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# Social Perception of Ecosystem Services in a Coastal Wetland Post-Earthquake: A Case Study in Chile

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**Abstract:** Natural disasters can cause abrupt disturbances in coastal wetlands, affecting the social perception of ecosystem services (ES). The Tubul-Raqui coastal wetland is one of the most important wetlands in south-central Chile. Rich in biodiversity, these wetlands provide ES to a population of 2238 inhabitants. The recent  $M_W = 8.8$  earthquake of 2010 caused a coastal uplift of 1.4 m and substantial morphological, social, and environmental changes. This paper analyzes the social perceptions of the inhabitants of the village of Tubul-Raqui following a large earthquake disturbance with regards to ES provision frequency and their future changes. A statistically representative semi-structured survey was conducted (175 valid surveys) and the data interpreted through factor analysis and statistical tests for independent categorical variables. The perception of cultural and regulating services was significantly greater than that of provisioning services, which were probably the most affected by the earthquake. Residents identified habitat for species, recreation, and hazard regulation as the most important ES. Perception was influenced by the categorical variables of gender, age, and ethnicity; for example, hazard regulation services varied strongly by gender. According to the respondents, the availability of ES will remain stable (50%) or decrease (40%) in the next 50 years, mainly due to anthropogenic drivers; the effect of natural disasters was not mentioned among the main drivers of change.

**Keywords:** ecosystem services; social perception; earthquake; abrupt disturbances; wetland; Chile

## 1. Introduction

Ecosystem services (ES) are defined as benefits that people obtain directly or indirectly from ecosystems, which are usually classified as provisioning, regulating, or cultural [1–4]. In this sense, wetlands provide a wide range of ES that contribute to human well-being [5–8], including algae and fish, ornamental species, natural disaster mitigation, microclimate regulation, aesthetic value, and tourism, among many others [1,9,10]. Thus, it is important to ensure the ecological integrity of these ecosystems to guarantee the continuity of their provision of ES. However, on a global scale, many studies agree that their loss and degradation are greater than those of other ecosystems, and are more severe in freshwater and coastal wetlands, particularly in the Mediterranean region [3,11,12]. In coastal wetlands, drivers of change are associated with direct (land-use cover changes, diversion of freshwater

flows, changes in water temperature, and species invasions) and indirect factors (human population growth and increasing economic activity) [1,3]. However, some natural disasters (e.g., earthquakes, tsunamis, volcanic eruptions, storms) can cause abrupt disturbances in these ecosystems [13–16], therefore altering their ES provision.

This paper focuses on the social perception of ecosystem services in a coastal wetland in Chile, which were disturbed by a major earthquake. Salt marshes are a type of wetland that are especially sensitive to such disturbances. The ecosystem function of salt marshes depends on the interaction of fresh and salt water, which occurs in estuarine channels [17,18]. Large earthquakes can have an appreciable impact on the morphology and evolution of tectonically active coastal areas [17]. Depending on the coseismic tectonic dynamics of the affected area, the coast may undergo subsidence and/or uplift [19,20]; in the latter case, the tidal inflow into the estuary is diminished due to the close relationship between the altitude of the wetland and the local sea level [17]. For example, the relationship between ecosystem status and earthquakes was observed in the Sumatra–Andaman earthquake ( $M_W = 9.1$ ), where the coseismic uplift (0.3–1.5 m) caused plant mortality in large areas of coastal mangroves mainly due to thermal shock, desiccation, and the gradual depletion of soil salinity [21]. Earthquakes and tsunami disturbances have been associated with severe impacts on local human communities, due to the devastation of their crucial subsistence resources, as reported historically in the southern northwestern coast of the United States [13].

The above-mentioned cases demonstrate the complex links between the natural and social systems associated with human well-being [1,4,14]; therefore, it is important to incorporate social perceptions, historical drivers of change, trends, and social values in the evaluation of ES to guide criteria for sound environmental management strategies [3,22], an approach that is gaining prominence in the ES research agenda [23]. The social approach focuses on the values that society attributes to each ES [24] and considers that all individuals establish judgments and values regarding ecosystems and landscapes [25], which implies a diversity of individual values, interests and lifestyles, and thus an appreciation that depends on each context [7,26,27].

The perceptions and preferences of the population regarding ecosystem services are influenced by a series of personal, geographic, and social characteristics such as age, gender, income, political orientations, environmental organizations, moral convictions, use and non-use of particular areas, life experiences, and living environment [4,22,23]. Maestre-Andrés et al. [28] identified education, age, and place of residence as the characteristics that most affected the sociocultural valuation of ES in a nature park (Spain). Other studies have identified ES provision based on the perceptions of the local people [2,3,7,22,28,29]; however, few have focused on the time after the occurrence of a major disaster (see Reference [14]), which is a priority in developing countries, where it has been estimated that the effects of the loss of ecosystem services on human well-being will be serious due to the low incomes and land-based personal economies of the affected populations [5]. Therefore, in areas prone to natural disasters, the analysis of current perceptions of ES and the understanding of their trends and drivers of change are of increased importance to maintain biodiversity, ecosystem functions, and assure population well-being.

