Supplementary Information:

A framework for assessing and intervening in markets driving unsustainable wildlife use

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Methodology

* 1. ***Key Informant Interviews***

Key-informant open-ended semi-structured interviews started with an explanation of the project scope and objectives and followed with a list of reference questions (see below). Reference questions were divided into four categories, regarding: a) actors' motivations (focusing on why they trade legal or unreported products), b) how actors access the benefits of the fishery, the supply-chain structure and component interaction, c) the operation of the legal/illegal market, and d) the overarching market dynamic. Interviews were performed during March-April 2019. Due to COVID-19, all interviews were done over the phone or email. Before each interview, we informed participants that participation was voluntary and that participants could refuse to answer any particular question. We used snowballing sampling, starting with leaders of the main fishers' associations in the region and known contacts of the researchers. In total, we interviewed 23 informants, including fishers, government officials, intermediaries, vendors, NGOs staff, and enforcement agents. Depending on the key-informant's role, some questions were omitted, and others were explored in more depth. Interviews over the phone lasted between 30 and 90 minutes. The study complied with Oxford University's ethical requirements (approval number R68516/RE001).

**Key-informant interview list of reference questions**

1. *Factors affecting actor’s decision to trade legal or unreported products*

* What are the main factors that affect the decision to trade legal or unreported common hake?
* Do intermediaries always carry legal hake?
* What determines the legal/unreported purchase ratio?
* Does this ratio vary?
* What affects its variability?

1. *How actors access the benefits of the fishery, the supply-chain structure and* component interaction

* Are there groups of actors with excessive (or lack of) capacity to access the benefits of the market?
* Do fishers have power to negotiate prices with intermediaries?
* Do intermediaries set prices?
* How would you characterize the nature of the relationship between actors in the market?
* Do intermediaries finance the activity of fishers?
* Do actors enter and exit the fishery?
* What causes actors to enter or leave the fishery?
* Are there barriers to entry for new actors? Why?

1. *Operation of the legal/unreported market*

* Can legal and unreported products be distinguished at the market?
* How does fish enter the market without a permit?
* Is there a price premium for legal products?

1. *Overarching market dynamic*

* What are the most important factors that determine prices?
* Does fishing activity respond to prices? Or, alternatively, are prices driven by the quantities of fish landed
  1. **Typology Construction**

For the actor level analysis, typologies were constructed to characterise participants in the market. Typologies refer to the systematic construction of types - which are unique combinations of dimension's attributes that influence the relevant outcome. We used motivations and access as dimensions for constructing the typologies for each of the three main market components (harvesters, intermediaries, vendors).

Following (Kluge, 2000) we divided the typology construction process into four steps:

1. *Development of relevant analysis dimensions*

Based on our framework’s actor analytical level, we defined motivation and access as the analytical dimensions for constructing the typologies. We used three motivation attributes: instrumental motivations, mixed motivations and non-instrumental motivations. We used two access attributes: limited/low access and varied/high access

1. *Grouping the cases and analysis of empirical regularities*

From the results of the key-informant survey, we were able to group actors into empirical regularities (Supplementary Table 1). This process allowed to identify which combination of dimensions’ attributes were present and absent in the actors of the case study. Moreover, this step confirmed that the dimensions and attributes selected contained sufficient heterogeneity, which is necessary for creating types.

**Supplementary Table 1**. Analysis of empirical regularities (present/absent) to construct typologies at the actor-level analysis.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Motivation** | | | **Type of Access** |
| Sector | Only Instrumental | Mixed | Non-instrumental |  |
| Harvester | *Absent* | *Present* | *Absent* | Limited/low Access |
| *Absent* | *Present* | *Absent* | Varied/high access |
| Intermediaries | *Present* | *Absent* | *Absent* | Limited/low Access |
| *Present* | *Absent* | *Absent* | Varied/high access |
| Vendors | *Absent* | *Absent* | *Absent* | Limited/low Access |
| *Present* | *Absent* | *Absent* | Varied/high access |

1. *Analysis of meaningful relationships and type construction*

After we grouped the cases based on the selected attributes, we eliminated the “non-instrumental” attribute from the motivation dimension, as there were no present cases for that attribute (Supplementary Table 2). From this we were able to identify the 6 different empirically founded groups that share combination of the selected attributes. We named each type according to the attribute that differentiated them. Each attribute space that was present was considered a type and two types were constructed for vendors with instrumental motivations and varied/high access.

**Supplementary Table 2.** Type construction process. Non-instrumental motivations were eliminated from the final matrix and each type was named according to its differentiating attributes.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Motivation** | | **Type of Access** |
| Sector | Only Instrumental | Mixed |  |
| Harvester | *x* | *Type I*  *“Low quota fishers”* | Limited/low Access |
| *x* | *Type II*  *“High quota fishers”* | Varied/high access |
| Intermediaries | *Type III*  *“Temporal intermediary”* | *x* | Limited/low access |
| *Type IV*  *“Permanent intermediary”* | *x* | Varied/high access |
| Vendors | *x* | *x* | Limited/low access |
| *Type V*  *“Fishing terminal vendor”*  *Type VI*  *“Open-air market vendor”* | *x* | Varied/high access |

1. Characterization of the constructed types

For the results of the characterization of the constructed type please refer to Table 2 in the article.

