1ST DOCKSIDE SUMMER SCHOOL

TRANSBOUNDARY RIVER ECOSYSTEM MANAGEMENT

Risk management Issues in Fisheries Management

Selles Jules

PhD candidate

University of Nantes & Ifremer

Co-funded by the Erasmus+ Programme of the European Union

UNIVERSITY OF BATTAMBANG, CAMBODIA

1st-5th October 2018

Outlines

1. Fisheries: what are we talking about ?
2. Fisheries Management
3. Risk Management: Precautionnary Approach
4. Defining Management Strategy
5. The case of Atlantic Bluefin tuna

Outlines

1. Fisheries: what are we talking about
2. Fisheries Management
3. Risk Management: Precautionnary Approach
4. Defining Management Strategy
5. The case of Atlantic Bluefin tuna

Multiple dimension of fisheries

> Economic (Direct incomes from products and fishery sector)

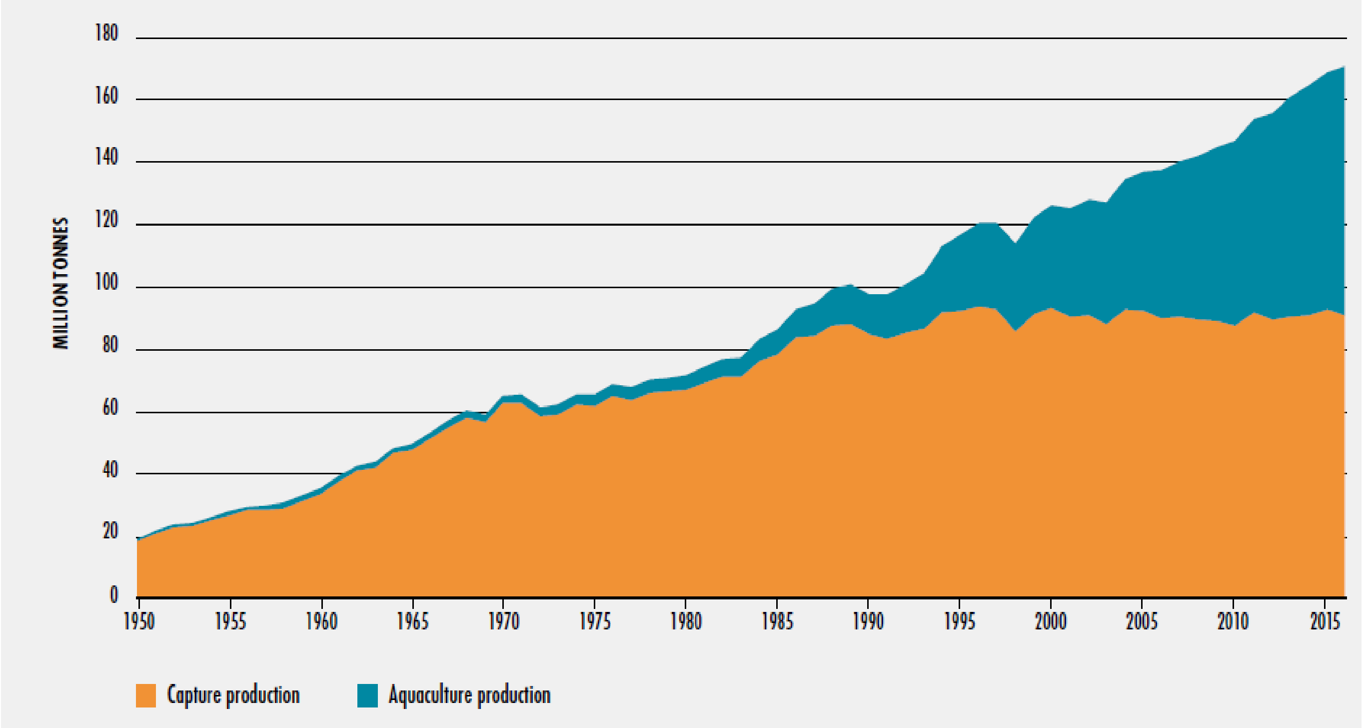
> Food security (~20% proteins)