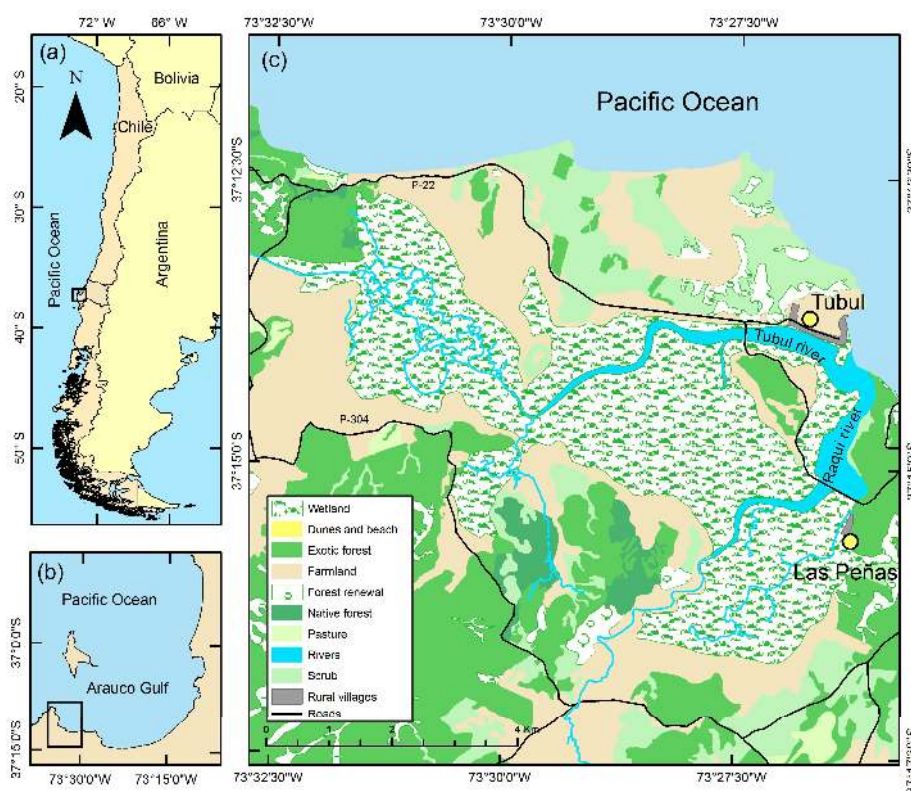
Located in South America, Chile is a developing country that is highly exposed to natural disasters. The central region of Chile has a history of destructive earthquakes (1575, 1580, 1647, 1730, 1822, 1906, 1985 [30,31]) with the most recent event being the 2010  $M_W = 8.8$  earthquake, that devastated south-central Chile [31]. The 2010  $M_W = 8.8$  earthquake caused substantial morphological, social, and environmental changes in the coastal area of central Chile [15,32–37]. One of the most affected sectors was the Tubul-Raqui fishing village, located south of the Concepcion metropolitan area (thereafter CMA). Here, the Tubul-Raqui salt marsh offers ES provision mainly to a rural population with a high poverty rate [34,37]. In this area, the 2010 earthquake generated a coseismic coastal uplift estimated at  $1.62 \pm 0.22$  m (see Reference [20]), these dynamics have previously been observed in other events such as the great earthquake of 1835 [31,38]. The coastal uplift interrupted the entrance of the tide and partially dried the salt marsh, and generated a variation in the availability of ES provision,

associated mainly with the extraction of the alga *Gracilaria* sp. (or pelillo in Spanish), which is important for the maintenance of the local economy [37,39,40]. In this context, we analyzed the social perception of the inhabitants of the village of Tubul-Raqui on the coast of central Chile to assess ES provision after the occurrence of a large earthquake. The data and methods applied can be replicated in areas of high ecological value affected by major disasters to understand the importance of ES after a great disturbance, therefore allowing an understanding of the implicit sociocultural differences based on each context.

## 2. Materials and Methods

### 2.1. Study Area

The Tubul-Raqui wetland (2238 ha) is a coastal salt marsh located on the Arauco Gulf, south of the CMA (37°S, 73°W) (Figure 1). Due to its extension and high biological biodiversity, it is one of the most important wetlands in south-central Chile [37,39,41]. Its ecosystem functions depend on the interaction and gradients of salt and fresh water. The intrusion of brackish water into the syzygy extended 5–6 km upstream from the mouths of the Tubul and Raqui rivers [39,42,43]. These natural dynamics generate optimum conditions for the cultivation of the alga *Gracilaria* sp., or pelillo [37,39]. The exploitation of pelillo, combined with the extraction of marine mollusks and fish, generated income linked to the food supply. In addition, the water supplied by the wetland allowed the development of small-scale agricultural and livestock activity, which is limited by the poor quality of soils in the area [37,39]; furthermore, these economic activities are undertaken by a vulnerable population [34,37].



**Figure 1.** Study area. (a,b) indicate the geographical contexts in the South America region; (c) Location of the wetland and land use cover in the Tubul-Raqui basin.

The estimated human population is about 2683, which is concentrated in the rural villages of Tubul (75%) and Las Peñas (12%) [37,39]. In addition, official statistics from the government of Chile [44] report that about 200 people in Tubul belong to indigenous ethnic groups. Their main economic

activities focus on fishing, agriculture, and livestock, where the latter two are carried out on a family scale mostly for local supply [37]. Fishing comprises of artisanal fishing and the extraction of the alga *Gracilaria* sp., which was carried out by about 500 people before the earthquake of 2010 [39]. The population has a low income, even lower than the legal minimum wage established in Chile [37].

## 2.2. Methodology

Data collection to analyze the social perception or perceived benefits of ecosystem services was carried out by conducting a semi-structured survey. The process was divided into three consecutive steps: (1) survey design; (2) determination of population and sample size; and (3) data analysis.

### 2.2.1. Survey Design

The instrument was designed with three main sections: (a) personal background of the head of the household; (b) socioeconomic data; and (c) their perception of ecosystem services. For background information on the head of the household, subjects were asked about gender, age, years of schooling, and indigenous group membership. The socioeconomic information comprised household members, economic activity, individuals with incomes, the incomes of household members, and government subsidies. Income information was detailed to obtain better reliability in income declarations, as proposed by Paul [45] and Rojas et al. [37].

To construct the section on the perception of ecosystem services, an initial stage consisted of a literature review of the services and subservices provided by wetlands including the Millennium Ecosystem Assessment, among other works described in References [1,12], which were then used to establish a final base of 64 subservices. An assessment of the services provided by the Tubul-Raqui wetland was carried out and 64 possible services were rated by a commission of ten experts from different fields of sociology, environmental sciences, biology, forestry engineering and geography, who determined the relative magnitude (high, medium, low) of the ecosystem services of the studied system. Finally, a list of 30 services (Table 1) were obtained for assessment, which consisted of provisioning, regulating, and cultural services.

