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A Review of the Economic Valuation of Harmful Algal Blooms (HAB): Methodological Challenges, Policy Implications, and Application

To apply for a Master's degree in Environmental and Natural Resources Economics

By

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Gratitude

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Abstract

In most marine and fresh-water environments, microscopic, plant-like organisms occur naturally in the surface layer, referred to as phytoplankton or microalgae. They form the base of the food chain upon which nearly all other marine organisms depend. Human activity and climate change can increase the nutrients the algae feed, leading to algal blooms. Some of these algal blooms can be detrimental to humans and have been called Harmful Algal Blooms (HABs). This study has three objectives. First, we revisited and updated the literature review on the economic valuation of the impacts of HABs suggested by Adams et al. (2018). Second, unlike Adams et al. (2018), we are particularly interested in identifying whether or not economic valuations have any policy implications. To some extent, many studies account for the economic impact without linking them to any feasible policy interventions and therefore are sterile from a practical perspective. Third, we designed and applied a Stated Preferences (SP) study to evaluate one specific policy. We estimate a "price premium" that could be incorporated into some seafood products and serve as an "insurance-type" policy to create a fund to support monitoring systems and to be used for damage compensation in the presence of HABs to avoid social unrest. Results shows that people in Chile are willing to pay a premium price of mussels of $ 963,28 Chilean pesos. So, this research represents a starting point to make an economic valuation that aims to determine the people's willingness to pay to compensate the damages of the HABs events.

Keywords: Harmful Algal Blooms (HABs), Willingness to Pay, Damages, Institutional Trust.

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1. Introduction

In most marine and freshwater environments, microscopic, plant-like organisms occur naturally in the surface layer, known as phytoplankton or microalgae, which form the base of the food chain upon nearly all other marine organisms depend (Lucas, Larkin & Adams, 2010, Anderson, 2009). However, climate change transforms aquatic ecosystems through progressive warming, acidification, and deoxygenation (Gobler, 2020). Climate change and human activity alter some environments increasing the algae's nutrients and algal blooms, which can be detrimental to humans because some algal species produce potent toxins that accumulate in shellfish, resulting in poisoning syndromes[1] (Hoagland et al., 2002). This phenomenon has been called Harmful Algal Blooms (HABs).

There is a scientific consensus that public health, recreation, tourism, fishery, aquaculture, and ecosystem impacts from HABs have increased over the last decades. HABs are natural hazards that can lead to severe health and socioeconomic consequences depending on spatial distributions relative to human populations; durations and frequencies of occurrence; cell densities and toxicities; and weather conditions (Adams et al., 2018). Among the main harmful effects caused by HABs are fish mortality, shellfish poisonousness, and numerous other problems in marine coastal waters. From an economics perspective, the main sectors that have been severely affected and responsible for substantial economic losses are human health; commercial fishery; tourism and recreation; and monitoring and management (Sanseverino et al., 2016).

The three most extreme HAB events of the century are the Alexandrium catenella bloom in southeastern Australia (2012-2017), the Pseudo-Nitzschia bloom that spanned from Alaska to Mexico in 2015, and the "Godzilla red tide" of A. catenella and Pseudochattonella Verruculosa in Chile in 2016. These events have been related to climate change conditions such as warming, stratification intensity, freshwater inputs, and natural patterns of climate variability. The latter event resulted in the most significant fish farm mortality recorded worldwide, equivalent to a loss of $800 million in exports. It also

[1] Paralytic, diarrhetic, amnesic, or neurotoxic shellfish poisoning, PSP, DSP, ASP, or NSP, respectively. A related phenomenon, known as ciguatera fish poisoning (CFP), occurs when toxic algae living on coral reef seaweeds are consumed by herbivorous fish, which pass the toxins on to larger predators and then deliver the neurotoxins to human consumers

produced substantial social unrest and rioting in southern Chile (Trainer et al., 2020). Nevertheless, this amount does not comprise the total economic impacts of HABs since it does not consider other direct and indirect costs associated with the main sectors affected.

The US National Office for Harmful Algal Blooms indicates that estimating the full range of societal impacts of HABs is as tricky as assessing human behavior in response to a traumatic event. They identify effects such as disruption of working patterns, reduction in boat reservations and pier attendance for recreational anglers; the ruin of vacation; and adverse impact on property values. Other impacts of HABs are related to social issues, including unwillingness/inability to swim in the contaminated water; concerns about the possible presence of toxins in the drinking water; decrease in the tap water quality; or even the cessation of water supply to the population (Namsaraev et al., 2019).

Economic losses (damage) are expected to increase due to the intensification of HABs. Therefore, researchers and policymakers need to understand the economic implications of HABs and identify policies that can cope with the effects of HABs. However, both research areas still have limitations (economic valuation and policy interventions) (Borger et al., 2014, Hanemann, 2022). While the economic valuation of the impacts of HABs may contribute to this goal since it can assess the direct and indirect implications of HABs, we recognize that the economic valuation of damages is not enough to deal with HABs. Policymakers need to have a pool of policy options based not only on economic principles but also on equity, fairness, and social objectives. In any case, the economic valuation of damages needs to be grounded in a solid cost-benefit analysis of clearly identified policy interventions if it wants to be helpful for policy design (Whittington, 2010). Unfortunately, this paper shows that many economic studies in the context of HAB are not linked to any cost-benefit analysis of policy interventions. Instead, they focus on accounting for the damages, translating into incomplete and sometimes frustrating information for policymakers. As Castro and Moser (2020) pointed out, from a public policy perspective, there is a difference in the way countries monitor HABs, and communicate risks, so creating a coherent system with consistent messaging and inter-agency communication can reduce risks, enhance public knowledge and induce more collaboration on HABs monitoring and management

This thesis has three objectives. First, we revisited and updated the literature review on the economic valuation of the impacts of HABs suggested by Adams et al. (2018), identifying methodological challenges to performing an economic valuation that seeks to determine the welfare effects of this phenomenon. We focus on the "goods or services" valued, the methodologies used, and the gaps in the economic valuation of HABs events. Second, unlike Adams et al. (2018), we are particularly interested in identifying whether or not economic valuations have any policy implications. To some extent, many studies account for the economic impact without linking them to any feasible policy interventions and therefore are sterile from a practical perspective. Third, we designed and applied a Stated Preferences (SP) study to evaluate one specific policy. We estimate a "price premium" that could be incorporated into some seafood products and serve as an "insurance-type" policy to create a fund to support monitoring systems and to be used for damage compensation in the presence of HABs to avoid social unrest. This paper contributes to the scarce literature using SP to evaluate HAB. Adams et al. show that only 6 out of 36 articles used SP.

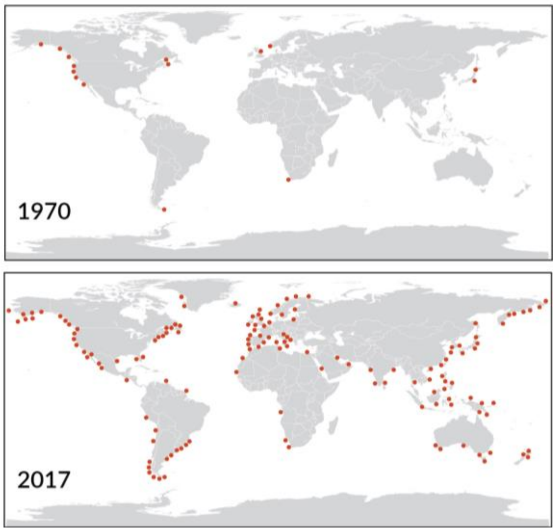
Specifically, our application is based on the experience in southern Chile, where a strong mussels production sector was sharply affected by HABs in 2016. We applied a survey in two big cities to determine the willingness to pay (WTP) an additional price for mussels to support a seawater monitoring system to predict the emergence of a red tide and to generate a "*crisis fund*" to support affected producer families in crisis periods. Our results show a positive WTP for that policy. At the same time, our results show that trust in the institution responsible for the implementation o the policy is relevant to explain people´s WTP. This is a problematic result, given the increasing distrust in institutions in many countries.

