Evaluation of Management Procedures

Application to Chilean Jack Mackerel Fishery

Vincent Martinet[1] Julio Peña[2] Héctor Ramírez C.[3]
Michel de Lara [4]

[1]Economie Publique, UMR INRA - AgroParisTech, France
[2]Universidad Alberto Hurtado, Santiago de Chile
[3]DIM & CMM, Universidad de Chile, Santiago de Chile
[4]Université Paris-Est, CERMICS, France

XXIX Congreso Ciencias del Mar
25 al 28 de Mayo 2009 -INPESCA, Concepción, Chile

Outline

Outline

Introduction

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

- This pelagic fish is affected by climatic factors that generate uncertainties in its stock dynamic model (El Niño)

Introduction

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

- This pelagic fish is affected by climatic factors that generate uncertainties in its stock dynamic model (El Niño)

Introduction

- These uncertainties are an obstacle for the implementation of sustainable exploitation strategies
- Until now, this has been done via yearly Total Allowable Catches (TACs) and their assignation by using non-transferable individuals quotas
- TAC can be considered as a management procedures (MP)

Introduction

- These uncertainties are an obstacle for the implementation of sustainable exploitation strategies
- Until now, this has been done via yearly Total Allowable Catches (TACs) and their assignation by using non-transferable individuals quotas
- TAC can be considered as a management procedures (MP)

Introduction

- These uncertainties are an obstacle for the implementation of sustainable exploitation strategies
- Until now, this has been done via yearly Total Allowable Catches (TACs) and their assignation by using non-transferable individuals quotas
- TAC can be considered as a management procedures (MP)

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
- According to Oliveira and Butterworth 2004, such MPs have been developed (though not always implemented) for a number of disparate fisheries since their development within the International Whaling Commission in the late 1980s

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
- According to Oliveira and Butterworth 2004, such MPs have been developed (though not always implemented) for a number of disparate fisheries since their development within the International Whaling Commission in the late 1980s

Management Procedures (MPs)

- Ideally, before defining the MP to be applied, one should compare different potential MPs and rank them with respect to their ability to keep the fishery sustainable in an uncertain environment
- The so-called Management Strategy Evaluation (MSE) denotes a class of procedures based on simulation to compare alternative MPs

Management Procedures (MPs)

- Ideally, before defining the MP to be applied, one should compare different potential MPs and rank them with respect to their ability to keep the fishery sustainable in an uncertain environment
- The so-called Management Strategy Evaluation (MSE) denotes a class of procedures based on simulation to compare alternative MPs

Management Strategy Evaluation (MSE)

As detailed in Sainsbury et al. 2000, the MSE approach consists of two main steps:

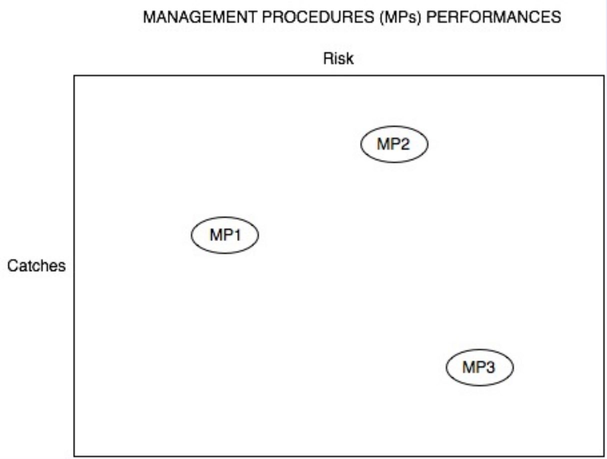
1. defining an operational set of management objectives,
2. and evaluating using simulations the performance of various alternative management strategies with respect to the specied objectives, taking into account uncertainty in the modeled processes

Management Strategy Evaluation (MSE)

As detailed in Sainsbury et al. 2000, the MSE approach consists of two main steps:

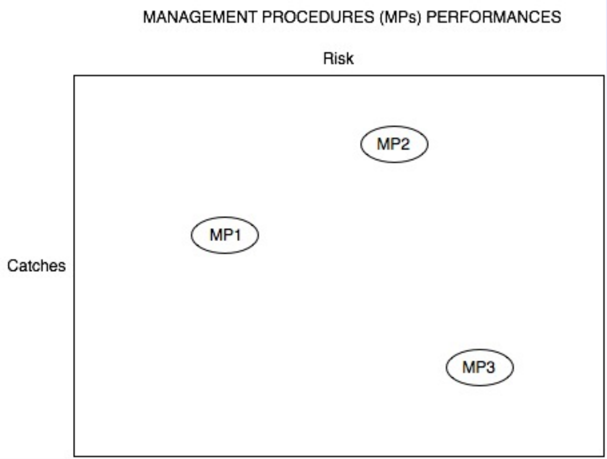
1. defining an operational set of management objectives,
2. and evaluating using simulations the performance of various alternative management strategies with respect to the specied objectives, taking into account uncertainty in the modeled processes

MPs and MSE



The MPs are not always comparable!!

MPs and MSE



The MPs are not always comparable!!

Outline

The Model

An age class dynamical model

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

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

The Model

An age class dynamical model

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

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

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

The stock-recruitment relationship

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

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

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

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

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

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

The Model

Incertitudes 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:

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

where

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

[1] M. Yepes 2008 (Thesis supervised by J. Peña)

The Model

Incertitudes 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:

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

where

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

[1] M. Yepes 2008 (Thesis supervised by J. Peña)

The Model

Incertitudes 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:

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

where

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

[1] M. Yepes 2008 (Thesis supervised by J. Peña)

The Model

Incertitudes 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:

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

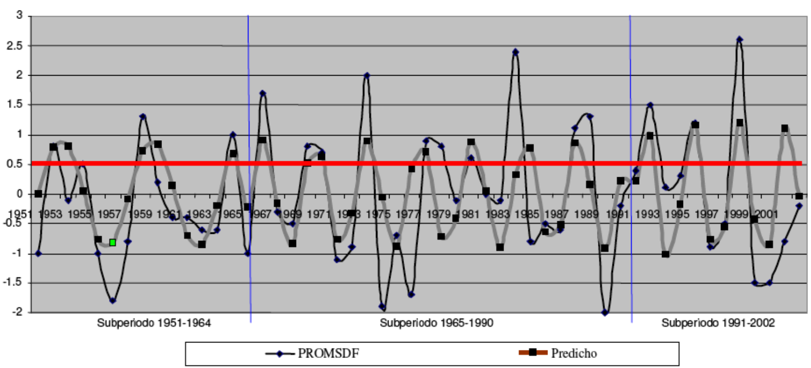
where

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

[1] M. Yepes 2008 (Thesis supervised by J. Peña)

The Model

Incertitudes in the stock-recruitment relationship



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 $w(\cdot) := (w(t_0), \ldots, w(T))$

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

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*)

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*)

New Methodology: Viability Approach

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

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

where

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

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

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

Constraints: Conflicting Indicators

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

They are given by indicators[2] $I_k = I_k(N, \lambda)$ and thresholds or reference points i_k.

So, we impose $I_k(N(t), \lambda(t)) \geq i_k$ 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

[2] It could be defined more general as functions of uncertainties $w(\cdot)$

Constraints: Conflicting Indicators

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

They are given by indicators[2] $I_k = I_k(N, \lambda)$ and thresholds or reference points i_k.

So, 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

[2] It could be defined more general as functions of uncertainties $w(\cdot)$

Constraints: Conflicting Indicators

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

They are given by indicators[2] $I_k = I_k(N, \lambda)$ and thresholds or reference points i_k.

So, we impose $I_k(N(t), \lambda(t)) \geq i_k$ 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

[2] It could be defined more general as functions of uncertainties $w(\cdot)$

Constraints: Conflicting Indicators

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

They are given by indicators[2] $I_k = I_k(N, \lambda)$ and thresholds or reference points i_k.

So, we impose $I_k(N(t), \lambda(t)) \geq i_k$ 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

[2]It could be defined more general as functions of uncertainties $w(\cdot)$

Constraints: Conflicting Indicators

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

They are given by indicators[2] $I_k = I_k(N, \lambda)$ and thresholds or reference points i_k.

