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Artisanal Fisher Association Leaders' Estimates of Poaching in Their Exclusive Access Management Areas

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In marine environments, poaching can become a key threat to marine ecosystem conservation. Poaching can occur in marine protected areas and/or in fishery management areas. Unfortunately, understanding the magnitude and characteristics of poaching under community based and co-management governance schemes in coastal and marine environments, has not received the attention it deserves. In Chile, a system of Territorial Users Rights for Fisheries (TURF) has been recognized as one of the largest experiences of small-scale fisheries co-management at a global scale. Currently, poaching is one of the main threats to the TURF system in Chile. In this article, we assessed poaching of a highly valuable benthic resource (*Concholepas concholepas*) from TURF management areas. We estimated artisanal fisher association leaders' perceptions of poaching within their TURFs and explore determinants of poaching for *Concholepas concholepas.* Poaching of *Concholepas concholepas* showed differences along the studied sites. As expected, the greater abundance of *Concholepas concholepas* in the management areas generates an increased incentive to poach. Areas that make the greatest investment in surveillance are those most affected by poaching. However, our study cannot determine the effectiveness of current levels of surveillance on illegal extraction. Results show older areas tend to reduce the levels of illegal extraction, which could indicate a greater capacity and experience to control poaching. Supporting fisher associations in enforcing TURFs and following up on sanctions against perpetrators are conditioning factors, highlighted by fisher leaders, for TURF sustainability. The approach used in this study provides insights to prioritize geographies and opportunities to address poaching in small-scale co-managed fisheries.

Keywords: ***Concholepas concholepas*, traditional knowledge, illegal fishing, benthic, AMERBs, TURF, poaching, Chile**

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INTRODUCTION

Illegal, unreported, and unregulated fishing (IUU) is one of the main threats to marine ecosystem conservation worldwide (Agnew et al., 2009; FAO, 2020). IUU directly impacts the sustainable management of fisheries, hindering the recovery of stocks, and contributing to the loss of marine biodiversity (Pikitch et al., 2005; Tesfamichael and Pitcher, 2007; Raemaekers et al., 2011). IUU leads to inappropriate fishing practices and encourages informal trade (Sumaila et al., 2006; Cabral et al., 2018; Pramod et al., 2019). In addition, IUU has caused the loss of billions of dollars from regulated fishing system (Varkey et al., 2010; Doumbouya et al., 2017), with estimates between $10 bn to $23.5 bn worldwide (Agnew et al., 2009). Therefore, controlling and reducing illegal fishing is an international priority and is a sustainable development goal of the United Nations (FAO, 2020).

Poaching is a type of illegal fishing (Plagányi et al., 2011), defined as illegally hunting birds, animals or fish on somebody's property or without permission (Hill, 2015). Poaching refers to the killing or removal of flora and fauna for trade or personal use, commonly observed in protected or management areas (Hill, 2015). This kind of illegal wildlife harvest has become one of the largest threats for biodiversity conservation worldwide (Harrison, 2011; Ayling, 2012; von Essen et al., 2014). In addition, wildlife crime entails significant social and economic problems, increasing vulnerability to local communities (Moreto, 2018). Poaching of wildlife has critical ecological consequences (Lemieux and Clarke, 2009; Bouché et al., 2010) and can generate negative impacts on the livelihoods and culture of local communities (Bowen-Jones et al., 2003; Bell et al., 2007; Sethi and Hilborn, 2008; Kahler and Gore, 2015). Accordingly, there is a growing interest in characterizing and evaluating poaching of wildlife to develop plausible solutions and intervention strategies (Bell et al., 2007; von Essen et al., 2014).

In marine environments, poaching can become a key threat to marine ecosystem conservation (Samoilys et al., 2007; Battista et al., 2018; Ballesteros and Rodríguez-Rodríguez, 2018a,b; Okes et al., 2018; FAO, 2020) and can occur in marine protected areas and/or in fishery management areas with formal or informal access right arrangements (Sethi and Hilborn, 2008; Silvy et al., 2018). Poaching may reduce the capacity of community-based natural resource management and co-management systems to deliver social, ecological, and economic improvements through sustainable use (Samoilys et al., 2007; Campbell et al., 2012; Harasti et al., 2019). Therefore, understanding poaching is particularly relevant as governments and natural resource management agencies increasingly attempt to improve compliance, devolving legal responsibility for surveillance, and enforcement to resource users (Linkie et al., 2015; Weekers et al., 2019, 2021; Thiault et al., 2020). Because poaching is illegal, efforts to engage resource users in enforcement to deter poaching could have serious repercussions such as increased conflict and retaliation by poachers (Moreto, 2018).