The following section provides a background of the HAB problem worldwide. Section 3 shows the methods used to reach our goals, while sections 4 and 5 show the review results in gaps in the economic valuation, policy instruments, and the estimate WTP exercise.

2. Background on HAB events

According to the US National Office for Harmful Algal Blooms, several decades ago, relatively few countries appeared to be affected by HAB (see figure 1). In contrast, these events threaten most coastal countries over larger geographic areas and by more than one toxic species, generating an increasing impact on fisheries and higher economic losses. The causes behind this expansion are in dispute, with possible explanations ranging from natural reasons to human-related phenomena such as pollution, climatic shifts, and transport of algal species via ship ballast water. Whatever the reasons, coastal regions worldwide are subject to unprecedented frequency of HAB events (Anderson, 2009).

Figure 1. Global distribution of PSP toxins in 2017 and 1970.



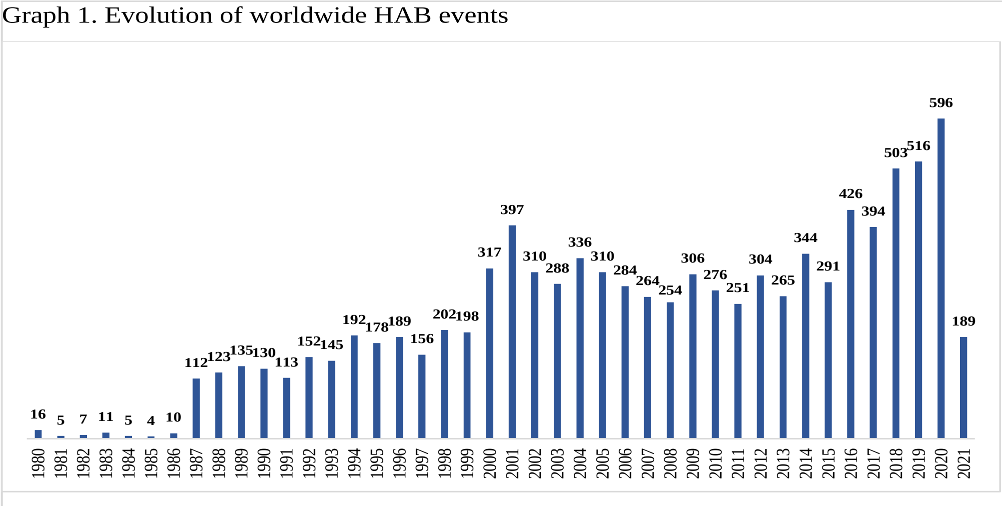
Source: US National Office for Harmful Algal Blooms

The global expansion of this phenomenon also reflects improved monitoring and detection capabilities. The Harmful Algae Event Database [HAEDAT] indicates that these events have increased considerably in the last decades, from 16 HAB events in 1980 to 596 in 2020. The causes behind this expansion are debated, with possible explanations ranging from natural reasons to human-related phenomena such as pollution or climatic shifts; resulting in unprecedented diversity and frequency of HAB events. As of 2021[2],

[2] Data from 2021 was retrieved on September 30, 2021.

there were 205 identified cases (Graph 1). The involvement of human activities in the HAB expansion suggests that policy decisions leading to mitigating the impacts of blooms are needed at several levels. Moreover, scientific evidence is also needed to justify these actions.

Graph 1. Evolution of worldwide HAB events



Source: Own elaboration with Harmful Algae Event Database [HAEDAT].

3. Material and Methods

3.1 Literature Review

For the review, we searched through google scholar using mixed of keywords such as "*Harmful algal blooms*," "*economic valuation*," "*policy instruments*," "*contingent valuation*," "*choice experiment*," "*willingness to pay*," and "*toxic algae*." We identified 1) methodologies used in valuation exercises, 2) the "good," 3) information gaps, and 4) policy instruments or interventions discussed in the articles. Table 1 summarizes the selected papers (country, year, authors, methods, good valued, estimated welfare measure, among others). We included in the revision only studies containing an identified methodology used to derive the economic effects of these phenomena.[3]

There are several valuation methods to estimate the economic impact of HABs. Those methods include: induced costs and losses, contingent valuation, choice experiments, input-output models, comparisons between scenarios, and times series models (Freeman III et al., 2014; Champ et al., 2017). These methodologies may be classified into Revealed

[3] Articles only focusing on social issues related to red tide (e.g., the state of current knowledge of red tides) were excluded.

Preferences (RP) or Stated Preferences (SP) (Haab and McConnell, 2002). RP relies upon data obtained through markets, such as observations of consumer expenditures (Bockstael and McConnell, 2007). In contrast, SP approaches ask individuals, through survey methods, to state their WTP or willingness to accept (WTA) for specific goods or services (Bateman et al., 2002). RP includes methods based on market prices, indirect markets (travel cost, hedonic prices), production function, and avoided or induced cost of an event.

SP approaches include contingent valuation (CV) and choice experiment (CE) (Kanninen, 2007). These methods often use surveys to ask people about their economic value by asking them how they would vote on a referendum to establish a program that would prevent HAB-related losses (Adams et al., 2018). In CV, people face only one alternative (besides the status quo). In contrast, in CE, respondents are asked to indicate their preference among two or more multi-attribute alternatives (Johnston et al., 2017). Including price as an attribute permits a multidimensional, preference-based valuation to be used in benefit-cost analysis or any other applicable policy analysis (Holmes, Adamowicz & Carlsson, 2017). RP data is unavailable for some economic losses, so SP approaches are the only possibility to measure nonmarket values. Furthermore, impacts on morbidity or mortality can be estimated using either RP or SP by the estimation of the Value of a Statistical Life (VSL) or injury (VSI) (Viscusi and Aldy, 2003; Vasquez-Lavin et al., 2022). A full description of these methodologies is beyond the scope of this paper (please see Freeman III et al., 2014; Champ et al., 2017, for details on these approaches).

We based our analysis on the conceptual framework for economic valuation applied to HABs, and summarized by Van den Bergh et al. (2002). It decomposes the ***total economic value*** (TEV) into ***use*** and ***nonuse value*** combined with identifying the methodologies (RP or SP methodologies) used for the economic valuation. *Use value* refers to the set of damages that arise from the impact of the alga blooms connected to the use value of the good or ecosystem services affected (own use or someone else). The use value is composed of the direct use value (DUV, damages caused by HABs to tourism, recreation, fishery, and human health), indirect use value (IUV, damages to the functioning of the marine ecosystem), and option value (OUV, possibility of own or someone else future use) (Hanemann, 2022). Nonuse values are not liked to any current or future use and are classified as bequest value (BV, benefit accruing to any individual from the knowledge that future generations might benefit from a marine ecosystem being free from HABs) and an existence value (EV refers to the benefit derived simply from the knowledge that marine species are protected without even being used) (Van den Bergh et al., 2002).

