligations. Tolerating non-compliance could favor the phenomenon occurrence.
- Little coordination and collaboration among state institutions which influences the management and prevention of HABs; little participation of other relevant actors in defining government actions, such as communities, civil society, academia and private actors.

Notwithstanding the exposed weaknesses, there are some recent trends providing a favorable scenario to move forward in these matters, (for example, modifications to the General Law on Fisheries and Aquaculture, the coming into effect of the Framework Law on Climate Change, and the Long-Term Climate Strategy, among others). This could facilitate the transition from the current fragmented management to a more robust governance model of HABs, introducing a climate governance approach being capable of addressing these phenomena in a preventive, integrative and territorial manner; aware of the challenges generated by climate change and the risks associated to HABs.

In addition, it should be borne in mind that, currently, HABs management is a relevant issue for the coastal communities inhabiting Patagonia. This relevance is expressed by these communities (See BOX 3), which opens an interesting window of opportunities to address these challenges in a collaborative way.

BOX 3 HABs governance, a look from Quellón

The Quellón Study delved into opinions on the following aspects of HABs governance: **1. information**, **2. decision-making** and **3. difficulties**. Those who participated in the study consider that the information in general is adequate and value positively health risk communication, since they are most aware of this area impacts. However, among the difficulties, they do not identify all the sectors linked to HABs management, but only some, such as the Red Tide Communal Work Group, a self-managed organization comprised of members from different social sectors:

> *"The Work Group has enabled the setup of a red tide sampling network. We are taking samples every week. This Work Group has generated protocols. We put out flyers indicating the importance of the red tide, the dangers entailed, the measures to be followed, and all the boats carry these flyers. Thus, sanction plans were generated for the same fishermen who failed to comply with the sanitary measures"*
>
> (Private sector member interview).

It is believed that, to strengthen the information, the causes of HABs and alternative responses must be clearly communicated.

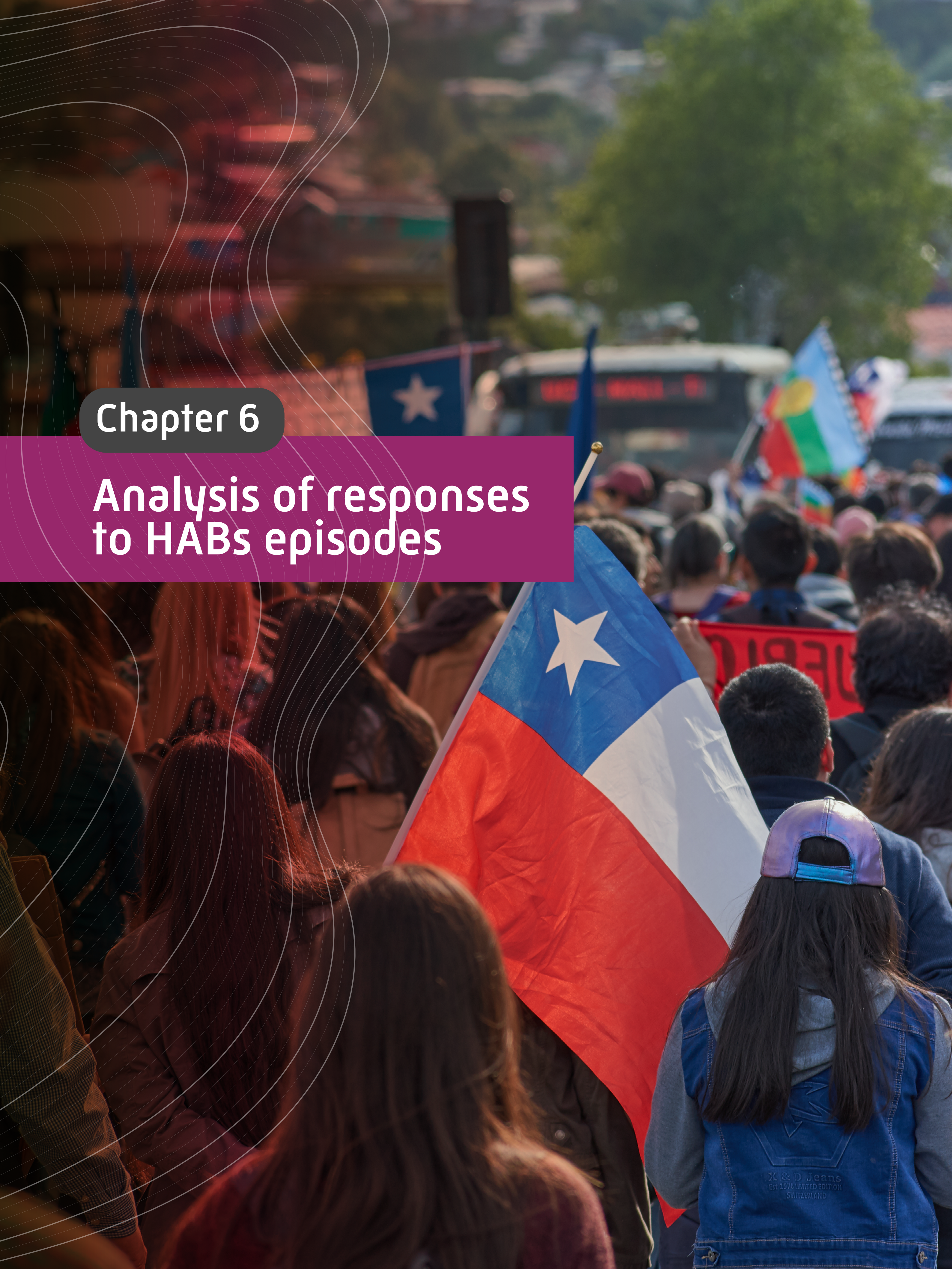
In relation to decision-making actions, the participants believe that the State should lead this effort by working as a team with other sectors, improving and strengthening coordination. But the difficulties are the inconvenience in the intersectoral dialogue, the delay in the response to HABs events of great magnitude and high centralization:

> *"The event happened in 2016 had a multiplied dimension and central government aid took too long. Decisions were delayed; they took too long when urgent action was needed, to meet the actual needs of people who were unable to work"*
>
> (Scientific sector member interview).

All these difficulties overlap and generate discontent in the population when they perceive that the efforts are insufficient and the response system collapses. They propose better management of HABs: decentralized, collaborative, with a territorial approach, at a local scale, and with emphasis on the areas most exposed and vulnerable to HABs.

Chapter 6

Analysis of responses to HABs episodes



Analysis of responses to HABs episodes

In this chapter we analyze some actions implemented by different social sectors, to confront the HABs in Chilean Patagonia, emphasizing the perception and evaluation to these measures by the groups thereof.

Likewise, we review some relevant international pieces of experience in the area. Although the responses that have been developed have contributed to minimizing the events impacts and it is necessary to maintain them, it is also important to generate actions involving major changes, making it possible to progressively increase the resilience of coastal communities in the face of these events, especially considering the increase in their frequency, magnitude and intensity.

Perceptions about the actions implemented in Quellón in the face of HABs episodes

Adaptive responses

According to the results of the Quellón Study, in terms of facing the health, social, economic, and cultural impacts of HABs, the different social sectors carry out various actions that have generally been implemented on the spot, entailing little planning and oriented to solve short-term specific problems.

In the case of the State, some of the responses are granting bonuses and subsidies, injecting specific resources for limited investigations, implementing of sanitary protocols, sampling, monitoring, and closure of extraction areas. In the case of private companies, the actions are mainly limited to the monitoring and implementation of emergency measures, although in some sectors, changes have also been made in the farming of mussels (mejillones or choros). The scientific sector has strengthened research on HABs; has created mobile applications and has promoted networks and alliances with the civil society to share knowledge. Finally, the civil society has created thematic work groups and pressed the authorities by means of mobilizations and public demonstrations.

It should be noted that the opinion of all social sectors, about most of these responses, is that they took place in a reactive fashion; being late, centralized, focused, and with little social participation. The previous is associated to a feeling that the nature of these responses makes them less impactful, thus preventing them from resolving social conflicts satisfactorily, and generating a perception of unpreparedness to face this type of catastrophes:

> *"All they do is buffer the impact with a couple of bonuses, which shows a lack of vision; it has no real transformative power. Everything remains the same, except for the granting of a few palliative actions"*
> (Civil Society member interview).

Regarding positive evaluations, the State's sanitary management to reduce poisonings and deaths of people stands out, for examples, applying more intensive monitoring and with better technology, applying more intensive monitoring and with better technology, the promotion of community organization, the establishment of information channels through social networks, and the creation and boosting of collaboration networks:

> *"Many of the decisions we currently make are fed by social networks. Up to 2016, I would not have thought of something like sending a closing resolution to a fisherman - and to have them send it back- through social networks. I think that helps a lot"*
> (State Sector member interview).

Developing these responses is influenced both by barriers that limit the ability to react and by facilitators that promote it.

In Quellón, the **following facilitators** are observed:

1. Infrastructure, technology and specialist availability for sampling.

2. Existence of links between local communities, organized groups (such as fishermen), and the scientific sector.

3. Coordination between health services and the armed forces for transportation and care in cases of poisoning.

4. Learning capacity in the different social sectors.

5. Existence of protected areas.

6. Greater awareness among citizens about HABs.

7. Traditional knowledge regarding marine and aquatic systems, as well as about environmental risks, which provides more comprehensive understanding of blooms and consequently, better event response.

Meanwhile, amongst **the barriers** we find:

1. Psychological (difficulties at the individual or micro-social level), such as selfishness, lack of confidence, little awareness of risk, and low social responsibility.

2. Cultural (related to cultural practices), such as eating habits, use of technical language, and productive practices.

3. Structural (difficulties at the macrosocial level), such as fragile governance, extractivism, digital divide, and isolation, among others (see Figure 1).

