Supplementary Information:

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

Rodrigo Oyanedel[1*], Stefan Gelcich[2] and EJ Milner-Gulland[1]

1) Department of Zoology, The Interdisciplinary Centre for Conservation Science, University of Oxford, Oxford, UK. 2) Center of Applied Ecology and Sustainability (CAPES) & Center for the Study of Multiple-Drivers on Marine Socio- Ecological Systems, Pontificia Universidad Catolica de Chile, Santiago, Chile

* Correspondence

Rodrigo Oyanedel, Department of Zoology, The Interdisciplinary Centre for Conservation Science, University of Oxford, 11a Mansfield Rd, Oxford OX1 3SZ, UK. Email: rodrigo.oyanedel@zoo.ox.ac.uk

Methodology

i.   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).

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

33 *a. Factors affecting actor's decision to trade legal or unreported products*

34 - What are the main factors that affect the decision to trade legal or unreported

35 common hake?

36 - Do intermediaries always carry legal hake?

37 - What determines the legal/unreported purchase ratio?

38 - Does this ratio vary?

39 - What affects its variability?

40

41 *b. How actors access the benefits of the fishery, the supply-chain structure and*

42 *component interaction*

43 - Are there groups of actors with excessive (or lack of) capacity to access the benefits

44 of the market?

45 - Do fishers have power to negotiate prices with intermediaries?

46 - Do intermediaries set prices?

47 - How would you characterize the nature of the relationship between actors in the

48 market?

49 - Do intermediaries finance the activity of fishers?

50 - Do actors enter and exit the fishery?

51 - What causes actors to enter or leave the fishery?

52 - Are there barriers to entry for new actors? Why?

53

54 *c. Operation of the legal/unreported market*

55 - Can legal and unreported products be distinguished at the market?

56 - How does fish enter the market without a permit?

57 - Is there a price premium for legal products?

58

59 *d. Overarching market dynamic*

60 - What are the most important factors that determine prices?

61 - Does fishing activity respond to prices? Or, alternatively, are prices driven by the

62 quantities of fish landed

63

64   **ii.   Typology Construction**

65

66   For the actor level analysis, typologies were constructed to characterise participants

67   in the market. Typologies refer to the systematic construction of types - which are unique

68   combinations of dimension's attributes that influence the relevant outcome. We used

69   motivations and access as dimensions for constructing the typologies for each of the three

70   main market components (harvesters, intermediaries, vendors). Following (Kluge, 2000) we

71   divided the typology construction process into four steps:

72

73   ***a)*** *Development of relevant analysis dimensions*

74   Based on our framework's actor analytical level, we defined motivation and access

75   as the analytical dimensions for constructing the typologies. We used three motivation

76   attributes: instrumental motivations, mixed motivations and non-instrumental

77   motivations. We used two access attributes: limited/low access and varied/high access

78

79   ***b)*** *Grouping the cases and analysis of empirical regularities*

80   From the results of the key-informant survey, we were able to group actors into

81   empirical regularities (Supplementary Table 1). This process allowed to identify which

82   combination of dimensions' attributes were present and absent in the actors of the case

83   study. Moreover, this step confirmed that the dimensions and attributes selected contained

84   sufficient heterogeneity, which is necessary for creating types.

85

86   **Supplementary Table 1**. Analysis of empirical regularities (present/absent) to construct

87   typologies at the actor-level analysis.

Sector	Motivation			Type of Access
	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

88

89   ***c)*** *Analysis of meaningful relationships and type construction*

90   After we grouped the cases based on the selected attributes, we eliminated the "non-

91 instrumental" attribute from the motivation dimension, as there were no present cases for

92 that attribute (Supplementary Table 2). From this we were able to identify the 6 different

93 empirically founded groups that share combination of the selected attributes. We named

94 each type according to the attribute that differentiated them. Each attribute space that was

95 present was considered a type and two types were constructed for vendors with instrumental

96 motivations and varied/high access.

97

98 **Supplementary Table 2.** Type construction process. Non-instrumental motivations were

99 eliminated from the final matrix and each type was named according to its differentiating

100 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
	x	x	Limited/low access

Vendors	Type V *"Fishing terminal vendor"* Type VI *"Open-air market vendor"*		x	Varied/high access

101

102

103   **d)** Characterization of the constructed types

104   For the results of the characterization of the constructed type please refer to Table 2

105   in the main text.

