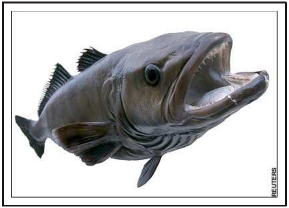
Sustainable reference points

P. Gajardo[1] M. De Lara[2] V. Martinet[3] H. Ramírez [4]

[1]Departamento de Matemática, Universidad Técnica Federico Santa María
[2]CERMICS, Université de Paris-Est, France
[3]INRA AgroParisTech, France
[4]Centro de Modelamiento Matemático, Universidad de Chile



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Concepción

Outline

Dynamics and decisions

- The state: $N = (N_a)_{a=1,\dots,A}$
  - Abundances at
    - age
    - size
    - age-size
  - Biomass
- The control (decision): λ

  Fishing effort multiplier
- The dynamics:

$$N(t+1) = g(N(t), \lambda(t))$$

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Indicators and reference points

Indicators and their associated reference points are key elements of current fisheries management advice, for example, in the ICES precautionary approach

Examples

- *$SSB(N)$: Spawning stock biomass*
- *$F(\lambda)$: Mean fishing mortality*
- *$Y(N,\lambda)$: catch in term of biomass*

Long term advise:

Examples

- *Keeping (or restoring) SSB above B_{lim}*
- *Restricting F below F_{lim}*
- *Keeping Y above y_{min}*

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Desirable configurations

A decision maker describes desirable configurations of the system through a set $\mathbb{D}$ (state - control) where $\mathbb{D}$ includes both system states and controls constraints

The activity is sustainable if: $(N(t), \lambda(t)) \in \mathbb{D} \quad t \geq t_0$

Examples

- $\mathbb{D}_{ICES} := \{(N, \lambda) \ : \ SSB(N) \geq B_{\lim} \ , \ F(\lambda) \leq F_{\lim}\}$
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Viability kernel

Definition

Given a dynamics g for the resource and a desirable configuration $\mathbb{D}$:

- *We define the* **viability kernel** $\mathbb{V}(g,\mathbb{D})$ *as the set of states (initial states) N from which there exists a desirable (in $\mathbb{D}$) evolution $(N(t),\lambda(t))$ (according to g)*

$$\mathbb{V}(g,\mathbb{D}) = \begin{cases} N \ : \ \text{there exist } \ \lambda(t_0), \lambda(t_0+1), \ldots \\ N(t_0), N(t_0+1), \ldots \text{such that } N(t_0) = N \\ N(t+1) = g(N(t),\lambda(t)) \ \ \text{and} \\ (N(t),\lambda(t)) \in \mathbb{D} \end{cases}$$

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Monotonicity properties on the dynamics

Evolution of the resource

$$N(t+1) = g(N(t), \lambda(t)) \qquad t = t_0, t_0 + 1, \ldots$$

Assumptions

Dynamics g is increasing with respect to the state i.e.

$$N' \geq N \Rightarrow g(N', \lambda) \geq g(N, \lambda)$$

and is decreasing with respect to the control i.e.

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Maximal sustainable SSB and catch

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$$\mathbb{D}_{y_{\min},B_{\lim}} := \{(N,\lambda) \ : \ Y(N,\lambda) \geq y_{\min}, \quad SSB(N) \geq B_{\lim}\}$$

we compute $y^*_{\min}$ and $B^*_{\lim}$ such that if

$$y_{\min} > y^*_{\min} \quad or \quad B_{\lim} > B^*_{\lim}$$

then

$$\mathbb{V}(g, \mathbb{D}_{y_{\min},B_{\lim}}) = \emptyset$$

implying that starting from any initial condition, independently of the taken decisions (applied controls), in a future period t we will have $(N(t),\lambda) \notin \mathbb{D}_{y_{\min},B_{\lim}}$ for all control λ

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Maximum sustainable catch starting from the current state (maximin)