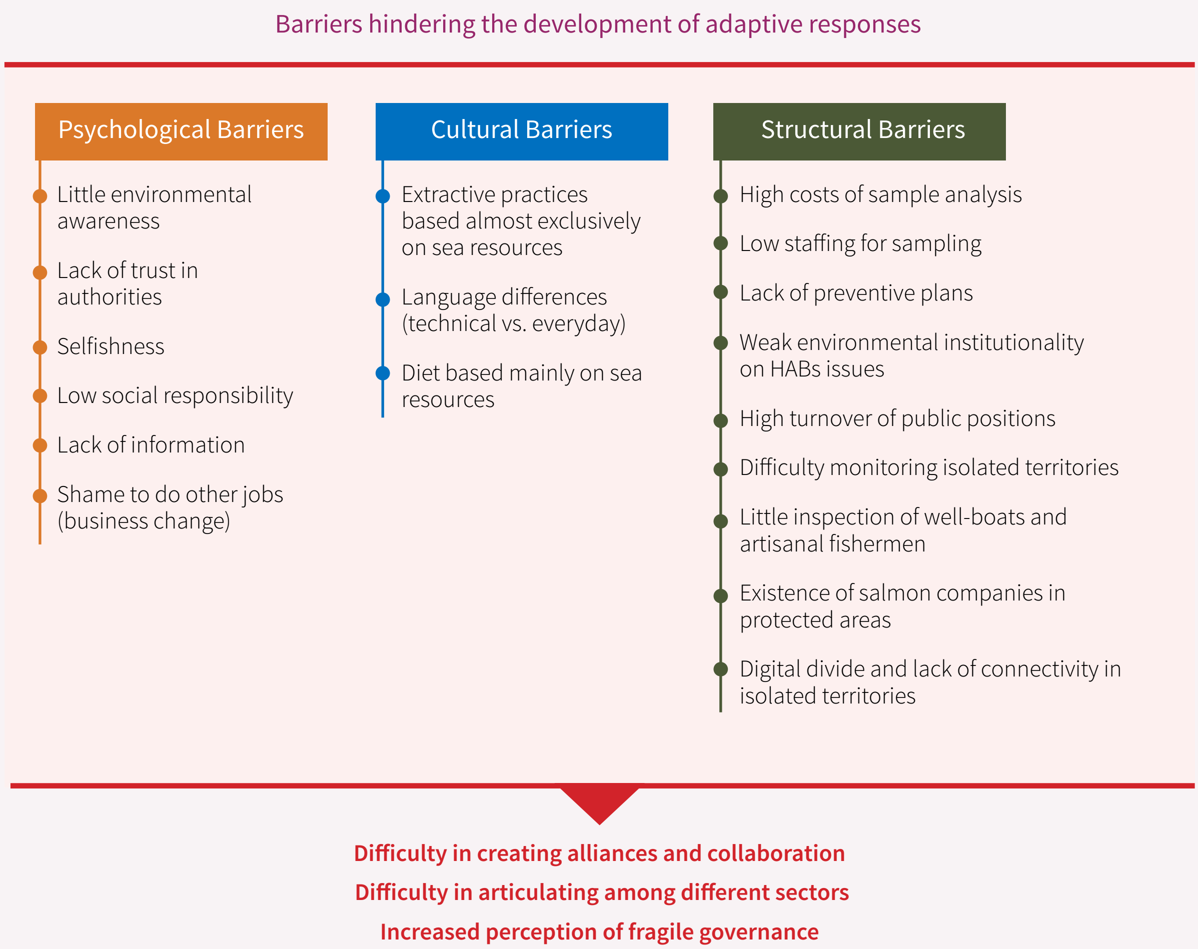


Figure 1: Action barriers in Quellón. Source: Self-Made

Transformative responses

In order to confront and prevent the impacts of HABs in the area, the different social sectors mention that additionally, responses that could be defined as transformative, have been implemented. This means that such responses are associated with profound change.

Among these actions, the creation of formal coordination instances stands out, such as the red tide workgroup, which brings various local actors together; the generation and development of links between the academy and the community, which materializes in the creation of training programs and socialization of knowledge related to the HABs phenomenon and its consequences; the training of people and interventions in educational spaces that seek, on the one hand, to enhance their capacities and supplement their income, and on the other, to promote the development of preventive and care strategies based on knowledge of the effects of this type of event[1]. All these actions have had a significant impact on the community, generating profound changes in the ways of relating, incorporating innovative practices and new governance structures.

In general terms, the need to produce changes involving the community, the State, private companies, and academia is recognized. Nevertheless, the risk of these changes benefiting a particular social sector to the detriment of others is detected. This means that these profound changes can have potential negative consequences for some (what is known as negative trajectory transformations).

It is also recognized that the value and the need to produce profound changes collectively and in different areas as responses to these events, especially as a mechanism to prevent their impacts. To implement these transformations some difficulties arise:

1. Distrust of local communities towards State and private agencies, which emerges with more force in crisis episodes, impacting and limiting the possibilities of joint work.

2. Permanent disagreement among different social sectors, such as the private sector and the civil society, which materialize in the productive, cultural and technical spheres, in terms of the understanding and knowledge of HABs events and their impacts.

3. Precarious informal relations amongst the local community, as well as fragile local formal structures, which are the competent decision-making entities that must implement responses and solutions when facing this type of event.

Out of the potentially transformative changes, one most relevant is the modifications of productive structures, in response to the risk and uncertainty associated with HABs events. This has led some producers to incorporate micro-scale agricultural and livestock production activities, relegating the fishing to a sideline. These changes impact family and community economy and, in addition, culture, society, and relationships that need to be studied and considered, since they can lead to positive consequences (such as greater resilience and food sovereignty), but also to negative ones (loss of traditions and impacts on the identity of communities).

Other potentially positive transformative actions tare related to the education and training of local leaders. These actions take place among teachers and students, thanks to the joint work of the academy and the schools, by means of training associated to the identification and prevention of the health impacts derived from HABs events. This work has brought scientific research closer to the community. Along the same lines, the red tide workgroup also stands out, positively impacting the relationship between actors and institutions, making the process more prone to integration and collaboration thereof.

[1] For more details review (in spanish):
https://www.cr2.cl/datos-acciones-transformacion/

Analysis and comparison of government responses at the legal level in the HABs events of 2016 and 2021

In order to analyze the government actions to tackle HABs in Patagonia, two study cases were selected: **1. the HABs event that occurred in Reloncaví Sound** in the year 2016, **2. The one that occurred in the Comau fjord** in 2021. The first one is considered a milestone, because of the case prosecution associated with HABs, and the fact that the public entities involved were deemed accountable. The second, although on a smaller scale, constitutes a relevant milestone, to analyze eventual take-aways or progress on the matter, from 2016 to the date.

Regarding the case of Reloncaví Sound, the HABs event caused large-scale salmon mortality, affecting 45 farming centers and generating a loss reached 40,000 tons. This led to exceptional measures by Directemar (supported by a technical report from Sernapesca), which instructed the dumping of 9,000 tons of rotting salmon into the sea. This specific fact led to the prosecution of the case in different instances. The Supreme Court accepted the protection action filed by a group of fishermen before the dumping authorization, and rebuked the contingency activation failure, as well as the inaction of ministries, and the lack of coordination and late action (or inaction) of the National Service of Fishing and Aquaculture, the General Directorate of the Territory, the Merchant Marine, the Ministries of the Environment and Health, and the Superintendence of the Environment.

In relation to the event occured in March 2021, HABs episodes arose in the Comau and Puyuhuapi fjords, and the Jacaf channel. Nevertheless, the most affected area was Comau. There was also a massive mortality of fish farmed in aquaculture centers, but the problem was concentrated in the private management of the contingency, since a company violated the deadline for the withdrawal of dead salmon in its farming centers, which motivated different administrative measures and the prosecution of the cases.

In both events, the public entities responses can be analyzed from three main pillars or groups: regulatory, supervisory and sanctioning. However, each case seems to have been approached differently. The one of 2016 focused on the responsibilities and actions of public entities, mainly the absence of inspections and coordinated responses; while the one of 2021 focused on the response of the company that owned the affected farming centers and the sanctions against it.

This difference can be related to a process of improvements in the regulation and coordination of State entities from the case of 2016. Some of the improvements detected are management regulations adaptations, mainly related to modifications in the determination of the minimum contents of action in the face of contingencies, the incorporation of the category "mortality systems certifiers[2]", methodologies and a greater frequency of monitoring of variables of contingency plans. However, these betterments do not seem to solve the eventual existence of regulatory structural problems, which is manifested, among other aspects, in the probable outdatedness of a pertaining national plan, as well as a lack of transparent coordination procedures among the agencies involved in this area.

Gender and responses to confront HABs

Global changes due to anthropogenic factors, especially those linked to climate change, generate consequences in society, but do not affect all people in the same way: it is women and girls, among other vulnerable groups, who suffer the most from their impacts (UN, 2020). These global phenomena generate higher school dropouts for girls and fewer job opportunities for women, among multiple consequences that, ultimately, end up exacerbating gender gaps (Aguilar, 2021). Additionally, there are significant inequities in terms of natural resources ownership and the decisions made around them, where women are often marginalized. Despite this marginalization and when faced with these problems, women propose solutions and act collectively to cooperate with those who most in need in their communities (Das, 2014).

The Quellón Study about HABs perceptions portrays some gender-related results. For example, women tend to carry out more collective actions than men, such as soup kitchens throughout social protest situations, organizing of collectives or cooperatives groups to generate new income, and creating mutual support and social pressure groups, which they also lead. In the face of socioeconomic crises, many women who are dedicated mainly to domestic tasks, find work outside the home to contribute financially, since men, who are usually the providers, lose their sources of income. This situation implies an increase of women's workload because they continue performing their normal duties. Likewise, women who already work outside the home seek second jobs to increase family income.

These gender-related findings must be taken into account, given that the knowledge and experience of women are essential antecedents to adapt to global change, as well as for making progress, in terms of gender equality and sustainability.

> *"(…) and the issue began that children started school and had no shoes, because they no longer fit them. So, I came up with the idea to work with my artisanal fishing women. I gathered nearly 1,500 women and decided to barter. The child's shoes size was 36, for example, she had a size 37 and it was new, we exchanged shoes"*
>
> (Civil Society member interview).

[2] A certifier of mortality systems is a natural or legal person in charge of certifying the compliance of extraction, denaturation and storage of salmonid mortality equipment or systems in farming centers located in rivers, lakes, estuaries and the sea. The previous per capacities required by article 4 A of the Supreme Decree 320/2011 of the Ministry of Economy, Development and Tourism, Environmental Regulation for Aquaculture (RAMA), which are: that the centers accredit a minimum daily mortality extraction capacity and a minimum daily denaturation mortality capacity of 15 tons; and that they have a storage system for denatured mortality, with a minimum capacity that allows the storage of denatured biomass on a daily basis of at least 20 tons. The mortality certifier figure was incorporated into the aquaculture activities regulation by means of the Supreme Decree 68/2019 (DS 68/2019), of the Ministry of Economy, Development and Tourism, with the aim of materialization the requirements introduced into the RAMA by Supreme Decree 151/2017 (DS 151/2017), of the aforementioned Ministry, in relation to the events associated with massive fish mortalities and other environmental contingencies.

Analysis of responses at the international level: What are other countries doing to respond to HABs?

The HABs are a widespread phenomenon in the different water bodies around the world; they are observed from the oceans south of China (Tian & Huang, 2019) to the Red Sea (Gokul et al., 2020). In these places, as in Chile, the occurrence of HABs appears to have increased (Glibert, 2020) and intensified.

The concern of countries exposed to HABs is based on the possible impacts, mainly, over the general health and on local economy. Thus, the measures taken in different countries focus on death and disease prevention, as a consequence of poisoning when consuming food (*United States Agency for International Development [USAID], n.d.*) or contaminated water, and on damage reduction to fish production (Harley et al., 2020), as well as to aquaculture (Kimura et al., 2019) and tourism (Borja et al., 2020).

If we look at these measures from the perspective of climate change adaptation, analysis, we can conclude that, firstly, there is an attempt to acknowledge and monitor the risk. There are scientific programs to monitor the phenomenon in place, systematic sampling of fishing areas and sea products collection, and studies various types of algae that are harmful to human activities, as well as their behavior and projections in various regions of the planet (Sanseverino et al., 2016; Cuellar-Martínez et al., 2018; Harmful Algal Events Dataset, 2018; Lee & Lee, 2018; An - derson et al., 2019; Kimura et al., 2019; Tian & Huang, 2019; Borja et al., 2020; Smith & Bernard, 2020; Gokul et al., 2020; RAMOGE, n.d.; USAID, n.d.). Secondly, there are exposure reduction measures to the HABs effects, that range from prohibitions on fishing (USAID, n.d.) and collection in contaminated areas to limitations on coastal areas access for recreational uses. Finally, in terms of reducing vulnerability, the measures aim to diversify food and economic dependence on products and activities at risk of suffering damage due to HABs, so that communities continue to sustain themselves and generate resources, even when they are affected (Moore et al., 2020).