So, we impose $I_k(N(t), \lambda(t)) \geq i_k$ 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

[2]It could be defined more general as functions of uncertainties $w(\cdot)$

A Common Currency: Viability Probability

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

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

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

We use this probability to compare different exploitation strategies

A Common Currency: Viability Probability

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

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

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

We use this probability to compare different exploitation strategies

A Common Currency: Viability Probability

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

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

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

We use this probability to compare different exploitation strategies

A Common Currency: Viability Probability

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

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

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

We use this probability to compare different exploitation strategies

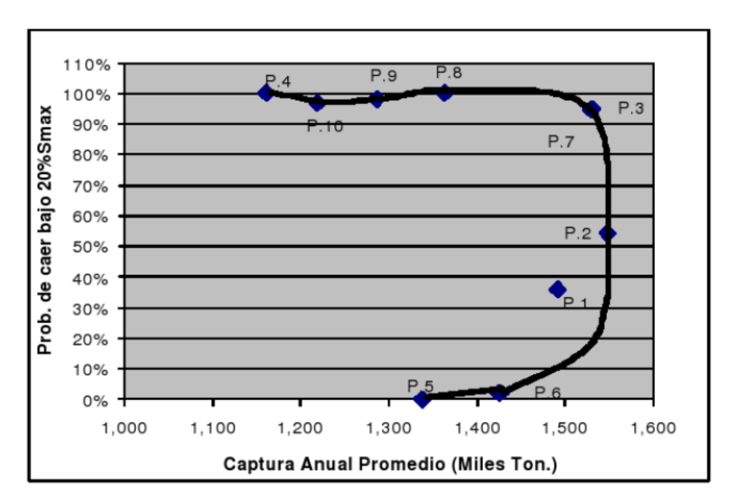
Outline

MPs Evaluation
Classical approach: MSE

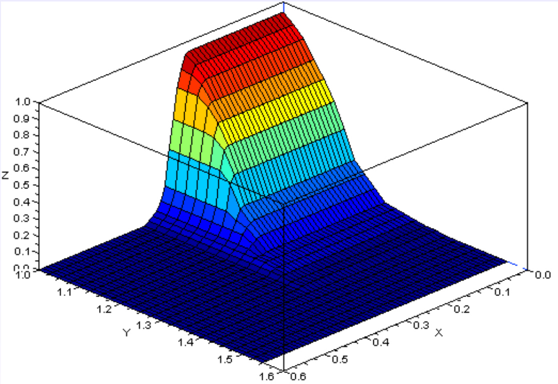
As detailed in Sainsbury et al. (2000), the MSE approach consists of two main steps:

1. defining an operational set of management objectives,
2. and evaluating using simulations the performance of various alternative management strategies with respect to the specied objectives, taking into account uncertainty in the modeled processes

MSE example (M. Yepes 2008):



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



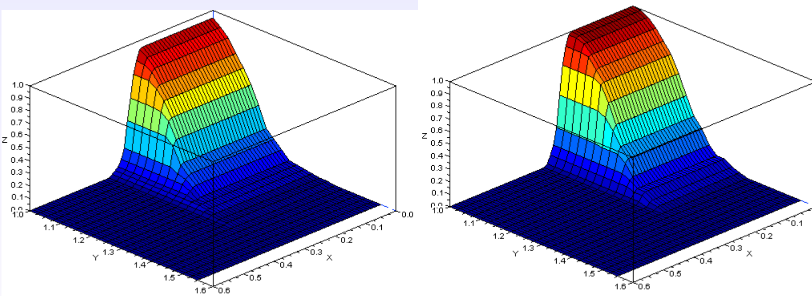
When percentage $= 0.2$ and $y_{\min} = 1.2$ millions tons. we have:

$$P(\lambda(t) = 0.2) = 0.155$$

MPs Evaluation

Visual comparison of two given strategies

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



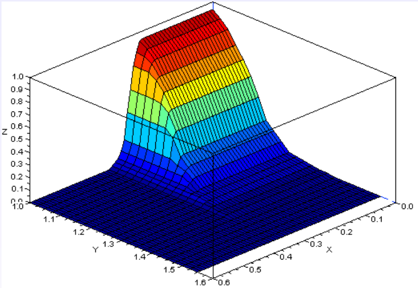
If percentage $= 0.2$ and $y_{\min} = 1.2$ millions tons. we have:

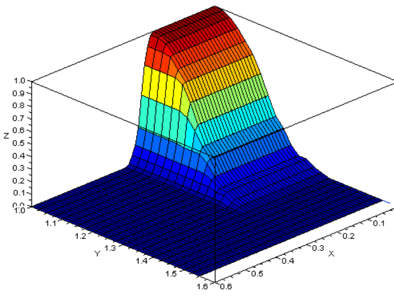
$$P(\lambda(t) = 0.2) = 0.155 \leq 0.438 = P(\lambda(t) = 0.23)$$

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

MPs Evaluation
Visual comparison of two given strategies

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



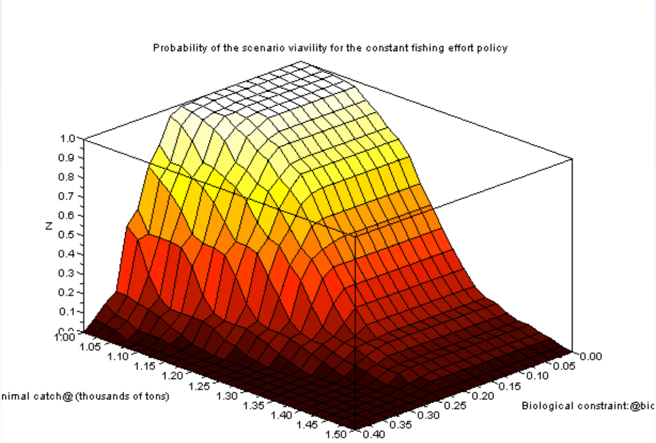


If percentage $= 0.2$ and $y_{\min} = 1.2$ millions tons. we have:

$$\boldsymbol{P}(\lambda(t) = 0.2) = 0.155 \leq 0.438 = \boldsymbol{P}(\lambda(t) = 0.23)$$

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

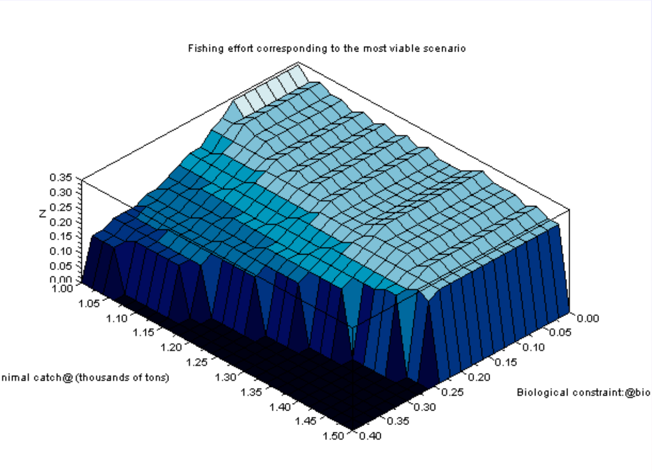
For the range of reference points, percentage and $y_{\min}$, we compute the highest viability property we can obtain via a constant fishing effort strategy:



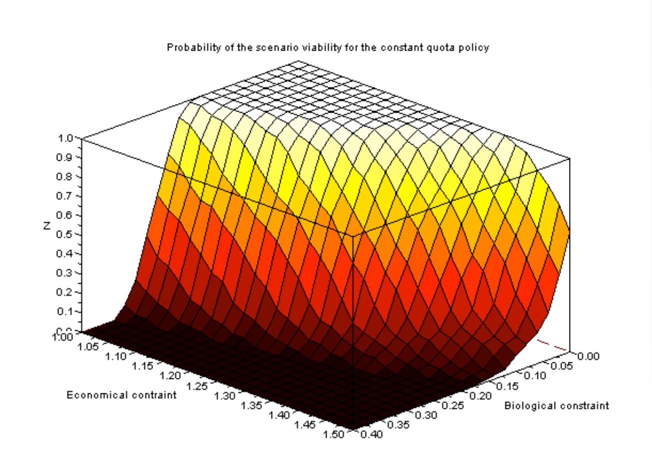
MPs Evaluation: TAC and Constant Fishing Effort

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):