> Social and Political stakes (jobs, ports activity, tourism)

> Ethical notion related to sustainable development

1. Fisheries: what are we talking about

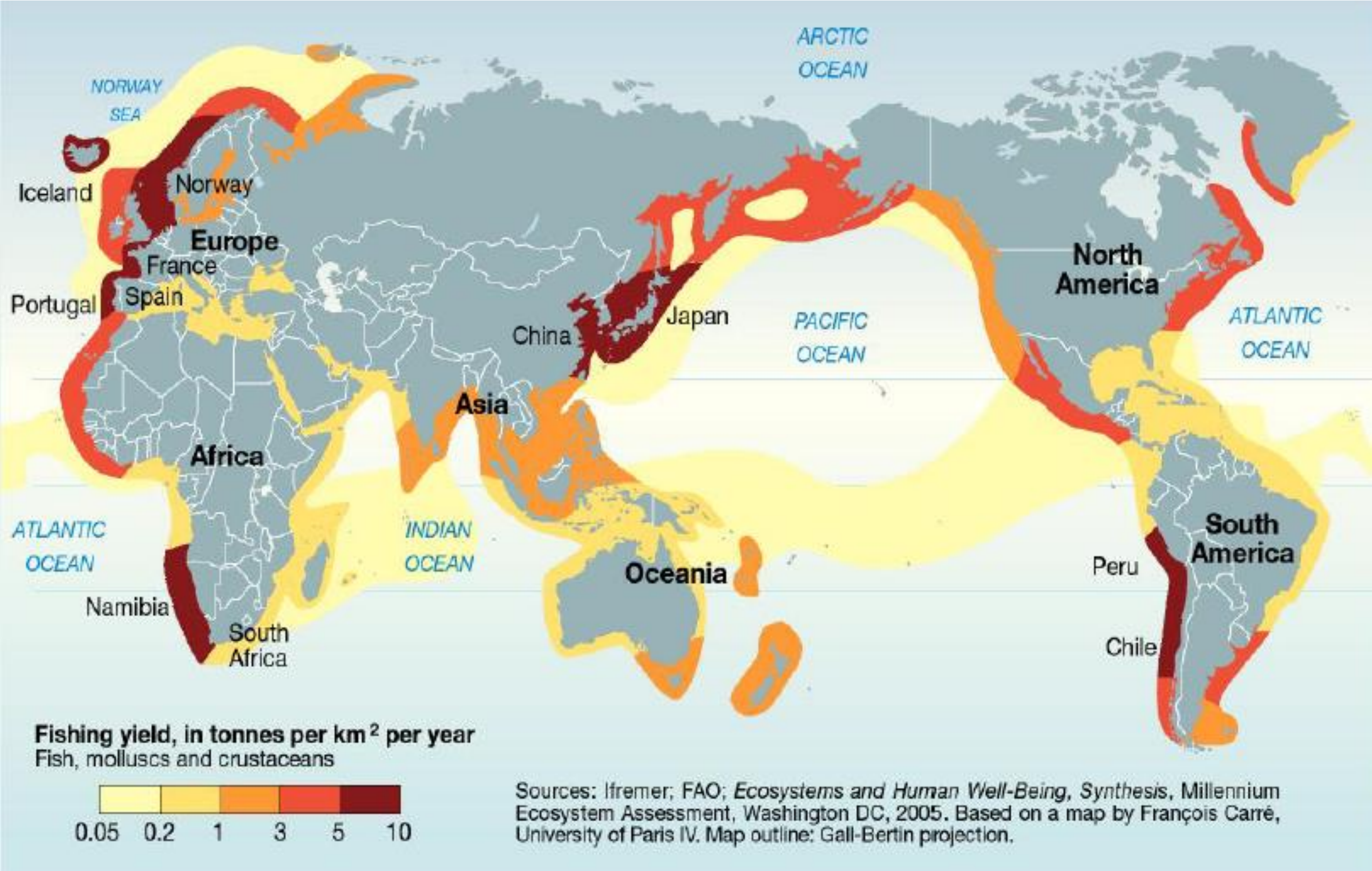
How much do we fish?