At an international level, one important action area aims at controlling organic matter level in greater confined water bodies, such as lakes, rivers and some fjords, because a higher nutrient concentration in the water, such as nitrogen and phosphorous, favors microalgae flourish, as they feed microalgae (Young et al., 2015; Paerl et al., 2019). Nutrient concentration in a confined water body can be controlled by limiting organic matter input, for example, the one resulting from sewage discharges or in water that drains into rivers from fertilized crops. This is the objective of many of the actions to prevent and control the HABs increase and these actions result in regulations and prohibitions for the dumping of waste into lakes, rivers and fjords, as well as measures to prevent nutrient arrival through water drainage from agricultural areas, such as planting native forests on river banks as filters for organic matter (Marraro et al., 2016; Lee et al., 2017), among other actions. Likewise, sediment removal with high nutrient concentration by means of suction has been attempted, but the efficacy of this method and its side effects are controversial (Paerl et al., 2018; Paerl et al., 2019).

HABs are also a widespread problem in freshwater bodies. The countries sharing lakes and rivers have been forced to reach agreements associated to jointly limit the organic load dumped in these waters, as is the experience in the Great Lakes, shared by the United States and Canada (Marraro et al., 2016; International Joint Commission, n.d.). A similar situation is the one of countries whose borders are in the ocean, which establish agreements in relation to HABs, especially in the monitoring and evaluation of different species (Borja et al., 2020; RAMOGE, n.d.).

1 Early warning system (SEATOR) – USA (Alaska)

2 Water quality protocol of Great Lakes (2012) Canada and USA

3 Conservation Initiative of *Western Lake Erie Basin* – USA

4 *A. fundyense* bloom modeling and predictizon project and building a model to predict *Alexandrium* blooms, both in the Gulf of Maine (PCMHAB) – USA

5 Toxin Monitoring Network USA (Puget Sound)

6 PCMHAB project of *K. brevis* conceptual model– USA (Florida)

7 California Monitoring and Alert Program (CAL-HAB-MAP) – USA (California)

8 Investigation into how bubbles could disintegrate CyanoHABs (United States Army Corps of Engineers' Aquatic Plant Control Research Program) – USA

9 PCMHAB Project– use of local bacteria to destroy cyanotoxins - USA

10 Seas, Oceans and Public Health in Europe (SOPHIE) "Mapping Ostreopsis spp" citizen science project of the European Community (EC)

11 Applied simulations and integrated modelling for the understanding of toxic and HABs (ASIMUTH) – EC, Ireland, France, Spain and Scotland

12 Study and revive the cysts (dormancy) of HABs – Sweden

13 Lake Trummen – Sweden

14 RAMOGE agreement – France, Monaco and Italy

15 Atlantic Area Network for introduction of innovative toxicity alert systems for safer seafood prodcuts (Alertox-Net) – EC

16 Co-development of Climate Services for adaptation to changing Marine Ecosystems (CoCLIME) – EC

17 SERVIR/CATHALAC Collaboration for monitoring – El Salvador

18 Study on the diffusion of ciguatera in three coastal communities – Cuba

19 Study of perceptions of "red tide" in coastal communities – Ecuador

20 LAC regional collaboration network for early Regional warning (Latin America)

21 Atlas HABs – Saudi Arabia

22 Phytoplankton community classification (PPCC) South Africa

23 Chinese Ecology and Oceanography of HABs Program (CEOHAB) – China

24 National Fisheries Research and Development Institute (INFRDI) – South Korea

25 Experimentation with acoustic waves for HABs monitoring - South Korea

26 The Northwest Pacific Action Plan (NOWPAP) – Pacific Northwest Regional Plan

27 The HABs section of the North Pacific Marine Science Organization (PICES) Regional (North-Pacific)

28 The Intergovernmental Oceanographic Commission Sub-Commission for the Western Pacific HAB (IOC/ESTPAC-HAB) – Plan Regional (Western Pacific)

29 Program monitoring HABs species in East Asian waters (EASTHAB) - Regional Program (East Asia)

30 Chemical treatment (by CSIRO) – Australia

31 Use of fish as a filter to reduce CyanoHABs - China (among other countries)

32 Investigations in Lake Taihu – China

33 Use of deep automatic learning – South Korea

34 Use of drones for monitoring Japan

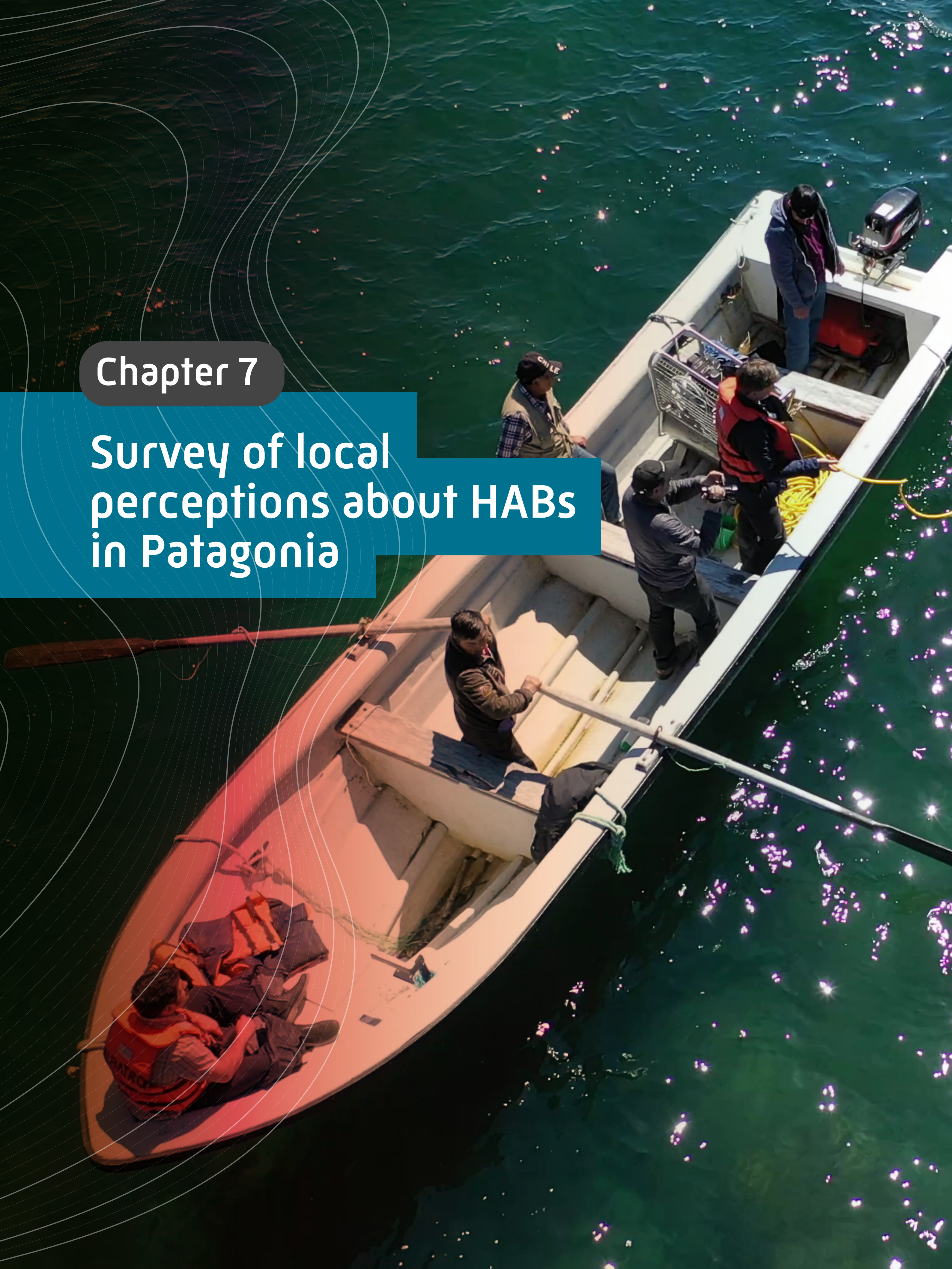
35 Ecology and Oceanography of Harmful Algal Blooms in the Philippines (PhilHABS) – Philippines

36 Shen Zhen City Monitoring System – China

Figure 2: Map of international responses. Source: Adapted from Mitchell, R. (2021).

Chapter 7

Survey of local perceptions about HABs in Patagonia



Survey of local perceptions about HABs in Patagonia

As mentioned in this Report's Introduction, a team from (CR)2 developed an opinion study on the local perceptions of coastal communities in Chilean Patagonia regarding different aspects related to HABs events. During December 2021, a total of 1,718 people over 18 years of age (50% women and 50% men) responded the surveys, a statistically representative figure of the total population of the pertaining area. To analyze the results, the participants age (by sections), gender (man/woman), educational level (basic, secondary, technical education), the territory they inhabit (Chiloé-Llanquihue, Puerto Aysén and Punta Arenas-Porvenir), main activity (salaried, independent, unemployed), and economic dependence on seafood were considered. Regarding the latter and in general terms, most people declare a medium dependence on this resource, except the inhabitants of Chiloé-Llanquihue, who expressed a greater economic dependence thereof (48%). In order to create familiarity, the term "red tide" was used instead of "HABs", since the phenomenon is better recognized as such.

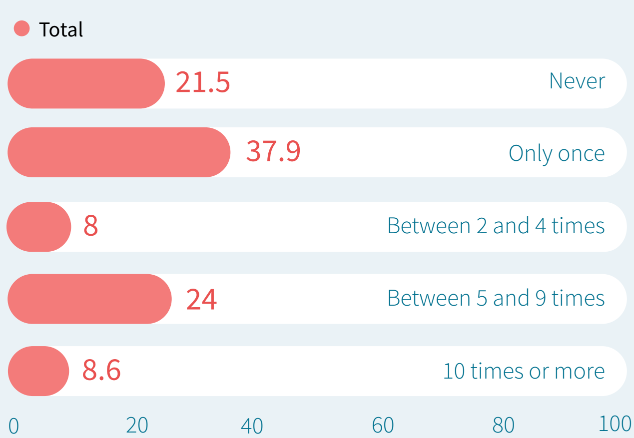
A general vision

The results show that **79%** of people have experienced at least **one red tide event** in their lives, although important differences among the territories are detected: 85% of the people who inhabit Chiloé-Llanquihue report having experienced an episode at least once, compared to 51% in Puerto Aysén, and 56% in Punta Arenas-Porvenir (see Figure 1).

** All figures are Self-Made*

Figure 1: Red tide episodes experienced at the total level and by sub-territory. Percentage / N: 1718.

Throughout your life, how many red tide episodes have you faced?
(Single answer)



The community highlights how the red tide has **impacted public health and economic activities** (see Figure 2). Deeper economic analysis also shows important differences by territory: in Chiloé-Llanquihue, the main impacts perceived are "unemployment" and "job instability". It is worth mentioning that individuals highly dependent on the sea have this last opinion. Meanwhile, in Aysén and Punta Arenas-Porvenir, the main impacts declared are "lower family income" and "being forced to find other work and productive activities".