**Table 1.** Ecosystem services provision analyzed.

Provisioning ES	Regulating ES	Cultural ES
Livestock development	Control of soil erosion	Appreciation of fauna
Food cultivation	Hydrological hazard protection (tsunamis, floods)	Appreciation of flora
Fodder for cattle	Fire protection	Mental recreation (relaxation, stress reduction)
Wild fruit collection	Microclimate regulation	Maintenance of social relations
Water for domestic use	Discharge regulation	Aesthetic value
Fuelwood collection	Water purification	Maintenance of traditional knowledge
Water for agricultural use	Air purification	Opportunities for sports
Ornamental resource collection	Habitat for species	Opportunities for eco-tourism
Medicinal plant collection	Pollination	Opportunities for scientific activity
Fish and algae production	Groundwater recharge	Opportunities for environmental education

### 2.2.2. Determination of Population and Sample Size

To calculate a sample that determined the social perception of the ecosystem services in the Tubul-Raqui coastal wetland, we used the methodological parameters of Rojas et al. [37]. The population (N) was defined as the heads of households older than 18 years, either female or

male, who resided in the Tubul-Raqui area; through a housing census, 280 households were obtained. The sample size ( $n$ ) was calculated using the formula for finite populations (Equation (1)):

$$n \geq \frac{Nz^2_{1-a/2}PQ}{z^2_{1-a/2}PQ + d^2(N-1)} \quad (1)$$

where  $n$  corresponds to sample size;  $N$  is the population size (280);  $Z$  is the normal distribution value (95%);  $P$  is the estimated population proportion (70%);  $d$  is the precision (5%); and  $Q$  the proportion of unfavorable results in the population ( $q = 1 - p$ ). In this study, the population proportion was estimated based on the percentage of people working in the different economic sectors.

The application of the formula for finite populations fixed 160 heads of households as  $n$  (sample size). For reasons of loss or rejection, it was necessary to apply 10% more surveys than the calculated sample size. Finally, 175 valid surveys were obtained. Five interviewers were trained to apply the instrument. The house-to-house survey was randomly conducted during four days of fieldwork, and the time associated with each questionnaire was approximately 25 min. Table 3 shows general information regarding the survey respondents.

### 2.2.3. Data Analysis

The data were analyzed using IBM SPSS (Statistical Package for the Social Sciences) version 24.0 [46] and InfoStat version 2015p [47]. The general information regarding the survey respondents was categorized (Table 2). Age was categorized according to the stages of development proposed by Martín [48], who considered young adults (18–35 years), intermediate adults (36–49 years), mature adults (50–64 years), and seniors ( $\geq 65$  years). Work activities were classified based on the recommendations of the National Institute of Statistics of Chile, by primary (e.g., agriculture, livestock), secondary (e.g., industry), and tertiary (e.g., commerce) economic sectors. For education, years of study grouped into three levels were considered: basic (0–4 years), advanced basic (5–8 years), and secondary (9–12 years). To identify conditions of poverty, the national economic characterization survey [49] model was applied, which determines poverty according to the number of household members and their per capita income.

**Table 2.** General information regarding survey respondents.

Category	Category	Frequency (Person)	Ratio (%)
Gender	Male	37	79.0
	Female	138	21.0
Age	18–35	32	18.3
	36–49	54	30.9
	50–64	59	33.7
	$\geq 65$	30	17.1
Economic sector	Primary sector	139	79.4
	Secondary sector	5	2.9
	Tertiary sector	18	10.3
	Retirees and pensioners	13	7.4
Education (years)	0–4	40	22.9
	5–8	84	48.0
	9–12	51	29.1
Poverty situation	Poverty	129	73.7
	No poverty	46	26.3
Ethnicity	Indigenous	23	13.1
	Non-indigenous	152	86.9
Total (n)		175	100

The reliability of the obtained perception results on a Likert scale (Table 3) was determined using Cronbach's alpha coefficient, which was generally applied for all ecosystem services and for particular service categories. The minimum value for accepting the test was 0.70 [50], and the analyses gave coefficients above 0.70 in all areas with an overall value of 0.83 (Table 4), indicating high instrument reliability. Construct validity was obtained through factor analysis. To analyze the data, a factor analysis was applied, which allowed groups of variables (components) with common characteristics to be identified to explain the greatest possible amount of information.

To determine the relationship between the components of the three dimensions and the independent categorical variables (gender, age, education, poverty, ethnicity, and economic sector), the Student's *t*-test (Mann–Whitney U.) was applied in the case of two groups and the analysis of variance (Kruskal–Wallis) in the case of more than two groups. For age, the Pearson correlation coefficient was obtained. When a sub-dimension was composed of only one question, the chi-squared test was applied. Three levels of significance was used (0.10, 0.05 and 0.01).

**Table 3.** Likert scale example applied to determine the current perception of ecosystem services.

Ecosystem Services	Never	Very Rarely	Occasionally	Very Frequently	Always
Fodder for cattle	1	2	3	4	5
Wild fruit collection	1	2	3	4	5

**Table 4.** Cronbach's alpha reliability coefficients by dimension.

Dimension	Number of Elements	Cronbach's Alpha
Provisioning services	10	0.72
Regulating services	10	0.76
Cultural services	10	0.78
Total	30	0.83

To calculate the perception of change trend for the different ecosystem services, the overall perceived trend index proposed by Oteros-Rozas et al. [29] was used. The index is defined by (Equation (2)):