Source : FAO (2018)

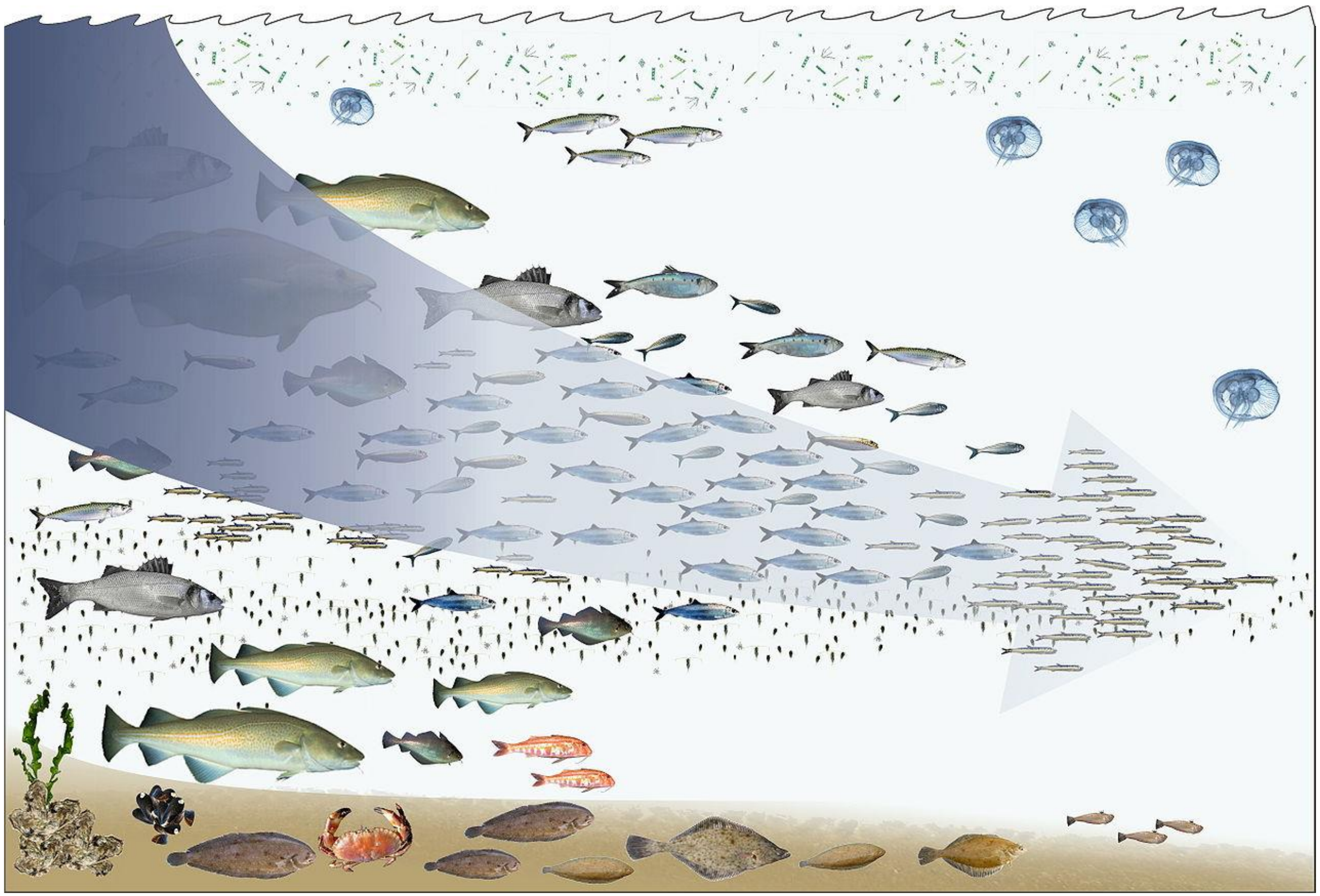
1. Fisheries: what are we talking about

Where do we fish?