In your opinion, what **activities or areas** are most affected when a red tide episode occurs?
(Multiple answer / 3 alternatives)

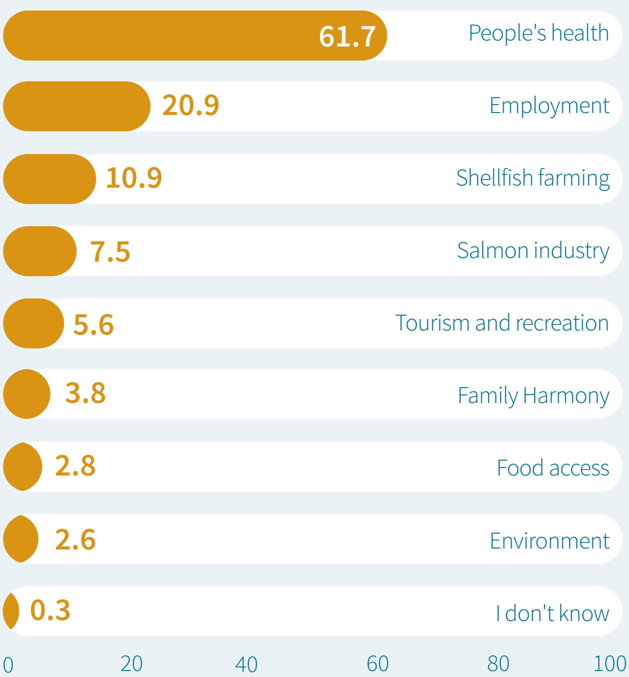


Figure 2: Perception of the main areas affected by red tide at a total level. Percentage / N: 1584.

Regarding the communities' preparedness to confront red tide impacts, 80% of the participants perceive that their communities are **little or not at all prepared to confront the health impacts** (see Figure 3), and 63% consider that they are **little or not at all prepared to confront the socioeconomic impacts**. It is worth mentioning that the provinces of Chiloé and Llanquihue were the ones that perceived a lower preparedness level (see Figure 4).

In general terms, how prepared is your community to deal with the **health risks** of red tide?
(Single answer)

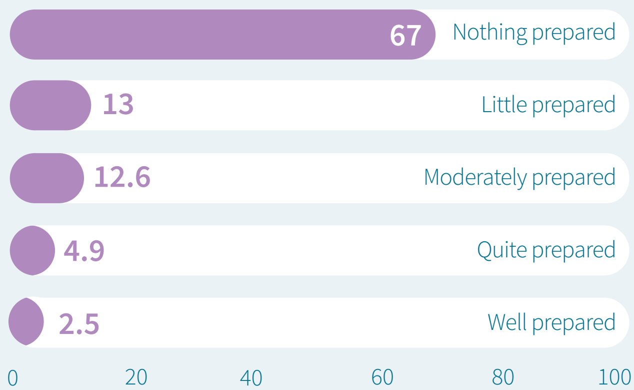


Figure 3: Perception of the level of preparation of the community to confront health risks derived from red tide, at a total level. Percentage / N: 1718.

In general, how prepared do you think your community is to deal with the **socioeconomic impacts** of red tide?
(Single answer)

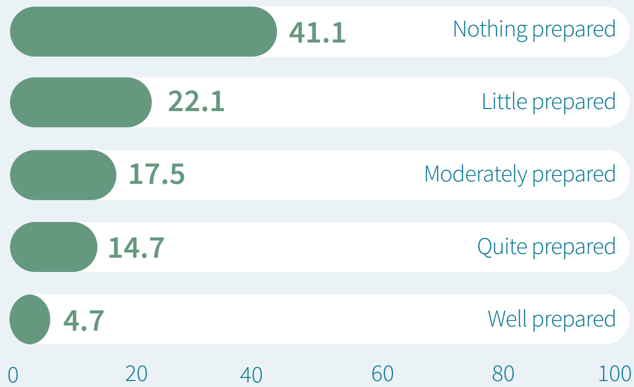


Figure 4: Perception of the level of preparation of the community to confront socioeconomic impacts derived from red tide, at a total level. Percentage / N: 1718.

When faced with the question: "what **actions** have been taken to confront the red tide **consequences** in your place of residence?", (see Figure 5) the prevailing answer was "greater care for the environment", followed by "none", and "creation of new jobs", although in Chiloé-Llanquihue, the third place is shared with "greater link with scientific institutions". This shows us that the existing association between the red tide problem and a need to **better care** for the environment, but additionally, it portrays that an important part of the population is unaware of the actions carried out, at the local level, to deal with HABs events.

Likewise, in all three territories, participants were asked to assess the **effectiveness** of the authority and individual **actions** ("you and your family"), when facing red tide impacts on the **health** and socioeconomic areas. In terms of health (see Figure 6), authorities' actions were evaluated as being less effective ("not at all effective" and "not very effective") than that of individuals, and the most negative evaluation (83%) came from Chiloé-Llanquihue. However, in Punta Arenas-Porvenir the perception is opposite, assessing their own actions as inferior in comparison to the authorities'.

What **actions** have been taken to confront the red tide consequences in your place of residence?
(Multiple answer / 3 alternatives)

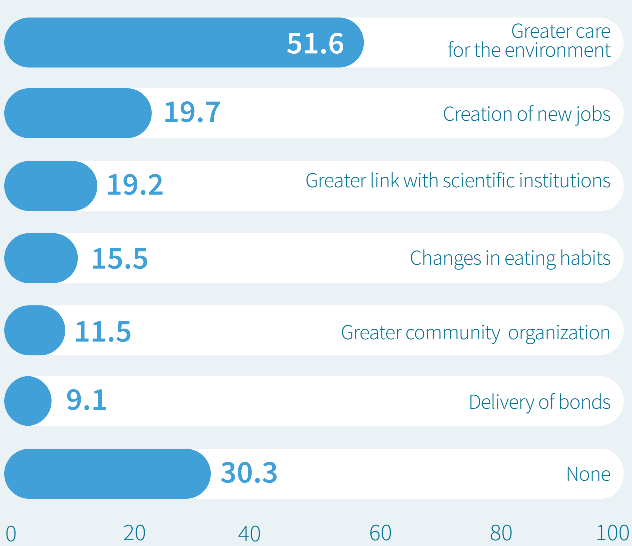


Figure 5: Perception of actions taken in the own territory to confront red tide consequences, at a total level. Percentage / N: 1439.

How effective are measures taken to address **the health risks** of red tide in the past?
(Sum of Not at all effective + Not very effective)

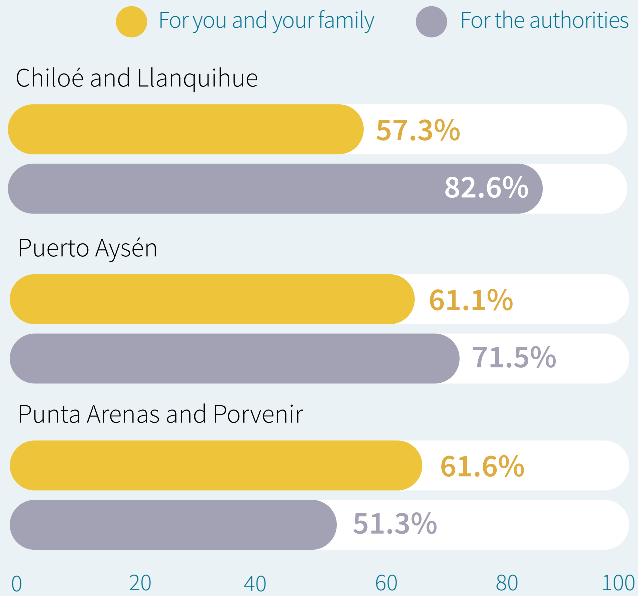


Figure 6: Perception of the effectiveness of the measures taken to address health risks due to red tides in the past.

In general, the **poor evaluation** of authorities' actions in the **health area** is striking, since the ones implemented have resulted in an actual prevention of poisonings and deaths (Institute of Public Health of Chile 2010, 2012, 2022). It is probable that the participants' opinion is more related to a **subjective risk perception** and the communication of what is done than to its effectiveness.

Meanwhile, it is important to note that in general terms, the public **assesses their own ability to deal with health impacts that stem from the red tide rather negatively**, which evidences a need to strengthen prevention and preparedness strategies at the community level.

Regarding measures to confront the **socioeconomic consequences** (see Figure 7), the negative way in which individuals evaluate their own contributions increases significantly throughout the three pertaining territories. In relation to the general actions taken by the authorities, these are better evaluated than the ones associated to health. Moreover, the results of Chiloé and Llanquihue are particularly striking, which might depend on the positive impact of financial support provided at times of red tide crises. However, it is clear that individuals feel severely constrained in terms of their own scope of action when dealing with the socioeconomic impacts of the red tide.

How effective are measures taken to address the **socioeconomic consequences** of red tide in the past?
(Sum of Not at all effective + Not very effective)

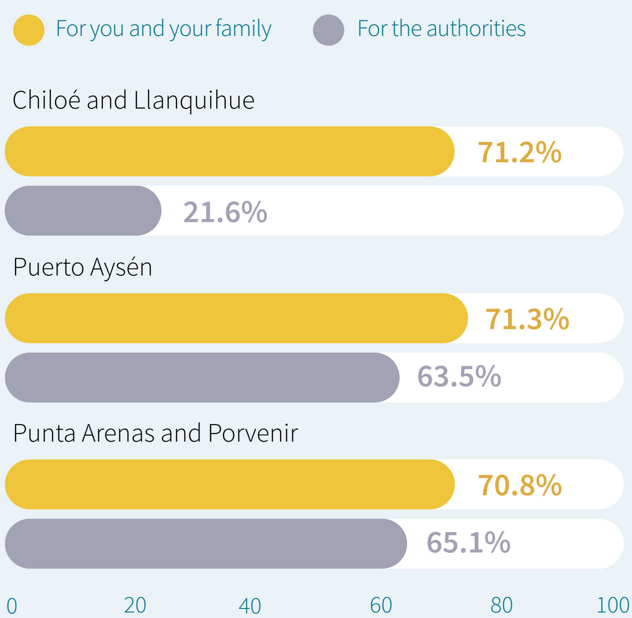


Figure 7: Perception of the effectiveness of the measures taken to address the socioeconomic consequences of the red tide in the past.

When **forecasting future HABs events**, 66% of people consider that it is 'quite likely', or 'highly likely', in the next five years, an event of this type will occur in their location (see Figure 8). The number rises to about 74 % in the provinces of Chiloé and Llanquihue, and more than half (56 %) of the population states being 'quite worried' or 'very worried' about such events taking place (see Figure 9).

In your opinion, **how likely** is it that a red tide event will occur in the next 5 years where you live?
(Single answer)

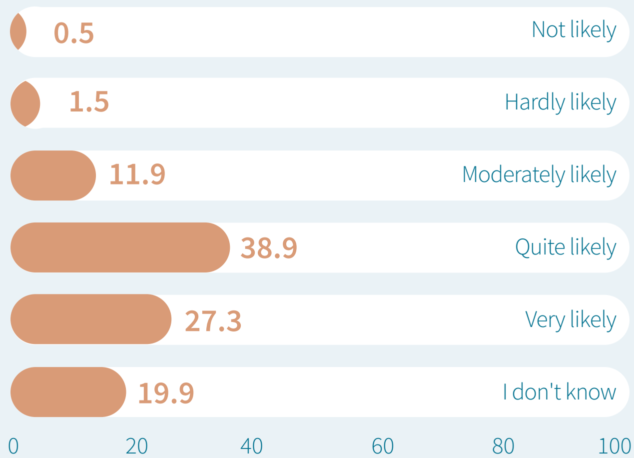


Figure 8: Perception of the probability of future red tide episodes, at a total level.
Percentage / N: 1718

In general terms, how **worried** do you feel about the possibility of new episodes of red tides occurring in the place where you live?
(Single answer)

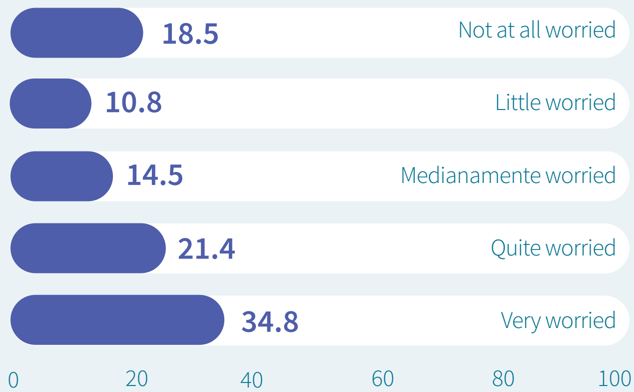


Figure 9: Concern about future episodes of red tide, at the total level.
Percentage / N: 1718

They were also consulted on **HABs governance** aspects, specifically about future events. As Figure 10 shows, most survey participants consider that, although preparing for future HABs episodes is one of the current priorities for regional authorities, the economic resources invested to deal with the impact are insufficient (see Figure 11).

