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A country's response to tackling plastic pollution in aquatic ecosystems: The Chilean way

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Abstract

1. Marine plastic pollution is worse than expected, and we are starting to realize its full extent and severity. Solving the plastic pollution problem is not easy, as it requires the action and commitment of all sectors of our society. With a coastline extending over 4,000 km (from 18°S to 56°S), Chile is a maritime country, and since plastics are potentially harmful for marine and coastal ecosystems, food security, and public health, plastic pollution is a real threat.
2. Chile is the sixth-largest exporter of seafood (fish, invertebrates, and algae) in the world, but the extent of plastic contamination of marine organisms, its potential effects on commercial species and aquaculture, and its subsequent effects on human health are mostly unknown.
3. Chile has recently introduced some legislation to prevent plastics from reaching the environment and the coastal ocean. Governmental and non-governmental organizations have joined an informal alliance to take action against plastic pollution, both at a national and regional level, but stronger involvement of producers and commerce is required for effective measures.
4. Chilean scientists working on plastic pollution have created the Scientific Plastic Pollution Alliance of Chile network, aiming to promote collaborative and coordinated research focused on this pollutant. The wide geographical extent of Chile, with researchers working in diverse ecosystems, provides a unique opportunity to better understand the consequences of one of the most recent and severe threats to biodiversity.
5. Rather than solely presenting the plastic pollution problem from the scientific perspective, this paper includes views from different sectors of society. Mitigating plastic pollution is exceptionally complex, with this study highlighting the importance of local engagement, media, solving social inequities, new legislation, and law enforcement in order to advance on decreasing plastic pollution from a country-wide perspective.

KEYWORDS

Chilean society, legal commitments, media and social perception, ocean, plastic pollution

1 | INTRODUCTION

It is widely recognized that plastic pollution has an ecological, social, and economic cost, and it is perceived as one of the most serious threats to aquatic conservation. In fact, plastic pollution has direct effects on organisms that could exacerbate biodiversity losses. It is also known that the sustained production of various types and sizes of plastics, associated with indiscriminate use and improper handling, poses a potentially severe risk for the functioning of aquatic ecosystems (Worm, Lotze, Jubinville, Wilcox, & Jambeck, 2017). The sources of the plastic items that enter freshwater, coastal, and oceanic habitats are diverse, including landfills, industrial production, urban litter, fisheries, and aquaculture. Plastic litter has been found in every ecosystem on Earth that has been searched for; and although oceanic islands are far away from the major pollution sources, plastic debris is found at levels comparable to that of industrialized areas (Barnes et al., 2018). Therefore, the idea of these remote and pristine oceanic islands being untouchable habitats does not hold true for plastic pollution (Luna-Jorquera, Thiel, Portflitt-Toro, & Dewitte, 2019). The risks that plastic debris poses for the conservation of these once 'pristine' oceanic islands needs to be properly evaluated.

Regardless of the source, globally between 4.8×10^6 and 12.7×10^6 t of plastic waste reach the ocean every year (Jambeck et al., 2015). Though it was considered innocuous until the late 20th century, its durability and persistence make plastic litter a ubiquitous contaminant, with a high potential to cause adverse effects on aquatic, terrestrial, and marine biodiversity (Worm et al., 2017). Plastic pollution has been recognized as one of the main challenges currently facing humans (United Nations, 2015). However, the use of plastics is so widespread, and economic pressure so strong, that a solution focused on completely banning plastics from our daily lives is not viable. Nevertheless, some countries have developed initiatives aimed at reducing, at least, the daily use of single-use plastics, and thereby preventing the entry of more plastic into the ecosystems (Penca, 2018).

In Chile, as everywhere else, most of the coastal habitats, rivers, and lakes near urban centres are contaminated with plastics (Rech et al., 2015; Thiel et al., 2011). With the Chilean coastline extending over 4,000 km (from 18°S to 56°S), plastic pollution is a real threat, potentially harmful for marine and coastal ecosystems, food security, and public health. The Chilean coast is heavily influenced by the Humboldt Current System, with predominantly equatorward flow of surface waters, characterized by strong upwelling of cold and nutrient-rich waters (Thiel et al., 2007). The Humboldt Current System is recognized as being highly productive, supporting one of the largest fisheries in the world, providing about 10% of the world fish catch (Aguilera et al., 2019; http://www.subpesca.cl). Furthermore, Chile is the sixth-largest exporter of seafood and aquaculture products, mainly fish, invertebrates, and algae, with a production of 1,214,500 tons in 2014 (Food and Agriculture Organization of the United Nations, 2016). In addition, in many coastal cities, seafood is relatively important in the diet, with an individual average consumption of 13.2 kg per year (Food and Agriculture Organization of the United Nations, 2005), although this amount is still low compared with the global average of consumption (~20 kg). Chile hopes to increase seafood consumption per capita by 50% by 2027 (Subsecretaría de Pesca y Acuicultura, del Ministerio de Economía, Fomento y Turismo, 2017), which poses a great challenge to food security and natural ecosystems in the context of future plastic production, use, and disposal. However, the extent of plastic contamination of marine organisms that are consumed by the population is unknown, as well as the potential effects on species used extensively in aquaculture. Potential subsequent effects on human health are therefore worrisome.

Chile has a unique diversity of freshwater (e.g. rivers, lakes), coastal (e.g. wetlands, fjords), and oceanic ecosystems (e.g. seamounts and oceanic islands) with diverse degrees of protection, such as Ramsar sites, national parks, and marine protected areas (e.g. Petit, Campoy, Hevia, Gaymer, & Squeo, 2018). Plastic pollution, however, has reached the remote Chilean oceanic islands (Easter Island and Juan Fernandez), which receive huge volumes of marine litter coming from the continental coast of Chile and the industrial fishery (Luna-Jorquera et al., 2019; van Gennip et al., 2019). This opened a debate on whether these conservation instruments are sufficient to prevent plastics from entering protected areas (Barnes et al., 2018; Luna-Jorquera et al., 2019).

Therefore, it would not be sensible to elaborate on aquatic conservation whilst ignoring one of its main threats. For plastic pollution, the efficient protection of aquatic ecosystems requires a considerable effort that involves society as a whole and should include government decisions and its entire administrative apparatus, scientists, social organizations, public and private companies, and, of course, citizens, with their behaviours and views included. Acknowledging the complexity and the many actors involved in the plastic pollution problem, an integrated view as a country's perspective is provided. Herein, we explore the different prospects related to plastic pollution in the aquatic environments of Chile. We first report general information on plastic production and disposal, public perceptions of plastic pollution, and the role of the media in informing and raising awareness among the general public and decision-makers. This is followed by an overview of the current scientific knowledge on aquatic plastic pollution in Chile and the views and role of scientists in providing information for decision-makers. All existing, national and international, regulations and policies pertaining to plastic pollution in Chile are reviewed, and the political and economic models that have shaped the current state of plastic usage and pollution in Chile are mentioned throughout the paper. We conclude by proposing the scientific, political, and societal agenda needed to prevent the progressive accumulation of plastic in Chilean aquatic ecosystems.

2 | PLASTIC PRODUCTION AND DISPOSAL IN CHILE

In the 1950s, the world annual production of plastics was around 1.5×10^6 tons (Freinkel, 2011), with an average annual growth of 9% during the following six decades (Nuelle, Dekiff, Remy, & Fries, 2014). However, the annual increase was 25% between 2009 and 2014, reaching 311×10^6 t in 2014 (PlasticsEurope, 2015). It is estimated that approximately $6{,}300 \times 10^6$ tons of plastic waste have so far been produced globally, of which 21% was recycled or incinerated and the rest diverted to landfills or the natural environment (Geyer, Jambeck, & Law, 2017). Plastics now constitute 54% of the global mass of anthropogenic waste (Hoellein, Rojas, Pink, Gasior, & Kelly, 2014), and it is projected that, given the current trend of production and handling of plastic waste, about 12×10^9 tons of plastic waste will be in landfills or the environment by 2050 (Geyer et al., 2017).

The plastics industry in Chile started in the 1930s, mainly focused on the use of Bakelite; after the 1950s, melamine was incorporated for producing panels and covers. In 1970, the petrochemical industry started in the country (Chapman, 1992), with a growing number of factories for ethylene manufacturing (Amenábar Cristi et al., 2020). During the 1980s and 1990s, the expansion of supermarkets and the retailing sector played a major role introducing plastic packaging on large scales (Amenábar Cristi et al., 2020; Faiguenbaum, Berdegué, & Reardon, 2002). According to the Asociación de Industriales del Plástico, Chile exported ~70,700 tons of raw materials (resins) and

~76,300 tons of manufactured products mainly to other South American countries in 2016. In the same year, however, Chile imported ~740,000 tons of resins and ~305,000 tons of manufactured products, primarily from the USA (29%), Brazil (15%), and China (12%) (Asociación de Industriales del Plástico, 2016). These numbers offer an indication of the magnitude of plastic importation and production in Chile.