Studies have addressed IUU from different perspectives. Some studies focus on the underlying motivations for people to comply or not with regulations (Oyanedel et al., 2020), other studies focus on opportunities for IUU and assume that illegal behavior is not distributed randomly across space and time. These studies focus on the role that the immediate environment plays in illegality (Oyanedel et al., 2020). Opportunity based approaches are key to determine patterns of poaching by external fishers under community based and co-management governance schemes, but have not received the attention they deserve (Curcione, 1992; Bell et al., 2007).

Poaching control and monitoring activities require an understanding of context-specific drivers, as well as its spatial and temporal distribution (Oyanedel et al., 2020; Thiault et al., 2020). Studies have shown that poaching tends to be concentrated in determined geographic locations and periods of the year (Brill and Raemaekers, 2013; Weekers et al., 2019, 2021; Weekers and Zahnow, 2019; Thiault et al., 2020). These studies suggest that poaching is not random, but rather a highly structured activity that relates to the characteristics of the protected and managed areas, and the individual incentives and perceptions of poachers (Moreto and Pires, 2018). The patterns of space, time, and individuals associated with poaching enable the identification of intervention hotspots (Kyando et al., 2017; Weekers et al., 2019, 2021; Thiault et al., 2020). Understanding social dynamics associated with these hotspots can further provide authorities and managers with information to enhance control and surveillance efforts (Hill, 2015; Moreto and Lemieux, 2015).

Poaching can become a main threat for well-intended policies that aim toward increased participation and co-management of resources (Hill, 2015). In Chile, a system of Territorial Users Rights for Fisheries (TURF) (known in Chile as Management and Exploitation Areas for Benthic Resources, AMERB for its acronym in Spanish) has been recognized as one of the largest experiences of small-scale fisheries co-management at a global scale (Leiva and Castilla, 2002; Prince, 2005). Currently, poaching from fishers who are not part of the fishing associations responsible for management, is one of the main threats to the TURF system in Chile (Gelcich et al., 2017; Oyanedel et al., 2018). Accordingly, poaching is jeopardizing sustainability in Chile's fisheries system and has become a priority for the national government (Oyanedel et al., 2018; Donlan et al., 2020). Here, we assessed poaching of one of the most highly valuable benthic resource (*Concholepas concholepas*) from TURF management areas. We focus exclusively on poaching carried out by fishers/divers external to the associations that have the legal right to manage the TURF. We assess artisanal fisher association leaders' perceptions of poaching within their TURFs and explore patterns and determinants of poaching for *Concholepas concholepas*.

MATERIALS AND METHODS

Research Setting

In the early 1990s, Chile initiated a governance transformation in the fishery system and assigned exclusive TURF to artisanal fisher associations for the management of benthic resources (Gelcich et al., 2010). The shift toward a TURF model was driven by the failure of more traditional top-down approaches based on global quotas, which caused deterioration of some fisheries, economic losses, and social disruption (Orensanz et al., 2005). In the TURF system, fisher associations must perform stock assessments with the help of biologists and establish monitoring and surveillance protocols. The TURF co-management system has generated important benefits for conservation and fisher associations (Gelcich et al., 2019). Ecologically, studies show a greater abundance and richness of organisms in TURFs compared to open access fishing areas (Gelcich et al., 2008, 2012; Blanco et al., 2017). Socially, the Chilean TURF system has strengthened the participation of artisanal fishers in the administration of marine resources, building social capital and developing stewardship in many communities (Gelcich et al., 2013: Rosas et al., 2014).

In 2018, the Chilean TURF system had 531 active management areas administrated by 392 fisher associations, covering a surface area of approximately 1,240 square kilometers, and benefiting more than 7,000 artisanal fishers (Ariz et al., 2018). Although there are 45 benthic species that can be included within the TURF management plans, most organizations direct their commercial efforts at extracting the gastropod *Concholepas concholepas* as the main target species (Ariz et al., 2018). This resource has a high value in both the domestic and international markets. Unfortunately, a study of more than 55 communities along the Chilean coast determined that poaching of *Concholepas concholepas,* from fishers/divers external to the organizations, was the main threat of the TURF system (Gelcich et al., 2017). Poached catch can be sold directly by the poachers to consumers (general public, restaurants, and hotels, etc.), intermediaries and processing plants (Bandin and Quiñones, 2014; Castilla et al., 2016; Donlan et al., 2020). These actions endanger the sustainability of the TURF system and the safety of fisher communities (Oyanedel et al., 2018).