How much do **you agree** with this sentence? "Preparing for future Red Tide episodes is currently a priority for authorities in my region"
(Single answer)

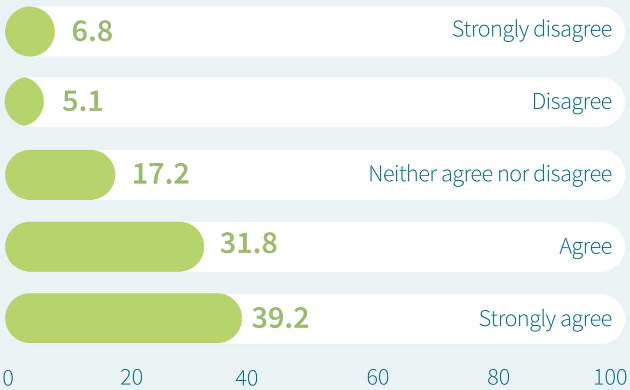
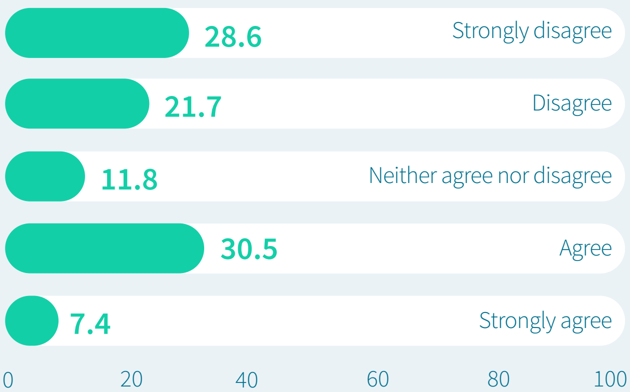


Figure 10: Level of agreement with the sentence on red tide as a priority for regional authorities, at a total level. Percentage / N: 1718.

How much do **you agree** with this sentence? "The economic resources invested in the region to deal with red tide impacts are sufficient"
(Single answer)



FFigure 11: Level of agreement with the sentence on the sufficiency of resources invested in the region to deal with red tide impacts, at a total level. Percentage / N: 1718

Regarding decision-making and **institutional responsibility**, survey participants expressed that for all three sub-territories, the main institutions in charge should be the Ministry of Economy (Sernapesca and Subpesca), IFOP, and the respective Regional Government (see Figure 12).

In your opinion, which institutions or organizations are **primarily responsible** for taking measures to deal with future red tide episodes?
(Multiple answer / 3 alternatives)

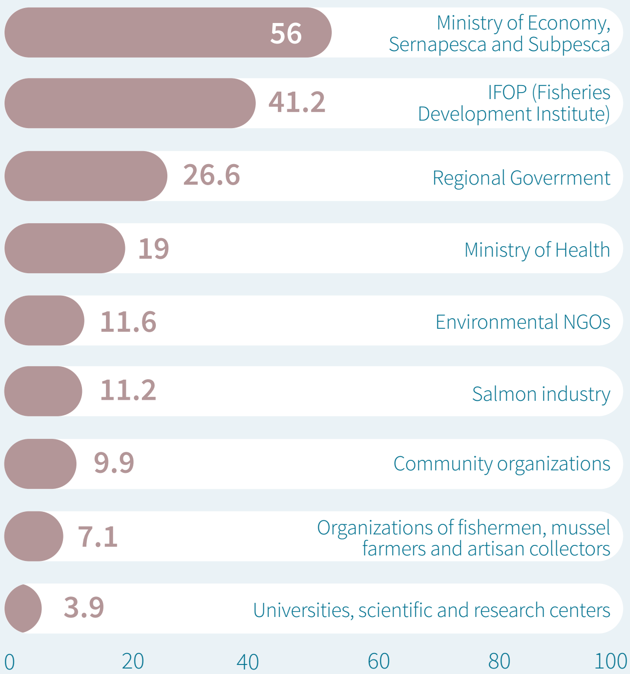


Figure 12: Perception of the primarily responsible for taking measures against red tide, at a total level. Percentage / N: 1718.

On the topic of the **most reliable information** sources associated with HABs, the media, environmental NGOs, universities and research centers appear most frequently (see Figure 13).

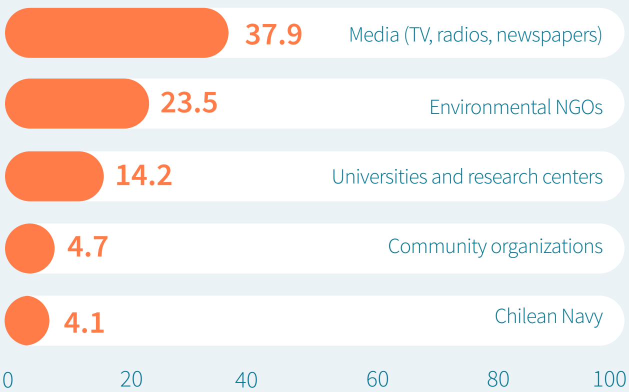


Figure 13: Most trusted agent for information regarding red tide.
Percentage / N: 1718.

Finally, individuals were asked about **other potential effects** that could stem from the measures to deal with red tide (see Figure 14). All three sub-territories mainly chose the option of "Reduction of poverty and inequality". In Chiloé-Llanquihue, the second option was “clean water access”, while in Puerto Aysén, and Punta Arenas-Porvenir the second preference was “People's health and well-being”.

In your opinion, what **other effects** that could stem from the measures to deal with red tide?
(Multiple answer / 3 alternatives)

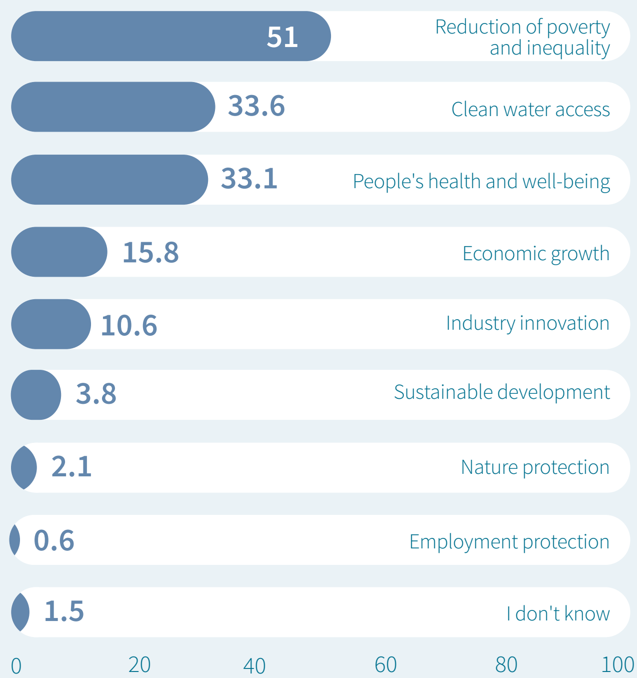


Figure 14: Perception of additional effects of measures to deal with red tide, at a total level.
Percentage / N: 1141

Different experiences and beliefs

Beyond general trends, there are **two human groups** existing with different perceptions of HABs.

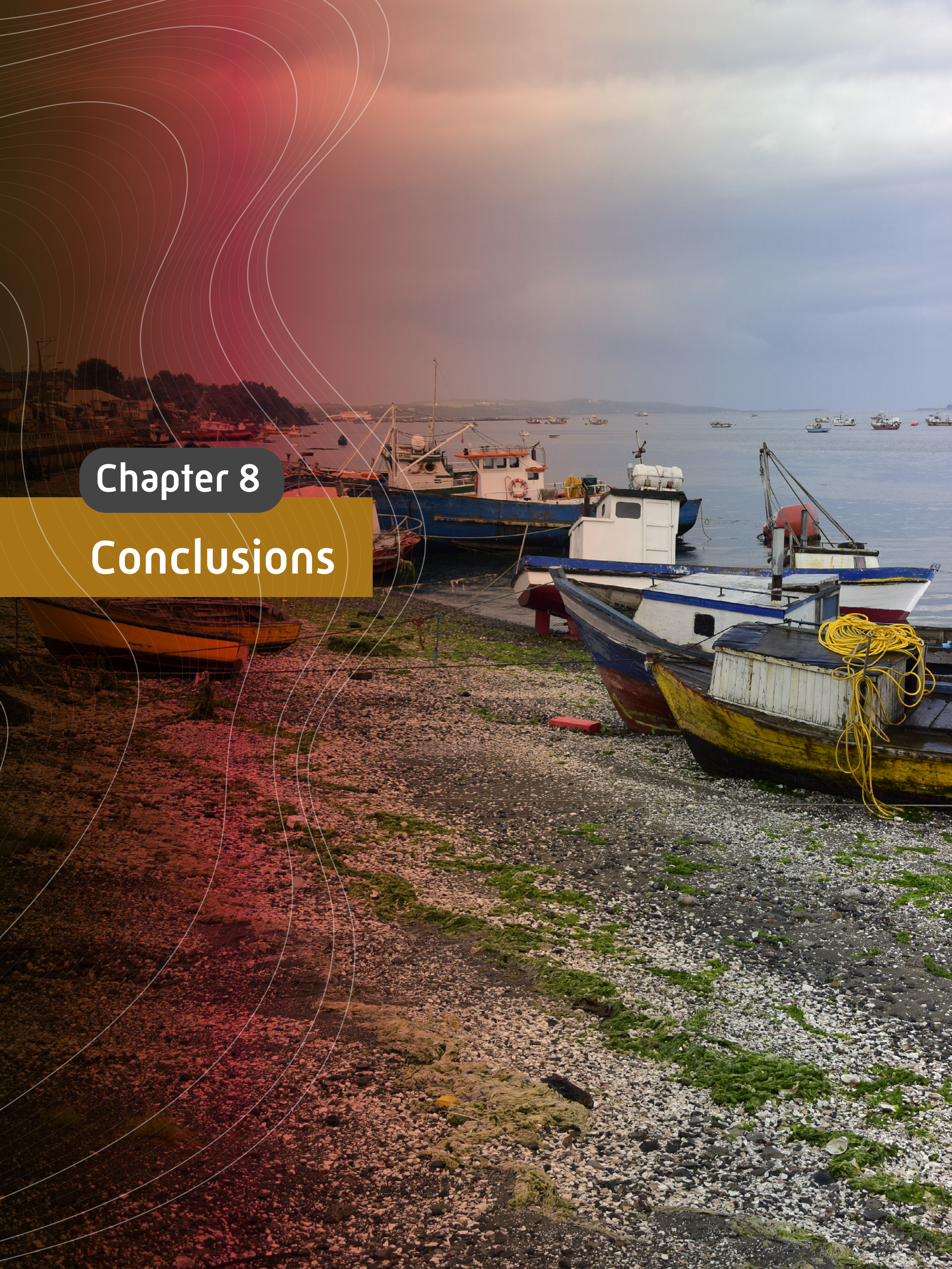
The first of them amounts to **37% of the population**, and is made up of inhabitants of Chiloé and Llanquihue, whose income mostly depends on seafood. It appears to affect their awareness of the symptoms carried by HABs poisoning. With regard to this group, the following is observed:

1. They consider that employment is affected by the occurrence of HABs, and that food shortage is the main impact.
2. They trust media information about HABs.
3. They consider that the occurrence of a new event in the next five years is quite likely.
4. In terms of health consequences, measures adopted by the authorities to confront HABs are deemed ineffective.
5. They consider the socioeconomic measures taken as moderately effective, which is associated to a positive evaluation of the resources allocated to their region to confront HABs.
6. They consider that clean water access may be a positive effect stemmed from the measures adopted to deal with HABs, probably because people associate HABs with contaminated water.