The open economic policy and the lack of regulations on plastic waste led Chile to become the number one country in plastic waste generation in South America, with a per capita annual average of 456 kg, more than Brazil (383 kg), Uruguay (376 kg), Panama (343 kg), and Argentina (341 kg) (Waste Atlas, 2018). In Chile, most waste is generated in the Santiago Metropolitan Region (39%), followed by the regions of BioBio (11%) and Valparaíso (11%), according to the Fourth Report of the State of the Environment of Chile (Barrera & Meijar, 2018). That report estimated that the proportion of waste collection in Chile was on average 78% and 77% of the total garbage disposed off in 2015 and 2016, respectively. This scenario might improve slightly in subsequent years after the banning of single-use plastic bags in the entire country as of 2019, and if other laws are correctly enforced.

3 | SOCIAL PERCEPTION

One of the most representative tools for evaluating citizen perception of environmental problems in Chile is the environmental survey conducted by the Ministerio del Medio Ambiente (MMA, 2018). According to that official survey, environmental pollution, litter production, and air quality are of major concern, and similar as in other countries (Dilkes-Hoffman, Ashworth, Laycock, Pratt, & Lant, 2019). Over the last 5 years, awareness about waste management has significantly increased in Chile. However, when asked to identify the sectors responsible for the litter that is impacting coastal environments, citizens blamed producers and non-permanent residents (Kiessling, Salas, Mutafoglu, & Thiel, 2017), without considering their personal contribution and responsibility in the plastic pollution issue (see Section 7).

A study about Chilean citizen behaviour revealed that ~44% of respondents reported some littering behaviour; in the same study, citizens also highlighted education, application of fines, and constant cleaning of beaches as the main solutions for plastic pollution (Eastman, Núñez, Crettier, & Thiel, 2013). These perceptions are also in agreement with those reported in other countries (Hartley, Thompson, & Pahl, 2015). In terms of public engagement in Chile, collaboration in plastic management programmes has been strongly linked to the commitment of local authorities, socio-economic level, and educational level (Eastman et al., 2013; Kiessling et al., 2017). Local authorities, therefore, seem to play a significant role in shaping the attitudes of people towards plastic pollution. Members of the youngest cohort with a low educational level, and associated with the lowest socio-economic level, have been identified as having the lowest pro-environmental attitudes (Bronfman, Cisternas, López-Vázquez, De la Maza, & Oyanedel, 2015), although that study was conducted only in Santiago (the Chilean capital) and may not be representative of the entire Chilean society.

It has been shown that the political tendencies of a country affect material life cycle (circulation/flows) in capitalist economies, also shaping urban inequality (Swyngedouw, 2006). Waste residues, plastics among them, are resources that could be either deposited in landfills or reused, depending on the incentives for the relevant actors, such as producers, consumers, waste pickers, and global businesses, all of them articulated under multi-layered systems of governance (Hoornweg & Bhada-Tata, 2012). Waste management in the Chilean capital has prioritized the privatization of urban services, which has led to the concentration of services and economic activities in a minority of wealthy municipalities (Orellana, 2009). This privatization, driven by the neoliberal economic model inherited from the dictatorship period (1973–1990), has reduced public control over the waste management process (Guibrunet, Calvet, & Broto, 2017). The need for better planning and analysis to overcome urban inequalities and environmental injustice has already been pointed out (Guibrunet et al., 2017). Despite a number of privately led recycling initiatives and proposals to integrate waste-pickers in municipal recycling systems (Giovannini & Huybrechts, 2017; Navarrete-Hernández & Navarrete-Hernández, 2018; Rojas, Yabar, Mizunoya, & Higano, 2018), recycling rates in Chile are extremely low, rarely exceeding 5% (Valenzuela-Levi, 2019).

A generalized feeling of inequality and the existence of privileges for very few Chileans has recently led to one of the largest social movements, with widespread social unrest starting in October 2019 (Somma, Bargsted, Pavlic, & Medel, 2020). Because of the persistence of social inequalities, more than 20% of Chileans are classified as belonging to the lowest socio-economic level (Caracterización Socioeconómica Nacional, 2017), which often is linked to low pro-environmental attitudes (Bronfman et al., 2015). These inequalities are further linked to the litter problem. Large companies impose single-use plastics, whereas the government has formulated a law that promotes extended producer responsibility but which has not been implemented for the past 4 years, leaving it to the consumers to decide how to deal with vast amounts of packaging. It appears that large companies are privileged, and the needs of the people and the environment are of secondary importance, or just ignored (Somma et al., 2020).

Consequently, people are demanding that the government should take more initiative (i.e. a 'top-down' approach) for management and reduction of plastic pollution (Kiessling et al., 2017). Yet, a 'bottom-up' approach (i.e. community based) has also been proposed as a better long-term solution (Vince & Hardesty, 2016), improving education to create citizen–nature connection policies and motivating communities (local and national level) to cooperate in waste management programmes (Eastman et al., 2013; Kiessling et al., 2017). In Chile, some of this 'bottom-up' pressure can be seen in the participation of many social actors, becoming part of the solutions and generating interactions across broad sectors (public and private) of society that culminated in the recent ban of single-use plastic bags (Amenábar Cristi et al., 2020). In general, pro-environmental behaviours that

require lower personal investments and result in fewer behavioural restrictions are most favoured (Bronfman et al., 2015) and, therefore, are most likely to be supported and applied by a broad majority of the general public.

Local initiatives are valuable examples of how public and private actors collaborate with the international community on the beach clean-up day of the non-governmental organization Ocean Conservancy, which in Chile was first introduced in 2005 in some coastal cities, and subsequently expanded to the whole country. Another Chilean initiative is the 'Científicos de la Basura' Program that since 2008 has involved schoolchildren in citizen science studies generating valuable scientific information on the plastic pollution status of Chilean aquatic environments (e.g. Barahona-Segovia, Nuñez-Hidalgo, González-Césped, & Rojas-Osorio, 2019).

The urgency and the demand for scientific expertise associated with the plastic problem in the media have also increased in recent years as this environmental pollutant is increasingly being considered a threat to public health (a fact that has been exposed internationally by science, the United Nations, the Food and Agriculture Organization of the United Nations, etc.). This signals a transition, bringing science closer to society and decision-makers. In that sense, plastic pollution has made this interaction more frequent, as the public seeks reliable information and partnership for outreach. Rigorous quality checks on the scientific assessment of the potential impacts of plastics are required, however, before informing society and decision-makers.

4 | PLASTIC CONCERN IN CHILEAN MEDIA

The media have a strong impact on social perception, and therefore a large responsibility not only for informing the population but also for shaping public willingness towards solving the plastic pollution problem. In fact, mass media influence society, and thus can strongly contribute to social development (Schramm, 1964). Unfortunately, misconceptions arise when the media focus on alarming issues, preventing the public from gaining a more balanced perspective of the marine litter problem and its diverse solution pathways. Nowadays, the volume of information in the World Wide Web is continually rising, and it exceeds by far the information available via conventional media (television, radio, and newspapers). Online newspapers are mostly covered by web browsers, with billions of queries submitted every day. Herein, the interest in issues related to plastic in Chilean online newspapers was assessed following the approach by Chevallier et al. (2019), examining Chilean news articles about plastic pollution.

Using the Google search engine, news articles were selected per year from 1 January 2009 to 31 December 2018. Through the Google advanced settings, the search term 'plástico' was queried (plastic in Spanish), selecting exclusively Chilean online news articles. Then, the data set of articles was classified based on discourse analysis according to the following three categorical variables: the spatial scale of the article (international, national, or regional), the ecosystem mentioned with the plastic-related issues, and the main topics covered. Finally, a thematic analysis of the news articles was conducted depending on the main topics identified. The classification process (Figure 1) and thematic analysis (Table 1) were done according to the protocols developed by Taylor (2001) and Braun and Clarke (2006) respectively.

Results show that the annual number of news articles focused on plastic-related issues increased consistently from 2009 to 2016, with a substantial increase in 2017 (+134%) and reaching 100 articles in 2018 (Figure 1). Of the articles, 56% referred to international news, with national and regional news represented by 23% and 21% respectively (Figure 1a). In 2017, national news represented 38% of the information, in line with the project to legislate a ban on the use of single-use plastic bags in coastal cities of the country in order to mitigate marine contamination (the law was finally enacted for the entire national territory and officially published in August 2018; see Amenábar Cristi et al., 2020). Plastic-related issues were mostly related to society and marine ecosystems, which represented 54% and 39% of the news respectively (Figure 1b). In 2017, jointly with the draft law, articles referring to marine ecosystems increased by up to 50%.

