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Illegal fishing and territorial user rights in Chile

Rodrigo Oyanedel, * Andres Keim, Juan Carlos Castilla, and Stefan Gelcich *

Center of Applied Ecology and Sustainability (CAPES) & Centro de Conservacion Marina, Pontificia Universidad Católica de Chile, Avenida Libertador Bernardo O'Higgins 340, Santiago 8331150, Chile

Abstract: *Illegal fishing poses a major threat to conservation of marine resources worldwide. However, there is still limited empirical research that quantifies illegal catch levels. We used the randomized response technique to estimate the proportion of divers and the quantities of loco (*Concholepas concholepas*) they extracted illegally. Loco have been managed for the past 17 years through a territorial user rights for fisheries system (TURFs) in Chile. Illegal fishing of loco was widespread within the TURFs system. Official reported landings (i.e., legal landings) accounted for 14–30% of the total loco extraction. Our estimates suggest that ignoring the magnitude of illegal fishing and considering only official landing statistics may lead to false conclusions about the status and trends of a TURFs managed fishery. We found evidence of fisher associations authorizing their members to poach inside TURFs, highlighting the need to design TURFs systems so that government agencies and fishers' incentives and objectives align through continuous adaptation. Government support for enforcement is a key element for the TURFs system to secure the rights that are in place.*

Keywords: enforcement, fisheries conservation, noncompliance, poaching, randomized response technique, TURF

Pesca Ilegal y Derechos Territoriales del Usuario en Chile

Resumen: *La pesca ilegal presenta una gran amenaza para la conservación de los recursos marinos a nivel mundial. Sin embargo, todavía existen investigaciones empíricas limitadas que cuantifiquen los niveles de captura ilegal. Usamos la técnica de respuesta aleatoria para estimar la proporción de buzos y las cantidades de loco (*Concholepas concholepas*) que extraen ilegalmente. Los locos han sido manejados durante los últimos 17 años por medio de un sistema de manejo pesquero basado en derechos territoriales de uso (TURFs, en inglés) en Chile. La pesca ilegal del loco estaba distribuida ampliamente dentro del sistema de TURFs. Los desembarques reportados oficialmente (es decir, desembarques legales) representaban 14 – 30% de la extracción total de loco. Nuestras estimaciones sugieren que ignorar la magnitud de la pesca ilegal y considerar solamente las estadísticas de desembarques oficiales puede resultar en conclusiones falsas sobre el estado y las tendencias de una pesquería manejada por medio de TURFs. Encontramos evidencia de asociaciones de pesca que autorizan a sus miembros la pesca ilegal dentro de las TURFs, lo que resalta la necesidad de un diseño de sistemas de TURFs de tal manera que las agencias del gobierno y los incentivos y objetivos de los pescadores se alineen a lo largo de una adaptación continua. El apoyo del gobierno para la fiscalizacion es un elemento clave para que el sistema de TURFs asegure los derechos que están establecidos.*

Palabras Clave: aplicfiscalizacion, pesca ilegal, conservación de pesquerías, incumplimiento, técnica de respuesta aleatoria, TURFs

摘要: *非法捕捞是世界海洋资源保护主要的威胁。然而, 目前能够量化非法捕捞水平的实证研究还很有限。我们用随机应答技术估计了潜水者的比例以及他们非法捕捞智利鲍鱼(Concholepas concholepas)的数量。似鲍罗螺在过去的17年里虽然受到智利的渔业领土使用权系统 (TURFs) 的管理, 但在 TURFs 系统内, 对该物种的非法捕捞却仍然很普遍。官方报道的上市量(即合法上市量)仅占智利鲍鱼总捕捞量的14-30%。我们的估计结果显示, 如果忽视非法捕捞量, 只考虑官方公布的上市统计量, 可能会对智利鲍鱼保护情况和 TURFs 管理下的渔业产生错误的结论。我们还发现渔民协会授权其成员在 TURFs 区内非法捕猎, 这说明需要完善 TURFs 系统的设计,*

*Co-corresponding authors: Rodrigo Oyanedel and Stefan Gelcich; email royaned2@uc.cl; sgelcich@bio.puc.cl
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*使政府机构和渔民通过长期的相互适应达成动机和目标的一致性。政府对政策实施的支持是 **TURFs** 系统能保证权利到位的关键。* ***【翻译: 胡怡思; 审校: 魏辅文】***