An economic valuation should start by identifying the type of economic value (use or nonuse) affected by the HABs and the relevant population affected or depositary of these values (market extension) (Freemann III, 2014). Economic valuation aims to estimate the *consumer and producer surplus* (the area between the demand or supply functions and the market price)(Johansson,1991)[4]. Researchers and policymakers often use price and quantity information to estimate revenue (price times quantity) (For instance, Sanseverino et al., 2016, Adams et al., 2018, Dyson et al. 2010, Habas and Gilbert, 1975). Researchers argue that this and the standard approach (Dyson et al ,2010) and that is a direct market method that reflects a change in market value, revenues, or expenditures (lost seafood market sales or costs of HAB monitoring or cleanup) (Adams et al., 2018) and that it provides a relatively accurate means of estimating changes in a local, regional economy based upon an estimated change in direct expenditures (Dyson et al 2010). While this is a simple approach and very useful from a communicational perspective with policymakers and other stakeholders, it has two theoretical drawbacks. First, it ignores the consumer surplus, which represents a significant part of the economic value and the methodological developments in the literature. Second, it includes both producer´s surplus and the cost of production. The cost of production cannot be considered a measure of social welfare (it is indeed a cost, not a benefit). When market price information is available, social welfare changes can be calculated using price and quantities to estimate a demand and supply function and, from them, estimate surpluses (Khan and Rockel, 1988; Adams et al., 2018). This approach is hardly ever used due to the data limitation that does not allow proper econometric estimation of demand and supply functions. In other cases, it is possible to have reliable market data related to environmental goods. For instance, this could be the case for recreational and touristic activities and impacts on property values. We could use the travel cost or hedonic price method if that information is reliable. Finally, the VSL or VSI could be appropriate to estimate the economic value of mortality and morbidity. While VSL and VSI can, in principle, be estimated using RP, the prevalent RP case uses labor market data and might not be appropriate for the risk associated with HAB. In that case, the only option is to use SP.

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[4] Economists are interested in two other welfare measures, compensating variation or equivalent variation, that can be expressed as WTP or WTA (Hanemann, 1991). These two welfare measures can be approximated using the consumer surplus. We will not address this subtleness here. See Willig (1976) and Hausmann (1981) for a discussion.

3.2 SP application

Currently, the Chilean government relies on prohibiting seafood consumption from the areas affected by red tide. Unfortunately, people stop consuming other seafood immune to the red tide or products from unaffected places for fear of being contaminated, given the insecurity about where their seafood comes from. Based on the literature review, we identified a policy that could address the health impacts and the lack of information about the origin of the seafood and provide an insurance system for producers. The policy aims at creating a fund to support three components:

1. To create a seawater monitoring system to predict the emergence of a red tide to avoid acute health threat events associated with consuming contaminated seafood. This component aims at reducing uncertainty and increasing preparedness to deal with the event.
2. To inform people about the red tide event timely and certified the origin of seafood that has not been affected by the event. This component seeks to reduce ignorance about the origin of the seafood and to increase confidence regarding seafood that is secure to eat.
3. To generate a "crisis fund" to aid affected producers that need to stop commercialization in the presence of HAB. This last component looks at reducing social problems (riots, protests) and increasing fairness in the allocation of the adverse effects of the red tide. The fund accumulates during non-crisis periods and is financed jointly by companies, the government, and an increase in the mussels´ price.

The contingent valuation method was the most appropriate methodology for this objective. CV uses questionnaires to elicit people's WTP by creating a hypothetical market where respondents can choose between the situation with and without the program (status quo) (Bateman, Willis, & Arrow, 2001; Carson et al., 2003; Mitchell & Carson, 1989)).5 We conduct a CV study to evaluate the responses of mussels consumers from

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[5] The validity of CV applications has been the object of a long and tortuous discussion among economists and noneconomists. In particular after the Exxon Valdez oil spill in Alaska in the 1990s (Carson et al., 2003). Some issues evaluated are reliability (Arrow & Solow, 1993; Diamond, Hausman, Leonard, & Denning, 1993) and embedding effects (scope, order, etc.) Desvousges et al. (1993), Diamond et al. (1993), Kahneman and Knetsch (1992) and Payne, Schkade, Desvousges, and Aultman (2000). A symposium in the *Journal of Economic Perspective*'s CV (Carson, 2012; Hausman, 2012) and *Applied Economics Perspective and Policy* (Desvousges,

two big cities in the country (Santiago and Concepción) to an increase in the price of the product (prime) to finance the program. The survey explains (remains) respondents the past red tide and its impacts, together with the explanation of the program.

Since there are many product presentations (fresh with shell, fresh only meat, frozen with shell, frozen only meat, canned in oil or water), we identified the need to standardize the product to a quarter of mussel using focus groups and pilot surveys6. The survey offers 250 grams of meat regardless of the presence of shells in the product (equivalent to approximately 45 units). The cost of the product was, on average, CL$1,250. Then, the WTP question was: "*Would you be willing to pay an additional $At pesos for 250 grams (one quarter) of mussel meat for these measures to be implemented?*" The amount $At varies in different surveys to get enough variation to estimate a WTP response function. The bids were 250, 500, 650, 950, 1100, 1250, and 1500 Chilean pesos.

We applied the survey in the two largest cities (Santiago and Concepción) from October to December 2016, targeting individuals aged 18 years and above who were regular consumers of mussels (weekly or monthly). We conducted four focus groups and two pilot surveys (125 observations) to test the survey and followed a probabilistic multi-stage sampling design, randomly choosing neighborhoods and blocks and then selecting households. We reach 1,257 helpful information, with a nominal rejection rate.

Additionally, we evaluate people´s trust in the institutions in charge of carrying out the policy instruments that seek to prevent or mitigate the effects related to HABs and assess how this trust influences their WTP. For simplicity and to avoid an exhausting long survey, we decided to use a single question regarding trust instead of the multiple-question study suggested by the OECD Guidelines that are used to measure several trust constructions. Future research might evaluate whether a simple versus multiple-quest approach better explains people's WTP. The relevance of institutional trust, one form of social capital, on the WTP has been identified in several papers either theoretically (Oh, and Hong (2012)) or empirically (Birol and Das (2012), Krystallis and Chryssohoidis,

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Mathews, & Train, 2016; Haab, Interis, Petrolia, & Whitehead, 2013, 2016) summarized part of this discussion. A CV study involves much more than a mere question of WTP (Arrow et al 1993; Jhonston et al., 2017).

[6] Different products have different weights. We use visual aids to represent the 250 grs in each format. Sometime we need additions or subtractions to reach 250 grams.

2005, Meyerhoff and Liebe, 2006 and Jones et al. 2015). In particular, Jones et al. evaluate how social capital affects WTP for coastal defenses to cope with climate change events. We focus on institutional trust instead of generalized trust. Generalized trust refers to trust in unknown people by the respondent or in situations where the person being trusted is not specified. In contrast, institutional trust refers to trust in all types of institutions (OECD, 2017). In our case, we are interested in respondents' trust in the government that provides information about risks related to red tide.

The instrument starts with a series of filter questions to identify the target population. In that sense, the questions include the following: "Are you over 18 years of age?", "Are mussels normally consumed in your home?" and "Do they not consume because nobody likes them?" If the person is under 18 years of age or answers that "no one in their household likes mussels," thank the respondent for their time and survey another household. Otherwise, proceed with taking the survey. We asked people about their knowledge of the origin of the mussels they consume. The survey also included a section collecting sociodemographic information.

The survey also includes an explanation of the concept of red tide, stating that:

"It is a natural phenomenon caused by increasing some tiny algae (microalgae) in water. These algae are the food of mussels and other marine organisms. Red tide can cause damage to people's health who consume them. Additionally, it produces economic losses for aquaculture and extractive activity." (free translation from Spanish) Followed by:

"Scientists believe this phenomenon will repeat more often in the future and that it is inevitable, given the changes in the ocean. For this reason, mechanisms are currently sought to predict more accurately when a red tide event will occur to take protective measures".