In Chile, TURF areas present heterogeneous characteristics both in biological, spatial, and organizational aspects (Chevallier et al., 2021). This study focused in management areas located between the city of Tal Tal (Antofagasta region, 70,4°W and 25,5 south latitude) and Ancud (Los Lagos region, 74,1°W and 41,2° south latitude), which includes 82% ($N = 397$) of the active management areas in the TURF system (Ariz et al., 2016). The study area was divided into two zones, using as a reference the classifications of Jaramillo et al. (2006) and Spalding et al. (2007). The northern area (24° to 33° south latitude) includes the Humboldtian and Central Chile bioregions (Spalding et al., 2007), which correspond to the biogeographic zones I (northern Chile), II (northern buffer), III (Transitional north-central), and IV (central buffer). The southern area (33° to 48° south latitude) includes Araucanian and Chiloense bioregions (Spalding et al., 2007), which correspond to the biogeographic zones V (Transitional center-center), VI (south central buffer), and VII (southern Chile) (**Table 1**). Preliminary unpublished studies on poaching indicate the existence of potential differences between these two macro- zones (north and south).

Research Approach

Characterizing and quantifying poaching presents difficulties because it is a clandestine activity. For this, diverse qualitative and quantitative approaches have been used to estimate IUU (Varkey et al., 2010; Cisneros-Montemayor et al., 2013; Oyanedel et al., 2018, 2020; Donlan et al., 2020; FAO, 2021). Remote camera surveillance (Harasti et al., 2019), aerial observations (Smallwood and Beckley, 2012), confiscations data, and reported incidents (Brill and Raemaekers, 2013; Weekers and Zahnow, 2019) have been used to estimate poaching levels. In addition, social sciences provide key methodological tools to characterize and estimate poaching (Arias et al., 2016). These approaches allow valuable local knowledge of experts and public officials to be brought to bear (Oyanedel et al., 2018; Donlan et al., 2020). Techniques developed in the field of psychology, sociology and economics can reduce the biases of information based on perceptions and stakeholders' knowledge (Oyanedel et al., 2018; Donlan et al., 2020). This includes qualitative and quantitative techniques for the collection of poaching data (Brill and Raemaekers, 2013; Cisneros-Montemayor et al., 2013; Kahler et al., 2013; Bergseth et al., 2017; Silvy et al., 2018; Donlan et al., 2020).

TABLE 1 | Characteristics of the management areas in the study zone.

Administrative regions	Biogeographic zones	Study zones	Total TURF	Associations surveyed
Antofagasta	(a) Humboldtian and Central Chile (b) Zone I-IV	North	6	2
Atacama			19	10
Coquimbo			49	28
Valparaíso			12	7
Bio Bío	(a) Araucanian and Chiloense (b) Zone V-VII	South	6	6
Los Ríos			30	15
Los Lagos			45	32
Total			167	100

In this study, we used the traditional knowledge of artisanal fishers to describe and quantify poaching in TURF. The participation of fishers in the estimation of illegal fishing is valuable, not only because it allows the inclusion of the fishers' knowledge, but also because it strengthens the legitimacy of control and enforcement measures (FAO, 2021). For example, a recent study in Chile showed that artisanal fishers' knowledge is a reliable source of information for estimating abundance of *Concholepas concholepas* in TURF (Garmendia et al., 2021). However, certain limitations should be considered when using expert knowledge to make quantitative estimates, such as overconfidence, biases, and lack of replicability (Burgman, 2016).

We surveyed representatives of 100 artisanal fisher associations that operate TURFs in the study area, 47 in the northern zone and 53 in the southern zone (**Table 1**). This represents 55% of the associations that reported extractive activity in their TURF in 2017–2018 within the study area. **Figure 1** shows examples of landscapes in the northern and southern zones of the study. In each association, a questionnaire was applied to a board member (president, secretary, or treasurer of the fisher associations) to characterize and quantify the levels of poaching within their management area. In these associations, the board members are fishers who have a high level of knowledge of the resources available in the TURF. These positions are held by highly experienced fishers who are respected by the community, which has been reported in other studies on poaching in TURF (Ballesteros et al., 2017).