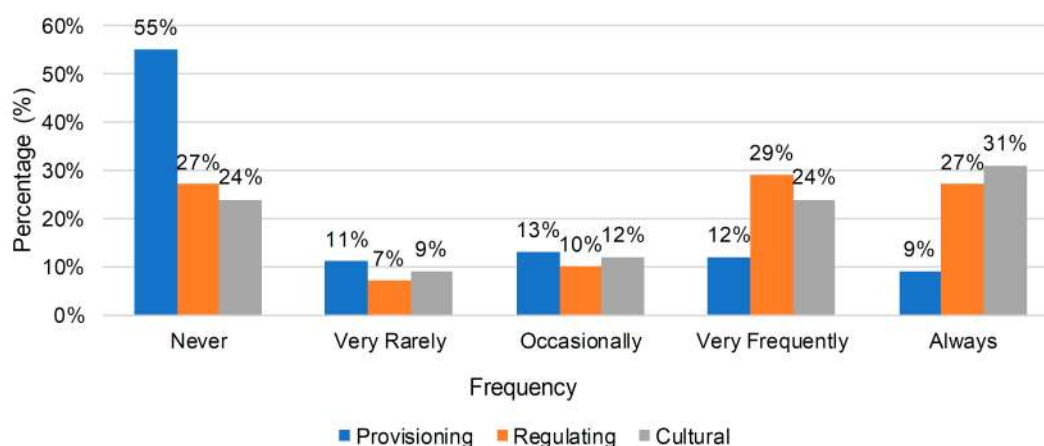
$$\text{Overall perceived trend} = \left[ \frac{I - D}{I + D + M} \right] \quad (2)$$

where *I* is the frequency of increases; *D* is the frequency of decreases; and *M* corresponds to the frequency of stability. The results were interpreted as: 1.00–0.60 were mostly increases; 0.59–0.29 were increases; 0.19–−0.19 was stable; −20–−0.59 were decreases; and −0.60–−1.00 were mostly decreases.

### 3. Results

#### 3.1. Current Perception

The perceived benefits of the ecosystem services of the Tubul-Raqui wetland according to the Likert scale categories is summarized in Figure 2. It was observed that the results were concentrated at the extremes of the scale (never, very rarely, very frequently, and always). Regarding provisioning services, there was a mostly negative perception with 66% of respondents indicating that they rarely or never used them. Regulating or cultural services were better evaluated, with approximately 56% and 55% of inhabitants, respectively, of the fishing village indicating that they frequently or always used them.



**Figure 2.** Likert results regarding the current perception of ecosystem services.

The internal relationship among the various services that made up each category was determined through factor analysis, which successfully grouped ecosystem services by dimension as per the Kaiser–Meyer–Olkin test ( $KMO = 0.716$ ). The provisioning services dimension was made up of four components (Table 5) that explained 66.7% of the total variance. The first component, referred to as livestock and crop development explained 30.7% of the variance, and the ecosystem services grouped in this component were livestock development, food cultivation, fodder for cattle, and wild fruit collection. The second component, related to the provision of water and fuelwood, explained 14.1% of the variance. The third and fourth components explained 11% of the variance, on average, respectively; the third was related to the collection of plants for ornamental and medicinal purposes and the final component to the fish and algae production.

**Table 5.** Rotated component matrix one and total variance explained for dimension one (provisioning).

Provision Ecosystem Services	Component			
	1	2	3	4
Livestock development	0.811			
Food cultivation	0.727			
Fodder for cattle	0.614			
Wild fruit collection	0.528			
Water for domestic use		0.870		
Fuelwood collection		0.810		
Water for agricultural use		0.676		
Ornamental resource collection			0.778	
Medicinal plant collection			0.681	
Fish and algae production				0.834
% Variance	30.7	14.1	11.1	10.8
% Cumulative variance	30.7	44.8	55.9	66.7

The second dimension, the regulating ecosystem services, was formed by three components that explained 69.7% of the total variance (Table 6). The first component related mainly to hazard regulation (29.1% of the variance), with soil erosion control, hydrological hazard protection and fire protection grouped in this component. The second component, made up of discharge and microclimate regulation, accounted for 21.1% of the common variance of the data. The last component was composed of the water and air purification services, and explained 19.5% of the variance. The ecosystem services of habitat for species, pollination, and groundwater recharge were not related to any component; therefore, their analysis by categorical variables was performed independently.

**Table 6.** Rotated component matrix and total variance explained for dimension two (regulating).

Regulating Ecosystem Services	Component		
	1	2	3
Control of soil erosion	0.786		
Hydrological hazard protection (tsunamis, floods)	0.766		
Fire protection	0.704		
Microclimate regulation		0.866	
Discharge regulation		0.628	
Water purification			0.757
Air purification			0.658
% Variance	29.1	21.1	19.5
% Cumulative variance	29.1	50.2	69.7

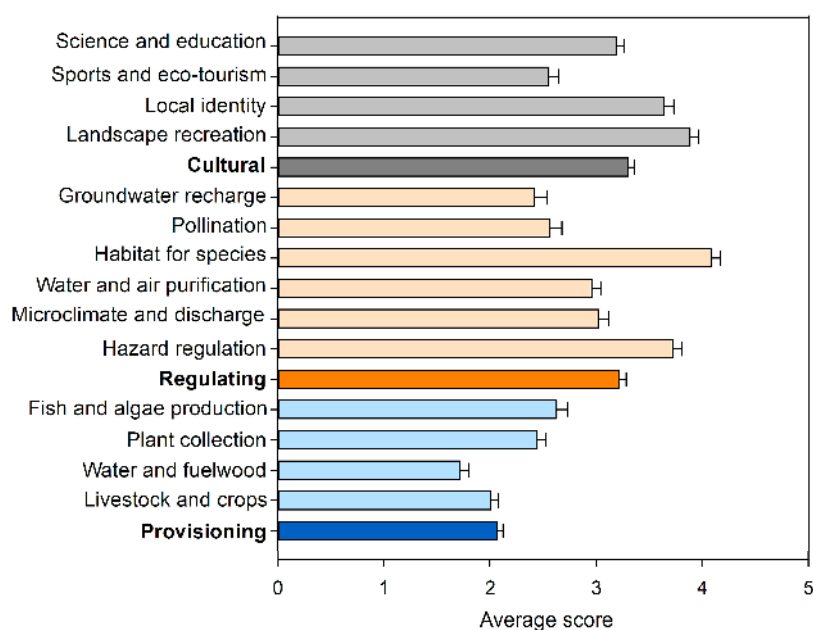
For cultural services, three components explained 74.2% of the total variance (Table 7). The first component was interpreted as landscape recreation related to the appreciation of natural attributes and mental recreation, and explained 22.9% of the variance. The second component, local identity, explained 18.7% of the variance, and was mainly associated with aspects of social relationships, local traditions, and a sense of place. The third component was linked to the development of tourism and eco-tourism, and explained 16.6% of the variance. Finally, the fourth component of scientific activity and environmental education accounted for 16.0% of the variance.

