Evaluation of Management Procedures

Application to Chilean Jack Mackerel Fishery

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Modelos y Métodos Cuantitativos para el
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Outline

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- Chilean Jack Mackerel (Jurel) fishery is the largest one in Chile in terms of catches as well as in economical terms

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Management Procedures (MPs)

- A Management Procedure (MP) is defined in Butterworth et al. 1997 as a set of rules, which translates data from a fishery into a regulatory mechanism, such as total allowable catches (TAC) or maximum fishing effort
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1. defining an operational set of management objectives,
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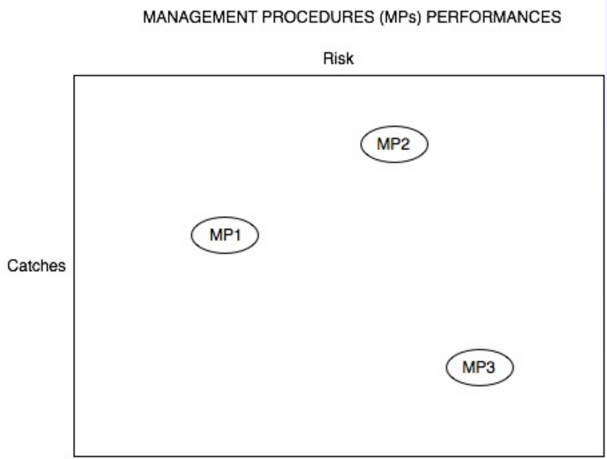
MPs and MSE



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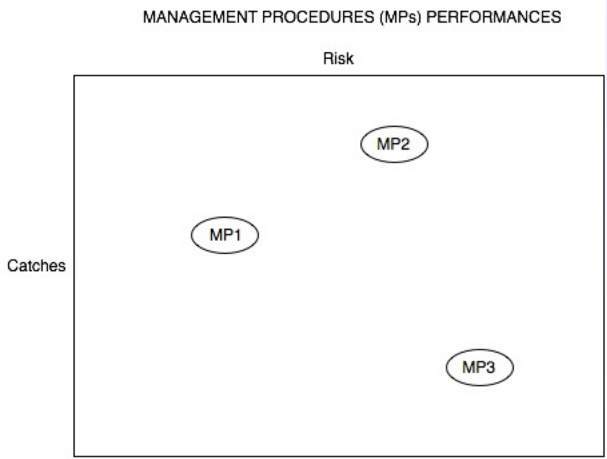

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The Model

An age class dynamical model

We consider an age structured abundance population model (Quinn & Deriso 1999) for the Chilean Jack Mackerel fishery

$$N_{a+1}(t+1) = e^{-(M_a+\lambda(t)F_a)} N_a(t), \quad a = 1, \dots, A-1,$$

where

- $A = 11$ age classes
- An horizon time of $T = 10$ years
- We perform our analysis for the initial year $t_0 = 2002$

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The recruits are supposed to be a Ricker function of the spawning stock biomass at time $t-1$ ($SSB(t-1)$):

$$N_1(t+1) = \alpha SSB(t-1)\exp(\beta SSB(t-1))$$

the random variable $w(t)$ reflects the uncertainties in the recruitment (*El Niño*)

The Model

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$$N_1(t+1) = \alpha SSB(t-1)\exp(\beta SSB(t-1) \underbrace{-\,0.12\text{niño}(t) + \epsilon(t)}_{w(t):\ \text{random part}})$$

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Uncertainties in the stock-recruitment relationship

The stock-recruitment relationship is given by[1]:

$$N_1(t+1) = \alpha SSB(t-1)\exp(\beta SSB(t-1) - 0.12\text{niño}(t) + \epsilon(t))$$

where the uncertainties are defined as follows:

- $\epsilon(t) \sim \mathcal{N}(0; 0.18)$
- $\text{niño}(t)$ is a dummy (0 or 1) random variable reflecting the presence of *El Niño* phenomena. It is defined by:

$$\text{niño}(t) = \begin{cases} 1\,, & \text{if } \mathit{promsdf} > 0.5 \\ 0\,, & \text{otherwise} \end{cases}$$

where

$$\mathit{promsdf} = -1.2\sin(18.19 + 2\pi(t-1959)/3.17)$$

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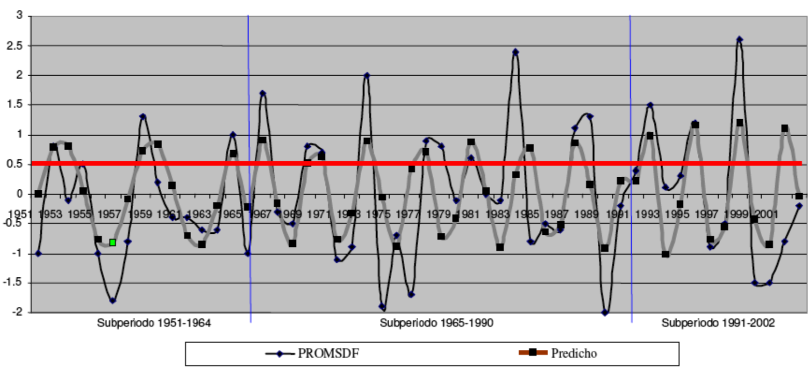

Outline

New Methodology: Viability Approach

Our model can be described in the following discrete time dynamic framework:

$$\begin{cases} N(t+1) = g(N(t), \lambda(t), w(t)), & t = t_0, \ldots, T \\ N(t_0) & \text{given,} \end{cases}$$

where

- state variable $N(t)$ (abundances)
- control $\lambda(t)$ (fishing effort)
- uncertainty $w(t)$ (recruitment uncertainties)

The notation for a scenario being $w(\cdot) := (w(t_0), ..., w(T))$

Scenarios are perturbations of the dynamics (in this case of the stock-recruitement relation) due to climate factors (*El Niño*)

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Constraints: Conflicting Indicators

Consider constraints to be satisfied at every time $t = t_0, \ldots, T$.

They are given by indicators $I_k = I_k(N, \lambda)$ and thresholds or reference points i_k.

We impose $I_k(N(t), \lambda(t)) \geq i_k \quad$ for all $t = t_0, \ldots, T$

In this talk we focus on two conflicting issues:

- Biological: $SSB(t) \geq \text{percentage} \cdot SSB_{\text{virg}}$ where
  - $SSB_{\text{virg}} = 6.44$ millions tons is the virginal spawning stock biomass
  - percentage is typically 0.2, 0.3 or 0.4
- Economical: $Y(N(t), \lambda(t)) \geq y_{\min}$ where
  - Y is the catches in term of biomass

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A Common Currency: Viability Probability

We use the probability on the set of all possible scenarios as a common currency.

This viability probability (VP) depends on the initial time t_0, the initial state N_0 and a given control rule λ^* (exploitation policy, for instance TAC or fixed constant fishing effort), and is defined by:

$$VP_{\lambda^*} = \boldsymbol{P}\left(w(\cdot) \ : \ \begin{array}{l} N(t_0) = N_0 \\ N(t+1) = g(N(t), \lambda(t), w(t)) \\ \lambda(t) = \lambda^*(t, N(t)) \\ I_k(N(t), \lambda(t)) \geq i_k \\ \text{for all } \ k = 1, 2 \text{ and } t = t_0, \ldots, T \end{array} \right)$$

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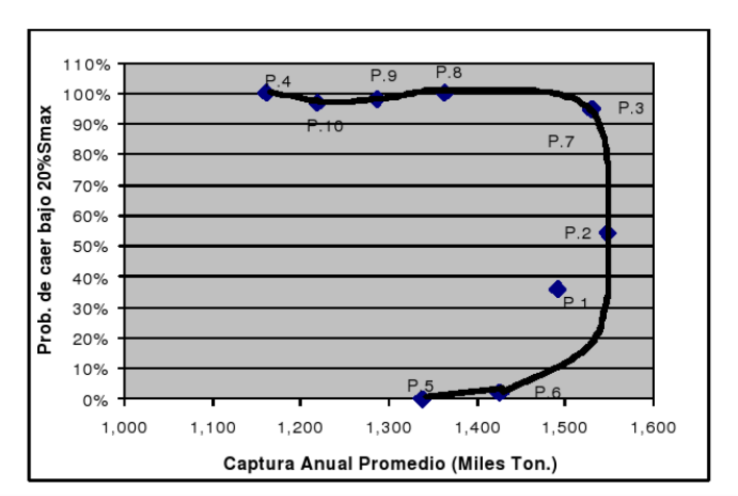
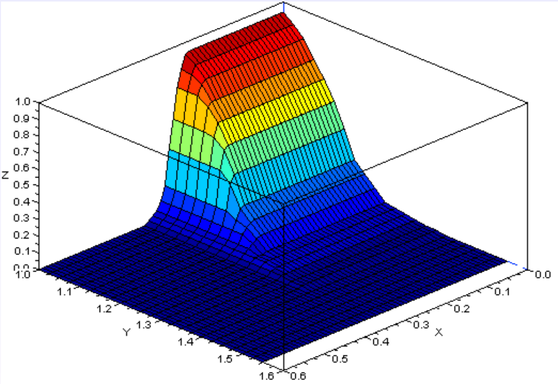
MSE example (M. Yepes 2008):