关键词: 渔业保护, 渔业领土使用权 (TURF), 违规行为, 随机应答技术, 非法捕捞, 实施

Introduction

Illegal fishing poses a major threat to the effective conservation of marine resources (Sumaila et al. 2006) and has been linked to depletion of stocks, habitat destruction, and the failure of some fisheries management policies (Gonzalez et al. 2006; Agnew et al. 2009; Raemaekers et al. 2011). Furthermore, noncompliance with regulations can lead to detrimental social–ecological impacts, causing mistrust and tensions among resource users, regulators, policy makers, and the public that undermine fishery conservation efforts (Pitcher et al. 2002; Faasen & Watts 2007; Lewis 2015). Likewise, the underreporting of catch may produce distorted stock assessments, which in turn may lead to intensification of illegal activities (Sumaila et al. 2006). This is especially alarming where small-scale rights-based fishery management schemes are in place and fishers have a bigger stake in the fishery (Castilla et al. 2016).

During the last 30 years, there has been an increasing global trend toward implementation of rights-based fisheries comanagement approaches to alleviate the threat of overfishing (e.g., Costello et al. 2008; Castillla 2010; Gelcich et al. 2010). These approaches are gaining traction, and around 10% of global fish catches comes from some type of right-based management scheme (Arnason 2001; McClanahan & Castilla 2007; Costello et al. 2016). One type of rights-based fisheries management that is gaining traction is communal, comanaged territorial use rights for fisheries (TURFs). This approach assigns management and exclusive spatial rights for medium-scale and small-scale fisheries to a defined group of users such as a fleet, community, cooperative, or union. This structure grants fishers a long-term secure stake in the fishery that ideally confers stewardship incentives and encourages enduring sustainability of the resource (Castilla 2010). Unfortunately, illegal fishing can undermine the potential of user-right programs. Although the negative impacts of illegal fishing over fisheries managed through rights-based approaches has received some attention (e.g., Copes 1986; Raemaekers et al. 2011; Castilla et al. 2016), there is still limited empirical research that quantifies illegal catch levels for small-scale fisheries under such governance arrangements.

The first issue to overcome when dealing with illegal fishing is to produce robust estimates of the activity (Conteh et al. 2015). Researchers and policy makers have used several methods to assess the extent of illegal fishing activities; however, many approaches suffer from bias generated from the perception of risk among respondents asked to confess or report illegal behavior (Fox & Tracy 1986; Pitcher et al. 2002). One method that has been proposed as a viable option to overcome this bias and produce robust estimates of illegal resource use is the randomized response technique (RRT) and its variations (Greenberg et al. 1971; Blank & Gavin 2009; St John et al. 2011). The RRT provides respondents with a guarantee of anonymity because it consists of a randomized process (e.g., throwing a die) that determines whether the respondent should answer truthfully or not to a sensitive question; the interviewer does not know the results of the randomized process (Buchman & Tracy 1982). This method has been used extensively in psychological and sociological research to explore the extent to which sensitive issues, such as illicit drug use, are present in society (Fox & Tracy 1986). The RRT has been proposed as a tool to assess illegal resource use (Blank & Gavin 2009; Gavin et al. 2010; St. John et al. 2011). Although it has been used to examine the proportion of users engaged in illegal activities, such as illegal hunting in a national park (Solomon et al. 2007) or rates of violation of certain regulations (Blank & Gavin 2009), it has not been used to quantify the extent of these activities (Conteh et al. 2015). A variation of the traditional RRT method proposed by Greenberg at al. (1971) allows quantifying the extent of illegal behaviors and therefore is well suited for quantitative estimates of illegal catches that may be incorporated in stock assessments and management plans.

Since 1997 a pioneer TURF system has been in place in Chile to comanage near-shore benthic resources (Castilla & Gelcich 2008; Castilla 2010; Gelcich et al. 2010). In this system, organized unions of small-scale artisanal fishers apply for TURFs that allow exclusive access to fish a group of benthic resources (extracted by divers) over demarcated, small, coastal seabed areas (Castilla et al. 1998; Gelcich et al. 2010). The gastropod *Concholepas concholepas* (i.e., loco) is one of the most valued benthic shellfish resources in Chile, and since 2000 its extraction has been allowed only inside TURF areas. Although fishers have pointed out that poaching of loco is one of the biggest challenges in managing their TURFs (Gelcich et al. 2017), little research has been done to quantitatively estimate the extent of illegal fishing of loco in Chile (but see González et al. 2006; Bandin & Quiñones 2014). We used the RRT and its quantitative adaptation to estimate the proportion of divers and the quantities of loco extract illegally within the TURFs system in central Chile. We used these data to provide insights on how the TURF policy is performing and moreover how governance may

be improved in the Chilean TURFs system and around the world.