The questionnaire was composed of three sections (see questionnaire in **Supplementary Material**). The first section focused on quantifying poaching. The second section focused on characterizing poaching. Finally, the third section focused on the costs incurred for the management and surveillance of the TURF. In December 2016, the survey was pre-tested in four fisher associations to evaluate the correct understanding of the questions by the respondents. In 2017 and 2018, the questionnaire was applied to 100 representatives of fisher

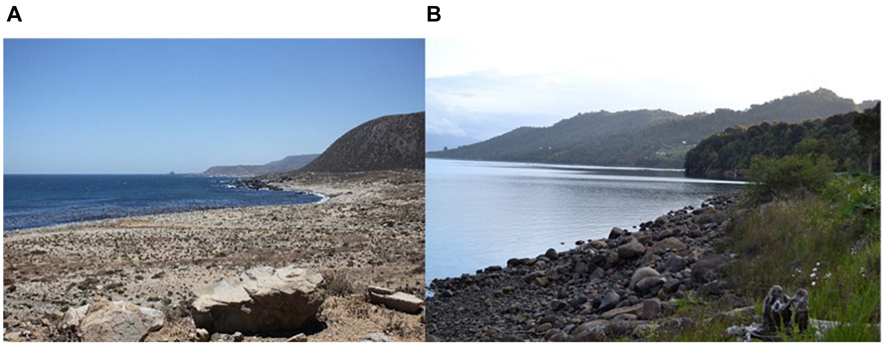

FIGURE 1 | Examples of landscapes in the northern and southern part of the study area. **(A)** Caleta Los Sauces in the northern study area. **(B)** Hualaihue Estero in the southern study area.

TABLE 2 | Indicators for evaluation and comparison of illegal activity within management areas.

Indicator	Purpose	Equation
Daily poached (unit/day) (DP)	Amount of *Concholepas concholepas* extracted illegally in one day from management areas (*i*)	$DP = \frac{\sum_i (Q_i)}{I}$
Poaching events (days) (PE)	Days of illegal events (E) per individual (*i*) within the management areas per year	$PE = \sum_i (E_i)$
Poaching proportion of total quota (% of TAC) (PPP)	Relationship between the daily poached (DP) with respect to the *Concholepas concholepas* Total Allowable Catch (TAC) for each management area (*i*)	$PPP = \frac{DP}{TAC_i}$
Investment in surveillance ratio (ISR)	Percentage of annual monitoring costs (S) with respect to the total cost of area management (TC)	$ISR = \frac{S}{TC}$
Percentage of complaints to the authorities (PC)	Ratio of the number of complaints to the authorities (C) to the number of poaching events (E) in each management area (*i*)	$PC = \frac{C}{\sum_i (E_i)}$
Sanctioned poaching events (SP)	Ratio of number of detentions (A) made to number of poaching events (E) in each management area (*i*)	$SP = \frac{A}{\sum_i (E_i)}$

associations distributed in the study area (**Table 1**). The levels and characteristics of poaching were assessed with a set of indicators, including harvesting, reporting to authorities, and surveillance cost (**Table 2**).

The comparison between geographic areas (north versus south, **Table 1**) was performed with a non-parametric Mann-Whitney test. In addition, a multivariate linear regression model analysis was conducted to assess the effect of independent variables on levels poaching. The independent variables used were the abundance of the resource in the TURF, cost of surveillance, distance to ports, number of members in the association, and antiquity of the area. These data were extracted from the public databases provided by the government services. The evaluation of the multiple regression model was carried out by the stepwise backward method using the AKAIKE criterion to identify the significant variables. For the multivariate linear regression model, residue normality (error), homoscedasticity, multicollinearity, and autocorrelation were evaluated to ensure that the predicted model meets assumptions. Statistical analyses were performed in R (version 3.5.3).