All news articles examined, focused on at least one of the following main topic categories (Figure 1c and Table 1): contamination (32%), solution (31%), outreach (19%), and policies (18%). Only one news article focused on the environmental awareness of the Chilean population regarding plastic-related issues. Indeed, that article summarized the main results of a study on the consumption of packaged food. When analysing the sub-topics corresponding to each of the main topic categories (Table 1), articles focusing on plastic contamination mostly referred to overproduction of plastic materials and accumulation of plastic waste and residuals in ecosystems (49%), and to the damage caused by the ingestion of plastic waste in animals (31%). Media articles focusing on potential solutions to plastic-related issues were mostly on the ban of single-use plastic items, like plastic bags, and how to replace them with reusable items (36%), on recycling plastic (30%) or reusing it as a construction material (13%), and on the decontamination of the most contaminated sites, like beaches or industrial areas (11%). The outreach activities mentioned in the news articles were mostly awareness campaigns to stop using single-use plastics (25%), decontamination campaigns like beach clean-ups (14%), committed works of art using plastic waste (14%), and documentaries on plastic-related issues and potential solutions (11%). Finally, most of the legislation covered by online media was designed to stop using single-use plastic (90%), primarily related to the national project to legislate a ban of single-use plastic bags in coastal cities.

This first analysis revealed that media play a critical role in the mitigation of plastic contamination through their agenda-building function (e.g. Bakir, 2015; Kiousis & Wu, 2008; Song, 2007), which serves stakeholders in focusing public attention on strategic themes. The general public, decision-makers, scientists and citizen scientists, non-governmental organizations and other activists, industries, and media all interact on multiple scales within a complex social system in which the plastic contamination issue is embedded. Each stakeholder has a personal vision and interest in the issue, as well as the power to control plastic contamination along with corresponding

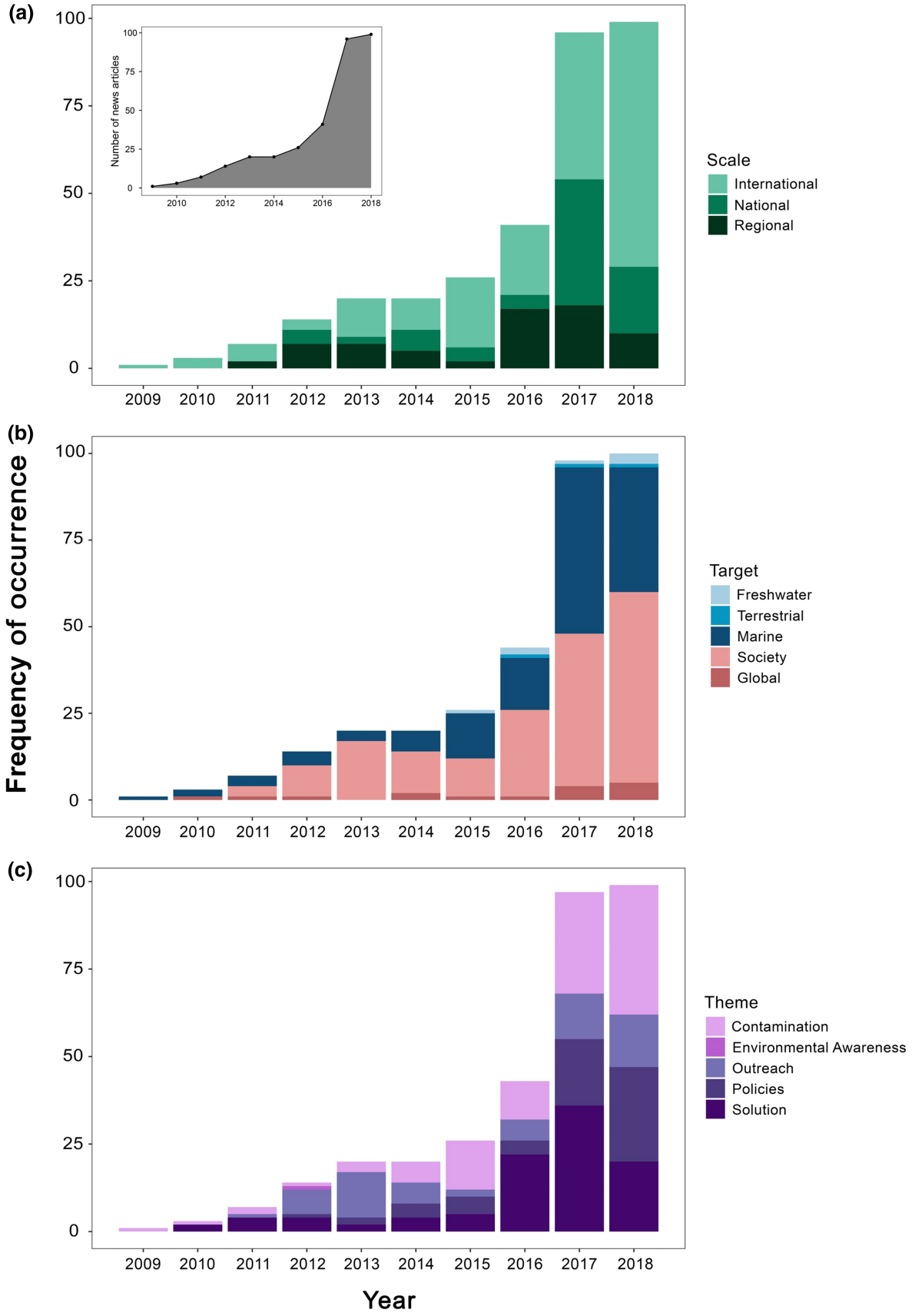

FIGURE 1 Media attention on plastic-related issues from 2009 to 2018, classified per topic. (a) Geographical/political scale of the article; the inset shows the number of news articles published from 2009 to 2018. (b) Ecosystem/compartment affected by the plastic-related issue mentioned in the article. (c) Main topic covered by the article

TABLE 1 Thematic analysis of the news articles focused on plastic-related issues in Chilean digital media from 2009 to 2018, depending on their main topics

Topic	Occurrence rate (%)
Contamination	31.8
Accumulation	**49.1**
Ingestion	**31.0**
Human health	7.8
Entanglement	6.9
Air contamination	3.5
Decontamination	0.9
Workshop	0.9
Solution	30.6
Non-use	**36.3**
Recycling	**30.1**
Eco-construction	**13.3**
Decontamination	**10.6**
Biodegradation	7.1
Reuse	0.9
Reducing	0.9
Energy	0.9
Outreach	19.1
Non-use	**25.0**
Decontamination	**14.1**
Work of art	**14.1**
Documentary	**10.9**
Recycling	9.4
Conference	7.8
Eco-construction	6.3
Ecological event	4.7
Workshop	4.7
Exposure trip	3.1
Policies	18.2
Non-use	**90.0**
Recycling	5.0
Decontamination	1.7
Incentive	1.7
Tax	1.7
Environmental awareness	0.3
Environmentally aware consumption	**100.0**

Note. Categories representing more than 10% are in bold.

responsibilities. In a broader perspective, digital media have proven their increasing role in modelling public opinion during the last decades, contributing actively to political, social, and environmental reforms; for example, see Chevallier et al. (2019) and references therein. Regarding plastic-related issues, Völker, Kramm, and Wagner (2019) observed that online newspapers alarmingly warned about the environmental risks of microplastics during recent years and frequently misrepresented the information in comparison with scientific publications. Furthermore, Henderson and Green (2020) suggested that people's representations of plastic pollution may be highly mediated as a remote issue, mostly associated with powerful images, such as plastic accumulations in the oceanic gyres and charismatic wildlife entangled with plastic waste. Although overly alarming news, sensationalism, and other misrepresentations that are conveyed in the media about social issues are frequently identified (e.g. Bomlitz & Brezis, 2008; Frost, Frank, & Maibach, 1997), limited effort has been done in order to raise long-term awareness and mitigate plastic contamination.

5 | WHAT DO WE KNOW IN CHILE? THE SCIENTIFIC PERSPECTIVE

The Chilean scientific community also acknowledges the importance of understanding the extent and effects of plastic pollution, yet most researchers are new to this topic. The first study published in Chile dates from 1979, and since then, until April 2020, 53 scientific articles were published on different topics related to plastic pollution in aquatic environments (see Supporting Information Table S1). Between 1979 and 2003 only four articles had been published, two of which were on haphazard observations of floating litter. Only from 2009 onwards has the number of publications increased more steadily (Figure 2; Supporting Information Table S1). Between 2016 and April 2020 there were 34 studies published (64.2% of the total); if this trend is maintained then the number of publications will continue to increase, mirroring the international trend of growing numbers of studies on plastic-related issues.