Methods

Research Setting

Chile designed an inshore benthic TURF comanagement system that was decreed in 1991 and implemented from 1997 onwards. Organized unions of small-scale artisanal fishers are granted TURFs in small, coastal seabed areas (Castilla 2010; Gelcich et al. 2010) upon meeting the legal requirement decreed for TURF assignments. Currently there are 809 officially designated TURFs, approximately 450 are in operation (Gelcich et al. 2017), and around 30,000 fishers engaged in TURFs (SERNAPESCA 2014). Benthic resources extracted from these TURFs must be reported to the National Fisheries Service (SERNAPESCA). Although fisher unions have the power to enforce internal norms, and therefore their members' actions, government agencies oversee enforcement to keep outsiders from poaching in union TURFs and avoid illegal fishing operations in open-access areas. Thus, the system is designed as a 2-tier enforcement scheme in which unions police their own fishers and collectively agreed-upon internal norms and the government assists in preventing outsiders poaching in TURFs. Although this description of the system is simplistic, in practice unions' lack of resources for surveillance and SERNAPESCA's reduced capacities undermine the effective enforcement of TURFs (Davis et al. 2017).

There are around 45 benthic species that can be included in TURF management plans (Gelcich et al. 2010). Most TURFs focus on the gastropod loco as the main target species (Castilla & Gelcich 2008; Gelcich et al. 2010). Under the TURF regulatory framework, illegal fishing of loco can take several forms: extraction of individuals under minimum legal size (<10 cm); extraction during fishing closures for biological reasons; extraction in the de facto open-access areas; extraction from within a TURF by free-riders who are not union members; and unreported extractions from TURF by union members. These actions jeopardize the TURF system in different ways. Illegal catch can be sold directly by fishers to consumers (general public, restaurants, hotels) or to intermediaries and processing plants (Bandin & Quiñones 2014; Castilla et al. 2016). Catch sold to intermediaries and processing plants is directed to domestic markets or exported illegally to Peru to be re-exported as Peruvian abalone (Gonzalez et al. 2006).

The capacity of fisher unions to enforce their TURF rules varies dramatically (Davis et al. 2015). For instance, in region V of Chile (central Chilean coast), the presence of poaching is generally mentioned as a constant threat by TURF members (Gelcich et al. 2017). But, despite the high levels of perceived poaching and the strong decrease of official loco landings (Castilla et al. 2016), the number of registered divers has been relatively constant in the last decade (Fig. 2). Decreased official landings could be interpreted as a sign of overexploitation or as a process by which illegal and unreported fishing is replacing legal catches. In Chile certain areas of coastal land are officially designated as *caletas*. These are strips of land above the high-tide mark that provide certain rights to users. These include the right to have access to the sea, land a boat, remove catch, and erect certain buildings (Gelcich et al 2005). We empirically quantified illegal catch with the RRT in 14 fishing caletas (Castilla et al. 1998) in region V (120 km of coast) and considered the different forms of illegality associated with loco extractions.

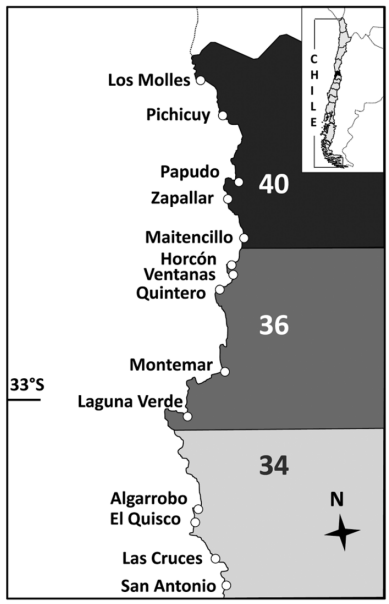

Figure 1. Study area in Chile (region V), the main fishing caletas, and the number of surveys of fishers administrated in each sector.