**Table 7.** Rotated component matrix and total variance explained for dimension three (cultural).

Cultural Ecosystem Services	Component			
	1	2	3	4
Appreciation of fauna	0.862			
Appreciation of flora	0.845			
Mental recreation (relaxation, stress reduction)	0.620			
Maintenance of social relations.		0.877		
Aesthetic value		0.695		
Maintenance of traditional knowledge		0.641		
Opportunities for sports			0.891	
Opportunities for eco-tourism			0.847	
Opportunities for scientific activity				0.858
Opportunities for environmental education				0.828
% Variance	22.9	18.7	16.6	16.0
% Cumulative variance	22.9	41.6	58.2	74.2

Figure 3 shows the average valuation and the standard error obtained for components associated with each dimension of the factor analysis. It was observed that the regulating and cultural services presented a higher valuation than the provisioning category. Regulating services were well perceived by the inhabitants of the fishing village, with habitat for species (4.1), hazard regulation (3.7), and microclimate and discharge regulation (3.0) standing out; water and air purification was also perceived to be on the same level of importance. Cultural services were also important, among which the possibility of recreation given the attributes of the landscape was the highest valued (3.9), followed by local identity (3.6), and the development of science and environmental education (3.2); however, opportunities for tourism and sports obtained the lowest value (2.5) in this category. In provisioning services, the development of livestock and crops (2.0) along with water and fuelwood (1.7) obtained the lowest weights, most likely due to the environmental conditions (e.g., brackish water and poor soil) of the salt marsh. In this final category, the positive assessment associated with plant extraction (2.4), and fish and algae production (2.6) stood out.





**Figure 3.** Average score and standard error for each evaluated component or ecosystem service.

This last positive assessment regarding fish and algae may be linked to the boom in the production of the alga *Gracilaria* sp. in the area. Indeed, in the data (corresponding to landings in tons) presented in Figure 4 showed that constant growth in activity was observed until 2010, with a peak in activity in the 2005–2010 period. The year 2010 marked a break in extraction; although levels similar to those in previous years were observed, these data corresponded to the months of January and February during which extraction reached 5436 tons. Following the earthquake and tsunami of 2010, there was a total loss of the resource, with large meadows completely exposed to an environment without salt water. Starting in 2013, a gradual recovery of the activity was observed, but was still at very low levels in comparison to pre-disturbance extraction levels.

The analysis of the assessment by independent categorical variables showed greater significant differences for gender, age, and ethnicity, while lower levels of significance were obtained for the education and economic sectors (Table 8). Regarding gender, women gave a higher valuation to hazard regulation ( $p = 0.002$ ), water and fuelwood ( $p = 0.026$ ), water and air purification ( $p = 0.032$ ), and groundwater recharge ( $p = 0.027$ ) services; in addition, slightly significant differences in microclimate and discharge ( $p = 0.099$ ) and local identity ( $p = 0.070$ ) were found. With respect to the age variable, a negative correlation in plant extraction ( $p = 0.033$ ), livestock and crops ( $p = 0.078$ ), and fish and algae ( $p = 0.040$ ) services was obtained, with the highest valuation given by young and intermediate adults (18–49 years). In contrast, in the microclimate and discharge ( $p = 0.050$ ) and habitat for species ( $p = 0.007$ ) services, a positive correlation regarding mature adults and seniors (over 50 years) was reported.

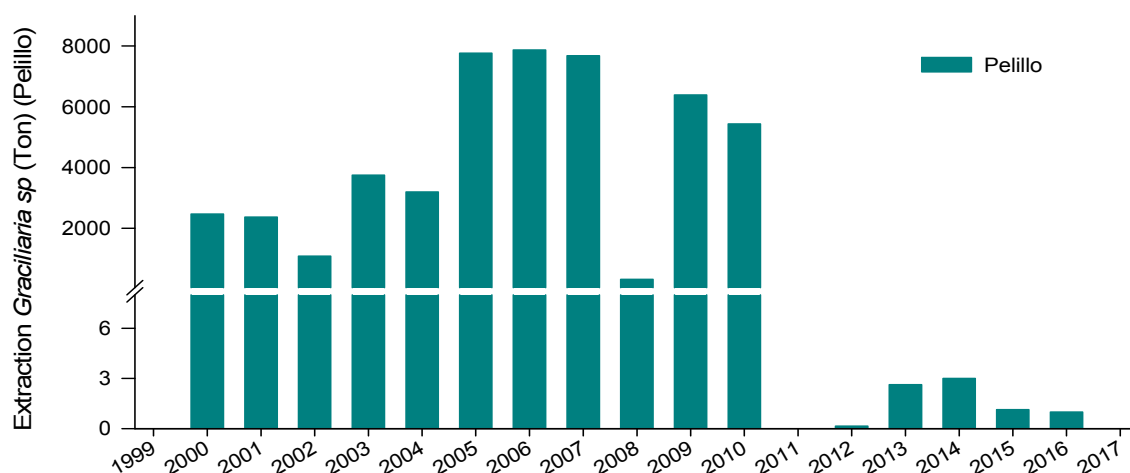


Figure 4. *Gracilaria* sp. extraction 2000–2017, Tubul-Raqui village (tons).