1. Fisheries: what are we talking about

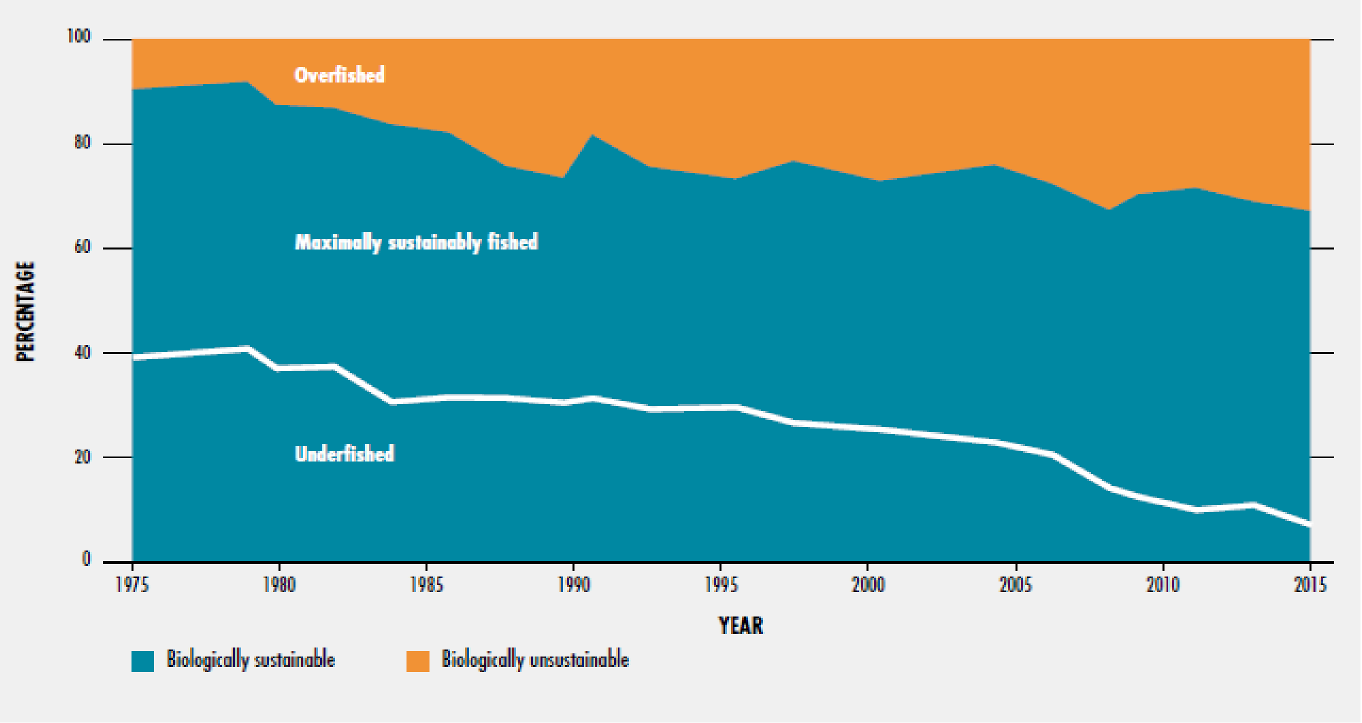
What kind of fish do we fish?



Fishing down the food web (Pauly 1998)

1. Fisheries: what are we talking about

How do we fish?



Source : FAO (2018)

How to reconcile exploitation and conservation?

How to manage marine resources sustainably while allowing their exploitation?

> What is the overexploitation of a stock ?

> How to quantify it? What are the limits of our estimates ?

> How to avoid or restore overexploited stock ?