Output for constant fishing effort $\lambda(t) = \lambda^* = 0.2$



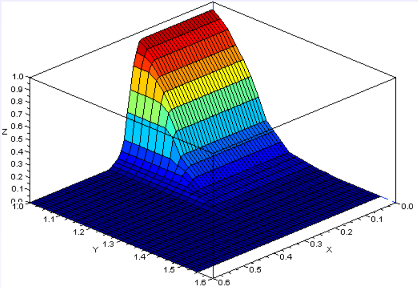
When percentage $= 0.2$ and $y_{\min} = 1.2$ millions tons. we have:

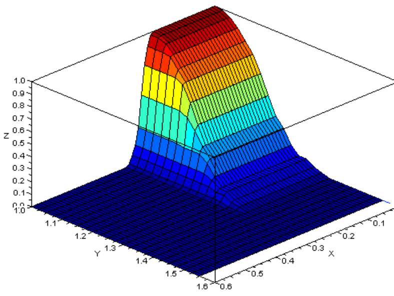
$$VP_{0.2} = 0.155$$

MPs Evaluation

Visual comparison of two given strategies

We can compare strategies $\lambda(t) = 0.2$ and $\lambda(t) = 0.23$:





If percentage $= 0.2$ and $y_{\min} = 1.2$ millions tons we have:

$$VP_{0.2} = 0.155 \leq 0.438 = VP_{0.23}$$

So, for these reference points, exploitation strategy $\lambda(t) = 0.23$ should be preferable to $\lambda(t) = 0.2$

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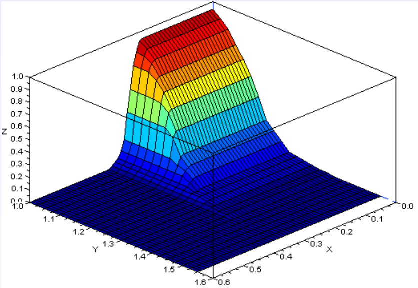