Ethnicity exhibited greater valuations in indigenous groups in five ecosystem services, with significant differences obtained in fish and algae production ( $p = 0.049$ ), groundwater recharge ( $p = 0.013$ ), opportunities for sports and eco-tourism ( $p = 0.031$ ), and science and education ( $p = 0.002$ ), along with a slightly significant difference in water and fuelwood provision ( $p = 0.074$ ). With respect to the economic sector, there was a slight significant difference in only one service, fish and alga extraction ( $p = 0.073$ ), which was valued to a greater degree by those who did not belong to the primary economic sector. Regarding the poverty variable, there were no significant differences.

Table 8. Component significance for independent categorical variables.

Component or ES	Gender	Age	Education	Ethnicity	Poverty	Economic Sector
<b>Provisioning</b>	0.061 +	0.021 *	0.794	0.318	0.366	0.924
Livestock and crops	0.300	0.078 +	0.602	0.309	0.509	0.871
Water and fuelwood	0.026 *	0.427	0.033*	0.074 +	0.389	0.438
Plant collection	0.633	0.033 *	0.379	0.268	0.776	0.299
Fish and algae production	0.981	0.040 *	0.717	0.049 *	0.331	0.073 +
<b>Regulating</b>	0.002 **	0.271	0.259	0.217	0.741	0.274
Hazard regulation	0.002 **	0.133	0.226	0.771	0.829	0.675
Microclimate and discharge	0.099 +	0.050 *	0.426	0.351	0.423	0.805
Water and air purification	0.032 *	0.516	0.713	0.511	0.278	0.159
Habitat for species	0.247	0.007 **	0.923	0.487	0.432	0.366
Pollination	0.651	0.793	0.001**	0.264	0.618	0.694
Groundwater recharge	0.027 *	0.171	0.798	0.013 *	0.489	0.902
<b>Cultural</b>	0.199	0.372	0.614	0.067 +	0.727	0.612
Landscape recreation	0.122	0.163	0.885	0.765	0.504	0.600
Local identity	0.070 +	0.636	0.647	0.279	0.601	0.572
Sports and eco-tourism	0.883	0.770	0.331	0.031 *	0.847	0.895
Science and education	0.637	0.256	0.292	0.002 **	0.410	0.131

Significance levels: \*\*  $p < 0.01$ ; \*  $p < 0.05$ ; +  $p < 0.10$ .

### 3.2. Perception of Future Change

The perception of future ecosystem service change trends index over 50 years showed that 50% of the ES provision should remain stable, along with a 33.3% decrease, and a 6.7% of mostly decrease (Figure 5). The perception of growth was low among the respondents, with only 6.7% and 3.3% holding that the services would increase or mostly increase, respectively. The analysis by service dimension—the greatest perception of future change—was obtained in cultural services, which should increase or remain stable in the coming years. Indeed, this category contained the only assessed services that would increase, such as opportunities for eco-tourism, sports, and scientific research. The population estimated that the services associated with regulating and provisioning would decrease

and mostly decrease by 60%; in the slight decrease category, air purification, microclimate regulation, and water for domestic and agricultural use ES, among others, stood out. The service that would decrease most was the provision of fish and algae, with 85% of the population estimating that it would undergo a significant decrease.

Perception regarding increases, stability, or decreases in ES provision was found to be linked to drivers of disturbance and loss. Through an open question, we detected 11 drivers of change that would produce a decrease in the availability of ES. As observed in Figure 6, for the category of gender, no significant differences with other independent categorical variables were reported ( $p \geq 0.05$ ). The main drivers were contamination (54.3%), droughts (32.6%), forestry industry presence (28%), global climate change (22.9%), human interventions associated with energy projects (20.6%), and lack of environmental education (19.4%). Percentages lower than 10% were obtained for overexploitation, absence of protection laws, natural disasters, religion, and natural degradation.