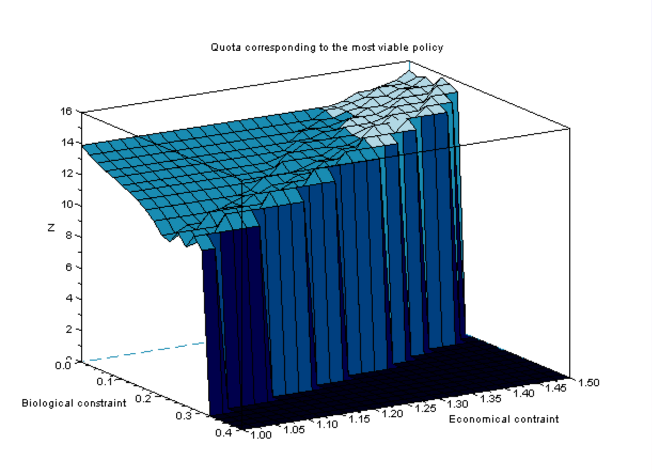
For the range of reference points, percentage and $y_{\min}$, we compute the highest viability property we can obtain via a TAC strategy:



MPs Evaluation: TAC and Constant Fishing Effort

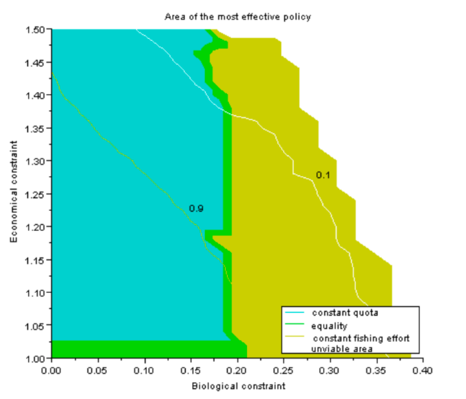
Best TAC strategy

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



MPs Evaluation: TAC vs Constant Fishing Effort

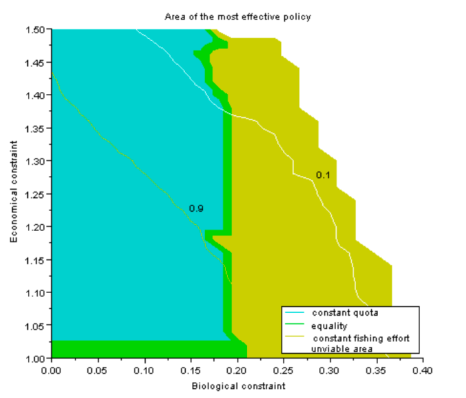
We can also compare both types of strategies:



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

MPs Evaluation: TAC vs Constant Fishing Effort

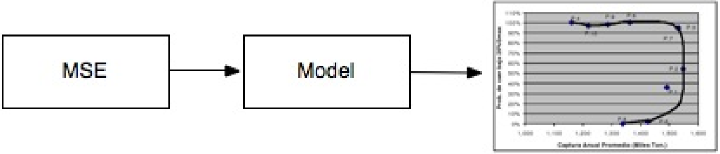
We can also compare both types of strategies:



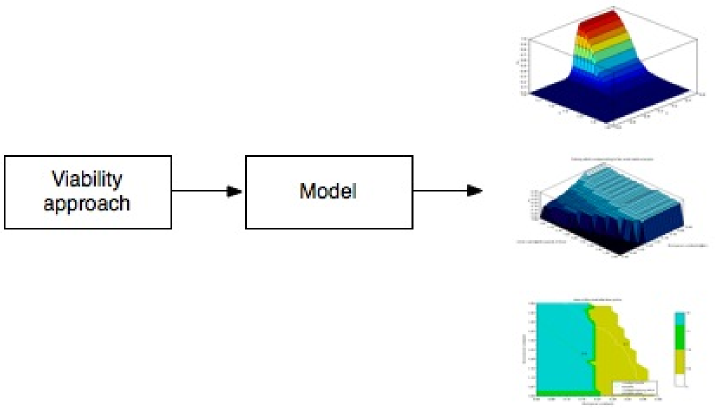
Note that TAC type strategy is always more efficient than a constant fishing effort type strategy when the probability ≥ 0.9

Outline

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 reflects 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)

Thanks!!


280195
Grilled mackerel
©Fotos mitgeschmack / Stockfood
Viewed by Guest on 9/7/2006