The 1979 study (Jara & Jaramillo, 1979) was on a small aggregation of crustacean epibionts living on a lost fishing buoy. This, and the second scientific publication mentioning marine litter, hinted already at the potential interaction of marine organisms with floating litter: Bourne and Clark (1984) highlighted the co-occurrence of pelagic seabirds and litter at a coastal front that accumulates 'scum', including organic debris and floating plastics. Following these two brief observations, no reports about marine litter from Chile were published until the study by Hucke-Gaete, Torres, and Vallejos (1997), which synthesized data on the entanglement of Antarctic fur seals obtained from a monitoring programme conducted between 1988 and 1997. After that article, 6 years passed until the study by Thiel, Hinojosa, Vasquez, and Macaya (2003), which suggested that most of the floating plastics in coastal waters of the South-east Pacific have their origin in nearby urban areas. All those studies were on macroplastics; the first studies about micro- and mesoplastics only appeared around 10 years later (Browne et al., 2011; Eriksen et al., 2013; Hidalgo-Ruz & Thiel, 2013) (Figure 2a). A significant number of studies related to microplastics were published between 2016 and 2020 (Figure 2a). There is only one experimental study on nanoplastics, conducted in Antarctica, which investigated the harmful effects of nanoplastic ingestion in a sea urchin (Bergami et al., 2019).

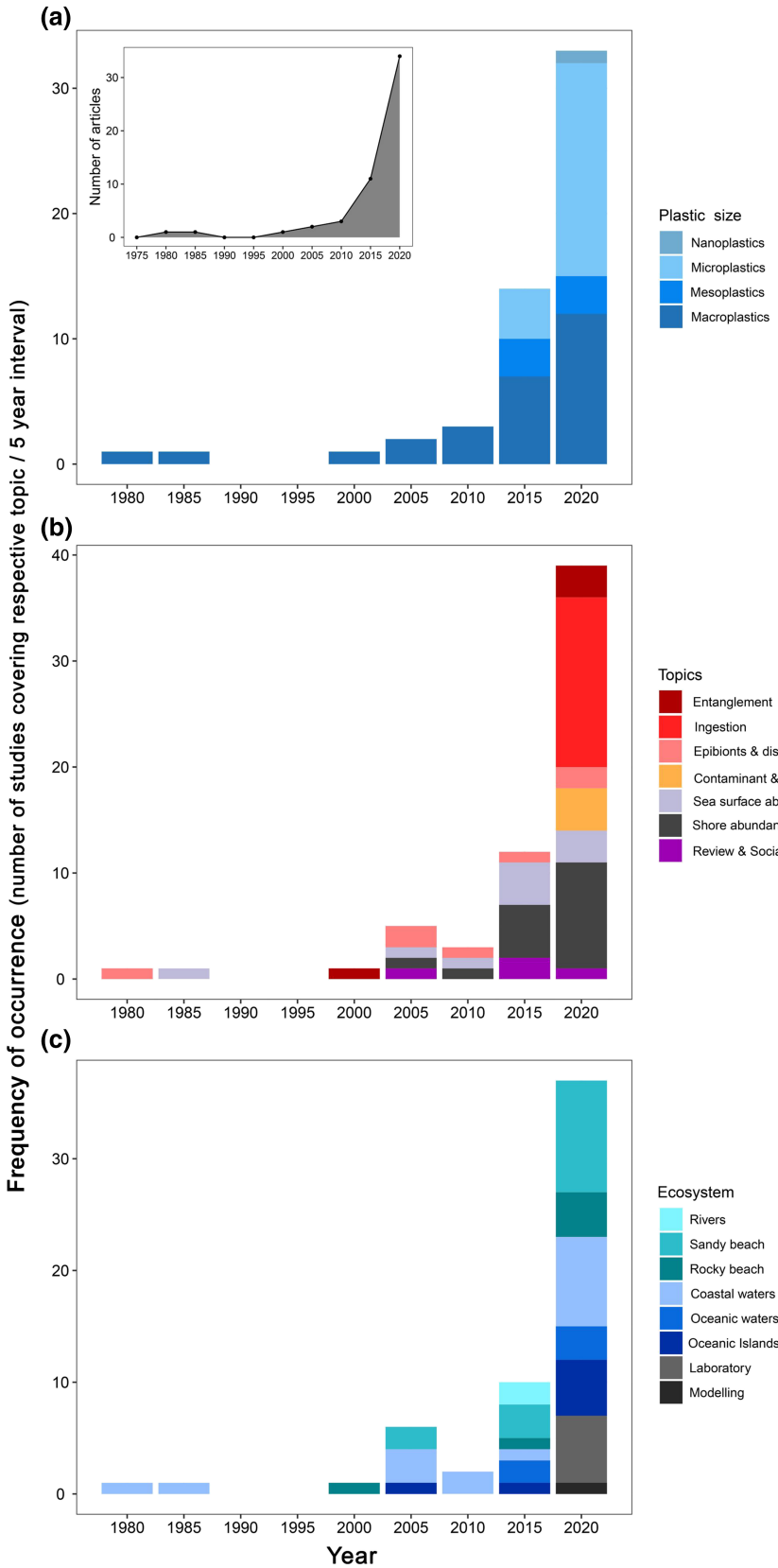

FIGURE 2 Number of scientific articles on plastic litter published over the last 36 years, presented as 5-6 year intervals (1975–1980, 1981–1985, 1986–1990, 1991–1995, 1996–2000, 2001–2005, 2006–2010, 2011–2015, 2016–2020). The last interval considers the studies published until April 2020. (a) Frequency of occurrence according to the size categories suggested by Kershaw, Turra, and Galgani (2019), where nanoplastics <1 μm; microplastics 1 μm to 5 mm; mesoplastics 5–25 mm; macroplastics >25 mm. The inset shows the number of scientific articles published from 1975 to 2020. (b) Frequency of occurrence of main topics investigated in each article. (c) Frequency of occurrence of principal marine ecosystems studied. Supporting Information Table S1 provides the full list of the studies investigating plastic pollution in Chile, serving as the basis for preparing this figure

The diversity of topics studied has increased from 2005 onwards (Figure 2b), reflecting the growing number of researchers interested in plastic pollution issues. Topics are relatively diverse, including studies investigating biotic interactions (entanglement, ingestion, epibionts, and dispersal), abundance and distribution, and contaminants and microbes on microplastics (see Supporting Information Table S1 for references and details). The majority of currently published studies are on ingestion and shore abundance and distribution, including

10 studies that identified fisheries and aquaculture activities as common sources of anthropogenic litter (e.g. buoys, lines, bins). Apart from anecdotal reports (Thiel et al., 2011), no published information is available on submarine litter from the Chilean coast. Two studies in 2009 and 2011 examined the organisms growing on floating plastics: one was an empirical study on the biota from detached aquaculture buoys (Astudillo, Bravo, Dumont, & Thiel, 2009), and one was an experimental study on the colonization and community succession on two types of floating plastics (Styrofoam, polyethene jar; Bravo et al., 2011). More recent work showed an increasing focus on interactions of plastic debris with marine fauna (e.g. Rech, Thiel, Yaisel, Borrell, & García-Vazquez, 2018; Thiel et al., 2018).