Survey Instrument

We developed a semistructured survey that we piloted with 20 artisanal fishers. After revising the survey considering the feedback form the pilot exercise, we sampled fishers from 14 out of 24 fishing caletas with registered loco divers along region V of Chile (Fig. 1). We selected caletas by dividing the area into 3 main sectors and choosing 5 caletas at random from the northern, central, and southern sectors. One president of a fishing union in the southern sector decided fishers in that union would not participate in the study.

Surveys were performed from December 2013 to March 2014. To adjust sampling to fisher-union governance structure, fisher union leaders were first

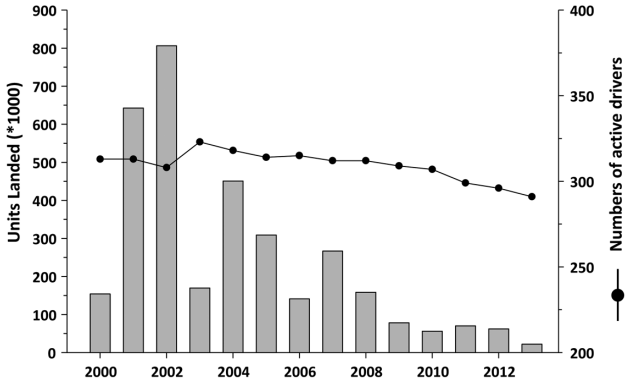

Figure 2. Government statistics on the number of locos legally extracted from territorial user rights for fisheries system and number of active divers from 2000 to 2013.

approached independently and told the scope of the study and its methods. Participating fishers were interviewed using a snowball sampling technique (i.e., new interviewees were identified through recommendations from previous participants) (Goodman 1961). Union leaders assisted in the initial identification of divers that were part of the association (unionized fishers). Snowballing led to surveying fishers who were not part of any organization (free-riders) and therefore did not participate in any TURF. To ensure survey design was adequate, we followed the recommendations of Fox and Tracy (1986). Surveys were performed by one interviewer, in private, and in a language that is locally relevant to fishers.

We surveyed 110 divers: 76 unionized and 34 free-riders. The RRT technique was applied, so respondents were anonymous. The survey had 3 sections: assessment of engagement in illegal fishing with the RRT technique; quantification of illegally extracted loco with the RRT quantitative adaptation (described below in "Quantification of Illegal Loco"); and assessment of markets and prices for illegally extracted loco. Before starting each survey, we informed respondents that the survey was voluntary and that they could refuse to participate or answer any particular question. The survey complied with the ethical requirements of the Pontificia Universidad Católica de Chile.

Proportion of Fishers Engaged in Illegal Fishing

To estimate the proportion of respondents engaged in illegal fishing, we adapted Boruch's (1971) forced-response RRT model, which is described as the most statistically efficient (Lensvelt -Mulders et al. 2005) and used recently in studies related to natural resources (Gavin et al. 2010; St John et al. 2011). Three sensitive questions were assessed with this method: Do you extract illegal loco from open access areas? Do you extract illegal loco from TURF areas? Do you extract illegal loco from TURF areas with consent from your union? For this section, respondents rolled a die in an opaque beaker before answering each question. The die had 6 sides; 1 side had the word "yes," 1 side had the word "no," and 4 other sides had a capital letter *R*. Depending on the roll, interviewees were asked to respond to the sensitive question truthfully (roll of *R*) (probability [*p*] of 4/6) or to answer "yes" or "no" if they rolled a "yes" or a "no" (forced responses, *p* of 1/6 for each roll). The result of the die roll was never revealed to the interviewer, so a respondent's privacy was fully protected. By knowing the probability of respondents being required to answer the sensitive question and the probability that respondents were forced to say yes irrespective of the truth, the aggregate level of the sensitive behavior can be calculated (Fox & Tracy 1986; Hox & Lensvelt-Mulders 2004):

$$\pi = \frac{\lambda - \theta}{s}$$

where π is the estimated proportion of the sample who have undertaken the behavior, λ is the proportion of all responses in the sample that are *yes* responses, θ is the probability of the answer being a forced *yes*, and *s* is the probability of having to answer the sensitive question truthfully (Hox & Lensvelt-Mulders 2004). Each time before asking the sensitive questions, the interviewer gave a demonstration of the method to guarantee the personal confidentiality of the respondent and to ensure comprehension of the method before proceeding (Fox & Tracy 1986).

Quantification of Illegal Loco Extraction

To estimate the amount of illegal loco extraction, we used a quantitative adaptation of the RRT (Greenberg et al. 1971). Two separate sensitive questions were assessed with this method: How many days a month do you fish for illegal loco? and How many illegal locos do you extract per diving day?