Consider the desirable configuration

$$\mathbb{D}_{y_{\min}, B_{\lim}} = \{(N, \lambda) \mid Y(N, \lambda) \geq y_{\min}, \quad SSB(N) \geq B_{\lim}\}$$

Given an initial stock vector $N(t_0) = N$ and a SSB threshold $B_{\lim}$, we compute $B_{\lim} - \text{Maximin}(N) = \overline{y_{\min}}$ as the maximal catch threshold for which, starting from N there exists an evolution $(N(t), \lambda(t))$ satisfying

$$Y(N(t), \lambda(t)) \geq \overline{y_{\min}} \quad \text{and} \quad SSB(N(t)) \geq B_{\lim} \qquad \text{for all} \quad t$$

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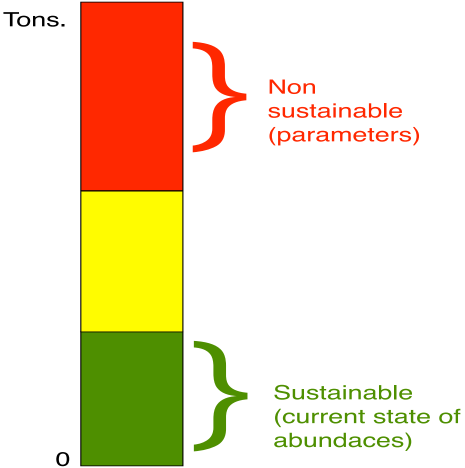
Proposition

If

$$Y(N(t), \lambda(t)) < B_{\mathsf{lim}} - \text{Maximin}(N(t))$$

then,

$$B_{\mathsf{lim}} - \text{Maximin}(N(t+1)) > B_{\mathsf{lim}} - \text{Maximin}(N(t))$$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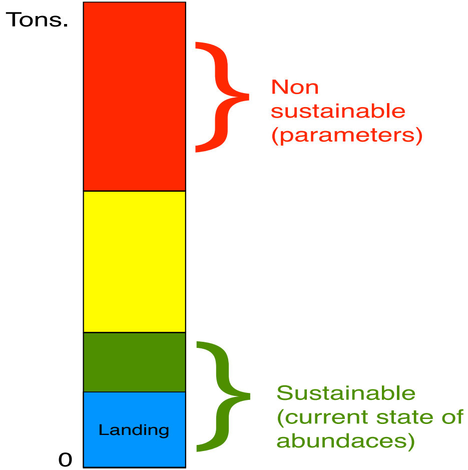
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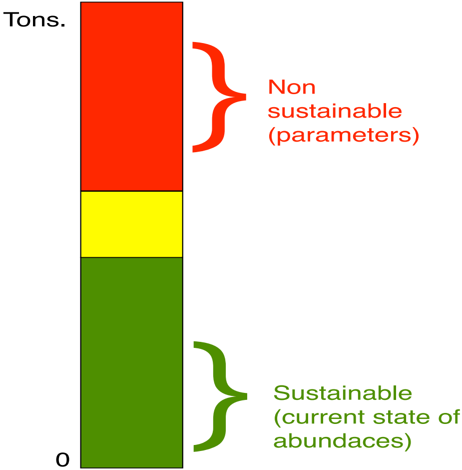
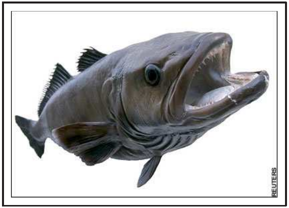

Tons.
0
Non sustainable (parameters)
Sustainable (current state of abundaces)

Example: Chilean sea bass

joint work with A. Zuleta and P. Rubilar - CEPES



Questions

- *Before starting the harvest (ignoring the current state N) : what are the maximal sustainable reference points*
    - B^*_{lim} *for the spawning stock biomass SSB?*
    - y^*_{min} *for the catches Y?*
- *During the harvesting (knowing the current state N): what are the sustainable reference points starting from N?*
    - *Given a threshold B_{lim} for the SSB to compute* $B_{\mathrm{lim}} \to \mathrm{Maximin}(N)$