During recent years, experimental studies have contributed to our understanding of microplastic ingestion in mussels (Détrée & Gallardo-Escárate, 2018) and fishes (Ahrendt et al., 2020; Ory, Gallardo, Lenz, & Thiel, 2018). In other regions of the world, the ingestion of microplastics <1 mm has been widely reported for a large number of marine organisms of different trophic levels. Plastic has entered the food webs in the ocean from the plankton (Moore, Moore, Leecasterb, & Weisbergb, 2001; Setälä, Fleming-Lehtinen, & Lehtiniemi, 2014) to seabirds and marine mammals (Auman, Woehler, Riddle, & Burton, 2004; Jacobsen, Massey, & Gulland, 2010; Thiel et al., 2018). Microplastics and plastic microfibres have been found in the gut contents, intestines, and in faecal pellets of invertebrates with different feeding mechanisms, such as crustaceans, polychaetes, bivalves, and echinoderms (Auta, Emenike, & Fauziah, 2017). These observations suggest that plastic debris is present at all levels of the food web (Auta et al., 2017; Browne, Dissanayake, Galloway, Lowe, & Thompson, 2008; Murray & Cowie, 2011; Taylor, Gwinnett, Robinson, & Woodall, 2016). However, studies on the ingestion of microplastics by Chilean marine fauna are few. They are mainly related to small plastics in lithodid crabs (Andrade & Ovando, 2017), fishes from both continental coast (Mizraji et al., 2017; Ory et al., 2018) and oceanic islands (revealing very high incidences of plastic ingestion for Rapa Nui; Markic et al., 2018; Ory, Sobral, Ferreira, & Thiel, 2017), and in other marine vertebrates (Thiel et al., 2018). Recently, plastic microfibres were also found in scats of seals from southern Chile (Perez-Venegas et al., 2018; Perez-Venegas et al., 2020). Laboratory studies showed that intestinal injuries in intertidal fishes can be caused by microplastics (Ahrendt et al., 2020). It seems that studies examining the impacts of microplastic ingestion on organisms' health are still scarce, and future research should address this issue. New studies are also aiming to understand the role of marine microplastics both as vectors for persistent organic pollutants and in the biogeochemical cycles of greenhouse gases (Cornejo-D'Ottone, Molina, Pavez, & Silva, 2020; Pozo et al., 2020).

Most information about plastic pollutants in Chilean aquatic environments is about their abundance and distribution. During the period from 1985 to 2010, most studies were on the distribution of macrolitter in coastal waters and on sandy beaches (Figure 2c). Nevertheless, from 2015 onwards, studies covering rivers, rocky beaches, and oceanic waters and islands have steadily increased, including remote-sensing applications for quantifying beached macrolitter (Acuña-Ruz et al., 2018). Studies on the presence and quantification of 'microplastics on sandy beaches' and 'macroplastics floating at sea' have been conducted throughout the entire Chilean territory (Figure 3). Despite the increase in the number and diversity of studies conducted during the last 5 years (Figure 2), it seems that not all topics are evenly investigated along the Chilean coast (Figure 3). For example, the risk that land-based deposits of microplastics reach the ocean due to runoff or occasional alluvial events must be taken into account (Corradini et al., 2019). This highlights the importance of determining baselines of plastic and microplastic concentration and characterization across the entire Chilean territory to ensure that laboratory experiments use environmentally relevant concentrations and to evaluate changes and potential risks in order to inform society and decision-makers.

Even though research about marine plastics is still in its initial phase, there is already good evidence that most marine litter in Chile comes from local sources, with beach visitors, fisheries, and aquaculture activities being among the most significant sources (Bravo et al., 2009; Hidalgo-Ruz et al., 2018; Hinojosa & Thiel, 2009; Honorato-Zimmer et al., 2019; Perez-Venegas et al., 2018; Thiel et al., 2013). In central and southern Chile, large amounts of plastics are also reaching the coastal waters through rivers (Rech et al., 2014; Rech et al., 2015). On oceanic islands and in oceanic waters, most recognizable marine litter items are plastics that come from the open ocean fisheries and the continental coast of South America (Kiessling et al., 2017; Luna-Jorquera et al., 2019; Miranda-Urbina, Thiel, & Luna-Jorquera, 2015), which is confirmed by a recent study using modelling techniques (van Gennip et al., 2019). The need for protecting oceanic islands through declaring them marine protected areas has been broadly accepted as a conservation tool for preserving the unique biodiversity they harbour. However, these conservation goals are threatened by plastic litter reaching their coasts. Marine plastic pollution impedes effective protection of oceanic islands, requiring global coordination and international efforts to prevent and reduce the generation and spreading of plastic litter in the environment.

6 | A NASCENT SCIENTIFIC ALLIANCE IN CHILE, BRIDGING GAPS AND OPPORTUNITIES

Research on plastic pollution in Chile (see previous section) has responded, mainly, to the individual efforts of scientists motivated by their observations about the seriousness of the problem. However, the magnitude and complexity of plastic pollution deserve a higher level of response from the scientific community. The plastic contamination in terrestrial, aquatic, and oceanic systems of Chile is a multidimensional problem in which plastic litter of various sizes (i.e. nano, micro, meso, macro, mega) is getting into the physical, chemical, and biological processes of ecosystems. Plastic litter interacts with living organisms in diverse forms, from entanglement with floating marine litter (e.g. turtles and seabirds), ingestion of microplastics (e.g. fish and

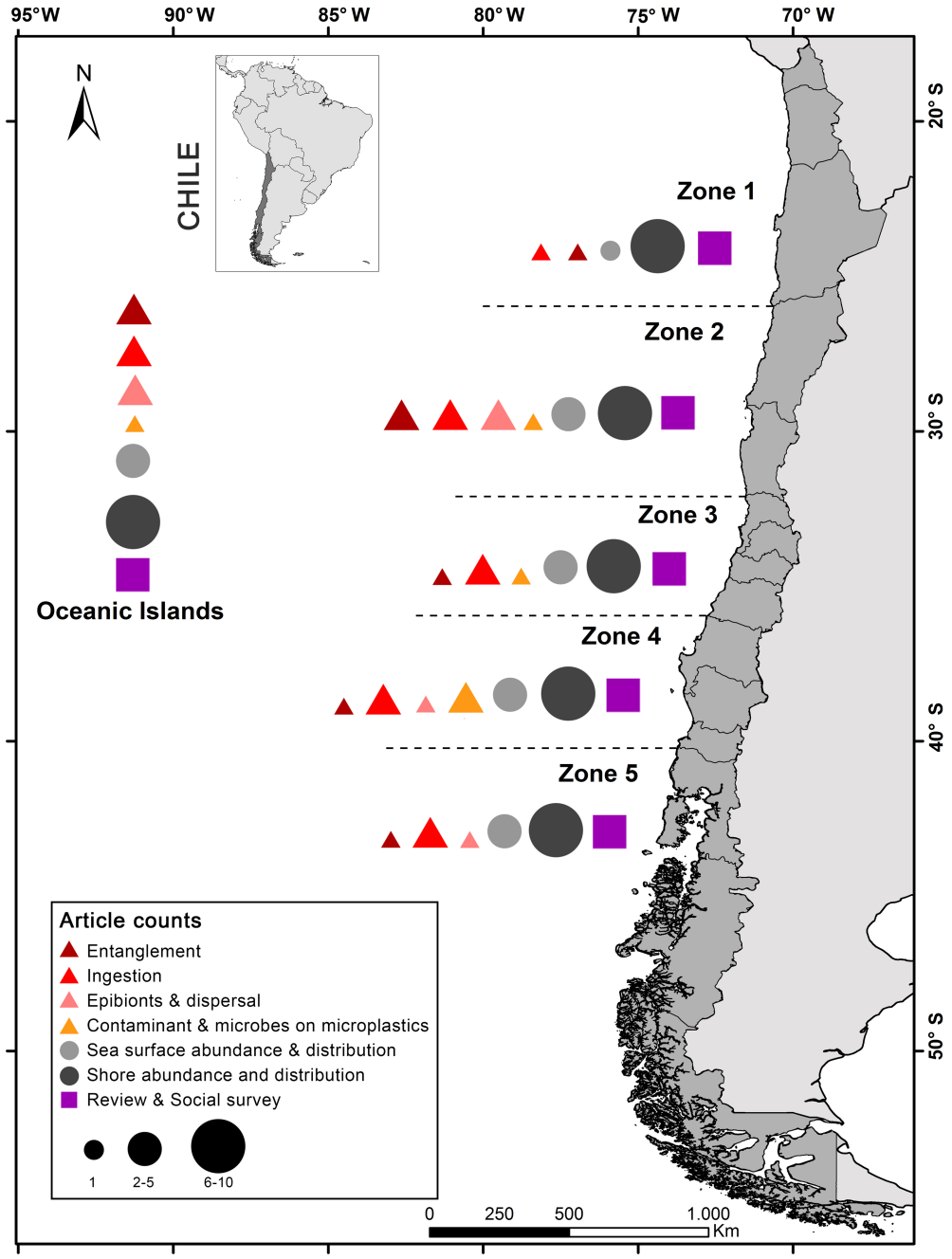

FIGURE 3 General overview of the main plastic-related topics investigated across the five geographical zones in Chile. The size of the symbol reflects the frequency of occurrence; that is, the number of studies covering each topic in the respective geographical zone as suggested by Bravo et al. (2009). Supporting Information Table S1 provides the full list of the studies investigating plastic pollution in Chile, serving as the basis for preparing this figure

crustaceans), to the absorption of plastic particles through breathing (e.g. crustaceans, mussels).