"According to the Chilean Ministry of Health, from 1970 to date, HABs have increased the frequency and extension of diarrheal, amnesic, and paralyzing toxin events. Its development and duration depend on biological, hydrological, and meteorological factors. The toxins of importance in Chile are Diarrheal Poison of Shellfish (VDM), Amnesic Poison of Shellfish (VAM), and Paralyzing Poison of Shellfish (VPM)."

"In addition, since 1995, Chile has had a National Program for Surveillance and Control of Harmful Algal Phenomena in all affected regions. This program aims to minimize health risks, understand the phenomenon's magnitude and evolution, and timely detect levels of toxins to adopt measures to protect the population. Among the activities performed are control at disembarkation, cultivation and natural banks areas and prohibiting extraction and commercialization, health promotion actions, risk communication, and surveillance of clinical cases.

The Ministry of Health annually promotes a preventive campaign that includes a clear description of what HAB is, what the symptoms are, ways to prevent poisoning, and a series of recommendations to prevent intoxication.

Nevertheless, these actions are insufficient given the recurrence of the phenomenon, the larger areas affected, and its severity. That is why we are implementing a tripartite fundraising program (government, industry, and consumers) to create a seawater monitoring system to predict the emergence of red tides, inform people opportunely, and help small and medium-sized producers when these events occur. The idea is to reduce social problems (riots and protests) and increased fairness in the allocation of the adverse effects of the red tide. This section is followed by the valuation question described above.

3.3 Statistical approach

Estimating the WTP from discrete choice CV studies requires certain specific techniques that allow us to use parametric and nonparametric approaches (Champ et al. (2003), Haab and McConnell (2002), Hanemann and Kanninen (1999)). This paper follows the most straightforward parametric model that permits the inclusion of covariates in the regression. A linear utility function is $v_j = \alpha + \beta y + \varepsilon_j$, where v_j is the indirect utility in the situation j (0 for status quo and 1 for new situation), y is income, ε_j is an error term (normally distributed in the Probit model) and (α, β) are parameters to be estimated.

This is the most common function used in CV because of its simplicity in assessing and interpreting the parameters and calculating the WTP (Louviere, Hensher, & Swait, 2000).

The dependent variable is defined as $y_i=1$ for a positive answer and a $y_i=0$ otherwise. A respondent will be willing to pay the amount A_t only if the utility or benefits of doing so is higher than the utility of the status quo (Hanemann (1984) and Haab and McConnell (2002)). Other covariates enter the model through α, and the income effect is captured by coefficient β. Given the linear utility function, the WTP's mean (and median) is E(WTP)= α/β.

We include in the explanatory variables age of individuals (***AGE***), years of education (***EDUC***), a dummy variable that takes a value of 1 if the individual only eats fish when there is a red tide (**Fish only**), a dummy variable that takes a value of 1 if the respondent consumes fish and shellfish from unaffected areas in the event of a red tide (***other areas***) and a dummy variable that takes value one if the individual trusts the government when it provides information and certifies that the products, they consume are free of red tide (**TRUST**).

4 Results

We organized the presentation of the results as follows. First, we summarize the studies that estimated the economic impacts of single or multiple HAB events over time in different countries and identify information gaps. Second, we identify policy instruments for HAB management. Third, we estimate the WTP for a defined policy and evaluate the importance of trust in the WTP.

4.1 Literature review

Table 1 summarizes the selected papers, which include the economic valuation of HAB events explicitly (country, year, authors, methods, good evaluation, and estimated welfare measure, among others). The main conclusion from this table is that the articles vary significantly regarding the scope of the analysis, the methodologies, and the type of policy evaluated. Therefore is difficult to make any meaningful comparison. Some of them are comprehensive analyses, including the whole world or vast coastal areas, several events (different types of alga blooms), diverse economic losses (health, productivity, recreation, etc.), and products (clams, oysters, recreational fishing, scallops). Others are regional analysis (one site, one product, one event). For instance, Sanseverino et al. (2016) use a simple unit value transfer approach based on previous literature. Unfortunately, this report presents values from different papers and years, so it is impossible to add them up. They also cover different economic losses (production, health, sales, revenues, WTP for products). Global analyses use, in general, "**benefit transfer**" as a way to estimate and aggregate the economic cost of the events and therefore, they rely on previous estimates.

Identifying the economic impact of HAB is essential to know the magnitude of the problem so policymakers can take action when this phenomenon happens. Sanseverino et al. (2016) estimated an annual economic loss of $10,3 billion as a global effect of HABs. In the case of the United States, Hoagland et al. (2002) estimated the impacts to total $83 million in losses for coastal states. In Canada, Wessells, Miller, & Brooks (1995) estimated 8% less annual sales due to this phenomenon and Kouakou & Poder (2019) estimated health costs for digestive illness to be $86, $1015 and $12605, respectively, for mild, moderate and severe cases and for respiratory illness to be $86, $1235 and $14600, respectively, for mild, moderate and severe cases.

In the specific case of US states the annual impacts have been estimated to be $82 million for Florida (Lucas, Larkin & Adams, 2010), $30,9 million for Texas (Evans & Jones, 2000), $20,42 for Washington (Dyson & Huppert, 2010) and $20,4 for New England (Jin, Thunberg & Hoagland, 2007). In 2002, Whitehead, Haab & Parsons estimated that consumers were willing to pay an increase of 70% in seafood meals to ensure product inspection.

In Bulgaria, Taylor & Longo (2010) estimated the willingness to pay to be €9,73 for a one-time tax for the implementation of a program that provides beaches free of HABs. In France, Osseni, Bareille & Dupraz (2019) estimated a WTP of € 208 to reduce HAB pollution levels. In Scotland, Martino, Gianella & Davidson (2020) estimated a yearly production loss of 15% and an economic loss of £ 1.37 million per year in Scottish shellfish farms.

In Finland, Salojärvi (2014) estimated the WTP per respondent for the moderate management of the Gulf of Finland of € 179,9 to 329,5 and a substantial management of € 334,1 to 540,0. In Chile, Ramos et al (2020) found that the total output and total income show declines of 5.64% and 1.81%, respectively and Anderson & Villarreal (2020).estimated 28% loss of ocean-based exports of the Los Lagos region. Finally, in Ghana, Ofori & Rouleau (2020) calculated a WTP of GH₵ 59,62 (US$ 12,42), GH₵ 26,28 (US$ 5,48) and GH₵ 33,43 (US$ 6,96) as mean monthly WTP for high-income, low-income, and all households, respectively to fund seaweed cleanup.

In order to estimate the impact of HABS the authors used several estimation methods which include: costs and losses, contingent valuation, input output models, comparison between scenarios and times series models. Contingent valuation represents the most used method utilizing methods such as: choice models (Morgan, Larkin, & Adams, 2010) (Lucas, Larkin, & Adams, 2010), choice experiment (Zhang & Sohngen, 2018) (L'Ecuyer-Sauvageau, 2019) (Taylor, & Longo, 2010) (Salojärvi, 2014), willingness to pay (Ofori & Rouleau, 2020) (Whitehead, Haab, & Parsons, 2002), travel cost (Wolf et al.,2019). and hedonic price (Osseni, Bareille, & Dupraz, 2019).

Followed by studies that have been done using time series regression such as the ones by: Morgan & Larkin (2006); Morgan (2007); Morgan, Larkin & Adams (2009); Morgan, Larkin & Adams (2010); Larkin & Adams (2007); Martino, Gianella, & Davidson (2020); Hoagland et al. (2009); Hoagland et al. (2014) and Anderson & Villarreal (2020). Econometric techniques in particular allow for the use of consistently collected data and bias-free estimation of red tide impacts. Bechard (2020) used a different approach using a difference in differences model and Nierenberg (2010) measured the statistical test of reduced lifeguard attendance during a bloom and average daily salary extrapolated to annual county-level total cost.