* 1. ***Sensitive Questioning Surveys Analysis***

Per-trip quantitative estimates of unreported catch from Oyanedel et al. 2020 were used to calculate regional yearly quantities of unreported catch, to assess the legal/illegal interaction dimension (market analysis). Oyanedel et al. 2020, using sensitive questioning methods (the Randomised Response Technique) and direct questions, estimated under-reporting per trip to be 548.37 [SE = 66.42], and 594.54 [SE = 33.75] kg for RRT and direct questions, respectively. To extrapolate the per boat/per trip unreported catch rates from (Oyanedel et al., 2020) to an overall yearly estimate, we first fitted a linear model with unreported catch rates as the response variable and a binomial predictor of whether boats had high or low quota. We were able to categorise boats into low or high quota based on their port of operation. From this, we obtained unreported catch rates estimates for low and high quota boats. Then, from the records of SERNAPESCA, we obtained the total number of high and low quota boats in the region to calculate a region-wide per-trip estimate. Since these estimates were per trip, the second step was to calculate yearly rates of unreported catch. For this, we built two scenarios of the number of trips per boat in a year. The first one considered a 3-day local rule (high scenario), and therefore that fishers' fish three days a week for 11 months (because of a reproductive ban in September) (Oyanedel et al. 2020). For the low scenario, we obtained data from SERNAPESCA on the number of registered trips for the region between 2015-2018. From this, we calculated an average per boat number of trips a year. Estimates from these two scenarios were compared to the annual quota limit for the VII region.

**Supplementary Table 3**. Quantitative estimates of unreported catch and comparison to assigned quota in 2018 (in tons), data from Oyanedel et al. 2020.

|  |  |  |
| --- | --- | --- |
|  | **High Scenario** | **Low Scenario** |
| Low Quota Boats/trip (Std. Error) | *0.73 (0.046)* | |
| High Quota Boats/trip (Std. Error) | *0.41 (0.063)* | |
| Per year Region | 24204 | 6658 |
| Quota | 3267 | |
| Total Catch | 27471 | 9925 |
| **Unreported Catch (%)** | **88** | **67** |

* 1. ***Econometric Model***

We used an econometric model to assess the quantity and price determinant dimension of the market analysis level. We used three different datasets from the Chilean government. First, legal landings data which included anonymised legal transaction (reporting) from fishers to intermediaries per day for the 2014-2019 period in the VII region. We collapsed this daily data into monthly data for posterior analysis. Second, we used data on enforcement effort by government authorities. This dataset included all enforcement activities done per day for the 2014-2019 period. We counted the number of enforcement activities per month in the VII region to obtain monthly enforcement indexes. Lastly, we explored average monthly ex-vessel price in the 2014-2019 period for common hake, as well as pacific pomfret (*Brama australis*) at the country level. Pacific pomfret is an important fishery in the VII region of the country, in which common hake fishers actively participate. A log-log linear model was fitted using reported landings as a response variable and prices of common hake, pacific pomfret and enforcement indexes as predictor variables. Year and four seasons (Jan-Feb, Eastern (March-April), May-Jul, Aug-Dec) were used as dummy variables to account for temporal variation in reported landings. September was removed from the analysis because of a fishing ban that prevents reporting of common hake.

We took several steps to validate the econometric model. First, we tested whether the response variable (supply of common hake) was stationary using a Dickey-Fuller test. We found that it was non-stationary (Dickey-Fuller = -3.2423, p-value = 0.08865, Ho = non-stationary). However, after replacing two outliers (data points 12 and 13, January and February 2015) for an average of the values of their corresponding month across years, the Dickey-Fuller test show that the landings data was stationary (Dickey-Fuller = -3.6729, p-value = 0.03402, Ho = non-stationary). Concurrently, we proceeded with the analysis using the dataset with the replaced values.

We then use a Ramsey’ RESET test for functional form to validate the choice of using a log-log model. Results supported the hypothesis that the model was correctly specified (RESET = 2.89, p-value = 0.06431, Ho = model is correctly specified). We tested for multicollinearity between predictive variables using Variance Inflation Factors (VIF) and found that ﻿all predictor variables had VIF values<3.3, showing no multicollinearity. We used a studentized Breusch-Pagan test for residual heteroskedasticity, and found no heteroskedastic residuals (BP = 16.496, p-value = 0.1237, Ho = variance of the residuals is constant). We tested serial residual autocorrelation with Durbin-Watson test and found no autocorrelation of residuals (Autocorrelation=0.0401, p-value = 0.188, Ho = no autocorrelation). Finally, we tested residual stationarity with a Dickey-Fuller test and found residuals were stationary (Dickey-Fuller = -4.2384, p-value = 0.01, Ho = residuals are non-stationary).

**References**

Kluge, S. (2000). Empirically Grounded Construction of Types and Typologies in Qualitative Social Research. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *1*(1). https://doi.org/10.17169/fqs-1.1.1124

Oyanedel, R., Gelcich, S., & Milner-Gulland, E. J. (2020). Motivations for (non-)compliance with conservation rules by small-scale resource users. *Conservation Letters*, e12725. https://doi.org/10.1111/conl.12725