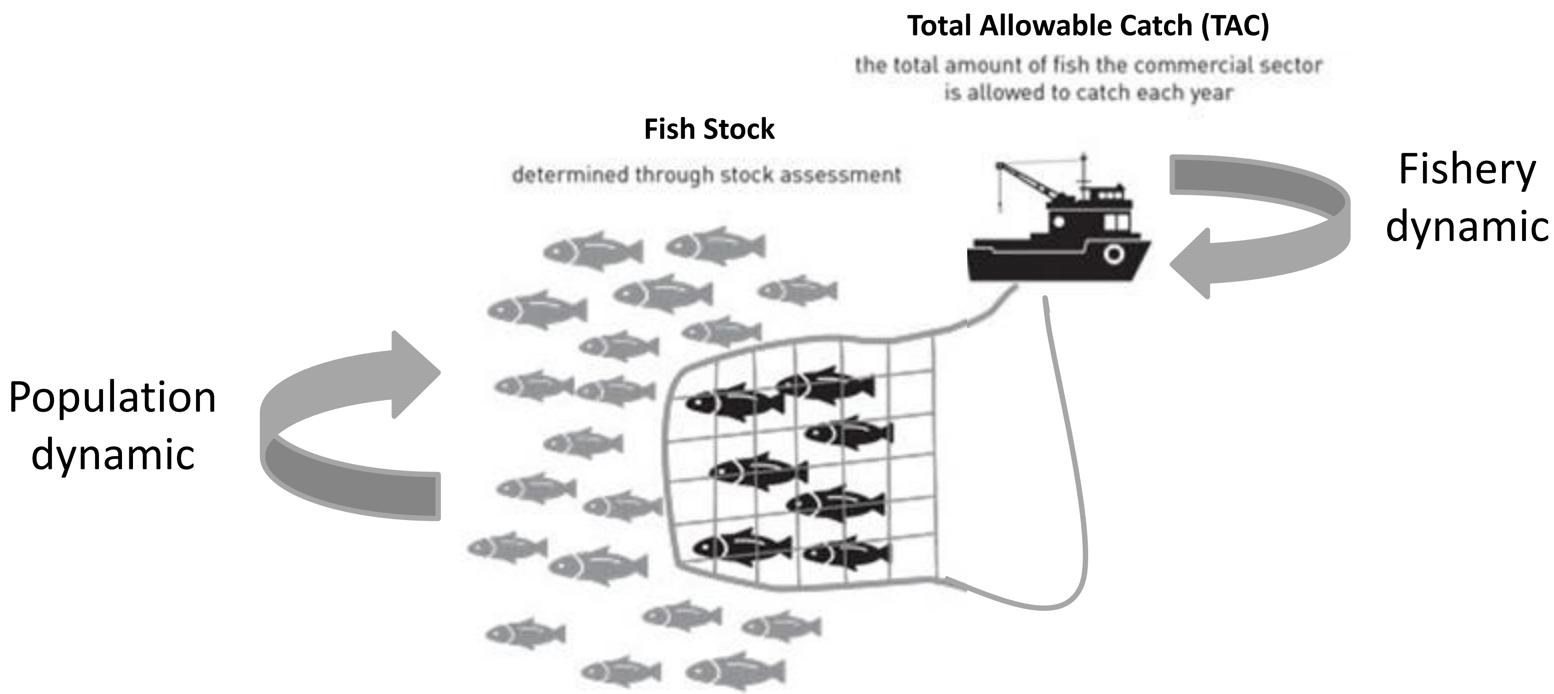
Outlines

1. Fisheries: what are we talking about
2. Fisheries Management

> Model and Base Concepts

3. Risk Management: Precautionnary Approach
4. Defining Management Strategy
5. The case of Atlantic Bluefin tuna

Fishery System

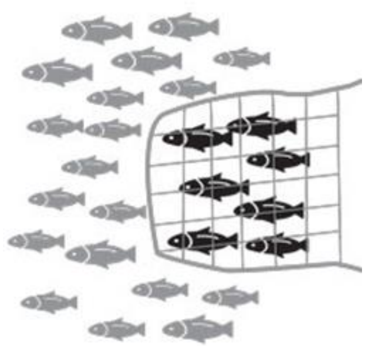


Population dynamic

A simple biomass dynamic model:

$$\frac{dB(t)}{dt} = rB(t)\left(1 - \frac{B(t)}{K}\right) - C(t)$$

B(t): Biomass
C(t): Catch in biomass or Yield
r: Growth rate
K: Environment carrying capacity