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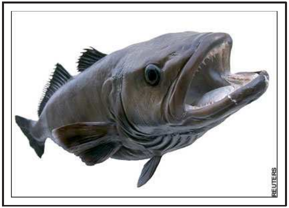

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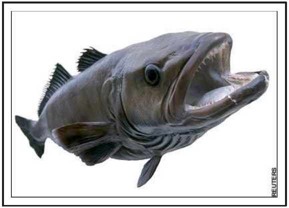

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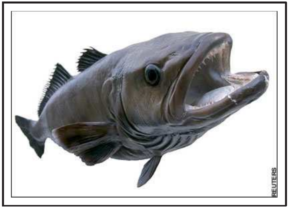

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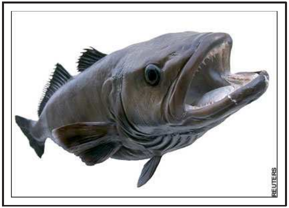

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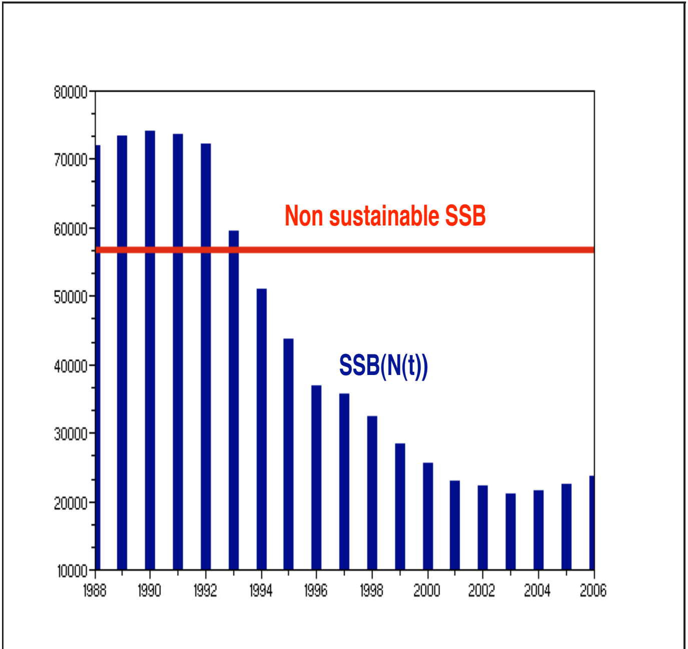
Maximal sustainable spawning stock biomass