For this section, the respondent rolled 2 regular 6-sided dice with numbers from 1 to 6 in an opaque beaker. Depending on the sum of the 2 dice, the respondent was instructed to answer the sensitive or an innocuous question (Supporting Information). The innocuous questions were, How many days a month is the sea in a condition suitable for diving? and How many dozens of loco per dive would be appropriate to legally extract without threatening the loco population? This pairing of questions and the use of 2 subsamples with different probabilities of rolling the sensitive ($p_{1,2}$) or innocuous ($1 - p_{1,2}$) question (Supporting Information) are needed to draw a system of equations to determine the quantitative estimation sought.

The result of the sum of the dice and the type of question answered was not revealed to the interviewer, which

protected the privacy of the respondent. The interviewer only knew the subsample and the quantitative answer and did not know whether the number rolled belonged to the sensitive or innocuous question. To obtain the quantitative estimates, we followed Greenberg's model set of equations (Greenberg et al. 1971):

$$\mu_A = \frac{(1-p_2)\bar{Z}_1 - (1-p_1)\bar{Z}_2}{p_1 - p_2}$$

and

$$\mu_Y = \frac{p_2 * \bar{Z}_1 - p_1 * \bar{Z}_2}{p_2 - p_1}$$

where μ_A and μ_Y are the quantitative average estimates for the sensitive and innocuous questions, respectively; p_1 and p_2 are the known probability to answer the sensitive question for each subgroup p_1 and p_2 (Supporting Information), and Z_1 and Z_2 are the average of the raw data collected for each subsample. In the same way, the variance (V) of the estimation was calculated using the variance of the raw data collected $V(\bar{Z}_1)$ and $V(\bar{Z}_2)$ for each subsample (Greenberg et al. 1971):

$$V(\mu_A) = \frac{(1-p_2)^2 V(\bar{Z}_1) + (1-p_1)^2 V(\bar{Z}_2)}{(p_1 - p_2)^2}$$

and

$$V(\mu_Y) = \frac{{p_2}^2 * V(\bar{Z}_1) + {p_1}^2 * V(\bar{Z}_2)}{(p_2 - p_1)^2}$$

This method allowed us to estimate a daily per capita rate of illegal loco extraction and the number of days fishers fished illegally for loco per month. To assess the total number of illegal locos extracted in region V, two hypothetical scenarios were created using the results from these two sensitive questions that allowed us to calculate a per-diver monthly rate (locos/day times days/month) (Table 1). The scenario of low-level illegal extraction was computed considering the per-diver monthly rate and the proportion of fishers engaged in illegal fishing in open-access areas out of the total number interviewed (110) (Fig. 3, open access). For the scenario of high-level illegal extraction, the same per-diver monthly rate was used, but we factored in the proportion of fishers engaged in illegal fishing in open-access areas out of the total number of active divers registered in the region (296) (Fig. 3, open access).

The quantitative estimations obtained with the two scenarios were compared with 4 reference points: average and highest historic official landings from years 2000 to 2012 and average and highest historic total allowable catches (TACs) from years 2000 to 2010 in the region. These reference points were adjusted to represent monthly averages considering diving for loco occurs 7 months/year due to legal fishery closures. Ratios were calculated by dividing the assessed number of illegal locos a month by the number of legal loco a month (Table 1) (e.g., a ratio of 1 means the illegal monthly estimation equals the reference point). Data were obtained from the official records of SERNAPESCA (National Fisheries Service).

Table 1. Estimates of illegal loco extraction and comparison with official reported landings and assigned total allowable catch in region V (Fig. 1) of Chile.

	Scenario	
Estimation	*low extraction*	*high extraction*
Diving days/month (SD)[a]	6 (2.57)	6 (2.57)
Locos/ day (SD)[a]	127.8 (35.64)	127.8 (35.64)
No. of divers engaged[b]	110	296
Average Locos extracted/month[c]	83505	224703
Average locos extracted/month: average landings[c,d]	2.3	6.8
Average locos extracted/month: highest historic landing[c,d]	0.725	1.951
Average locos extracted/month: average total allowable catch[d]	0.740	1.991
Average locos extracted/month: highest historic total allowable catch[d]	0.459	1.235