Investigating these problems and responding to the call for knowledge and solutions that society and decision-makers demand requires scientists to establish channels of communication and mutual collaboration, to define priorities, tasks, and commitments. In order to address these challenges, Chilean scientists working on plastic pollution gathered in July 2018 in Santiago, Chile, resulting, among other things, in the foundation of the Scientific Plastic Pollution Alliance of Chile (SPLACH). As a scientific alliance, the mission of SPLACH is to promote and stimulate the development of research related to plastic pollution and other activities of public interest, such as advice, education, and outreach.

Based on questionnaires, interviews, and presentations at the meeting, it was identified that SPLACH members were currently conducting studies on three principal topics: (a) quantification of marine litter in the environment and in organisms, (b) interaction between marine litter and organisms (vertebrates and invertebrates), and (c) interaction between marine litter and other pollutants. Furthermore, most researchers were interested to study the aforementioned topics in the water column, organisms, sandy beaches, and sediments.

When SPLACH members were asked to rank areas where future research should focus in Chile, they prioritized the quantification of plastics in different environmental compartments, trophic pathways and chemicals in plastics, and impacts of plastics on organisms. The establishment of one or two national laboratory facilities capable of

rigorously determining polymers in environmental samples (sediments, water, processed food, and organisms) was considered of highest priority by all workshop participants. After identifying the existing research expertise among SPLACH members and determining the key gaps, it was agreed that future research in Chile should focus on (a) the determination of ecological, physiological, and trophic effects of microplastics in organisms (e.g. birds, fishes, crustaceans, molluscs, and micro-organisms); (b) implementation and development of analytical techniques for polymer isolation and identification from environmental samples, and remote quantification; and (c) the study of synergism between microplastics, plastisphere, inorganic and organic compounds (e.g. polycyclic aromatic hydrocarbons and persistent organic pollutants, including additives used in fabrication of plastic polymers.

Finally, workshop participants were asked whether they had been interviewed by the press media or consulted by the local government, with almost all members answering positively (90%). The former indicates that a general interest in plastic pollution exists in society, with media and decision-makers demanding expert advice on plastic pollution issues. These demands can only be met if adequate funding is provided to answer the most urgent scientific questions. In particular, it seems important to articulate the scientific knowledge/expertise and focus it on the social and governmental requirements. All sectors of society are part of the plastic pollution problem, and they all should be part of the solutions.

7 | LEGAL (NATIONAL AND INTERNATIONAL) COMMITMENTS IN CHILE'S PLASTIC MANAGEMENT

Over the past decades (1940 to 2018), 15 legal instruments with national scope have been enacted in Chile, and 18 instruments with international scope have been ratified by Chile (Table 2). Nine of these instruments are directly related to plastic litter, and some are derived from international treaties, such as the decree DTO 1 of 1992 enacted by the Ministry of Defence, which prohibits littering into the sea. Also, the decree DTO 258 of 2008 from the Ministry of Foreign Affairs, enacting Annex V of the MARPOL 73/78 convention, establishes regulations for the prevention of pollution by litter from ships.

Local regulations of single-use plastic bags were first introduced in some tourist locations in southern Chile, with Pucón in 2013 being the first municipality, and since then 62 other cities throughout the country have enacted similar ordinances and with broad public support. In 2018, two laws were enacted specifically to reduce the entry of plastic items into natural environments: Law 21.100 that prohibits the use of single-use plastic bags, and Law 21.123 includes fines for those who pollute natural environments with plastics or other types of litter (Table 2). The enactment of Law 21.100 seems to be the result of the growing number of ordinances from municipal councils that promoted the ban of single-use plastic bags in supermarkets and stores. Although this law came with some political stumbling blocks, as plastic producers quickly opposed the measure, Chile has become the first Latin American country to regulate the use of single-use plastic bags by the general public (Amenábar Cristi et al., 2020). The effectiveness of these laws, however, relies heavily on society as the final users/enforcers, and so users/consumers must first be conscious of the problem and willing to change in order to have the expected positive impact. For instance, in 2016, Law 20.920 on Waste Management, Extended Producer Responsibility and Promotion of Recycling was approved, which establishes the regulation for six priority products (lubricants, electric and electronic devices, containers and packaging, tyres, car batteries, and alkaline batteries). This law makes producers liable for the disposal of their products after use, but specific rules of operation need to be enacted by a decree for each priority product.

The decree that defines the rules and the recovery goals for containers and packaging started the process of enactment in 2017. The first draft of the decree set goals to recover 45% of domestic plastic packages and 55% of non-domestic (industrial) products by 2030, following a principle of gradualism. The analysis of social and economic impacts elaborated by the environmental ministry estimated a cost of US$1.7 million to implement it, for which producers are responsible (MMA, 2019). The draft project was submitted to public consultation between June and August 2019 and received over 1,500 observations, including extensive objections from the plastics industry (MMA, 2020; País Circular, 2020). Following the incorporation of these observations, an updated decree was approved in May 2020, and now recovery goals of about 50% of plastic packaging will be delayed until 2032, at the earliest.

If all these legal projects are implemented with an integrative approach, and the plastic industry acts more collaboratively and is willing to change, Chile could make significant progress in stopping the local entry of plastics into aquatic environments. Nevertheless, since the first approval of Law 20.920 in 2016 it has become evident that recycling of plastic litter is itself problematic and thus far is not effective anywhere in the world (Dauvergne, 2018); consequently, the focus should be on prevention and use of reusable products. At the whole Pacific Ocean scale, the Asia Pacific Economic Cooperation has organized specific meetings and workshops about marine debris (August and December 2019), emphasizing that plastic pollution is of major concern and that future regulations should cover the entire Pacific region. One of the most important achievements was the adoption of the Asia Pacific Economic Cooperation Roadmap on marine debris (2019–2030), a non-binding document that aims to encourage member economies to take voluntary and concrete steps to reduce and mitigate all sources of marine debris in order to maintain a sustainable ocean, its resources, and economy (http://apec.org/Meeting-Papers/Annual-Ministerial-Meetings/2019/2019_AMM/Annex-B).

At the national level, a multiagency working group was established in 2018 to address the issue of marine litter and microplastics. This working group, led by the Ministry of the Environment, includes representatives from several agencies, such as the Ministry

TABLE 2 Legal instruments enacted in Chile and international agreements signed by Chile, aiming at preventing contamination with harmful substances (including plastics)

Instrument	Scope[a]	Enactment (year)	Entry into force (year)	Ratified by Chile (year)	Subject	Regulations	Link[b]
ART 16 DTO 655 Ministry of Labour and Social Welfare	N	1940	1941		Regulation for industrial hygiene and safety	Prohibits solid waste disposal in courses of water	D
IMO convention	I	1948	1958	1972	International organization, sea	Control of waste disposal by ships	I
ART 8 DFL 208 Ministry of Finances	N	1953	1953		Regulation for national fisheries	Prohibits solid waste disposal in the sea, rivers, and lakes	D
ART 18 DTO 130 Ministry of Agriculture	N	1959	1959		Regulation of permit for foreign fisheries ships in Chilean maritime area	Prohibits disposal of fisheries waste on shorelines	D
ART 73 DFL 725 Ministry of Health	N	1967	1968		Sanitary code	Prohibits disposal of industrial solid waste in rivers and lagoons	I
London Convention 1972	I	1972	1975	1977	Prevention of marine pollution by dumping of wastes and other matters	Prohibits deliberate disposal at sea of wastes; includes plastic and other persistent synthetic materials	D
CSC 1972	I	1972	1977	1980	Waste and hazardous substances, safety	Requirements to ensure safety in the handling and transporting of containers	I
MARPOL 73/78	I	1973	1988	2007	Waste and hazardous substances, sea	Prohibit the disposal of plastic and other garbage into the sea	D
INTERVENTION PROT 1973	I	1973	1983	1995	Waste and hazardous substances, sea	Measures on the high seas to prevent pollution from substances that are liable to create hazards to human health and marine life	I
DTO 1063 Ministry of National Defence	N	1973	1973		Orderliness, discipline and safety for ships	Prohibit waste disposal in harbours and national maritime territory	D
ART 6 DTO 890 Ministry of Interior	N	1975	1975		Safety for the state	The pollution of bodies of water is established as a crime	I
Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	I	1981	1986	1986	Marine coastal protection	Forbid the release of toxic or noxious substances from land-based sources and by dumping to the sea	D
Agreement on Regional Cooperation in Combating Pollution of the South-East Pacific by Hydrocarbons or other Harmful Substances in Cases of Emergency	I	1981	1986	1986	Sea, waste & hazardous substances	Measures to neutralize or control harmful effects from pollution in the marine environment	D
DL 3557 Ministry of Agriculture	N	1981	1981		Agricultural protection	Prohibit waste dumping and other products in bodies of water	I
UNCLOS	I	1982	1994	1997	Sea legal questions	Protection from the harmful effects of activities such as waste disposal in the marine environment	D