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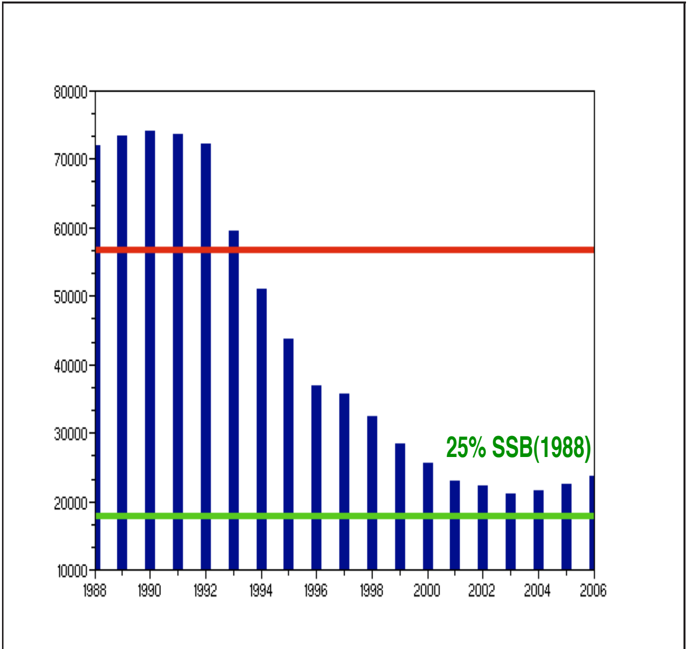
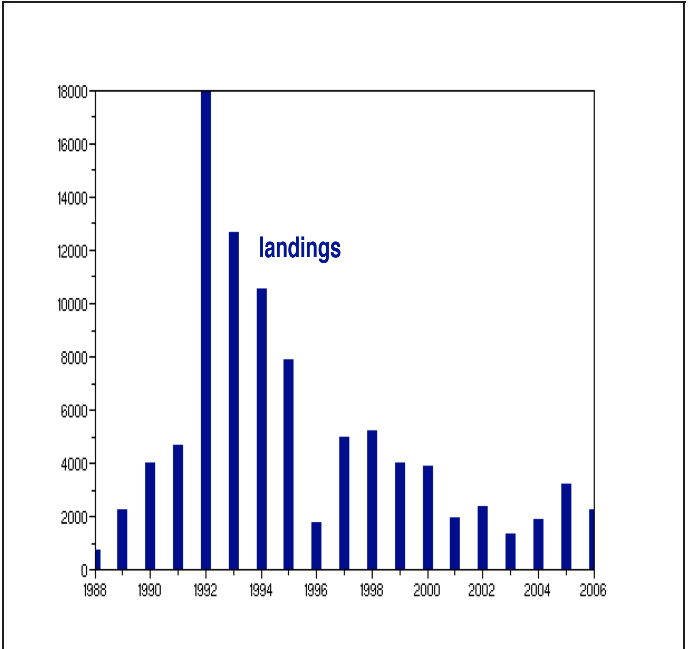


Maximal sustainable reference points



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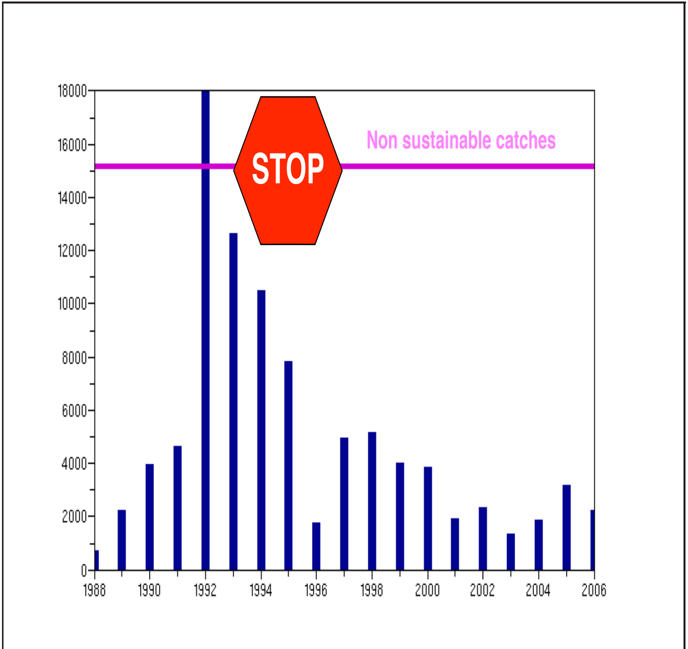
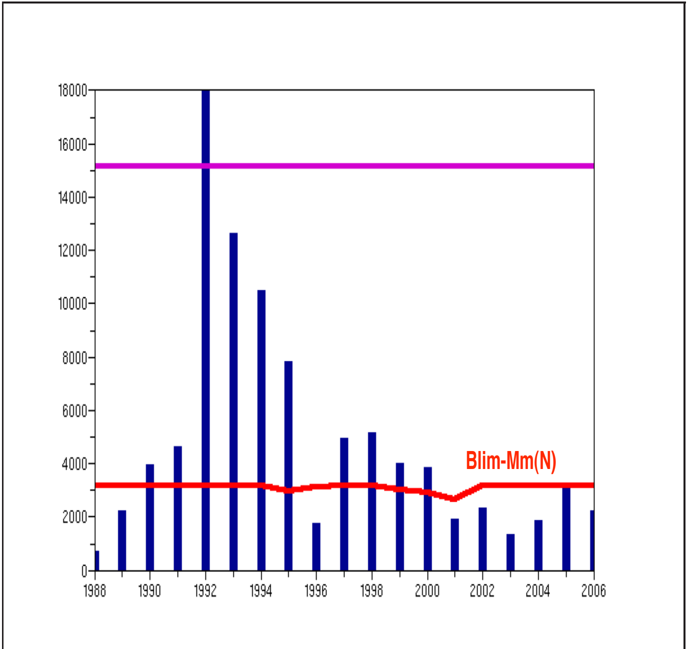