[a]*From quantitative randomized response analysis.*
[b]*Data used to build low- and high-extraction scenarios come from the number of divers assessed and number of legally registered divers in the region, respectively.*
[c]*SERNAPESCA (2012), 2000–2012.*
[d]*SERNAPESCA (2010), 2000–2010.*

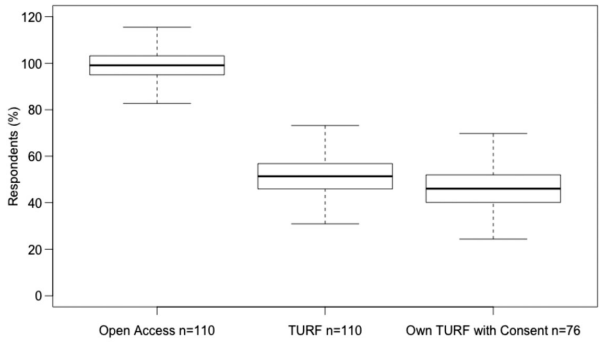

Figure 3. Estimation of respondents engaged in illegal loco extraction. Estimates in open access and territorial user rights for fisheries (TURF) areas are for unionized and free-rider fishers, whereas estimation in "own-TURF-with-consent" areas is for unionized divers only (whiskers, data range; black lines, median; rectangles, interquartile range). Estimate of variability >100% can occur because of the stochastic variability of the responses.

Market and Ex-Vessel Prices of Illegal Loco

We assessed the markets for illegal loco and the approximate ex-vessel price of illegally caught locos of different sizes. For the market section, we asked respondents to mention all potential buyers of illegal loco. Then, we showed respondents two loco shells of different sizes and asked respondents what was the average price they received for a dozen of each of the illegal shells. One shell was 7 cm long and represented a loco below the legal extraction size, and the other shell was 10 cm long, representing a loco above legal extraction size (but that was caught in an illegal manner).

Results

Illegal Extraction

Using the RRT, we estimate that 99% of respondents (unionized and free-riders) engaged some time in illegal extraction of loco in the de facto open-access areas (Fig. 3). From this same pool of respondents, we estimated that 51% of them extracted loco illegally from TURF areas. Forty-six percent of unionized fishers extracted loco illegally within their own TURFs and had the consent of their union leaders to do so. This fraction of loco is illegal because it is unreported.

Using the quantitative adaptation of the RRT, we estimated that fishers dived a mean of 6 days a month (SD 2.57) to extract illegal loco and extracted, on average, a mean of 127 locos per diving day (SD 35.27) (Table 1). Based on these results and from our 2 scenarios (number of divers assessed and total divers registered in the region), an estimated 83,505 to 224,703 locos per month were harvested illegally in region V.

When comparing illegal loco estimates with the RRT with average and historic official reported landings versus average and historic TAC, the scenario of low-level illegal extraction returned an estimate about 2.3 times higher than the average official reported landings (Table 1), and that was 0.72 of the highest historic official reported landings for the region. The scenario of high-level extraction returned higher ratios: 6.1 times the average official reported landings and 1.9 times the highest historic official reported landings. Relative to the assigned official TAC, the estimate based on low-level illegal extraction was 0.7 of the average TAC and 0.4 of the highest historic TAC. The estimate based on high-level extraction was 1.9 of the average and 1.2 of the highest official historic TAC.

Markets and Prices for and Revenues From Illegal Loco

According to respondents, the most important market for illegal loco is the general public, followed by intermediaries, restaurants, and hotels (Fig. 4). Processing plants, which are a common buyer of legal loco, account for only a small fraction. Some respondents also mentioned other unions as a market, in which illegal loco divers sell their catch to an established union for legal sale.

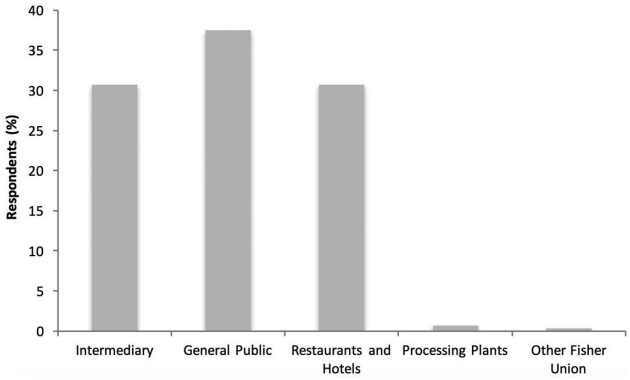

Figure 4. Markets for illegally extracted loco indicated by survey respondents.