The **second group (63%)** is made up of people from all regions, with little to no dependence on seafood. Regarding this group, the following is observed:

1. People in this group have diverse opinions and levels of awareness about HABs poisoning symptoms, and about occurrence probability in the next five years.
2. They trust the information provided by environmental NGOs, universities, and research centers.
3. They consider that HABs events mostly impact health.
4. They believe one of HABs main effects is that people are forced to change productive activities.
5. They express different perceptions about the effectiveness of measures adopted by the authorities.
6. They consider that these measures may have a positive impact on health.

These results reinforce the importance of addressing HABs from a territorial perspective; one that recognizes the environmental, social, and economic particularities of the different localities exposed to these events. The prevention and preparation work against the possible impacts of HABs must consider certain variables, such as the level of economic and social dependence on the sea, or the geographical location. Such variables can significantly impact the way in which people perceive the problem, as well as the importance attributed to the different impacts of HABs; how positive the evaluation to the measures implemented is, and on the most reliable information sources to this problem.



Chapter 8

Conclusions

Conclusions

This report aims to contribute to the understanding of the HABs phenomenon and its public discussion, by means of research and scientific evidence. We analyze this field's existing knowledge and integrate a transdisciplinary perspective from the IPCC risk approach, considering several factors, such as the impacts, threats, exposure, sensitivity, adaptive capacity, management, and responses of different social sectors. Additionally, the present document means to contribute to the discussion and design of prevention, mitigation, adaptation, and transformation strategies, to generate progress towards climate governance of HABs in the coastal areas of Chilean Patagonia.

Climate governance is based on fundamental principles that guide decision-making actions, and the development of regulatory instruments. Considering previous works of the (CR)2, and mainly the Report to the Nations "Climate Governance of the Elements"(Billi et al., 2021), we hereby state that a climate governance of HABs should adopt three fundamental principles:

1. Anticipatory Approach, which implies considering future scenarios on HABs, in terms of decisions adopted to confront these events. The aim should be to reduce the associated socio-environmental vulnerabilities, increasing the resilience of human communities, ecosystems and territories.

2. Territorial Socioecosystemic Approach, in which implemented actions are relevant to the reality of each territory, to the diverse existing socio-ecological interactions, and their different degrees of exposure and vulnerability, while being able to articulate or transcend the traditional forms of territorial administration.

3. Good Administration, that is, an objective, transparent, coordinated, efficient and effective administration (Correa, 2019; Espinoza, 2020), which operates by considering the best available scientific evidence, as well as local, traditional and indigenous knowledge. This implies prioritizing strategies that consider economic, environmental and social costs (including the indirect costs of inaction); ensuring broad inclusion, especially effective participation of all social sectors in decision-making; and ensuring transparency and active accountability on the part of decision-making actors and executive authorities.

In this context and based on the work performed, we consider that highlighting national progress and achievements in relation to how HABs have been addressed is the starting point to improve governance. Such progress and achievements are as follows:

- **Firstly**, the multiple efforts of the public system in the health area to prevent poisonings and deaths, have been highly effective.
- **Secondly**, the current progress in terms of scientific information about HABs, enables their identification and potential relationship with various causative factors (meteorological, hydrographic, oceanographic, and biological).
- **Thirdly**, the current technical capacities for observation and monitoring, have enabled the implementation of processes to adapt and reduce vulnerabilities of coastal human communities, and which may improve the protection of ecosystems and their services.
- **Fourthly**, the existing progress in terms of coordination and articulation of social sectors, jointly with HABs management, have enabled the construction of important action networks that channel dialogue and decision-making actions, while highlighting the creation of territorial-based "red tide" workgroups.
- **Fifthly**, political institutions have displayed the capacity to correct and use new learning to improve the management and responses to HABs events.
- **Sixthly**, the responses comprising scientific knowledge and local knowledge have been recognized and evaluated positively by the communities affected by HABs.

At the same time, we highlight two methodological tools, developed for this report, which allowed us to approach the risk perceptions of the communities inhabiting the territories, and that are most exposed and vulnerable to HABs: the Survey of Local Perceptions on HABs in Chilean Patagonia, and the Qualitative Study on Experiences, Impacts and Responses in relation to HABs, carried out in Quellón. These tools permitted the identification and learning of experiences, assessments, projections, ideas for change, motivations, apprehensions, and proposals of the communities affected by HABs events. Finally, the construction of socioeconomic indicators to assess the impact of HABs, also generated for this report, constituting another tool that can contribute both to understanding the multidimensionality of the problem and to monitoring the actions implemented.

Even though the registered progress is crucial, throughout the Report we identify different knowledge gaps and voids that represent a barrier to address HABs in a comprehensive manner, and which considers a climate governance approach. These gaps are distributed in four large areas

State and its divisions

Identified gaps:

1. **Institutional management** of HABs generally **fragmented** and sometimes only **reactive** and not preventive; **little coordination** between departments and lack of clear roles and responsibilities.
2. **Inappropriate regulatory** and normative **framework** to address the complexity of HABs and **outdated** fundamental public policy **instruments** (for example, the National Plan on HAB in Chile, 1999).
3. **Scarce citizen participation** in the design, implementation and evaluation of HABs policies, and weak or **unstable articulation between social sectors** (state, private, civil society, scientific).
4. **Risk management** approach that does **not consider** HABs as a potential **socioenvironmental disaster**, that severely impacts human communities' dependent on sea resources in a socioeconomic way. This mainly affects those with subsistence economies or poorly diversified ones.
5. **Significant state investment** for monitoring and prevention, but **not enough** to address risks and impacts of HABs that affect multiple sectors.

HABs knowledge

Identified gaps:

1. **HABs diversity**, their triggers and impact magnitude on socio-ecological systems is diverse.
2. Possible **interactions with human activities** that take place in rivers and the sea, which could favor HABs development.
3. **There is a lack of models and risk appraisal** for HABs events, at various spatial scales.
4. It is necessary to reinforce **interdisciplinary and transdisciplinary studies** about HABs, considering a territorial approach.

Monitoring System

Identified gaps:

1. There is a HABs **monitoring system** in Patagonia, but it lacks a socio-ecosystem vision, both in its design and in the interpretation and analysis of the data generated. There is a lack of a **perspective** that considers **environmental, biological** and **social variables**. This perspective should enable a diagnosis, to integrate both natural climate variability (local, regional and global) and climate and non-climate threats, prioritizing information on the impact on ecosystems structure and functions, and the socioeconomic reality of the territory.

2. The monitoring system does **not incorporate** variables such as **nutrients** throughout the entire region, and the microalgae species that should be monitored are not constantly updated.

Risk Communication

Identified gaps:

1. **Little public availability** of data, with high levels of dispersion and a very long periodicity/latency.

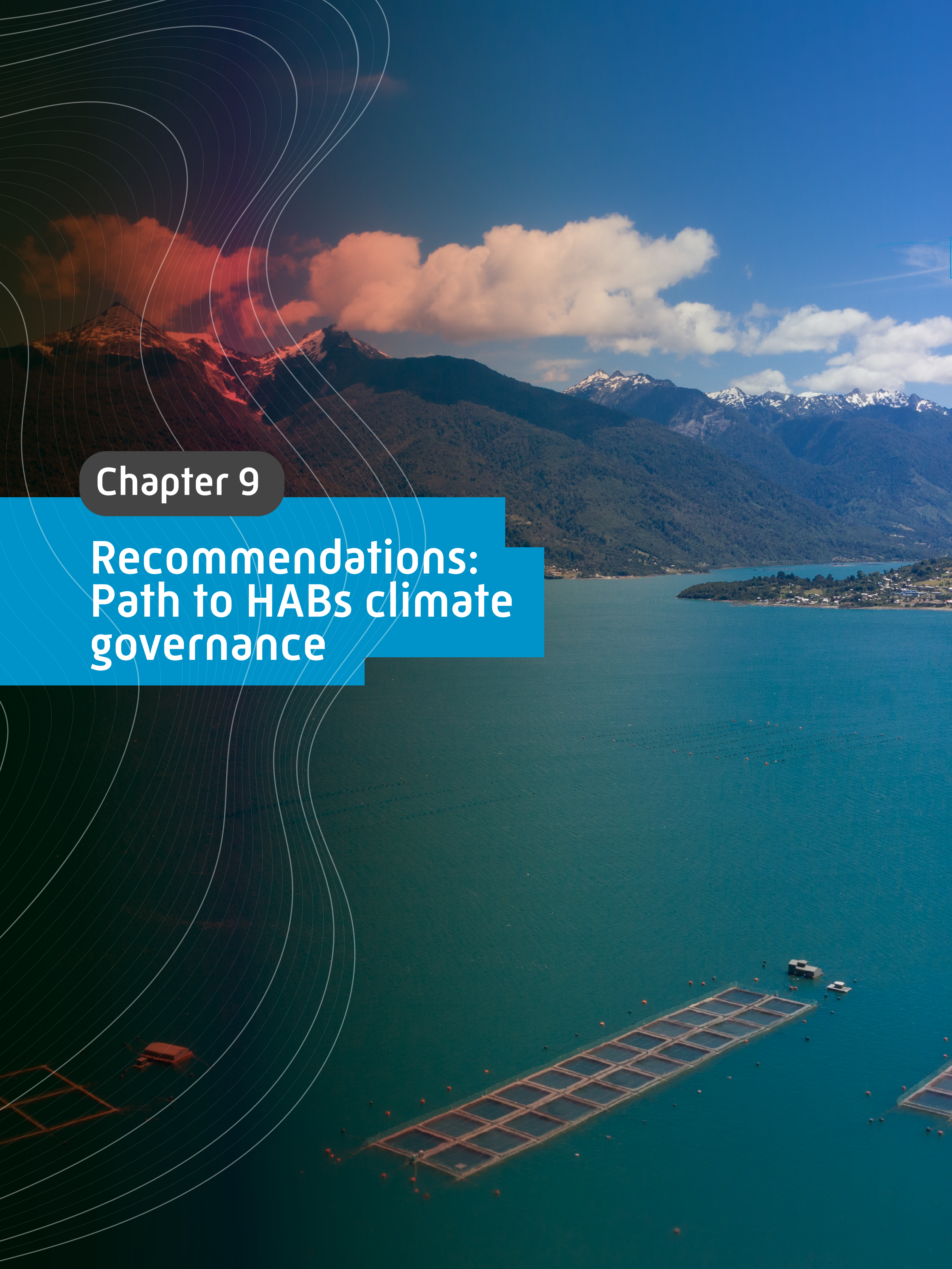
2. Human communities in isolated areas which are **difficult to reach**, thus don't receive direct and updated information regarding HABs.