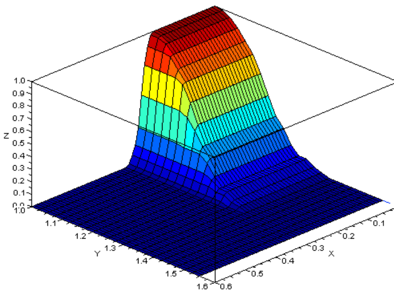

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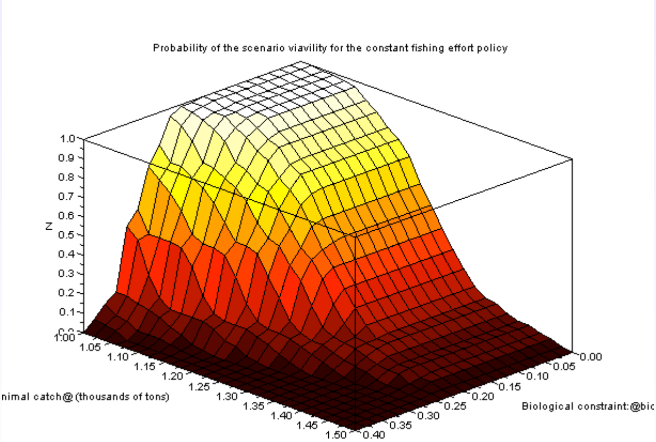
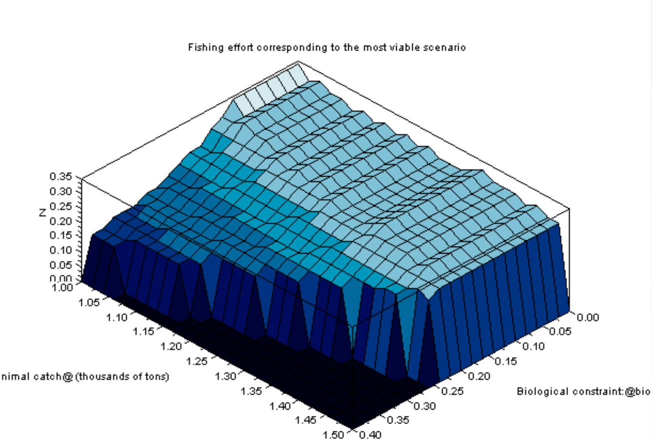
For the range of reference points, percentage and y_{min}, we compute the highest viability property we can obtain via a constant fishing effort strategy:



MPs Evaluation: Constant Fishing Effort

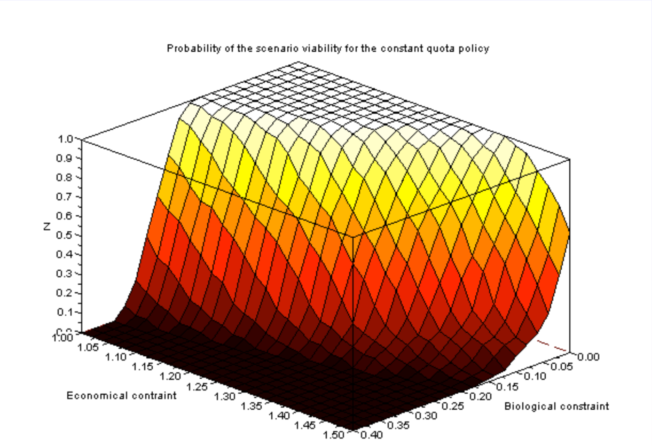
Best constant fishing effort strategy

For the range of reference points percentage and $y_{\min}$ we compute the larger constant fishing effort value (associated with the probability of the previous slide):



MPs Evaluation: TAC
Computation of Viability Probability

For the range of reference points, percentage and $y_{\min}$, we compute the highest viability property we can obtain via a TAC strategy:



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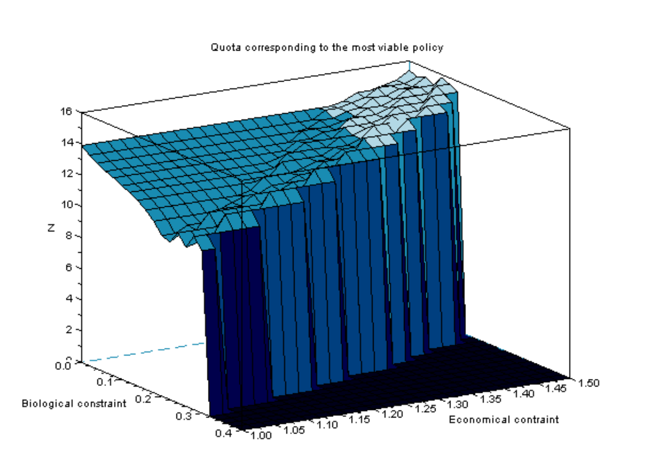
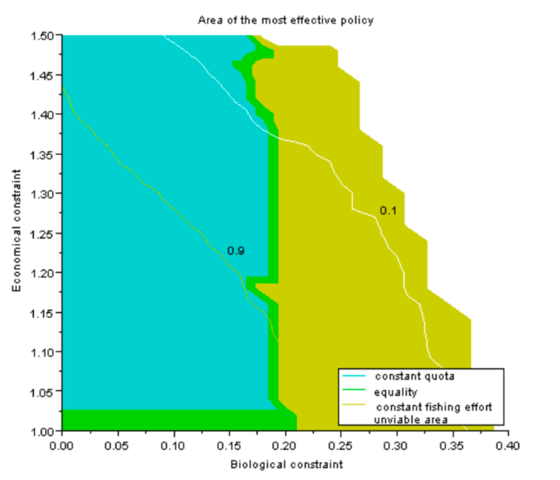