Another quite used method is the one that quantifies the costs (Sanseverino et al, 2016) (Cummins, 2012) (Kouakou & Poder, 2019) and losses (Hoagland et al, 2002) (Adams et al., 2018) (Nierenberg et al, 2010) (Wessells, Miller & Brooks, 1995) associated to HABs. It is pointed out the importance of defining multipliers to capture the full ramifications of economic impacts. An input-output analysis was also used to estimate the total effects of HABs on the economy (Evans & Jones, 2000) (Dyson & Huppert, 2010) (Ramos et al, 2020). Finally, another method proposed is based on a comparison between scenarios (with and without HABs) (Jin, Thunberg & Hoagland, 2007).

Table 1. Summary of previous studies on HABs

Country /spatial scope	North Carolina, Neuse River	Canada	Texas, Galveston county.	Global	US Costal States (east and west)	USA/ Mid-Atlantic Region (Maryland, North Carolina)		New England (Main and Massashusetts)	
Authors	Diaby	Wessells, et al.	Evans, G. et al.	Van den Bergh, J. et al.	Hoagland, P. et al.	Whitehead, et al.	Larkin, S. et al.	Jin, D., et al.	Morgan, K.,et al
year of publication	1996	1995	2001	2002	2002	2003	2007	2008	2009
temporal scope	1995	1987	2000	-	1987-1992	2001	1995-1999	1990-2005	1998-2005
Sample		198	-	-	170	1,807	47	NA	2,032
Published	Agent report	Marine Resource Economics	Report: Texas Parks and Wildlife, State of Texas	Marine Policy	Estuarine Research Federation	Ocean and Costal Management	Society & Natural Resources	Ocean and Costal Management	Harmful Algae
Impact Factor	-	1.851	-	4.173	2.13	4.295	1.758	4.295	4.273
Method Used	reduction in landings	Costs and Losses	Input-output analysis	-	Costs and Losses	Contingent valuation, contingent behavior, demand estimation	Time series analysis.	Scenarios Comparison: with and without the HAB event. Reduction in	Time series analysis.

								landings, imports, prices. Time series analysis (dummy variable for redtide)	
Aspect Valued	commercial fishing	Mussel Farms sale losses	Area Businesses Closures and Losses, Beach Clean Up, oyster producito n,	Human Health; Tourism and Recreation; Fishery	Lost sales or factor markets, medical costs (productivity), monitoring and management, other costs.	consumer surplus per seafood meal and WTP for seafood inspection.	Business sector: Restaurants and Lodging, Decision Making	Direct economic impacts and Net economic benefit of commercial shellfish fisheries	Daily Restaurant Sales Losses
Results	reduction of 47%	8% less annual sales	$30,9 million annually	-	$24-$ 83 million annually	Lost consumer surplus $2-$3 that is $37 million-$72 million aggregated. WTP $7 per meal form mandatory seafood inspection. 1.91 billion annually	$55,3 million annually	$2,4 to $18 million annually	$868 to $22404 per red tide event
Policy Proposal	NA	-	NO	-	NA	Yes, mandatory seafood inspection program	-	NO	-
Products	Neuse river commercial fisherman		oysters, tourism		Several, clams, oysters,	river fishes			
Polluter	Pfiesteria spp.		Karenia Brevis		Severals	Pfiesteria		Alexandrium Fundyense	

Country /spatial scope	Florida, Sarasota County				USA, Washington State.	Bulgaria	Texas, Calhoun county	France	Florida, Southwest
Authors	Hoagland, P. et al.	Morgan, K.,et al	Nierenberg, K. et al.	Lucas, K., et al.	Dyson, K.et al.	Taylor, T.et al.	Cummins, R.	Pérez et al.	Hoagland, P. et al.
year of publication	2009	2010	2010	2010	2010	2010	2012	2013	2014
temporal scope	2001-2006	2001	2001	2010	2008	2010	2011-2012	1997-2007	1988-2010
Sample	NA	755	1,006	14,400	240	850	-		NA
Published	Environmenal Health Perspectives	Harmful Algae	Harmful Algae	Southern Economic Association, New Orleans, LA	Harmful Algae	Journal of Environmental Management	Dolphin Talk (online publication) https://thedolphintalk.com/?p=6110	Aquaculture Economics and management	Environment International
Impact Factor	8.05	4.273	4.273	-	4.273	4.175	-	4.016	13.352

Method Used	Costs and Losses: cost of illness (number of cases multiplied by cost of ilnees. Time series	Choice model	Costs and Losses	Choice Model	Input-output analysis, recreational spending survey	Choice experiment	Costs and Losses Input output	Economic performance of specific technological adoptin. It does not value the imapcto fo HAB.	Time series analysis. Cost of illness,
Aspect Valued	Respiratory illnesses costs	Saltwater fishing from a boat, saltwater fishing from a pier or beach, beach-going and patronage of restaurants located near beach	Reduced Lifeguard attendance and salary loss	Human Health; Fishery; Tourism and Recreation; Monitoring and Management	Recreational razor clam fishery	One time tax (program that provides beaches free HAB)	Losses due to closures of local harvesting areas. Sacks of oysters, and their value (landed on the local docks).	cost benefit analysis of two technologicla solutions	human health
Results	$0.5 to $4,18 million annually	Residents affected ranged from 37% for restaurant patronage to 70% for beach-going	$100,000 annually	$82 million annually	$24,42 million annually	WTP: € 9,73	$8515,67 per vessel, $8515,67 per captain, and $5677,11 per deckhand	they do not pass a cost benfit analysis.	$2 to $24 million annually
Policy Proposal	NO	-	-	-	NO	Yes	NO	Yes Safeguarding storage and accelerated detoxification	NO
Products	NO				razor clams		oysters	oysters	NO
Polluter	karenia Brevis	NA			Pseudo-nitzchia, Alexandrium		Karenia Brevis		Karenia Brevis

Country /spatial scope	Finland	Global	Global	Ohio, Lake Erie	Ohio, Lake Erie	Canada	Canada	France	
Authors	Salojärvi, J.	Sanseverino, I, et al.	Adams, C., et al.	Zhang, W. et al.	Wolf, D. et al.	Kouakou, C. et al.	L'Ecuyer-Sauvageau, C.	Osseni, A., et al.	Bechard, A.
year of publication	2014	2016	2018	2018	2019	2019	2019	2019	2020
temporal scope	2012	-	-	2013-2014	2017	2019	2017	2010-2012	2005, 2006, 2018
Sample	158	-	-	767	20,000	16	252	8,003	-
Published	University of Helsinki	European Commission, Joint Research Centre	book chapter John Wiley & Sons Ltd.	American Journal fo agricultural economics	Board of Regents of the University of Wisconsin System	Journal of Water and Health	Journal of Environmental Management	Land Use Policy	The Review of Regional Studies
Impact Factor	-	-	-	-	-	1.349	4.175	3.682	1.449