RESULTS

In the study area, 83% of the fisher associations declared to be affected by poaching (N = 83) of which 84% indicated that the main resource being poached was *Concholepas concholepas* (N = 70). **Figure 2** shows the geographical distribution of the assessed indicators. Poaching events varied between 24 and 200 days per year per management area (mean = 78 days). Higher frequency of poaching was detected in the northern zone (mean = 87.0) than in the southern zone (mean = 66.7), although these differences were not statistically significant (**Table 3**). The daily poached (unit/day) in each management area varied between 50 and 1500 units per day (mean = 337 units). The highest average daily poached amounts occurred in the southern zone (mean = 425.6, ranged from 70 to 1,500 units per day) in comparison to the northern zone (mean = 240, ranged from 50 to 500 units per day), although differences were not statistically significant (**Table 3**).

On average, the poaching of *Concholepas concholepas* represented 98% of the estimated Total Allowable Catch (TAC) assigned to each management (confidence interval of 78% to 118%). The poaching proportion of total quota was higher in the southern zone (mean = 124.15%) versus the northern zone (mean = 80.9%) ($p < 0.01$) (**Table 3**). Considering a TAC of 11,260,091 units of *Concholepas concholepas* for the year 2017—and extrapolating the results of the sample to the total of management areas at the national level—poaching could generate losses between 8.7 and 13.5 million units of *Concholepas concholepas*, valued at between US$ 7.4 and 11.4 million dollars