Evidence determines the need to **strengthen**, **improve**, and in some cases, even **restructure** certain elements in these **four areas** in order to address the previously identified gaps and move towards **climate governance of HABs** in our country.

In the next chapter we make **recommendations** for each of these areas, proposing some **specific actions** to be developed in the short, medium and long term respectively.

Chapter 9

Recommendations: Path to HABs climate governance



Recommendations: Path to HABs climate governance

The following recommendations were built collectively among **(CR)2** and **external researchers**, and this compilation included the participation of representatives of the **state**, **scientific**, **private and civil society sectors**, which sums up to around fifty participants that wrote them.

The construction process consisted of **two discussion workshops** that focused on gaps, recommendations and actions, one that extended to all sectors, and another one only for (CR)2 researchers. The recommendations and actions were also validated through an **online survey** answered by all sectors.

Time period considered to implement the recommendations:

- Short term: **0-2 years**
- Medium term: **2-5 years**
- Long term: **more than 5 years**

Recommendations for the State and its divisions

"Pursuing a more proactive State for the well-being of human communities and ecosystems"

To strengthen coordination among public institutions associated with HABs, establishing hierarchies and clarifying roles, defining action areas, and assigning specific responsibilities.
(Response to gap **1**)

To establish formal instances of periodic communication among the public institutions involved in the HABs management at the national, regional and community levels.

Regarding the response protocols to HABs episodes, **to establish clearly** the **role**s, **responsibilities** and response terms of each institution, service, and organization involved.

To update the current public policy on HABs from a Disaster Risk Management approach and develop a regulatory and normative framework that facilitates an integrated governance of coastal zones.
(Response to gap **2**)

To analyze which **public policies** are associated with HABs to mainstream this predicament.

In regard to the programs and subprograms of the Superintendence of the Environment, to **prioritize** the **inspection** of environmental qualification resolutions of productive activities that take place in areas more prone to harmful algae blooms (carrying capacity of ecosystems and number of concessions, etc.) and strengthen the sanctions system.

To initiate a **process of co-construction** of a new National Plan to confront HABs with the participation of the public, private, scientific and civil society sectors.

To generate a **law for coastal zones** that defines integrated climate governance, promoting the coherence of productive and non-productive uses, and maintaining the oceans ecosystemic balance while considering the scenarios of a changing climate.

To review aspects related to the carrying capacity of **ecosystems affected** by HABs contained in the General Law on Fisheries and Aquaculture (Law No. 21,408), updating current and future climatic and non-climatic threats.

To design instruments and interventions for each stage of **Disaster Risk Management** applied to HABs, generating indicators that allow evaluating their effectiveness with a territorial approach.

To strengthen current collaboration networks among the public sector, the scientific sector, civil society and private companies, and if necessary, create new networks, that emphasize the participation of local communities.

(Response to gap **3**)

To create a "**HABs Governance Committee**" that joins the key sectors (state, scientific, private and civil society) periodically, provided with public budget that enables its setup and operation.

To generate **collaboration** instances **with the private sector**, aimed at exchanging learning and management experiences of HABs.

To **regularize procedures** so that representatives of local communities can make complaints about bad practices associated with HABs (Community Sentinels).

To develop productive diversification projects in the coastal areas affected by HABs.

(Response to gap **4**)

To generate a **diagnosis** tool for the **adaptive** and **transformation capacity** of local communities.

To develop **market studies** -complemented with socio-environmental studies- about the potential to generate new sustainable productive activities.

To design **curricular programs** (high school and college) that promote training in trades or other productive activities that do not depend highly on the sea.

To strengthen **permanent training** programs provided of an added value from which inhabitants of coastal areas can benefit, aimed at developing other alternative economic activities to the use of marine resources.

To increase the budget for the HABs management (beyond monitoring and alert).

(Response to gap **5**)

To provide **resources for the training**, interaction, dissemination, and exchange of knowledge among the various social sectors, emphasizing the interaction of the state and scientific sectors.

To ensure **resources at the regional and local level** for the acquisition of sample-analysis technology in the same territories thus not depend on external laboratories.

To make **public resources more available**, in order to increase public science and citizen science projects, aimed at HABs prevention and preparation.

Time period considered to implement the recommendations:

- Short term: **0-2 years**
- Medium term: **2-5 years**
- Long term: **more than 5 years**

Recommendations for HABs Knowledge

"Knowledge is our greatest ally; Know first, decide later"

To estimate and evaluate risk before HABs, considering a territorial approach in a participatory way.
(Response to gaps 1 and 3)

- To evaluate **new variables/processes** that pose **threats** to ecosystems (for example, ballast water from shipping or potential transfer of HABs by well-boats).

- To create **indicators/indexes** to quantify **risk** in different territories, that provide autonomous threats, exposures and vulnerabilities assessment.

- To generate **dynamic risk maps**, associated with the different types of HABs, that consider the differences among microalgae species.

To perform research actions that address the interactions among human activities, climate and HABs, emphasizing the characterization of socioeconomic and psychosocial impacts in coastal communities, considering a territorial approach.
(Response to gaps 2 and 4)

- To generate **transdisciplinary research** instances that take risk management into account, addressing the psychosocial impacts that HABs can generate in the territories, and reserving local memory thereof.

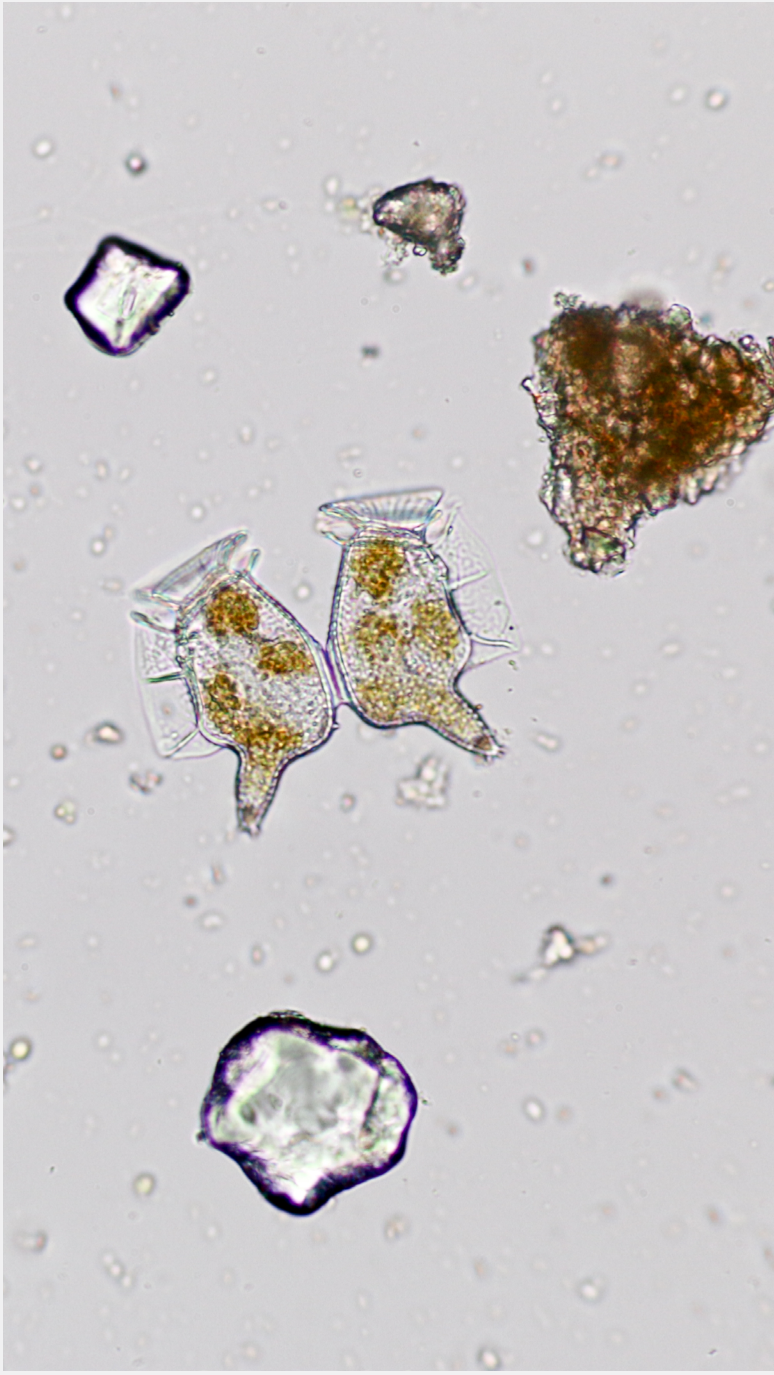
- To hold **regular surveys** about the perceptions and impacts of HABs in coastal communities, in order to visualize how these events affect people's lives.

- To generate **agreements with universities**, so that theses or practices are developed by students of social sciences careers, about the impacts of HABs.

- To integrate **social sciences professionals** in territorial intervention teams, institutions and research groups associated with HABs.

Time period considered to implement the recommendations:

- Short term: **0-2 years**
- Medium term: **2-5 years**
- Long term: **more than 5 years**



- To determine a set of indicators, validated at a local level, to **systematically monitor** the socioeconomic and socio-environmental impacts (carrying capacity) of HABs.

Recommendations for Monitoring System

"Monitor to understand and take action"

Time period considered to implement the recommendations:

- Short term: **0-2 years**
- Medium term: **2-5 years**
- Long term: **more than 5 years**

To define favorable and unfavorable climatic conditions for each of the significantly impactful HABs-producing species.

(Response to gap **1**)

- To articulate **existing scientific evidence** (based on observations and models) of observed and future climate trends (ENSO, SAM, MJO, PDO indexes) that may contribute to the development of HABs species. (Short term)

- To create a **scientific advisory** team, made up of specialists from national institutions that focus on HABs risk management. (Medium term)

- To generate an **integrated observation system** in some aquatic systems which present a greater sensitivity and risk of HABs, and which have an endemic presence of the causative species, nutrient enrichment, hypoxia, among some anthropogenic forcing factors. (Medium term)

- To initiate a **permanent regional economic fund** for the setup, integration and maintenance of online, real-time and long-term observation stations and platforms, incorporating the work of the Chilean Meteorological Directorate, the General Directorate of Water, and research centers, among other actors. (Long term)

To design systematic and integrated monitoring which covers environmental, biological and oceanographic aspects.

(Response to gap **2**)

- To setup a **multidisciplinary panel of experts** (academics and public administrators) to develop systematic and integrated monitoring (frequency, areas and density of monitoring). (Short term)

- To incorporate **nutrient monitoring**, especially in water bodies intervened by anthropic activities, which favor the development of local eutrophication indicators. (Short term)

- To enhance **freshwater bodies monitoring** that reveals more about the structure and operation of these systems regarding HABs, which considers international experience and the local knowledge of communities. (Medium term)

- To identify and define **priority monitoring areas** (areas sensitive to HABs) based on environmental (such as water residence times, productive load of the system, etc.), biological (presence and abundance of certain species that cause HABs) and social vulnerability (population in the area, socioeconomic activities, etc.) criteria, that enable the guidance of specific and local territorial strategies, in order to reduce vulnerability and improve HABs risk management in these areas. (Medium term)

- To strengthen the **preventive approach** through the generation of regional climate scenarios for variables favoring HABs events. (Medium term)

- To design **social intervention projects** integrating coastal communities into HABs follow-up/monitoring programs, based on their own experience, knowledge and daily practices. (Long term)

Recommendations for Risk Communication

"The importance of communication"

To have a modern and comprehensive system that makes systematized and unified information publicly available.
(Response to gap 1)

- To strengthen **web platforms** and **apps** to provide a continuous and updated view of the scientific information, generated about HABs, and available to the general public, making them more dynamic and improving their support.