Maximal sustainable catches ($B_{\mathrm{lim}} = 25\% SSB_{1988}$)



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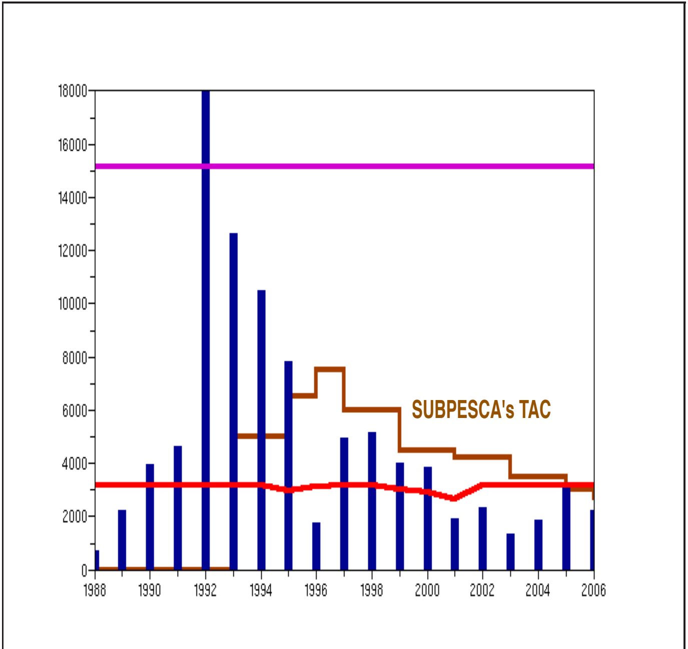
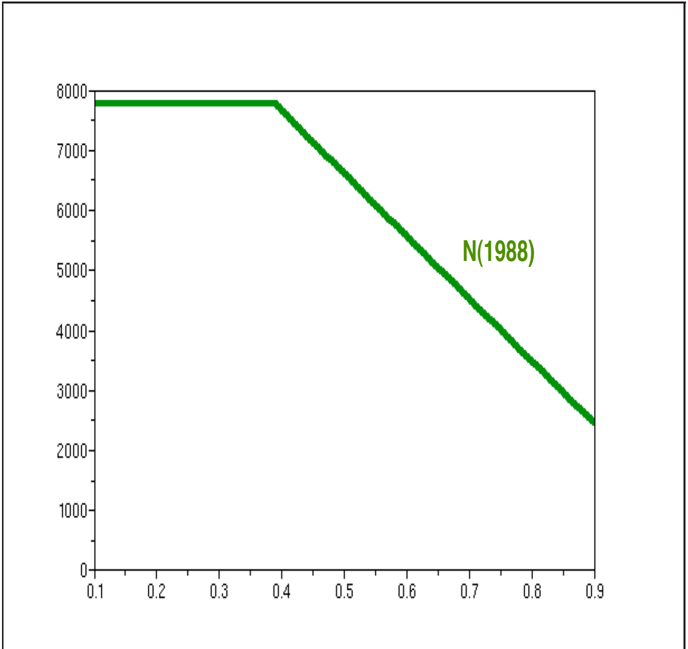


