Model Summary

Driving Sustainability in the Gulf of California: Fishery Management and Offshore Cultivation for *Totoaba macdonaldi*

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Introduction

Words!

Poaching

Growth: von Bertalanffy Function

$$\hat{L}_t^{poach} = L_\infty^{poach}(1 - e^{-k(t-t_0)})$$

Variable	Definition
$\hat{L}_t^{poach}$	Estimated length for totoaba
L_∞^{farm}	Upper limit for totoaba growth
t	Time *t*.
t_0	Time for $L_t = 0$
k	Growth coefficient

Data from INAPESCA.

Effort: Gorden-Schaefer Model

$$y_{a,t}^{poach} = q * E_t * S_a * N_{t-1}$$

$$E(y_{A,t}^{poach}) = max \sum \{p_{a,t-1}^{poach} * y_{a,t}^{poach} - c_{a,t-1}^{poach} * y_{a,t}^{poach}\}$$

Variable	Definition
$y_{a,t}^{poach}$	Poaching of cohort *a* at time t
E_t	Effort at time t
S_a	Poaching selectivity by cohort
N_{t-1}	Stock at time *t - 1*
q	Catchability
p_{t-1}^{poach}	Revenue per Unit Effort
c_t^{poach}	Cost per Unit Effort

Past output data from INAPESCA.

Catch / Unit Effort data from INAPESCA, C4ADS.

Catchability parameter from INAPESCA.

Price data from model feedbacks, regulatory agencies.

Cost data from C4ADS, EDF, correspondence.

Net Stock: Age-Structured INAPESCA Model

$$N_{A,t} = \sum \left(N_{0,t} - y_{0,t}^{poach}\right) + \left(N_{a,t-1} * e^{-M_a} - y_{a,t}^{poach}\right)$$

Variable	Definition
$N_{0,t}$	Recruitment, estimated by methods from Shepard (1982)
$y_{0,t}^{poach}$	Poaching mortality of recruits
$N_{A,t}$	Biomass for all cohorts after recruitment and mortality
$N_{a,t-1}$	Biomass by cohort before recruitment and mortality
$-M_a$	Natural mortality by cohort
$y_{a,t}^{poach}$	Poaching mortality by cohort

Data from INAPESCA, literature, model feedthroughs.

Aquaculture

Growth: von Bertalanffy Function

$$\hat{L}_t^{farm} = L_\infty^{farm}(1 - e^{-K(t-t_0)})$$

Variable	Definition
$\hat{L}_t^{poach}$	Estimated length for totoaba
L_∞^{farm}	Upper limit for totoaba growth
t	Time *t*.
t_0	Time for $L_t = 0$

Aquaculture data from COF, UABC.

Projected data from INAPESCA modeling.

Harvest: Modified Faustmann Model

$$TR_{A,t}\left(y_{A,t}^{farm}\right) = max \sum \left\{p_{a,t-1} * y_{a,t}^{farm} * h_{a,t} - c\left(y_{a,t}^{farm}\right) + \beta * p_{a+1,t-1} * y_{a+1,t+1}^{farm}\right\}$$

Variable	Definition
$TR_{A,t}$	Total revenue for all cohorts at time *t* by harvest decision
$p_{a,t-1}$	Price for cohort *a* in the previous period *t – 1*
$y_{a,t}^{farm}$	Harvested biomass for cohort *a* at time *t*
$h_{a,t}$	Harvest decision for cohort *a* at time *t*, scaled 0 – 1
$c\left(y_{a,t}^{farm}\right)$	Cost of keeping cohort *a* through period *t*
β	Discount rate, scaled 0 – 1
$p_{a+1,t-1}$	Price for cohort *a* in next period
$y_{a+1,t+1}^{farm}$	Harvested biomass for cohort *a* in the next period

Aquaculture data from COF, UABC, CREMES.

Projected data from INAPESCA modeling.

Net Stock: Age-Structured INAPESCA Model, Modified for Aquaculture

$$N_{A,t} = \sum N_{0,t} + (N_{a,t-1} * e^{-M_a} - y_{a,t}^{farm})$$

Variable	Definition
$N_{0,t}$	Recruitment from hatcheries
$N_{A,t}$	Biomass for all cohorts after recruitment and mortality
$N_{a,t-1}$	Biomass by cohort before recruitment and mortality
$-M_a$	Natural mortality by cohort
$y_{a,t}^{farm}$	Harvest mortality by cohort

Data from COF, UABC, INAPESCA, literature, model feedthroughs.

Markets

Demand: Linear Regression

Three Frameworks for Competition:
Static Competition (Jensen 2014)
Cournot Competition (Bulte and Damania 2007)
Bertrand Competition (Bulte and Damania 2007)

price and size data from investigation and seizures (NGOs, USFWS, PROFEPA, AFCD)
All return p subt, driving effort and harvest decisions in period t+1