- To initiate an **Inter-ministerial Commission** that manages the different data types related to HABs in a collaborative fashion.

- To generate a unified **national oceanographic data system** including HABs.

- To implement a friendly **alert system with a danger code** for the general public (example: SMS as in tremors and earthquakes).

Time period considered to implement the recommendations:

- Short term: **0-2 years**
- Medium term: **2-5 years**
- Long term: **more than 5 years**

To bolster the dissemination and socialization of HABs related information, at different levels, using language that is aimed at the general public, highlighting messages of prevention and response to emergencies, expanding socio-environmental education, and generating local capacities on the subject.
(Response to gap 2)

- To implement **training for state officials** about risk communication, thus providing them with tools to strengthen and expand their competencies, so that they can adequately inform the community.

- To increase efforts to **disseminate the actions** that institutions carry out so that citizens are more informed regarding existing surveillance plans to deal with HABs.

- To promote **science-society liaison schemes**, such as the advertisement of Public Science and Explore programs, the development of specialized literature for elementary and middle school teachers, and the strengthening of technological aspects in schools.

- To setup a **Risk Communication Team**, integrating professionals from education, creative and audiovisual areas, in charge of designing, implementing and evaluating prevention and preparation campaigns to confront HABs, especially in more exposed or isolated localities.

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Glossary

Introduction

Aquaculture: The farming of aquatic organisms including fish, mollusks, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production (FAO, n.d.-a).

Bivalves: Animals belonging to the Mollusca phylum whose soft parts of the body are completely or partially covered by a shell formed by two valves joined by a hinge (FAO, n.d.-b).

Phytoplankton: Set of microorganisms or microalgae that live dispersedly in the ocean. Oceanic food chains are based on these microorganisms.

Transformative climate governance: Interaction system among social sectors, institutions, norms and processes, oriented to public decision-making for the definition and implementation of objectives and strategies. This type of system considers environment care and the incorporation of challenges posed by climate change, as well as cause mitigation and adaptation to their effects (Zurbriggen, 2011).

Resilience: Capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (IPCC, 2014).

Transformation: Change in fundamental attributes of natural and human systems (IPCC, 2022). Broad and often irreversible set of changes that imply profound innovation in the economic, technological and social spheres. Changes in the way of thinking, decision-making, actions, behavior, power structures, governance systems, values, predefined objectives,

Socio-ecological system: Network of ecological and social relationships (human activities) that revolves around the resources necessary to sustain life on the planet (Ostrom, 2009). The environmental component and the social component are interrelated while not separate aspects.

Chapter 1

Ecoregion: Ecosystem unit that covers an extensive biogeographic area delimited by particular ecological, climatic, hydrological, geological and oceanographic characteristics, together with a relatively homogeneous species composition clearly differentiated from that of other adjacent areas.

Estuarine circulation: Circulation system characterized by presenting a double layer structure, with a superficial layer of fresh water coming from rivers that flows towards estuary entrance, and a second deeper layer of denser salty ocean water, that flows in the opposite direction from ocean into estuary.

Socio-environmental crisis: Situation in which the variables that make up the society-nature relationship are threatened, producing scenarios of conflict, impact or damage.

Diatoms: Group of unicellular microorganisms or microalgae that is part of the phytoplankton. It is characterized by having a silica wall and being able to form colonies.

Dinoflagellates: Group of unicellular microorganisms or microalgae that is part of the phytoplankton, and whose most characteristic feature is the presence of a structure called flagellum, that allows them to move throughout the water column.

Runoff: Rainwater or melting snow/ice water that flows freely over the surface of the earth without infiltrating into the ground and which can reach the coastal zone.

Sustainable development: Search for social and economic progress that ensures a healthy and productive life for human beings, and improves the quality of life, health, education and culture of all people, but that does not compromise the ability of future generations to meet their needs.

Biological productivity: Biomass production per unit of time and area. Regarding phytoplankton, which is central to this Report, it refers to the set of processes occurring in the ocean and associated to the primary production, generated mainly through photosynthesis. This productivity is essential for the dynamics of ecosystems since phytoplankton constitutes the basis of food webs.

Chapter 2

Food sovereignty: Food system whose consumers also control the production and distribution mechanisms. It places people's diet above trade at the core, promotes sustainable ways of life, and seeks to reduce the distances between producers and consumers, while valuing traditional knowledge and being compatible with nature (Gordillo & Méndez, 2013).

Chapter 3

Migratory anticyclone: High atmospheric pressure system in subtropical regions, and in middle and high latitudes. In the southern hemisphere it drives wind circulation in an anti-clockwise direction.

Phytoplankton biomass: Mass or quantity of microorganisms that constitute the phytoplankton recorded in a specific area at a given time.

Photic layer: Uppermost layer of the ocean (of variable depth) that receive up to 1% of sunlight or solar radiation, allowing phytoplankton to perform photosynthesis.

Westerlies: Intense prevailing winds in the middle latitudes of both hemispheres (between 40 and 60º S). They determine the climate and atmospheric dynamics of these regions.

Stratification: Density difference in the water column between the upper layer illuminated by the sun and the subsurface layers. The ocean stratification is stable, presenting densest layers near the bottom and the lightest ones on the surface.

Photosynthesis: Chemical process that occurs in plants when exposed to sunlight, as is the case of microalgae, such as phytoplankton. During photosynthesis, water and carbon dioxide combine to form carbohydrates (sugars) and oxygen is released.

Madden–Julian Oscillation (MJO): Climate variability mode of tropical origin that is characterized by the enhancement and suppression of storms over large tropical regions. These anomalous rainfalls move eastward and complete a cycle around the globe in a typical period of 30 to 90 days. The air rise associated to stormy regions can trigger large-scale atmospheric circulation patterns, whose impacts can reach extratropical regions. One example is the heat wave occurrence in Patagonia, which can be advantaged or burdened by specific and opposite conditions.

Nutrients: Elements or chemical compounds needed by an organism for metabolic purposes, and which are obtained from its environment. For example, phytoplankton require iron, nitrogen and phosphorus, among other essential elements for their growth.

Vertical mixing: Vertical movements of water that occurs as a result of temperature differences between water layers, amongst other causes.

Frontal system: Atmosphere circulation associated with the clash of air masses of different characteristics. It is the given name of atmospheric disturbances around a center of low atmospheric pressure and at sea level, that generally induce the development of strong winds, storms that triggerprecipitation, and noticeable changes in temperature and relative humidity.

Residence time: Water age to quantify the general dynamic conditions of a marine system.

Chapter 4

Marine Protected Areas (MPA): Geographically delimited and defined areas, whose administration and regulation have specific conservation or preservation objectives.

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Management and Exploitation Areas for Benthic Resources (MEABRs): Geographical area delimited and assigned by the National Fisheries and Aquaculture Service to one or more organizations of artisanal fishermen, for the execution of a project for the management and exploitation of benthic resources.

Adaptive capacity: Ability of systems, institutions, humans, and other organisms to adapt to potential harm, seize opportunities, or cope with consequences.

Salmon farming: Branch of aquaculture focused on farming fish of the family Salmonidae (eg Atlantic salmon, Pacific salmon) in the ocean.

Sensitivity: Degree to which a system or species is affected by natural variability or climate change, either negatively or positively.

Risk perception: Subjective criteria about the characteristics and severity of risks.

Marine Coastal Spaces of Indigenous Peoples (ECMPO in Spanish): Delimited marine spaces, whose administration is handed over to indigenous communities or associations that have exercised the customary use of mentioned space verified by Conadi.

N:P ratio: Indicator of the amount of nutrients in the marine environment, in this case of inorganic nutrients associated with nitrogen (N) and phosphorus (P).

N:Si ratio: Indicator of the amount of nutrients in the marine environment, in this case of inorganic nutrients associated with nitrogen (N) and silicate (Si).

Particulate organic nitrogen (PON): Organic nitrogen particles with pore sizes between 0.2 and 1.0 micrometers.

Dissolved organic nitrogen (DON): Organic nitrogen concentration that remains in a seawater sample after all particulate nitrogen has been removed by filtration. It includes compounds such as amino acids, urea, hydroxylamine, and amides.

Carrying capacity: Maximum population size of a biological species that can be sustained by that specific environment, given the food, habitat, water(oxygen), and other resources available.

Well-boat: Vessels dedicated to the transport of live fish. It is one of the most demanded services by the Chilean salmon industry. These boats transport young salmon (smolts) and larger ones (harvest), traveling through the fjords and channels of the south. Frequently, these vessels have been blamed for moving HABs from contaminated areas to toxin-free areas, because they tend to not comply with regulations (such as driving with their gates closed in areas where there is red tide) or do not have state-of-the-art technologies incorporated. In this regard, some transport companies have indicated ongoing progress in terms of development of new technologies to neutralize 100% of the algae (https://www.aqua.cl/informes-tecnicos/chile-well-boats-multiproposito/)

Chapter 5

Decree: Written order issued by the President of the Republic or a Minister (by order of the President of the Republic), on matters within their competence.

Socio-environmental externalities: External effects or costs that stem from decisions on how to inhabit the planet (for example, increased morbidity as a result of air pollution). These effects can also be benefits (such as the increase of certain species in areas declared under protection). Many times, these effects are difficult to value monetarily, which hinders their economic analysis when preparing public policies (Delacámara, 2008).

Resolutions: Regulations issued by the administrative authorities endowed with decision-making power (Billi et al., 2021).

Capítulo 6

Protection action: (Remedy or action of protection): Precautionary action whose objective is to protect fundamental rights against deprivation, disturbance or threats, with respect to specific rights and in accordance with the provisions of article 20 of the Political Constitution of the Republic of Chile. In the case of the right to live in a pollution-free environment, the established remedy proceeds when it is affected by an act or omission, attributable to a specific person or authority.

Climate change adaptation: Process of adjusting to current or expected climate and its effects. For humans, adaptation aims to moderate harm and exploit the beneficial opportunities (IPCC, 2018) and the integrity of a system, or process it at a certain scale. In some cases, gradual adaptation can culminate in a transformational adaptation (adapted from IPCC, 2018 and Aldunce et al., 2021).

Potentially positive transformative actions: Transformation in which society adjusts and adapts by acting quickly, to avoid deepening vulnerability and impacts, or transformation action characterized by a decrease in greenhouse gas emissions and accelerated sustainability for natural and human systems (adapted from Moser et al., 2019 y Aldunce et al., 2021).

Adaptive responses to HABs: Actions aimed at facing the impacts of HABs or learning from the opportunities that this problem presents.

Regulatory responses: Issuance of norms at a legal or regulatory level, or through another type of administrative act, whose elaboration process is directly related to a situation or problem that must be regulated, either through the creation of new regulations or the modification of current norms.

Supervisory responses: Effective inspection of entities with environmental, sanitary or fishing-aquaculture competence, before the occurrence of events or contingencies associated with eventual actions or omissions of the supervised subjects.

Sanctioning responses: Actions by public entities that hold environmental or sectorial competence, and with sanctioning powers. Such actions are exercised over infringing subjects, through the initiation of a sanctioning administrative procedure or the establishment of provisional measures

REPORT TO THE NATIONS

"Red tide" and global change:

Elements for the construction of an integrated governance of Harmful Algal Blooms (HABs)

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