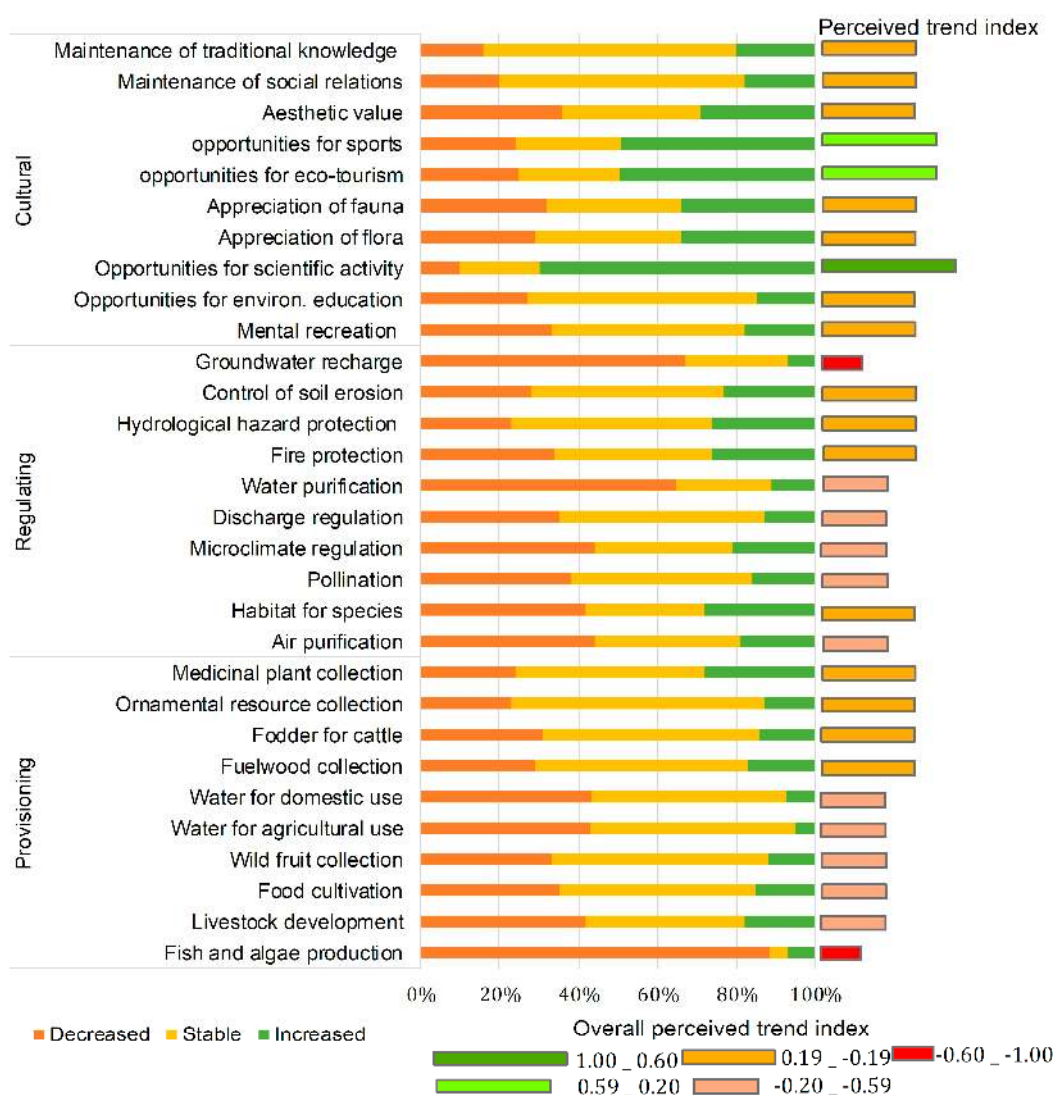


Figure 5. Perception of future change in ecosystem services and index of overall perceived trend.

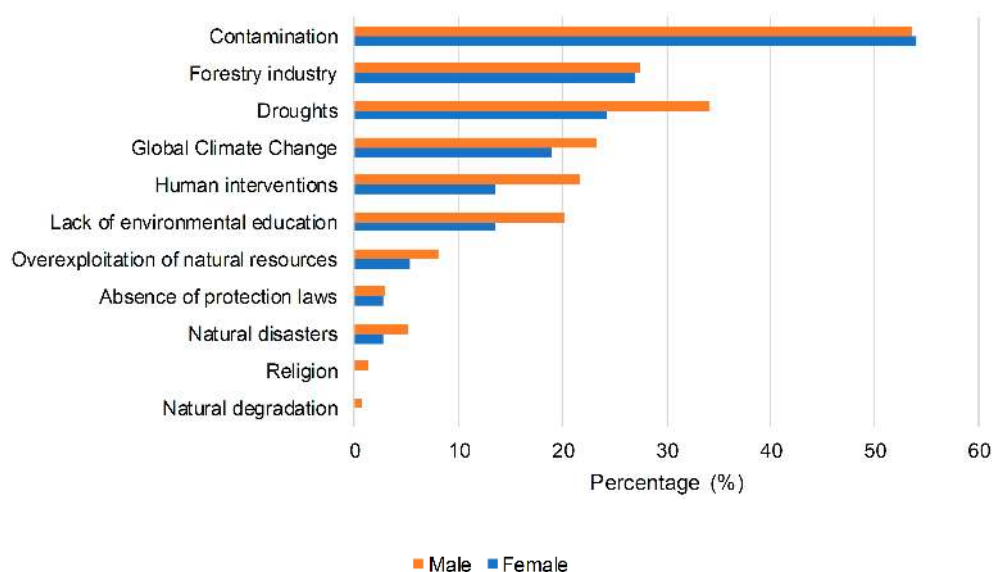


Figure 6. Perception of drivers of change in ecosystem services.

#### 4. Discussion

The perceived benefits of ES provision following a large disturbance such as the 2010  $M_W = 8.8$  earthquake provided a view of the positive valuation of the inhabitants of a Mediterranean salt marsh, which has been declared a Chilean priority site under the National Strategy for Biodiversity Conservation [41]. In general, it was observed that the regulating and cultural ecosystem services obtained a high valuation in terms of frequency of provision despite morphological, social, and environmental changes from the last earthquake. In fact, in the regulating services, the high recurrence of natural (tsunamis, floods) and anthropogenic disasters (fires) that affect the Chilean Mediterranean region [31,37,51] may have positively influenced the utilitarian valuation of the wetland by the population, as it forms part of the inhabitants' collective memory. This is not novel, and is consistent with Barbosa and Villagra [52] as wetlands are essential to mitigate the effects of such catastrophes, and are socially valued as spaces of recovery after earthquakes, especially if they provide biophysical attributes such as water [53].

A similar situation (high social perception) regarding regulating services occurred in the habitat for species service, in the study of Marín et al. [54], carried out 18 months after the earthquake, the diversity of bird species was one of the most important ES perceived by the inhabitants of the Tubul-Raqui fishing village. This perception can be linked to daily observations of the abundant biodiversity provided by the wetland, including local and migratory bird species (83), micromammals (4), reptiles (6), and amphibians (1), which provides a unique sense of landscape beauty. In this regard, the role of collective memory was fundamental. Kunstler (1994), cited by Bouahim et al. [3], recognized the importance of that and the beauty of places in promoting a sense of attachment and human belonging, both key factors in perception studies. Furthermore, Dobbie and Green [4] indicated that intrinsic (habitat, social, esthetic, educational, and tourism) values often dominate the perception of wetlands.

The highlighted result showed that the valuation of cultural services was the highest, with the Tubul-Raqui salt marsh identified as an ecosystem capable of providing opportunities for services related to recreation, local identity, science, and environmental education, as also demonstrated in Australia and the United States [4]. For example, according to Lindborg et al. [55], the positive perception of ES provision is dependent on the connection of people to the landscape, which has been linked to low-intensity primary activities (e.g., agriculture), where habitats maintained in a semi-natural landscape state can offer biological, cultural, and heritage values, a situation similar to that reported in Tubul-Raqui regarding the intensity of economic activities. Regarding science,

the opportunities for scientific research and environmental education were also highly recognized; the perception of these two services could be related to the large number of studies carried out in the wetland due to the environmental problems that emerged after the 2010 earthquake with various groups of scientists conducting research aimed at assessing the impact and socio-environmental recovery of the system [33,34,37,39] where studies have involved surveying the population and the use of artisanal fishing boats.