TABLE 2 (Continued)

Instrument	Scope[a]	Enactment (year)	Entry into force (year)	Ratified by Chile (year)	Subject	Regulations	Link[b]
Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	I	1989	1992	1992	Transport of waste and hazardous substances	Control for transboundary movements of solid plastic waste	D
Protocol on Environmental Protection to the Antarctic Treaty	I	1991	1998	1995	Air and atmosphere, mineral resources, waste & hazardous substances, sea, environment, wild species & ecosystems	Establish that plastic wastes shall be removed from the area under the Antarctic treaty, by the generator of such wastes	D
Treaty about environment between Chile and Argentina	I	1991	1993	1991	Wild species & ecosystems, land & soil, air & atmosphere, Environment gen., Water, Waste & hazardous substances, Sea	Measures for waste management and the prohibition of hazardous wastes traffic between the countries	D
UNFCCC	I	1992	1994	1994	Air & atmosphere, environment	Cooperation in the development of practices that reduce emissions of greenhouse gases from the waste management sector	I
DTO 1 Ministry of National Defence	N	1992	1992		Marine pollution	Prohibit waste release in the national maritime territory	D
Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas	I	1993	2003	2004	Sea fisheries	Promote cooperation with developing countries to ensure that fishing vessels entitled to fly its flag do not engage in any activity that undermines the effectiveness of international conservation and management measures	I
Law 19.300	N	1994	1994		Right to live in an environment free of pollution	Environment protection and control of pollution	I
Inter-American Convention for the Protection and Conservation of Sea Turtles	I	1996	2010	2010	Wild species and ecosystems, conservation, marine turtles, sea	Requires an impact assessment for activities that may affect sea turtle habitats such as the deposit of dredged materials and trash	D
HNS-OPRC	I	2000	2007	2007	Waste and hazardous substances	Cooperation in pollution incident by hazardous and noxious substances which poses or may pose a threat to the marine environment	I
ART 94 DTO 50 Ministry of Public Works	N	2002	2002		Regulation about home installations and sewage	Technical rules for pipelines to avoid water pollution	I
DTO 258 Ministry of Foreign Affairs	N	2008	2008		Prevent pollution from ships	Accept and enact annex V (facultative) of the MARPOL 73/78 convention	D

(Continues)

TABLE 2 (Continued)

Instrument	Scope[a]	Enactment (year)	Entry into force (year)	Ratified by Chile (year)	Subject	Regulations	Link[b]
SPRFMO	I	2009	2012	2012	Fishery conservation and management	Minimize pollution and waste originating from fishing vessels, discards, catch by lost or abandoned gear	D
Law 20417	N	2010	2010		Waste	The Ministry of the Environment should propose and elaborate policies, plans and programmes about the waste management	D
RAA	I	2012		2012	Fisheries, aquaculture	Includes sustainability into the development of aquaculture as one of the principles for the network	I
London Protocol	I	1996	2006	2012	Prevention of marine pollution by dumping of waste and other matters	Embracing the precautionary approach and prohibiting all dumping of waste and other matter, except for those on a prescribed list	D
Law REP-20.920	N	2016	2016		Recycling, waste management	Declares as one of the goals to diminish waste generation and to promote their reuse and recycling	D
Law 21.100	N	2018	2019		Ban single-use plastic bags	To protect the environment through the ban of single-use plastic bags into commerce	D
Law 21.123	N	2018	2018		Prohibit dumping of waste in natural environments	Prohibit to leave trash or any waste in beaches, rivers, lakes and national protected areas	D

[a]Scope of action. N: national; I: international.
[b]Link to plastic litter. D: direct; I: indirect.

of Health, the Undersecretariat for Fisheries and Aquaculture, the Directorate General of the Maritime Territory and Merchant Marine, and the National Fisheries and Aquaculture Service. This national task force has been working under the umbrella of the National Chemical Agenda, created in 2000, under Supreme Decree No. 184 of the Ministerio Secretaría General de la Presidencia. One of the main challenges for 2020–2021 is to develop a national strategy and action plan to address marine litter and microplastics.

The solutions to plastic pollution are multifaceted, and not only plastic-related regulations are required. Policies to achieve a better distribution of income, educational initiatives to promote conscientious consumption and disposal, territorial planning policies integrating waste management, and financial incentives to improve recycling and the consumption of reusable packaging should also be designed.

8 | SCIENCE AND EFFORTS TO TACKLE PLASTIC POLLUTION IN CHILE

Worldwide, including in Chile, plastic and microplastic research is growing at a fast pace (e.g. Anderson, Park, & Palace, 2016; Andrady, 2017; Li, Tse, & Fok, 2016) (Figure 2). However, national knowledge is still far lower than what is required to properly understand plastic distribution, concentration, and impacts on the ecosystems and biota of the Chilean territory. Most scientific knowledge available for Chile is from aquatic environments, but to our knowledge there have been few studies conducted in terrestrial habitats. Only one recent study examined sewage sludge as a conduit for microplastics to agricultural soils (Corradini et al., 2019). As a large proportion of anthropogenic litter is produced on land, this lack of terrestrial studies could be surprising at first, but it reflects the global trend (Rochman, 2018). It is important to encourage plastic pollution research on land, because both soils and air can contain high concentrations of microplastics (Corradini et al., 2019; Machado, Kloas, Zarfl, Hempel, & Rillig, 2018; Zhang et al., 2020). Consequently, future research in Chile should expand studies of microplastics to other ecosystems, such as farmland, wetlands, rivers, and lakes, and also include species such as bivalves, gastropods, crustaceans, marine mammals, and birds. One crucial initial step forward in the determination of the presence of microplastics is standardizing methodologies for detection, quantification, and identification of microplastics in both environmental and biological samples (Löder & Gerdts, 2015). Such standardization will guarantee the quality of baselines, and it is therefore relevant to emphasize its importance from this initial stage. It will also be important to assess the effectiveness of public policies and laws that have been implemented in recent years by evaluating plastic production and consumption during policy implementation. The commitment of producers and acceptability of the laws for citizens also need to be evaluated.

An aspect that is missing in Chilean studies on microplastics is the effects of these stressors on biological traits of different species (see Auta, Emenike, & Fauziah, 2017; Thiel et al., 2018). Future studies should assess how microplastics affect biological (e.g. physiology, reproduction or growth rate) and behavioural (e.g. locomotor activity or feeding behaviour) traits in species inhabiting the diverse terrestrial and aquatic ecosystems of Chile. Another relevant issue for future research is the analysis of ecological responses of organisms exposed to plastic pollution, from population (e.g. growth or intraspecific competition) to community (interspecific competition, predation, etc.) levels. Microplastics may also act as vectors transporting different chemicals; for example, persistent organic pollutants and polycyclic aromatic hydrocarbons (Brennecke, Duarte, Paiva, Caçador, & Canning-Clode, 2016; Hirai et al., 2011; Koelmans, 2015). These 'additives' could exacerbate the effects of microplastics on an organism's physiology (e.g. Browne, Niven, Galloway, Rowland, & Thompson, 2013), which is another aspect that has scarcely been addressed in the studies so far carried out in Chile. At present, only three studies report levels of chemicals sorbed on plastic debris in the country (Gómez et al., 2020; Pozo et al., 2020; Yamashita et al., 2018). Other contaminants geographically localized and derived from major economic activities, such as heavy metals in the north due to mining (Aguilera et al., 2019) and antibiotics and other pharmaceutics in the south due to aquaculture (Urbina, Cumillaf, Paschke, & Gebauer, 2019), may synergistically interact with plastic pollutants, potentially intensifying the impact of plastics on organism and ecosystem health.

The establishment of the SPLACH network is an opportunity to both conduct an updated diagnosis of this problem and to develop a coordinated research agenda, in coordination with societal and political needs. The main objective is the understanding of the potential impacts of plastic litter on organisms, the environment, and society, and to identify the solutions and the pathways necessary to establish vulnerability scenarios and mitigation strategies. Finally, the evidence produced by the SPLACH network is expected to aid in shaping government policies to mitigate the impacts and to support legal enforcement about plastic pollution in aquatic environments (Thiel et al., 2011). The implications of these future research developments will increase public awareness and could foster future science–society–governance alliances. The willingness and collaboration of all sectors of society is needed in order to achieve a sustainable use of plastic products (Figure 4). Chile is now at a turning point, where the effective implementation of policies banning single-use plastics and extending responsibilities to the producers will decide which of the two contrasting pathways it will follow in the near future (Figure 4).