Table 2. Ex-vessel prices (U.S. dollar values in January 2016) for illegal loco extraction of different size.*

Loco size (cm)	*Average price/unit (SD)*	*Total revenue/ month*	*Revenue/ diver/ month*	*Ratio of revenue/diver to minimum wage in Chile*
7	0.4 (0.19)	33,425	303.86	0.89
10	0.83 (0.32)	68,741	624.91	1.83

* *Revenues calculated with the scenario of low illegal loco extraction.*

Respondents estimated that the ex-vessel prices of loco varied but that loco above the legal extraction size (10 cm of maximum shell length) were twice as expensive as loco below legal extraction size (7 cm) (Table 2). Estimates of total revenues generated by the illegal extraction of loco in region V ranged from US$33,425 to $68,741/month (Table 2). When divided per diver, these revenues ranged from US$303.86 to $624.91/month. These values accounted for 0.89 to 1.83 of the minimum monthly wage in Chile.

Discussion

Although illegal fishing of locos is mentioned as a constant threat to the Chilean TURFs program (Gonzalez et al. 2006; Bandin & Quinones 2014; Castilla et al 2016), quantifying illegal catch has remained a difficult task. The RRT and its quantitative adaptation (Greenberg et al. 1971) revealed the different ways fishers engaged in illegal activities and provided estimates of the proportion of fishers engaged in different forms of illegal activities and the quantities of illegal loco extracted in region V.

We estimated that nearly all the fishers we interviewed extracted loco illegally from open-access areas that are supposed to be fully closed to loco fishing. Uncontrolled rates of extraction from open-access areas could have a large negative impact on the overall loco stock and affect the productivity of TURFs (Castilla et al. 2016). Thus, in Chile the TURFs scheme needs to incorporate what is really happening beyond managed boundaries as part of a broader comprehensive regulatory plan. Fortunately, recent legislation (Law 20.657, 2013) provides an enabling legal framework to create management plans for benthic species in these the de facto open-access areas (Gelcich 2014). This legal framework has the potential to manage loco beyond TURFs through complementary regulations under which free-riders are included in a broader management strategy. This would allow fishers who are non-TURF participants to be legally part of the fishery. Although developing management plans for loco in the open-access areas is not an easy task and will need to address issues of trust, participation, and enforcement mechanism, it could increase the sustainability of the fishery because it acknowledges, makes apparent, and deals with illegal fishing in open-access areas (Reyes et al. 2017).

Results of this study in region V of Chile showed that 51% of fishers extract loco illegally within other organizations TURFs. This is a general problem for the TURF system in Chile, as shown by Gelcich et al. (2017), who interviewed 535 artisanal fishers along 2000 km of the coast of Chile and found that 70% stated, in an open-ended question, that theft of loco from TURFs was the main problem as they perceived it. This is important because it relates directly to the emergence of social conflict between associations (Gelcich et al. 2005). Strong conflict between unionized fishers and poachers has been reported in many regions of Chile (i.e. regions IV, V, VIII, and X), where free-riders reap the benefits of TURFs without being involved in the costly management process (Bandin & Quinones 2014).

The problem of illegal poaching by free-riders within TURFs is consistent with the results of previous studies (Gonzalez et al. 2006; Bandin & Quinones 2014; Gelcich et al. 2017). Poaching implies increased costs associated with surveillance and reduced revenue of the TURFs (Davis et al. 2015). The importance and prevalence of poaching suggests the need for increased logistical support to stop and prosecute poachers who are caught in TURFs (Arias et al. 2016). The government is advancing in this direction by increasing sanctions through the SERNAPESCA Modernization Law Project (Bulletin Number 10482-21), which will categorize illegal fishing as a criminal offense. The main problem is that poachers have to be identified or caught in situ. To enforce this future law the government intends "to make use of all kinds of technological means available to carry out enforcement work." Accordingly, a new pilot enforcement program is being developed in 2 caletas in region V, where online video cameras are designed to increase enforcement capacity and support fishers when confronted with the need to provide evidence in court (Gelcich & Donlan 2015). There might be new opportunities to support TURFs from poaching by outsiders as cheaper technology is developed and becomes available.