Method Used	Choice experiment	Costs and Losses	literature review	Choice experiment	Choice experiment	Descriptive analysis	Choice experiment	Hedonic price	Difference-in-differences model
Aspect Valued	Ecological status of the Gulf of Finland	Human Health; Fishery; Tourism and Recreation; Monitoring and Management		U.S. recreational anglers (welfare losses from HABs not catch rate).	Beachgoers and recreational anglers	Health Costs	Fund a suite of solutions aimed at improving overall water quality	Rural housing market	Lodging Sector, Restaurant Sector
Results	Yearly WTP per respondent for the moderate management scenario is € 179,9–329,5 and for the substantial management scenario € 334,1–540,0.	Aprox $10,3 billion annually	-	WTP: $8 to $10 more per trip for 1 less mile of boating through HABs en route to a fishing site. WTP:. 437 to $51 per trip for one les hour needed. And $65 TO $96 for improving water claritiy. - $40 to $60 per trip for a policy that cuts upstream phosphorus loadings by 40%.	Beachgoers and recreational anglers would lose in aggregate $7,7 million and $69,1 million, respectively, each year	up to $12605 digestive illness and $14600 respiratory illness	WTP: CA$353/household per year to	WTP: € 208	$3,2 million monthly
Policy Proposal	Yes	-	-	Yes, reduction in the size and intensity. Linked to reduction of phosphorous and nitrogen.	-	-	Yes	Yes	-
Products									
Polluter				Cyanobacteria, microcystis					

Country /spatial scope	Scotland	Chile	Chile	Ghana	USA, national estimate.	US freshwater	US, Southwest Florida
Authors	Martino, S., et al.	Ramos, C. et al	Anderson, R. et al.	Ofori, R. et al.	Anderson et al	Dodds et al	Habas et al.
year of publication	2020	2020	2020	2020	2000	2008	1974

temporal scope	2009-2018	2013-2016	2010-2019	2020	1987-1992		1971
Sample	100	-	-	502	170 experts	241 facilities, several property values around 37 lakes,	NA
Published	Harmful Algae	Natural Hazards Review, American Society of Civil Engineers	University of Chile	Ocean and Coastal Management	report	Environmental science and tcehnology	Environmental letters
Impact Factor	4.273	1.667	-	3.284	NA	11.357	NA
Method Used	Time series analysis.	Input-output analysis	Time series analysis.	Contingent valuation	lost gross revenue, expenditures for environmental monitoring and management, and other csots. Lost wages, work days, expenditures in tourism.	annual value losses. Loss of trip related expenses, percent of gain or loss of property values, cost of recovering species. Drinking water treatment costs.	Losses to tourism industry and commercial fisheries
Aspect Valued	Scottish shellfish farms	Effects on families, who have seen their income diminish or have experienced the effects of rising unemployment.	Ocean derived products export of the Los Lagos region.	Seaweed cleanup to assist developing countries struggling to fund seaweed cleanup	public health, commercial fishery, recreation and tourism, monitoring, management.	recreation, real estate, spending on recovery of threatened and endangered species, and drinking water	Hotel, resturant, tourism expenditure. Commercial fishing, beack clean up.
Results	Yearly production loss of 15% and an economic loss of £ 1.37 m per year	The total output and total income show declines of 5.64% and 1.81%, respectively.	28% loss of ocean based exports	WTP: GH₵59.62 (US$12.42), GH₵26.28 (US$5.48) and GH₵33.43 (US$6.96) as mean monthly WTP for high-income, low-income, and all households, respectively	annual cost: $33.9-$81 millions (2000)	2.2 billion annually.	$20 million
Policy Proposal	-	-	-	Yes	No	NO	NO
Products					public health, commercial fishery, recreation and tourism, monitoring, management.		
Polluter					NSP, PSO, ASP, Ciguatera, brown tides.	Cianobacterias/ Microcystins	Karenia Brevis

The publishers of this studies include public and private organizations which include: European Commission, Joint Research Centre; Marine Policy; Estuarine Research

Federation; John Wiley & Sons Ltd.; Southern Economic Association, New Orleans, LA; Oxford University Press; Texas Parks and Wildlife, State of Texas; Dolphin Talk; Southern Agricultural Economics Association, Orlando, Florida; University of Florida; Harmful Algae; Environmenal Health Perspectives; National Science Foundation; The Review of Regional Studies; Society & Natural Resources; National Atmospheric and Oceanic Administration; Marine Resource Economics; Journal of Water and Health; Journal of Environmental Management; Land Use Policy; University of Helsinki; Natural Hazards Review, American Society of Civil Engineers; University of Chile; Board of Regents of the University of Wisconsin System and Ocean and Coastal Management.

From the bibliographic review it was also possible to identify certain information gaps in regards to the economic consequences of HABs that provide opportunities for future investigations on this topic. Among the gaps of information included in these studies, the most relevant include aspects such as: the incorporation of weather data has been sparse even though they are affected by weather conditions, few studies have investigated the role of intensity, and none appear to address the potential for a nonlinear relationship between economic losses and duration, and more research is needed on identifying feasible policies to insure against HAB risks, among others. (Larkin & Adams, 2013) (Adams et al, 2018).

In Chile there is scarce research on this topic. From the literature review, only 2 articles were found. The first uses input-output analysis to estimate the total effects of HABs on the economy, demonstrating that total output and total income showed declines of 5.64% and 1.81%, respectively (Ramos et al, 2020). The second uses time series regression which allows for the use of consistently collected data and bias-free estimation of red tide impacts resulting in a 28% loss of ocean-based exports (Anderson & Villarreal, 2020). This means that the method used in this investigation has not been used before in Chile and it also represents a way to measure the awareness in the population and their willingness to compensate for the damages of the HAB events.

From the literature review, it was also possible to identify specific information gaps that provide opportunities for future investigations on this topic. The most relevant include: the incorporation of weather data has been sparse, few studies have investigated the role of intensity and the potential for a nonlinear relationship between economic losses and duration, more research is needed on identifying feasible policies to insure against HAB risks, among others. (Larkin & Adams, 2013) (Adams et al, 2018).

Regarding the information gaps, additional ones were identified through the literature review discussed above, which include:

1) Little geographic coverage in the studies carried out in relation to HAB events, in the sense that most of the studies found that include economic estimates of the costs associated with this phenomenon are found in the United States.
2) The concept of Value has hardly been included in studies that make economic estimates of HABs and therefore it is unknown how informed people are of these events and what their WTP would be in order to generate policies to reduce risks and associated losses.
3) With regard to public policy, both for monitoring and management, few studies have included this aspect and there is no consensus on what would be the most effective policy to counteract the effects of HAB events.
4) It is difficult to determine which of the factors that have increased the intensity and duration of algal growth has the greatest effect in order to determine which factors to prioritize with specific policy.
5) The role of trust and its effect on the contingent valuation estimates has not been included in these studies.

It's important to analyze the effect trust has on WTP estimations since it can underestimate the results. Several authors study how trust in government influences citizens' WTP for a public project, for example, citizens' trust in government highly leveraged their WTP even when the project is desired (Oh & Hong, 2012). Similarly, it has been recognized that institutional distrust has mainly been ignored in the literature of non-market valuation involving stated preference studies which can lead individuals to refuse to participate in surveys or provide a protest response. (Kassahun, Swait & Jacobsen, 2021), meaning that in cases where distrust exist, the in cases of mistrust, the respondents are reluctant to answer the questions or indicate lower values than those that they really value the good or policy.

Studies in developing countries show that citizens are becoming more aware of environmental issues, however, they are not willing to pay for improvements in publicly provided goods, possibly due to their lack of trust in local governments (Birol & Das, 2010). Also, environmental quality in developing countries has been increasingly recognized as one of the key determinants of quality of life; however, distrust of authorities results in protest responses. (Chen & Hua, 2015).

Oh and Hong (2012) demonstrate theoretically that trust in institutions is a critical factor in determining WTP. This implies that the economic value of a public project can be underestimated and hindered by prevailing distrust toward the government, even when both the government and citizens desire the project. While there are many dimensions of trust as part of social capital parameters, such as social trust, institutional trust, social networks and social reciprocity (Jones et al., 2015, Nazim Habibov, 2019), we are interested in institutional trsut since this is relevant to explaining the WTP for the implementation od the policy (Jones et al 02011, Wiser, 2007, Nazim Habibov et al. 2019) Individuals with higher trust n institutions are expected to have a higher probability of paying to implement the policy.