106

107

108   ***iii.***   ***Sensitive Questioning Surveys Analysis***

109   Per-trip quantitative estimates of unreported catch from Oyanedel et al. 2020 were

110 used to calculate regional yearly quantities of unreported catch, to assess the legal/illegal

111 interaction dimension (market analysis). Oyanedel et al. 2020, using sensitive questioning

112 methods (the Randomised Response Technique) and direct questions, estimated under-

113 reporting per trip to be 548.37 [SE = 66.42], and 594.54 [SE = 33.75] kg for RRT and direct

114 questions, respectively. To extrapolate the per boat/per trip unreported catch rates from

115 (Oyanedel et al., 2020) to an overall yearly estimate, we first fitted a linear model with

116 unreported catch rates as the response variable and a binomial predictor of whether boats

117 had high or low quota. We were able to categorise boats into low or high quota based on

118 their port of operation. From this, we obtained unreported catch rates estimates for low

119 and high quota boats. Then, from the records of SERNAPESCA, we obtained the total

120 number of high and low quota boats in the region to calculate a region-wide per-trip

121 estimate. Since these estimates were per trip, the second step was to calculate yearly rates

122 of unreported catch. For this, we built two scenarios of the number of trips per boat in a

123 year. The "high" scenario considered a 3-day local rule (high scenario), and therefore that

124 fishers fish three days a week for 11 months (because of a reproductive ban in September)

125 (Oyanedel et al. 2020). For the "low" scenario, we obtained data from SERNAPESCA on the

126 number of registered trips for the region in 2015-2018. From this, we calculated an average

127 per boat number of trips a year. Estimates from these two scenarios were compared to the

128 annual quota limit for the VII region.

129

130 **Supplementary Table 3**. Quantitative estimates of unreported catch and comparison to assigned

131 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**

132

133

134   iv.   *Econometric Model*

135   We used an econometric model to assess the quantity and price determinant

136 dimension of the market analysis level. We used three different datasets from the Chilean

137 government. First, legal landings data which included anonymised legal transactions

138 (reporting) from fishers to intermediaries per day for the 2014-2019 period in the VII region.

139 We collapsed this daily data into monthly data for analysis. Second, we used data on

140 enforcement effort by government authorities. This dataset included all enforcement

141 activities done per day for the 2014-2019 period. We counted the number of enforcement

142 activities per month in the VII region to obtain monthly enforcement indexes. Lastly, we

143 explored average monthly ex-vessel price in the 2014-2019 period for common hake, as well

144 as Pacific pomfret (*Brama australis*) at the country level. Pacific pomfret is an important

145 fishery in the VII region of the country, in which common hake fishers actively participate. A

146 log-log linear model was fitted using reported landings as a response variable and prices of

147 common hake, pacific pomfret and enforcement indexes as predictor variables. Year and

148 four seasons (Jan-Feb, March-April (representing Easter when consumer demand for hake is

149 high), May-Jul, Aug-Dec) were used as dummy variables to account for temporal variation in

150 reported landings. September was removed from the analysis because of a fishing ban that

151 prevents reporting of common hake.

152

153   We took several steps to validate the econometric model. First, we tested whether

154   the response variable (supply of common hake) was stationary using a Dickey-Fuller test.

155   We found that it was non-stationary (Dickey-Fuller = -3.2423, p-value = 0.089, Ho = non-

156   stationary). However, after replacing two outliers (data points 12 and 13, January and

157   February 2015) for an average of the values of their corresponding month across years, the

158   Dickey-Fuller test show that the landings data was stationary (Dickey-Fuller = -3.6729, p-

159   value = 0.034, Ho = non-stationary). Consequently, we proceeded with the analysis using the

160   dataset with the replaced values.

161

162   We then used a Ramsey's RESET test for functional form to validate the choice of

163   using a log-log model. Results supported the hypothesis that the model was correctly

164   specified (RESET = 2.89, p-value = 0.064, Ho = model is correctly specified). We tested for

165   multicollinearity between predictive variables using Variance Inflation Factors (VIF) and

166   found that all predictor variables had VIF values <3.3, showing no multicollinearity. We used

167   a studentized Breusch-Pagan test for residual heteroskedasticity, and found no

168   heteroskedastic residuals (BP = 16.496, p-value = 0.123, Ho = variance of the residuals is

169   constant). We tested serial residual autocorrelation with a Durbin-Watson test and found no

170   autocorrelation of residuals (Autocorrelation=0.0401, p-value = 0.188, Ho = no

171   autocorrelation). Finally, we tested residual stationarity with a Dickey-Fuller test and found

172   residuals were stationary (Dickey-Fuller = -4.2384, p-value = 0.01, Ho = residuals are non-

173   stationary).

174

175

176   **References**

177   Kluge, S. (2000). Empirically Grounded Construction of Types and Typologies in Qualitative Social

178   Research. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *1*(1).

179   https://doi.org/10.17169/fqs-1.1.1124

180   Oyanedel, R., Gelcich, S., & Milner-Gulland, E. J. (2020). Motivations for (non-)compliance with

181   conservation rules by small-scale resource users. *Conservation Letters*, e12725.

182   https://doi.org/10.1111/conl.12725

183