For a *SSB* threshold what is the $B_{\mathrm{lim}} - Mm(N)$



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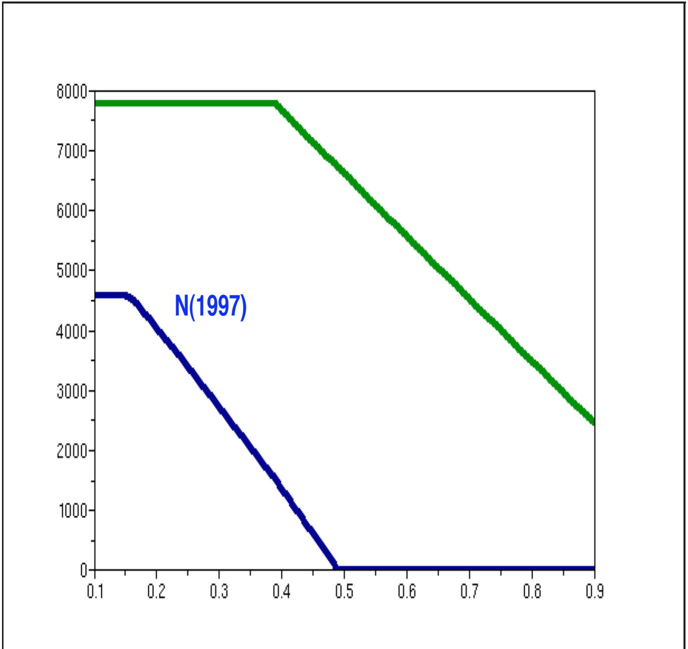

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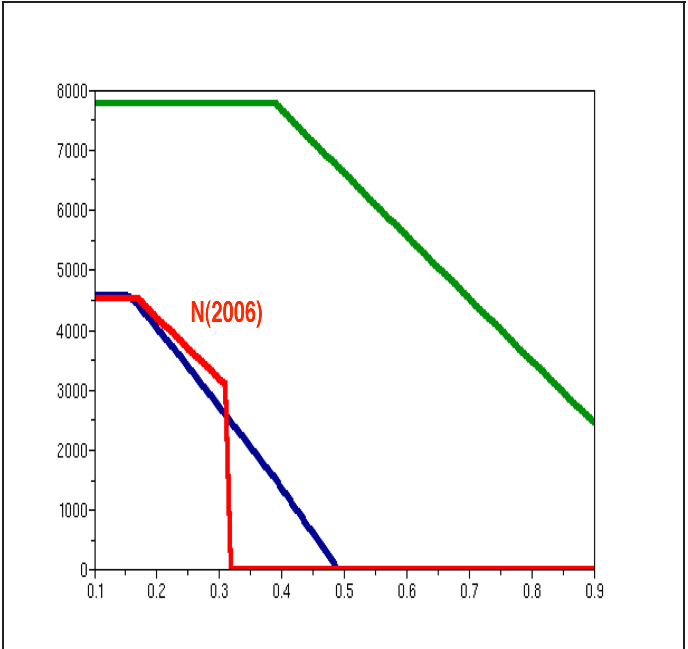

Conclusions

- Given a dynamics for the resource and an ideal configuration, we propose a methodology in order to:
  - determine if is possible to satisfy the desirable configuration (ignoring the state of the resource)
  - determine if starting of the current state is possible to satisfy the desirable configuration
- For the ideal configuration

$$\mathbb{D}_{y_{\min}, B_{\lim}} = \{(N, \lambda) \mid Y(N, \lambda) \geq y_{\min}, \quad SSB(N) \geq B_{\lim}\}$$

  we compute the upper sustainable thresholds $y^{\star}_{\min}$ and $B^{\star}_{\lim}$ given the current abundance N and a spawning stock biomass threshold, we compute the maximum sustainable catch $B_{\lim} \to \text{Maximin}(N)$ starting from N
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