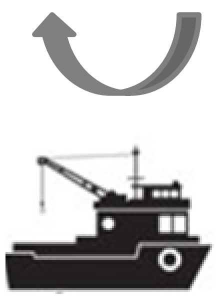


Resource growth

Fishery dynamic

A simple catch model:

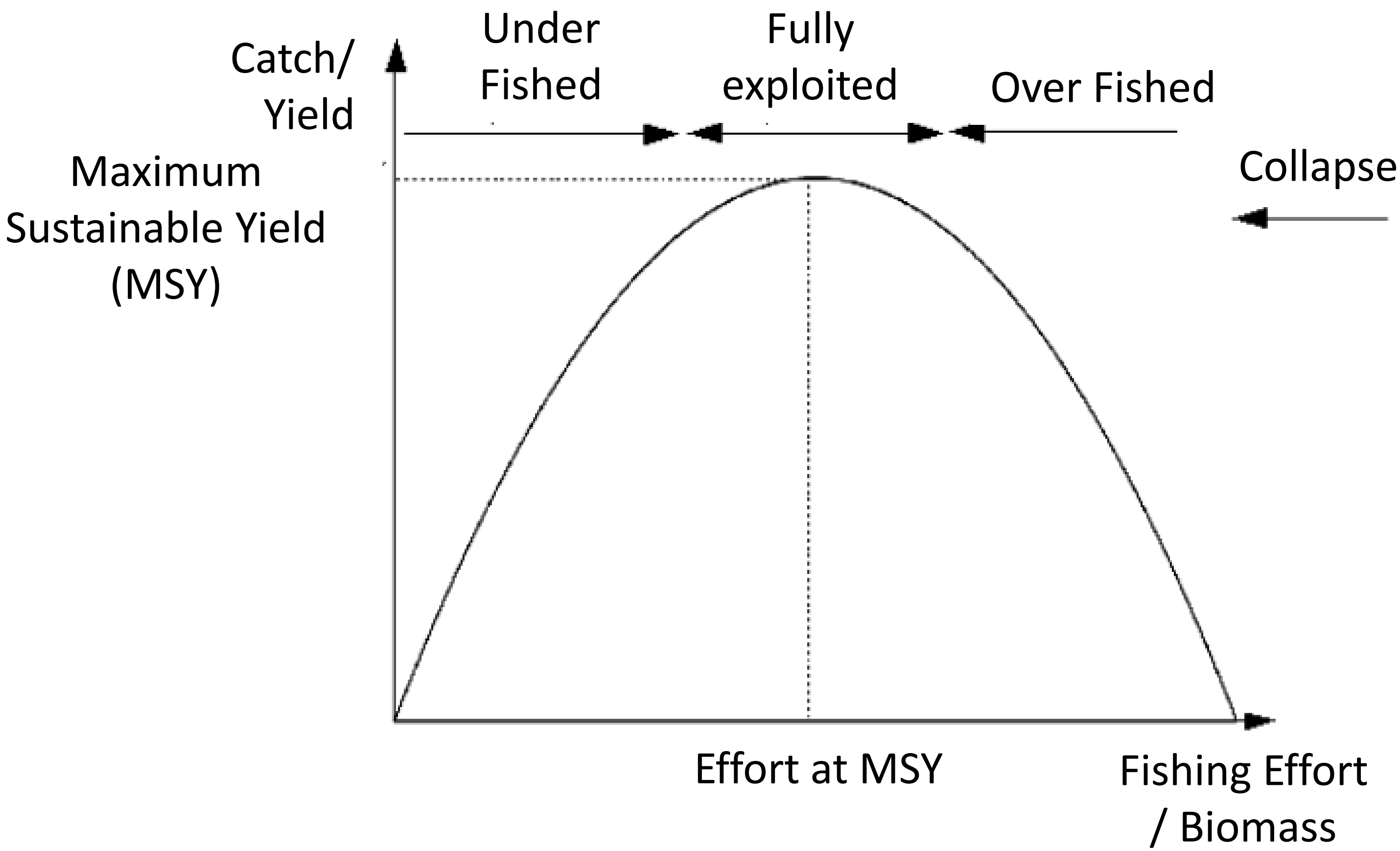
$$C(t) = qE(t)B(t)$$



Linear relationship between fishing effort E(t) and fish biomass B(t) through q the catchability coefficient

Equilibrium

$$\frac{dB(t)}{dt} = 0$$



Outlines

1. Fisheries: what are we talking about
2. Fisheries Management

> What Goal ?

3. Risk Management: Precautionnary Approach
4. Defining Management Strategy
5. The case of Atlantic Bluefin tuna

Maximum Sustainable Yield - MSY