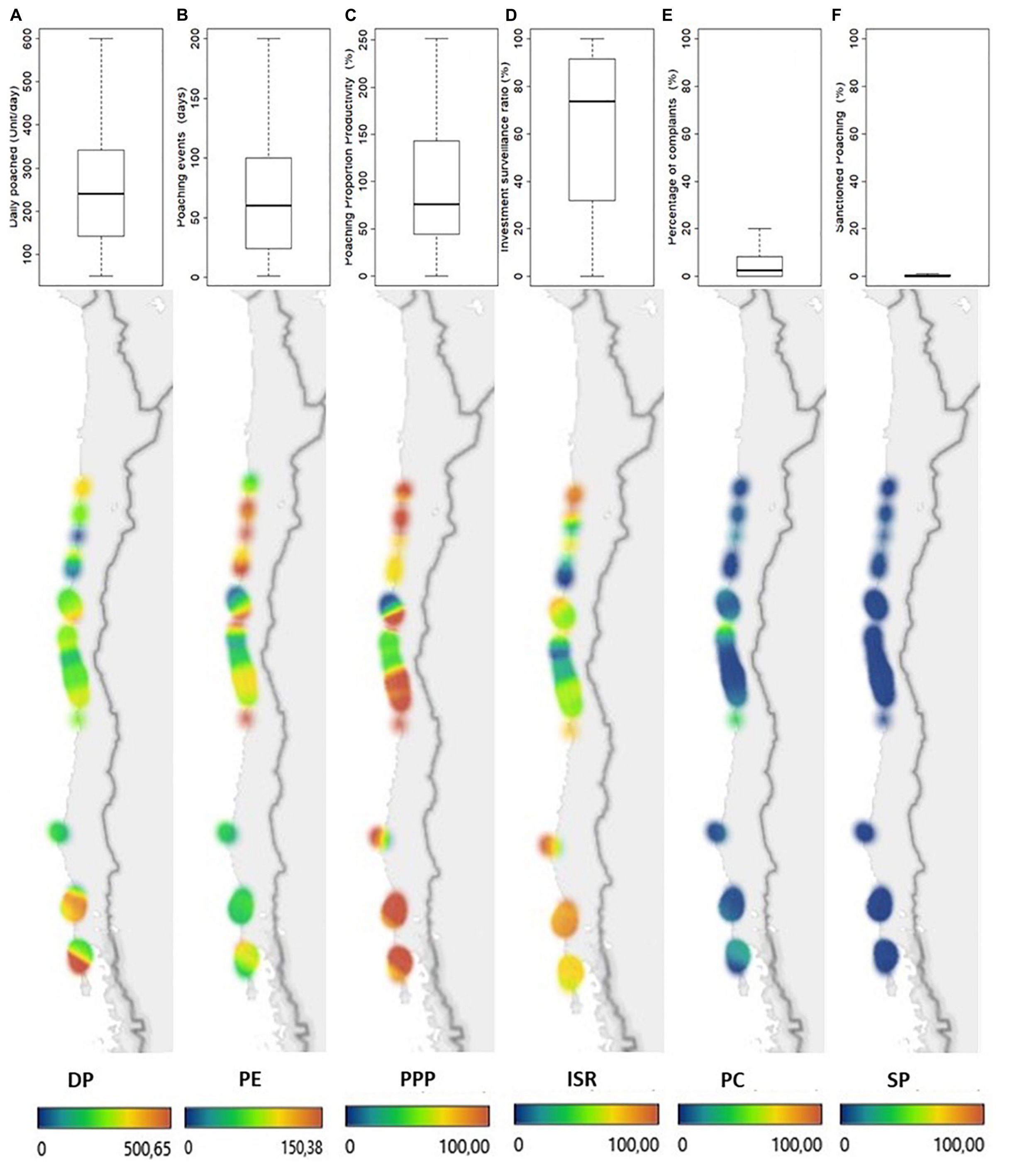

FIGURE 2 | Geographical comparison of indicators related to poaching: **(A)** daily poached (DP); **(B)** poaching events (PE); **(C)** poaching proportion of total quota (PPP); **(D)** investment in surveillance ratio (ISR); **(E)** percentage of complaints to the authorities (PC); and **(F)** sanctioned poaching events (SP), period 2017–2018.

for 2017–2018, considering a value of USD1.18 per unit of *Concholepas concholepas* (value for 2017).

The characteristics of poaching differ between the northern and southern areas of the study area. In the southern zone, poaching is mostly carried out by boats that operate in groups of 3 to 10 individuals, which extracted from several management areas per day. This might explain the higher levels of poaching detected. In the northern zone, poaching is mostly carried out by divers who enter the management areas from the shore, which limits the number of units extracted illegally. The higher frequency of poaching events in the northern zone could be explained by the better climate conditions, which allow the

TABLE 3 | Mann-Whitney analysis to evaluate differences between the northern and southern zones.

Indicator	Average North	Average South	*W*	*P*
Daily poached (unit/day) (DP)	240	425.6	374.5	0.103
Poaching events (days) (PE)	87	66.7	721.5	0.167
Poaching proportion of total quota (% of TAC) (PPP)	80.9	124.15	392	0.001**
Investment in surveillance ratio (ISR)	47.58	80.32	212.5	0.0002**

*** denotes a level of significance less than 1%.*

TABLE 4 | Multivariate regression model associated with the response variable "daily poached."

Intercept	Estimate	Std. Error	*t* value	*p*
	1.390.178	**1.722.178**	**0.807**	**0.4234**
Abundance of the resource (ln)	370.628	149.652	2.477	0.0167*
Antiquity of the area	−0.92973	0.53871	−1.726	0.0906
Distance to ports	−0.02569	0.03219	−0.798	0.4286
Surveillance Cost (ln)	0.57430	0.25083	2.290	0.0263*
Number of members	0.03253	0.03343	0.973	0.3351

Multiple R-squared: 0.3308 and adjusted R-squared: 0.2639.
F-statistic: 4.944 on 5 and p-value: 0.0009381.
** denotes a level of significance less than 5%.*

extraction of marine resources during most of the year. Due to the clandestine nature of poaching, it is not clear whether this extraction is carried out by fishers who live in or near the localities local or if they are external to local communities and travel different distances. In addition, interviewees highlight that illegal resources are sold in local markets, although there is no precise information regarding how and where these resources are sold.

The average expenditure on surveillance actions was USD $22,000 per year per management area, which represents 73% of the average total management cost for each management area (Investment in Surveillance Ratio). Expenditures on surveillance are mainly allocated to hiring guards or paying fishers for time spent in enforcement activities. Enforcement commitments can vary from those established all year-round and during the day and night, to situations where enforcement occurs only when sea conditions are good or during the harvest season. In the southern zone, the average expenditure on surveillance was US$ 16,978 per management area per year. In the northern zone there was a greater expenditure on surveillance with an average of USD $28,496 per management area per year. However, in the northern zone, expenditure on surveillance in relation to total administrative costs is significantly higher than in the northern zone (p-value < 0.01) (**Table 3**). On average, only 8% of poaching events were reported to the authorities, although up to 75% of poaching events were reported in some management areas. At the same time, a low level of sanctioned poaching events were reported (mean = 9%).

The multivariate linear regression model shows a low determination coefficient (Multiple R-squared: 0.33; p-value < 0.01), which is expected for heterogeneous units of analysis. In the model a greater abundance of *Concholepas concholepas* in the TURF leads to an increase in daily poached units (p-value < 0.05) (**Table 4**). Higher biological productivity in management areas seem to generate incentives for illegal activities. Similarly, areas that invest more in surveillance (Surveillance Cost) are the most affected by poaching (p-value < 0.05). In addition, older areas tend to reduce levels of illegal extraction, which could indicate a greater capacity and experience to control poaching (p-value = 0.09).