Some of the methods that have been used to estimate the effect of trust on WTP include a Discrete Choice Experiment (DCE) and latent class analysis for the product attributes, which reveals that consumers' attitude and trust significantly explain class membership and therefore, consumers' preferences for different attributes (Yeh, Hartmann & Langen, 2020). Similarly, latent class models showed that respondents who are generally trusting and also trust the food system are less averse to certain products, which indicates that generalized trust affects consumers' consumption choices (Ding, Veeman & Adamowicz, 2012).

As indicated, HABs are natural hazards that can lead to serious public health and socioeconomic consequences, and due to human interaction and climate change, these events are increasing in duration and intensity. That's why countries need to begin to study the ways these events affect them and find the best policies to monitor and mitigate their effects and the motivation behind this study. The WTP was chosen to estimate a premium price that consumers would pay in order to have a sea water monitoring system and generate a crisis fund.

As shown above, the problems and impacts of HABs are diverse, as are the causes and underlying mechanisms controlling the blooms. Pollution and other human activities have increased the abundance of harmful algae. We cannot blame all new outbreaks and new problems on these actions since they are natural phenomena that occurred long before humans exerted their influence on the ocean. However, there is a clear need to understand HAB phenomena and to develop scientifically solid management and mitigation policies (Anderson, 2009).

4.2 Policy Instruments for HAB management

It was identified that few studies have included public policies, this section aims to include the policy instruments and examples of policies that have been found regarding the research topic. Its important to note that in order to achieve public policy objectives, an effective governance is a necessary aspect.

Policies relevant to the prevention and mitigation of HAB can be classified into four categories: prevention, restoration, amelioration, and no action, which are described in greater detail in Table 3. However, Prevention (or minimizing significant risks) is nevertheless the preferred policy approach, because it is generally far more cost effective and environmentally desirable than measures taken following introduction of an alien invasive (Van den Bergh et al, 2002).

Table 2. Policy Categories for HAB management

Policy	Description	Examples
Prevention[7]	The minimization of the probability of formation of HAB and also reducing/eliminating the introduction of polluting matter into the sea from land-based sources and activities.	Law of the Sea (LOS) Convention requires States to take all measures necessary to prevent, reduce and control the intentional/accidental introduction of species to a

[7] Often assumed as an ambitious strategy because of the high costs incurred for the implementation and enforcement of prevention programs. Moreover, these costs are often not matched by the benefits counterpart.

		particular part of the marine environment.
Restoration[8]	Implemented once HABs have occurred, with the purpose to keep them from spreading. They may involve direct chemical, physical or biological control measures designed to target existing blooms.	Shipping companies are forced to internalize the costs (polluter pay principle).
		Early warning systems and national contingency plans.
		Reduce or eliminate inputs of nutrients from various land-based sources and activities.
Amelioration	Characterized by punctual, individual programs that comprise the various mitigation measures that can be adopted to reduce impacts on marine living resources, human health or recreation.	Cleaning activities such as the removing of algae foams from the beach.
No Action[9]	Accept all the damages. Limited by international law	

Source: Own elaboration using Van den Bergh et al's (2002) paper.

Diversity in blooms and their impacts presents a significant challenge to those responsible for managing coastal resources threatened by this phenomenon. The policies explained above can cover a range of necessary strategies that are needed to protect fisheries, minimize economic and ecosystem losses, and protect public health and can vary considerably among locations and HAB types (Anderson, 2009). Different examples of strategies of monitoring and management adopted by countries to monitor and manage include:

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[8] This policy strategy is traditionally preferred on the basis of its efficiency, that is the costs of intervention exceed the benefits of avoiding growth of HAB.

[9] From an economic perspective, this strategy makes sense when either all the mentioned policies are ineffective or the cost of no action is low.

Table 3. Management strategy examples

Category	Management Strategy
Mitigation	Routine monitoring programs for toxins in shellfish.
	Towing of fishnet pens away from the sites of intense HAB.
	Charge premium prices over seafood products.
Prevention	Control of sewage or waste discharges.
	Sewage reduction strategies.
Control:	
Mechanical	Removal of HAB cells from the water by dispersing clay over the water surface.
Biological	Biocontrol, releasing one organism to control another.
Chemical	Toxic chemical release.
Genetic	Genetic manipulation.
Environmental	Large-scale manipulation of nutrient levels in coastal waters through pollution control policies.

Source: Own elaboration using Anderson's (2009) paper.

In Latin America and the Caribbean region, a regional network for early warning of HAB and biotoxins in seafood has been integrated since 2009. However, most countries in the region are challenged by the lack of resources to maintain or expand monitoring programs (Cuellar 6xet al, 2018). Early warning of HAB is potential of great Value to reduce its consequences; however, achieving this is far from straightforward due to different life cycles and potentially variable toxicity and location, leading to uncertainties in risk assessment (Davidson et al, 2016).

Another policy instrument that could be implemented is to charge a higher price or premium prices for certain products in order to raise funds that can be used to mitigate these events. If these premium prices are paid in the market, this incentive may be acceptable, but in the context of agencies with limited conservation funding, there are more cost-effective ways to allocate economic incentives. However, enrollment in such programs depends only on the producer willingness to accept the offered premium. (Palm, Swinton & Shupp, 2017).

Although policies were identified, trust in the institution in charge of executing them plays an important role, as well as in WTP estimations. Since in cases where mistrust or lower trust levels are present, people will be reluctant to support such policies and WTP estimations can be underestimated.

As shown above, the problems and impacts of HABs are diverse, as are the causes and underlying mechanisms controlling the blooms. Pollution and other human activities have increased the abundance of harmful algae. We cannot blame all new outbreaks and new problems on these actions since they are natural phenomena that occurred long before humans exerted their influence on the ocean. However, there is a clear need to understand HAB phenomena and to develop scientifically sound management and mitigation policies (Anderson, 2009).

4.3 Willingness to Pay estimations

To carry out the economic valuation of HAB in Chile, a total of 1.298 surveys were applied in the cities of Santiago and Concepción for the Economic Assessment of the Consumption of Mussels. Specifically, when asked "Would you be willing to pay an additional number of pesos for 250 grams (a quarter) of mussel meat in order for these measures to be implemented?", five persons did not offer an answer and of the remaining, 691 (53,4%) gave a positive answer and the remaining 602 (46,6%) said they are not willing to pay more than current price.

The difference between the premium and the current price will be used to implement a seawater monitoring system which would be used to predict the emergence of a red tide as far in advance as possible. Also, a crisis fund would be created which would be accumulated in non-crisis periods (no HAB are present) to aid affected producer families and to finance a system for monitoring the quality of sea waters. This fund will be jointly financed by companies, the government and by an increase in the price of mussels.

Unfortunately, for some types of economic losses, revealed preference data is unavailable, so stated preference approaches must be used which measure nonmarket losses by determining user preferences by asking individuals how they value a certain good. This method necessarily involve surveys that ask users how they value certain nonmarket goods, often by asking them how they would vote on various referendums to establish programs that would prevent HAB-related losses. (Adams et al, 2018).

With the data collected, nine models were estimated to calculate the WTP as shown on Table 5. A base model was calculated only using two variables: the willingness to pay and the bid. While the rest models were estimated by incorporating different explanatory variables to observe and analyze the fluctuation of the WTP.