Regarding the negative valuation of provisioning services, in the case of water, fuelwood, livestock, and crop development, the results were impressive, especially in water provision, which could have been influenced by the inherent environmental conditions of the system with its low-quality soils and brackish water that do not favor intensive extraction activities or the provision of these services [39]. This situation was in agreement with Bouahim et al. [3], who stated that an increased perception of provision was related to the dependence of the survey respondents on the corresponding ES provision. Algae and fish obtained a greater valuation, even though the official data indicated a significant drop in pelillo extraction, an increase in unemployment, and a decrease in incomes following the 2010 earthquake [37]. Indeed, Marin et al. [54] indicate that navigation and algae services were completely lost after the event. In this study, the greater social perception of the fish and algae production service is explained by three factors. First, this valuation can be explained by the influence of categorical variables, which revealed a greater perception of the service and its benefits by young people, ethnic groups, and people not connected to the primary economic sector, which are also groups that mostly do not engage in extraction activities, a key aspect for making an accurate valuation of the ecosystem service [7], a situation related to the selection procedure of the population inherent to the study.

A second factor is related to the General Fisheries and Aquaculture Law of Chile, which establishes a 5% increase in extraction quotas following catastrophic events, allowing the extraction of other commercially important species in Tubul to be increased in order to strengthen the local economy (Fisheries and Aquaculture Law Number 20.657, 2013). Finally, despite the substantial physical and environmental disturbances resulting from the tsunami, pelillo extraction exhibited a gradual recovery in 2012, which is supported by recovery of the physical structure of the habitat and the aquatic biota two years after the event in Reference [39]. However, Aswani et al. [14] indicated that social recovery was not always concurrent with environmental recovery, which is undoubtedly related to the perception level of the population; possibly, this environmental recovery will influence the recovery of balance in the exploitation of ES in the Tubul-Raqui wetland, as evidenced by Marin et al. [54].

As previously mentioned, the perceived benefits detected in this study were influenced by the independent categorical variables of gender, age, and ethnicity. However, the main differences were reported regarding gender; for example, the perceived values for hazard regulation services varied strongly, with primarily women recognizing their importance. Possibly, the differences in gender perception may be related to the post-disaster economic effects, which were significantly higher among female gendered persons, who experienced substantial impacts to their labor activities, family incomes and unemployment rate, which reached nearly 31% [37]. The importance of gender is relevant to perception and has also been recognized in other Mediterranean case studies [3,29]. The differences were smaller in the education and economic sector of the sample, most likely due to the rural and socioeconomic homogeneity of the local population; for example, in the case of education, the percentage of inhabitants with college-level studies was minimal, a situation similar to other fishing villages in Chile [56]. A study of sociocultural valuation done in a nature park in Spain showed that the main characteristics that influenced the valuation were age, place of residence, and education [28]; however, the level of education in that study was higher than that reported in Tubul. Finally, regarding the age variable, we obtained results similar to those of Oteros-Rozas et al. [29], with young people having the highest perception of food-related services and older people having the highest perception of the habitat for species services.

Finally, the perception of the ES provision 50 years in the future indicated a proportion of stability and a decrease in services; in the drivers of loss, it was observed that the main causes pointed to anthropogenic factors (contamination and the forestry industry), with natural factors ranked second. According to Zorrilla-Miras et al. [12], engines of change are generally interrelated. Indeed, in the Mediterranean region of Chile—specifically in the closer coastal area—increases in production and industrial activities, population, and the level of urbanization have been associated with the loss of surface and biodiversity of these kinds of ecosystems [57–59]. The spread of exotic species such as *Pinus radiata* is a threat to wetlands as it affects native flora and fauna and causes an alteration in ecosystem functions. Furthermore, it has also been shown that *Pinus radiata*, with its widespread growth as a monoculture, absorbs a substantial amount of water, therefore decreasing its availability, generating soil changes, and affecting livestock and agricultural activities due to high soil acidity and erosion [39,42,60].

Additionally, natural disasters, as one of the key interests in this study, was the ninth driver of change mentioned by people, despite the scientific community recognizing that the decrease in ES provision (resulting from coseismic uplift of the  $M_W = 8.8$  earthquake), was linked mainly to the loss of pelillo. Future research could address the phenomena related to the time of personal exposure to these drivers. While pollution and the forestry industry have a more prolonged effect, events such as earthquakes and tsunamis have a shorter duration, making it possible that people with a long history in the location understand that these disturbances occur at certain time intervals and that measures to address them must be developed [13]. This assessment of the perceptions of drivers of loss could be used to manage actions related to conservation, preservation, and the restoration of the system [61] by considering that the opinion of the population is a fundamental element in the current territorial management instruments.

## 5. Conclusions

Salt marshes are sensitive to natural disturbances, as reported following the 2010  $M_W = 8.8$  earthquake-tsunami in Chile. The perception of ES provision after a major disaster was significantly more important in cultural and regulating services; in this sense, residents identified habitat for species, recreation, and hazard regulation as the most important ES. Perception was influenced by the categorical variables of gender, age, and ethnicity; for example, hazard regulation services varied strongly by gender, where the strong post-disaster socioeconomic effects experienced by persons of female gender could be related to their greater perception of this ES. In addition, in the provisioning services category, the fish and algae production were more valued, possibly due to the slight recovery of the activity, but is still at levels that are far below those of the pre-earthquake period (before 2010). In relation to scenarios of ES provision in the next 50 years, the inhabitants of Tubul-Raqui indicate that ES will remain stable (50%) or decrease (40%), mainly due to anthropogenic drivers (contamination, the forestry industry); the effect of natural disasters was not mentioned among the main future drivers of change.

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