Any level of abundance can be kept constant, but with low biomass levels when fishing effort is high (and vice versa).
MSY corresponds to the maximum of the balanced catch curve,

Common goal in fishery Management worldwide defined since the United Nations Convention on the Law of the Sea in 1982.

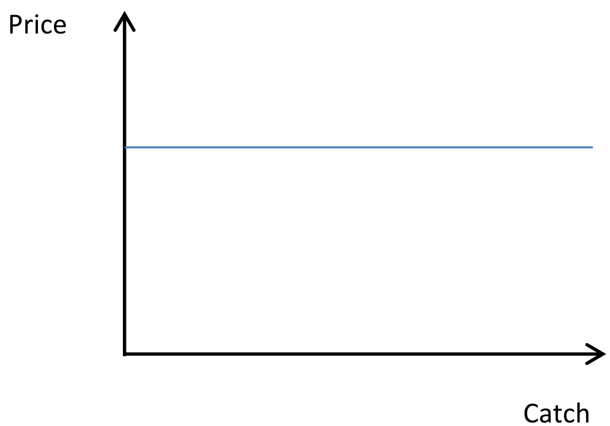
> Depend on the intrinsic rate of increase (r) and the biotic capacity of the medium (K)

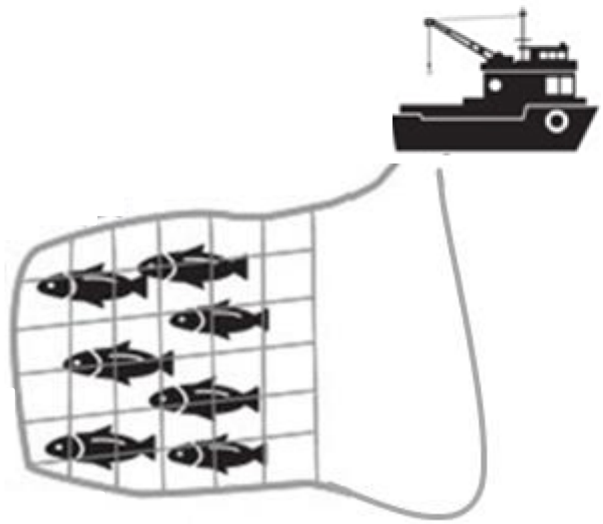
So it is the biological production of the stock and not directly its abundance that determines the catch potential