DISCUSSION

In Chile, poaching is a serious threat to the sustainability of the TURF system (Gelcich et al., 2017). In this manuscript we focus on estimating poaching performed by fishers/divers external to the organization that manages the TURF. In this way we complement studies on under-reporting and poaching by members within the fisher associations (Oyanedel et al., 2018). Poaching of *Concholepas concholepas* showed differences along the studied sites. The highest amount of poaching were concentrated in the southern part of the country. In the northern zone, the volume of illegally extracted resources was lower than in the southern zone although the frequency of illegal events was higher. This can be explained by the productivity of the system (Anguita et al., 2020) and the fact that in the southern zone poaching is mostly done by groups of people entering the TURF in several boats, as opposed to the northern zone where poaching is mostly done by divers accessing the TURF from the shore. Other studies have reported that the use of boats increases levels of illegal extraction (Ramajal et al., 2016). As expected, the greater abundance of *Concholepas concholepas* in the management areas generates an increased incentive to poach. Similarly, the areas that make the greatest investment in surveillance are those most affected by poaching. However, our study cannot determine the effectiveness of surveillance on illegal extraction. On the other hand, older areas tend to reduce the levels of illegal extraction, which could indicate a greater capacity and experience to control poaching. This may be due to greater experience in implementing surveillance systems and/or established networks of contacts with government services for surveillance purposes.

Monitoring poaching of *Concholepas concholepas* is key to determine its level of threat and evaluate conservation strategies. Since poaching is an illegal activity, seldom registered by government agencies, available information is scarce. In these highly uncertain decision-making scenarios, local knowledge is a valuable source of information, especially in coastal communities and fisheries (Burgman, 2016; Garmendia et al., 2021). In this study, the representatives of the fisher associations surveyed focused their estimates on TURFs under their management, where they regularly conduct dives for monitoring and evaluation of available resources. This work complements other methodological advances for estimating poaching in the Chilean TURF system. Oyanedel et al. (2018) applied a randomized response technique to estimate poaching of *Concholepas concholepas* in central Chile. These authors conclude that between 83,505 and 224,703 individuals per month were harvested illegally in Valparaiso region (the lower volumes are explained by the fact that the Valparaiso region has a lower number of TURFs, and quotas of *Concholepas concholepas* are less than other regions of the country). On the other hand, Fernández et al. (2020) found that TURFs are effective in reducing catches below the legal minimum size, compared to open areas.

The use of expert elicitation techniques and local knowledge has been recognized as a valid source of information for natural resource management (Kahindi et al., 2010; Hemming et al., 2018). Particularly when structured methods are used for the collection of these data (Estévez et al., 2019). Data based on experts and local knowledge should be used in a complementary manner with biological and ecological information (Kahler and Gore, 2015). In this sense, there is an important challenge to establish control and monitoring systems for the poaching of benthic resources. Sustainable wildlife management will depend in part on the ability to integrate diverse sources of knowledge that allow for a comprehensive understanding of poaching.

A central element in reducing non-compliance and poaching is the likelihood of being detected when illegally extracting the resource, as well as the legal consequences that poaching entails (Kuperan and Sutinen, 1998; Bergseth and Roscher, 2018). In the case of poaching in TURF areas for *Concholepas concholepas*, fisher associations spend an average of USD 22,000 on surveillance, which represents about 75% of the total costs of operation. This important effort of the fisher associations contrasts with the low level of formal complaints to the authorities for poaching events (8% on average) and the low level of sanctions with respect to the formal complaints (9% on average). In this sense, it would be advisable to evaluate whether the transaction costs of implementing coercive measures are so high as to make them economically unviable. On the other hand, it is important to consider the existence of chronic offenders, who engage in illegal behaviors without caring about fines or sanctions (Kuperan and Sutinen, 1998; Sutinen and Kuperan, 1999). This is a great challenge for the authorities, where it is urgent that the surveillance effort of the organizations leads to a greater capacity of control and sanction from the government services. One of the reasons for the low level of complaints to the authorities is "*the complexity of the process, as well as the difficulties in generating evidence of poaching*" (fisher interviewed). When fishers/divers are caught at sea poaching, "*they return the resources to the sea before they are captured*" (fisher interviewed). This discourages fisher associations from filing complaints with the competent authorities. For this, it is necessary to establish abbreviated procedures for complaints, as well as to evaluate a regulatory change that establishes sanctions for entering the TURF area without permission.