An unexpected result from this study is that 46% of unionized fishers illegally extract loco with the unions consent from their own TURF. This practice indicates a decoupling of the assumptions being made by regulators and what is occurring on the ground. Because fisher unions find it too complicated, costly, or useless to officially report their catches, they are not reporting to authorities, even if they fish within legal margins (respecting the minimum size and closures). An underlying aspect to consider when analyzing this type of illegal behavior relates to the fact that from 2003 onwards, due to the huge development of abalone (*Haliotis* spp.) aquaculture, the price of exported loco has dropped (Castilla et al. 2016). This factor may be a determinant in the decrease of Chilean loco exports from 2400 t in 1993 to 522 t in 2012 (Castilla et al. 2016). This link between the loco fishery and global trade, which resulted in price and export drops, may be a factor strongly influencing fishers' tendency to not report extractions to the authorities. Unreported catch is an important component of illegal behavior in central Chile, and managers may consider developing mechanisms to facilitate reporting by providing easier pathways to do so (Davis et al. 2015). This would make the system more transparent. In the same vein, improving the traceability of products landed from TURFs and associating catch to a price premium could generate the necessary incentives to comply with reporting (Gelcich & Donlan 2015).

Estimating the proportion of fishers engaged in illegal fishing is useful to the understanding of the dynamics behind illegal extraction; however, it says little about how much is being extracted (Conteh et al. 2015). Using the RRT quantitative adaptation, we estimated 1 diver diving 6 days/month illegally extracts 127.8 loco/day. We estimated the illegal catch is from 2.3 to 6.1 times the legal, average, official reported loco landings (from 2000 to 2012). This means that official legal landings account for only 14–30% of the total loco extraction. These numbers are close to the highest historic loco landing levels in the region (0.72–1.95 times) and similar to the average (0.74–1.99) and highest historic TAC (0.45–1.23) assigned to the TURFs of region V. Hence, in situations where there is strong illegal resource extraction, it is important not to judge the TURFs management regime exclusively based on the official reported landings (Castilla et al. 2016). Our results focus on one region of Chile; however, evidence of illegal activity of this magnitude also has been observed for loco in regions III, IV, and VIII

of Chile (Gonzalez et al. 2006; Bandin & Quiñones 2014) and for the South African abalone fishery (Plaganyi et al. 2011).

We assessed the most important markets for illegal loco and ex-vessel prices by directly asking interviewees to identify where illegal loco is sold. We were not able to use the RRT technique to assess prices, but this conventional direct method was appropriate for this type of question because it was not sensitive because the respondent identity was protected and knowing this information did not link the interviewee directly to an illegal behavior. Ex-vessel price assessment showed that illegal fishing can provide important economic benefits, can earn a fisher more than the minimum monthly wage in Chile, and is a large part of fisher livelihoods, irrespective of whether they are unionized or free-riders. We found that markets for illegal loco are diverse but centered on intermediaries, restaurants and hotels, and the general public. This distribution could be different in other more rural and isolated regions of Chile, where the general public and restaurants might be less common. Given the heterogeneity of illegal markets for loco and the high number of illegal fishers, a stronger SERNAPESCA with new legal mechanisms and greater capacity to enforce regulations across the entire supply chain is needed.

Our empirical estimates for region V of Chile show that legal landings may account for 14–30% of the total loco extraction, and although our results highlight the magnitude of the problem, there is a need for future research to unravel the complexities and to generate the right incentives to tackle illegal loco fishing in the Chilean TURFs system. If illegal fishing is the main issue the TURFs system is facing, it may be time to rethink some of the management and support for the system. Educating legislators and judges and providing ways to estimate fraud in the fishery through multidisciplinary approaches are important steps forward. Adaptive comanagement (Berkes 2009) has led to many successful governance arrangements. These systems generally rely on learning-by-doing approaches, where problems are solved using knowledge generated from experience (Berkes 2009). It is time to devise different ways to deal with illegal fishing. It is only by creating learning platforms and testing novel approaches that new approaches to solving illegal fishing can emerge.

In region V of Chile, illegal loco fishing is widespread. Ignoring the magnitude of this problem and considering only official landings can lead to erroneous conclusions about the status and trends of TURFs managed fisheries. Our finding that unions are authorizing their members to poach inside TURFs, highlights the need for adaptive comanagement in TURFs design so that government and fishers' incentives and objectives will be aligned and not at odds. Management systems are not static and must continually evolve to solve emerging issues such as illegal fishing under user-right management regimes.

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Supporting Information

A framework for determining which question an interviewee answered (Appendix S1) is available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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