In Table 5, Model 1 was the benchmark model which estimated that that people were willing to pay an increase in the price of 250 grams of mussels' meat of $963,28 Chilean pesos. Through models 2-7 different explanatory variables are introduce to see how much payment willingness varies, as shown in Table 6, which resulted in a range between $849,00 and $1.162,00 Chilean pesos. In addition to this, when analyzing the lower bound and upper bound of each model, results show that the WTP can get as low as $426,00 Chilean pesos and as high as $1.495,00 Chilean.

Ash shown above, trust and gender (male) had a significant impact on peoples' willingness to pay for environmental protection. Trust had a positive significant impact on peoples' willingness to pay for environmental protection which means that higher levels of trust will translate into a higher WTP. This effect was present in all models that included trust (Model 5, Model 6, Model 7). This indicated that trust plays an important role on how people respond to government policies. On the other hand, gender had a negative significant impact on peoples' willingness to pay for environmental protection, which means that men are more likely to be willing to pay less than women. However, age, educational level and consumption during red tides events variables were not statistically significant.

For policy instruments to be applied efficiently, there must be strong governance and trust in the institutions responsible for managing and monitoring HAB events. As previously identified that few studies have included the role of trust and its effect on the contingent valuation estimates, this section aims to explain the relationship between trust and willingness to pay.

Trust is an aspect that takes on greater relevance when estimating WTP since it can be underestimated when there is little or no trust in the entity responsible for carrying out the policy. This has been studied by several authors and has been determined how trust in government influences citizens' WTP for a public project and it has been found that in fact the citizens' trust in government highly leveraged their WTP for the project which implies that the economic Value of a public project can be underestimated and hindered even when the project is desired by both the government and citizens (Oh & Hong, 2012).

Similarly, it has been recognized that institutional distrust has been largely ignored in the literature of non-market valuation involving stated preference studies which can lead individuals to refuse to participate in the stated preference survey at all or provide a protest response. (Kassahun, Swait & Jacobsen, 2021).

Studies in developing countries show that citizens are becoming more aware of environmental issues and are willing to pay for their conservation and management, however, citizens are not willing to pay for improvements in publically provided goods, possibly due to their lack of trust in the efficacy of the local governments in their provision (Birol & Das, 2010). Also, environmental quality in developing countries has been increasingly recognized as one of the key determinants of quality of life however, distrust of authorities responsible for the provision of environmental goods results in protest responses. (Chen & Hua, 2015).

Table 4. Estimations of Logit Models

Dependent variable Y=1 for a positive response, 0 otherwise.		
BID	-0.00173***	-0.00170***
	(0.000209)	(0.000212)
Age		-0.00414
		(0.00323)
Years of education		-0.0101
		(0.0159)
Only Fish		0.118
		(0.173)
consumelejos		-0.0144
		(0.133)
Trust in institution		0.335**
		(0.127)
Family size		0.0126
		(0.0337)
Male		-0.204+
		(0.118)
Constant	1.669***	1.753***
	(0.194)	(0.396)
WTP	963.28	947.60
S.d	34.33	224.25
CI	(895.99, 1030.56)	(508.061, 1387.14)
N	1293	1275

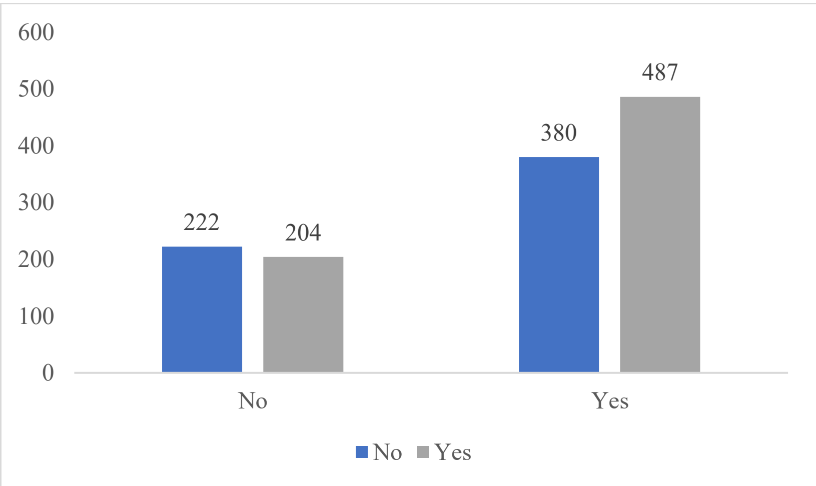
Standard errors in parenthese, $^{+}$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: Own elaboration.

To carry out the economic valuation of BAHs in Chile, a total of 1,298 surveys were applied in the cities of Santiago and Concepción for the Economic Assessment of the Consumption of Mussels. Specifically, when asked "Would you be willing to pay an additional $ 1,100 pesos for 250 grams (a quarter) of mussel meat in order for these measures to be implemented? That is, you will pay $ 2,350 pesos for the 250 grams.", five persons did not offer an answer and of the remaining, 691 (53.4%) gave a positive answer and the remaining 602 (46.6%) said they are not willing to pay more than current price. With the data collected, seven models were estimated to calculate the WTP as shown on Table 2. A base model was calculated only using two variables: the willingness to pay and the bid. The following models were estimated by incorporating different explanatory variables to observe and analyze the fluctuation of the WTP.

Once the logit models had been estimated, then the WTP of the sample can be calculated. For the base model, results shows that people were willing to pay an increase in the price of 250 grams of mussels' meat of $ 963,28 Chilean pesos. When introducing other of the explanatory variables, this value ranges between $ 849,00 and & 1162,00 Chilean pesos as shown in Table 3. In addition to this, when analyzing the lower bound and upper bound, the WTP can get as low as $426,00 Chilean pesos and as high as $1495,00 Chilean pesos for the price of 250 grams of mussels' meat.

Finally, the surveyed were asked "If you knew for sure, that is, you had products certified by an institution you TRUST: would you continue to consume seafood if that institution assures you that they are not contaminated by Red Tide?", relating this question to the DAP, it was found that the people who indicated that they would not consume seafood from an institution although it is assured that they products are not contaminated presented a greater number of negative responses regarding the DAP (222 negative responses versus 204 positive) and the opposite occurred with the people who stated that they they trust the responsible institution presenting a greater amount of positive responses regarding their WTP (487 positive responses versus 380 negative) as shown in the graph below.

Graph 2. Relation between trust and WTP.



Source: Own elaboration.

5 Conclusions

As indicated, HABs are natural hazards that can lead to serious public health and socioeconomic consequences, and due to human interaction and climate change these events are increasing in duration and intensity. That's the main reason that it's important for countries to begin to study the ways HABs are affecting them and find the best policies to monitor and mitigate their effects.

Through the literature overview of this topic, we can assess the economic loss these events have on the world, which globally represent billions of dollars in losses in the main sectors discussed in this paper which include 1) human health, 2) commercial fishery, 3) tourism and recreation, and 4) monitoring and management. Regarding the methodology used in these studies, they show that there are various statistical and econometric methods to make an economic assessment of HABs. The best method to use really depends on the goal you want to achieve.

Given that in Chile not many studies have been carried out in this regard and given the importance of the subject, this represents a starting point to make an economic valuation (incorporating some of the information and methodological gaps identified) that aims to determine the price that people are willing to pay to compensate the damages of the HABs events.

Effective governance is an aspect required to achieve policy goals. Policies regarding HABs can be broadly classified into four categories: prevention, restoration, amelioration and no action at all. Prevention policies are often assumed as an ambitious strategy because of the high costs incurred for their implementation and enforcement. On the other hand, restoration policies is traditionally preferred on the basis of its efficiency.

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