Poaching control cannot be based solely on coercive actions. Fishers' awareness of the negative impact of poaching on the ecosystem and the co-management system is an enabling condition for its control (Bergseth and Roscher, 2018). In addition, stakeholder participation in community-based management and the improvement of the communities' livelihoods tends to reduce poaching levels, over strategies based on poaching ban (Epanda et al., 2019; Gaodirelwe et al., 2020a,b; Garmendia et al., 2021). In addition, poaching bans may be associated with situations of poverty, exclusion from access to territorial rights, and moral concerns (Sutinen and Kuperan, 1999; Gezelius, 2002). International evidence has showed that coercive measures in shellfish communities highly dependent on shellfish resources can be counterproductive (Ballesteros and Rodríguez-Rodríguez, 2018a,b, 2019). In these communities, some poaching actions (generally due to necessity, poverty, unemployment, or self-consumption) may be acceptable and allowed by the members of the sea communities. However, in the case of Chile, poaching levels indicate that it does not involve subsistence activities, but rather the provision of illegal resources to a highly lucrative informal market. Thus, poaching is one of the main concerns for the sustainability of TURFs according to fisher associations (Gelcich et al., 2017). Accordingly, in co-management regimes, poaching control should combine coercive measures with organizational strengthening and participatory monitoring, which promote compliance (Ballesteros et al., 2021). Therefore, understanding human perceptions of IUU and their motivations is a starting point for proposing comprehensive control strategies (Reyes et al., 2009; Kahler and Gore, 2015; Ballesteros and Rodríguez-Rodríguez, 2018a,b; Epanda et al., 2019). This poses an important challenge for Chile, in which the characterization and quantification of attitudes and motivations for IUU is necessary to make progress in in the sustainable management of fisheries (Hampshire et al., 2004).

We compared our results with a market study that estimated the frequency of consumption of hydrobiological resources in Chile (Lohse et al., 2017). Lohse et al. (2017) found that 51% of the buyers acquire the resource once a year, 23% every 2 to 3 times a month, 17% once a month, and 4% once a week. Based on this information, we estimate an approximate national demand of 14 million units of *Concholepas concholepas* by year. Considering this national demand, the official national landing in 2017 (data provided by SERNAPESCA), and international supply for the same year (Romero et al., 2019), the illegal extraction of *Concholepas concholepas* would be approximately 12,600,000 units a year. This corresponds to 112% of the national quota granted for the period 2017. Based on these results, the economic loss for artisanal fisher associations due to the illegal extraction of *Concholepas concholepas* would be between USD $15,336,611 and USD $7,668,306 (considering the price of the unit of *Concholepas concholepas* as 50% less than the price of the legally extracted resource). Although, it is important to consider that these estimates include multiple types of illegality in the extraction of C*oncholepas concholepas* (e.g., the illegally extraction of the resource banned areas). This value is similar to our results, where an average of 98% of poaching was estimated with respect to the quota allocated to these organizations. Based in our results, losses at the national level were estimated between US $7.4 and $11.4 million dollars for 2017–2018.

Our study indicates that in the TURF system approximately 98% more than the TAC value assigned for each year is illegally extracted. High levels of *Concholepas concholepas* IUU have been reported previously (Oyanedel et al., 2018; Donlan et al., 2020). It will be necessary to evaluate the capacity of the ecological system to support these levels of legal and illegal extraction of *Concholepas concholepas* in the future. There is evidence that due poaching some organizations are not able to extract the complete TAC. It is also possible that some TAC are over or underestimated. In addition, identifying and addressing drivers of poaching, supporting communities enforcing TURFs, and enforcing sanctions against the largest perpetrators are urgent needs for action. The opportunity based approach used in this study is a key step to prioritize geographies and opportunities, however, actor based approaches, based on behavioral sciences, are still needed to enable novel framings to address non-compliance and illegality in small-scale fisheries.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

PeR and RAE conceived the study. PeR, RAE, PaR, and SG analyzed the data. PeR, RAE, PaR, and SG contributed with field work and analytical material. PeR, RAE, and SG wrote the manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2021.796518/full#supplementary-material

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