MPs Evaluation: TAC vs Constant Fishing Effort



Note that TAC type strategy is always more efficient than a constant fishing effort type strategy when the probability ≥ 0.9

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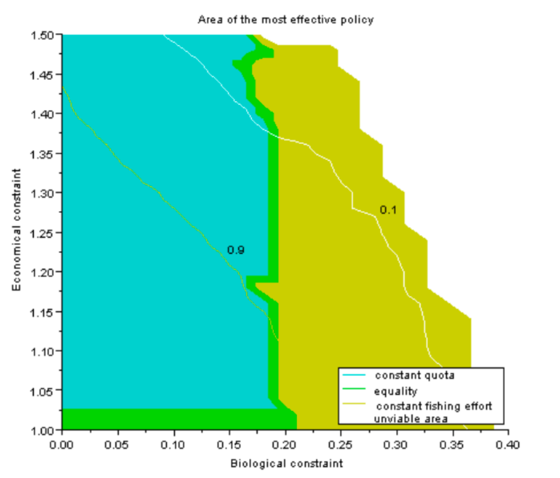

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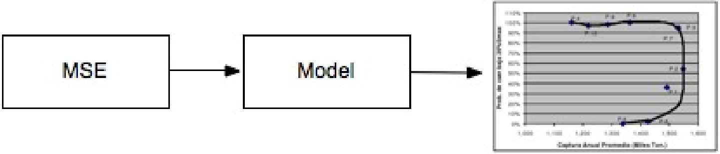
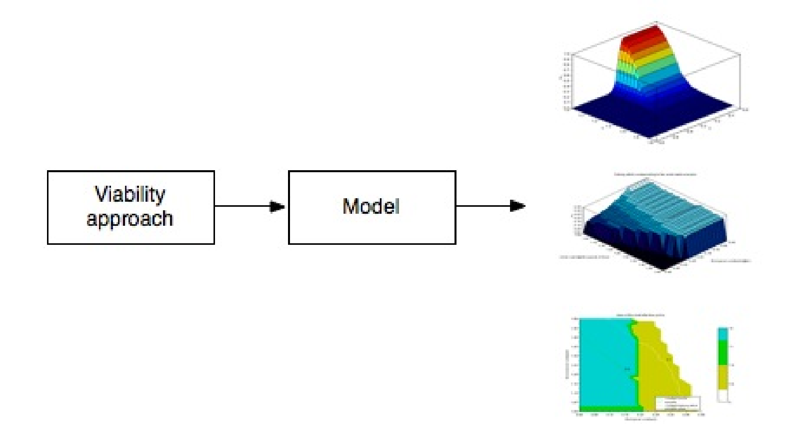
Tool Scheme: MSE



Tool Scheme: Viability Approach



Conclusions

- We consider an age structured abundance population model where the uncertainties only appears in the stock-recruitement relationship
- These uncertainties reflect the impact of *El Niño* phenomena
- We apply a new methodology which establishes a common currency (the viability probability) for the study of MPs
- This methodology provides a flexible tool for the comparison of fishery exploitation strategies

Bibliography

M. De Lara & L. Doyen
Sustainable Management of Natural Resources
Springer-Verlag (2008)

M. De Lara & V. Martinet
Multi-criteria dynamic decision under uncertainty: a stochastic viability analysis and an application to sustainable fishery management.
Math. Biosci. 217 (2009), no. 2, 118–124

V. Martinet, J. Peña, H. Ramírez & M. De Lara
Risk and Sustainability: Assessing Resource Management Procedures
Working paper

M. Yepes, J. Peña, P. Barría & A. Gomez-Lobos
Pesquería del Jurel en Chile: Reclutamiento, El Niño y efectos sobre la captura
Working paper (UAH Master thesis)

ICCOPT 2010

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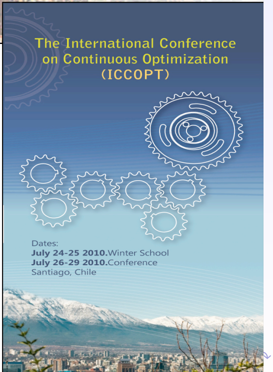

Thanks!!


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