Similar united efforts between science, government, commerce, and society have been achieved in other regions and countries. In Europe, science has importantly contributed to knowledge, public awareness, and legislation (Maes, Perry, Aliji, Clarke, & Birchenough, 2019). In South America, Brazil has been at the forefront of scientific research on marine plastic pollution (do Sul & Costa, 2007), generating scientific evidence of the widespread contamination of marine systems (e.g. Costa & Barletta, 2015; Turra et al., 2014) and impacts on marine life (e.g. Nobre et al., 2015; Rizzi et al., 2019), contributing enormously to fostering public support for marine conservation and culminating in the recent publication of a

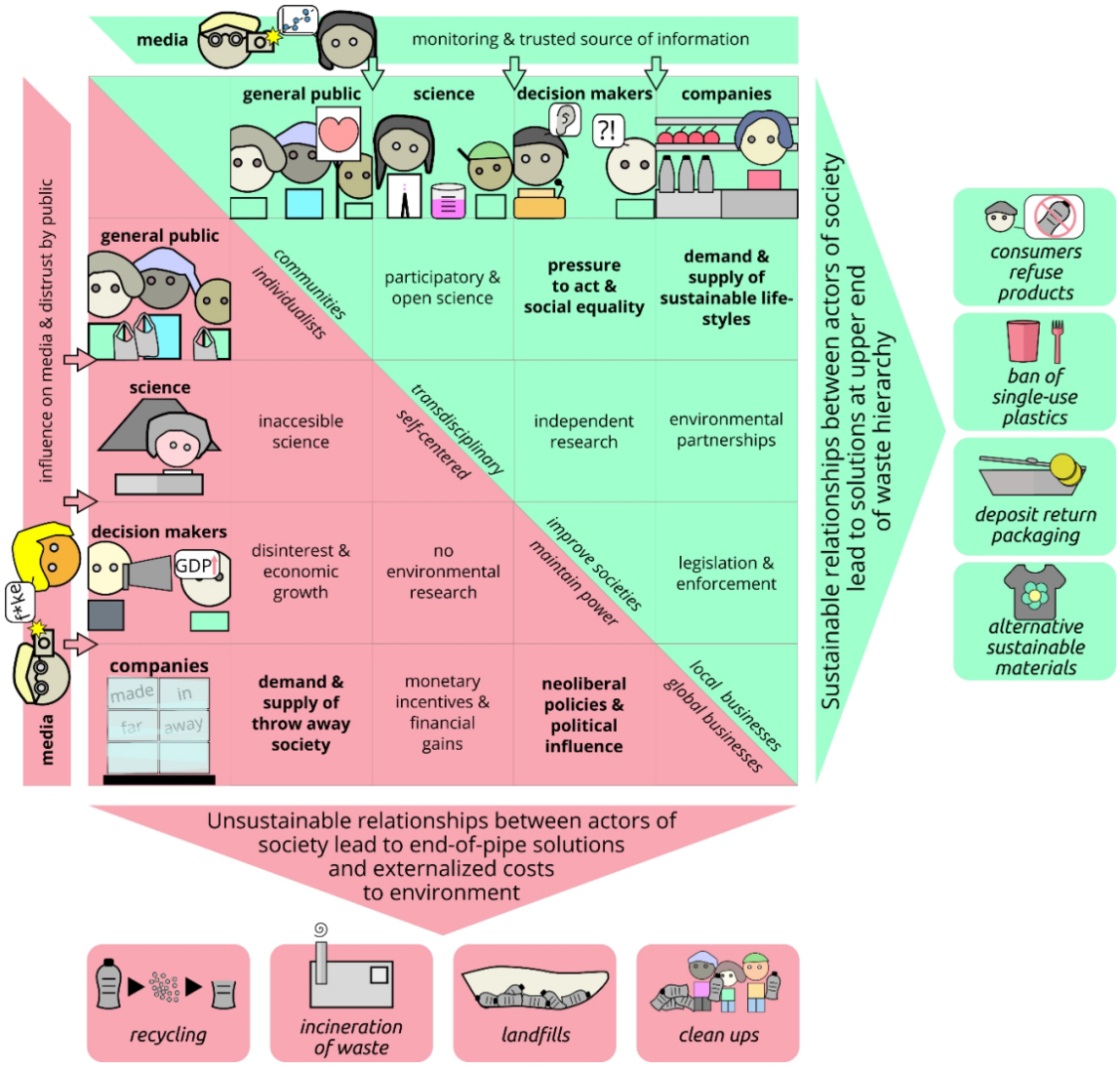

FIGURE 4 Schematic overview of stakeholder interactions and potential consequences for plastic pollution. Actors and their interactions favouring an equal and democratic society (in green) lead to more wholesome solutions than interactions based on status quo (in red). Creative Commons license CC-BY 4.0

national plan to combat marine litter (Environmental Ministry of Brazil, 2019). Though there is an informal alliance between science and diverse sectors of the government and society in Chile, this alliance has so far not been formalized; and despite multiple local and national initiatives dedicated to reducing plastic pollution, no national plan exists to combat the problem of marine litter. One goal of SPLACH for the near future could thus be to generate the scientific basis for a national action plan, articulating the actions required for the different sectors of society; namely, consumers, producers, manufacturers, politicians, scientists, and media. We hope that by bringing all these aspects, viewpoints, perceptions, regulations, and state-of-the-art knowledge together in this paper to have fulfilled the first step towards an action plan. A better dialogue with decision-makers and society is urgently required, so all actors can be part of this action plan.

From this overview, it is evident that the possibilities/actions to solve plastic pollution are on land. There is some indication that Chilean consumers are aware of environmental problems (including litter) and willing to take actions (Bronfman et al., 2015; Otto, Kaiser, & Arnold, 2014), but pro-environmental behaviours are typically impeded by lack of infrastructure and environmentally friendly products (Rojas et al., 2018; Valenzuela-Levi, 2019). Thus, whereas better knowledge by consumers is desirable, implementing the legal basis and creating a landscape facilitating responsible consumer behaviour seems far more important. In accordance with these considerations, Alpizar et al. (2020) recommended that Chile enforces extended producer responsibility, reinstates an encompassing deposit scheme, and fosters infrastructure and education. Given that municipalities are in charge of waste management, a closer involvement is needed, strengthening also economic equity at all levels of

society, personal, institutions, and at the regional level (Guibrunet et al., 2017; Rojas et al., 2018). The SPLACH network can help in these efforts by supporting integration among the different sectors of society, incorporating social sciences in the study agenda, innovation in the development of reusable products (in order to avoid the flawed concept of plastic recycling), and by conducting transdisciplinary research in order to achieve applied solutions to the problem.

9 | CONCLUDING REMARKS

The problem of marine plastic pollution has attracted the attention of scientists during recent decades, appearing as one of the most critical anthropogenic issues affecting the biosphere. The increasing number of papers published demonstrates the strong scientific interest on this topic. Moreover, several workshops and special sessions have focused on plastics and marine debris to propose a holistic solution based on a transdisciplinary approach. For instance, the European Space Agency proposed two main special sessions on plastic marine debris detection by satellites over the ocean and land in the next European Space Agency Living Planet Symposium 2019. Likewise, the last United Nations Environment Assembly identified marine plastic pollution as a special challenge to be addressed in the next years following the sustainability agenda 2030 (Haward, 2018; United Nations, 2015;).

Over the past two decades, the scientific community has contributed enormously to generate information about the plastic issues, but there are still substantial gaps in scientific knowledge (e.g. about the volume or final destinations of plastics in the ocean, and in particular about the impacts on wildlife and humankind). Thus, it is necessary to create effective strategies for sustainable development and in parallel to promote long-term research assets in order to improve knowledge about plastic pollution (Borrelle et al., 2017). At the global scale, other factors, such as the COVID-19 pandemic, will likely have long-lasting economic consequences, which might not only modify people's perception on plastic-related issues, but also change the priority on solving any environmental problem, including plastic pollution. Nowadays, it seems impossible to stop the production of plastic, particularly when the management of a pandemic such as COVID-19 relies on plastic/disposable medical items for public and health workers' use. This, however, is quite different to a pineapple wrapped in plastic film at the supermarket. We should create different frameworks in order to restrict the use of disposable plastics in some activities. High public awareness exists (Amenábar Cristi et al., 2020; Bronfman et al., 2015), and also an initial willingness from the Chilean Government, as is reflected in recent laws oriented to tackle the plastic pollution problem. Science must provide united and robust information to shape the changes required to tackle plastic pollution at the national level. However, there is an urgent need to improve the mechanisms of communication between all the actors of society (government, industry, population) in order to foster an integrative and comprehensive solution at the national level.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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