> Overexploitation does not mean a risk of collapse

Introducing Economic

> Relationship price and yield



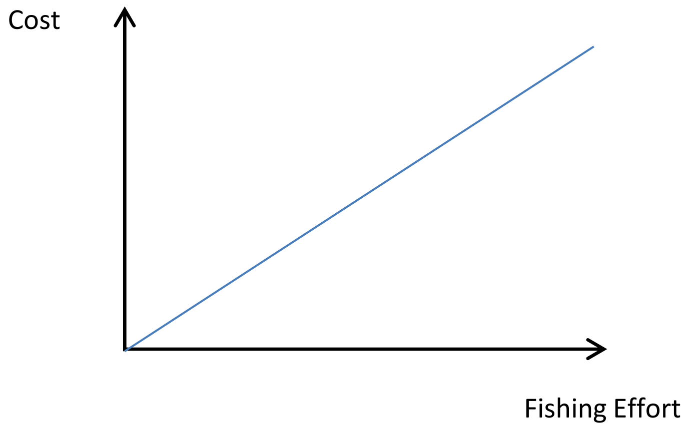


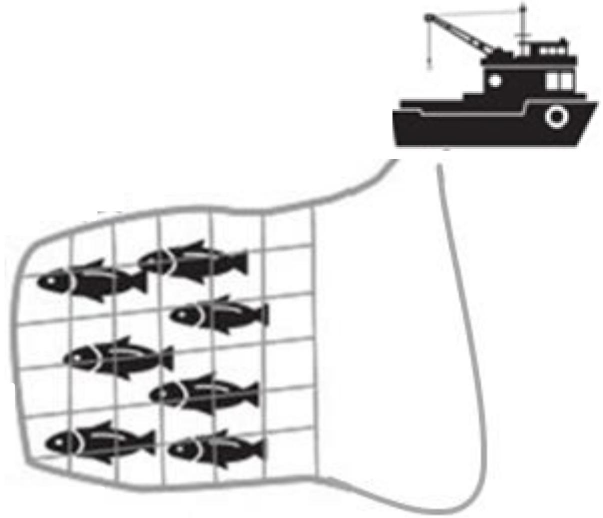
Price takers hypothesis

>This is the common case of fishermen whose products are destined for the world market and lacking the market share to influence market price on its own,

Introducing Economic

> Relationship between cost and fishing effort E(t)





Constant cost per unit of effort hypothesis

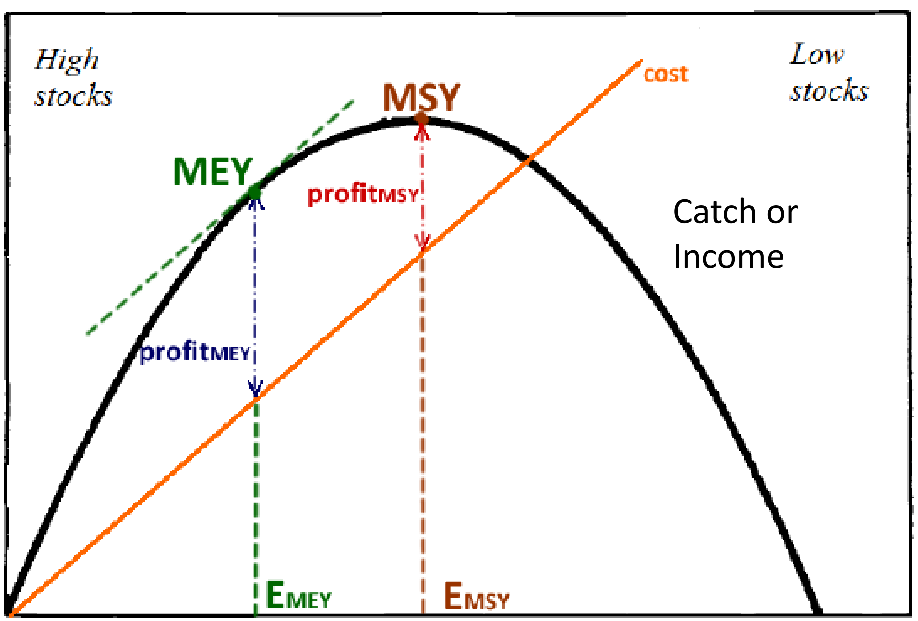
> All fishing units are considered identical.

Introducing Economic

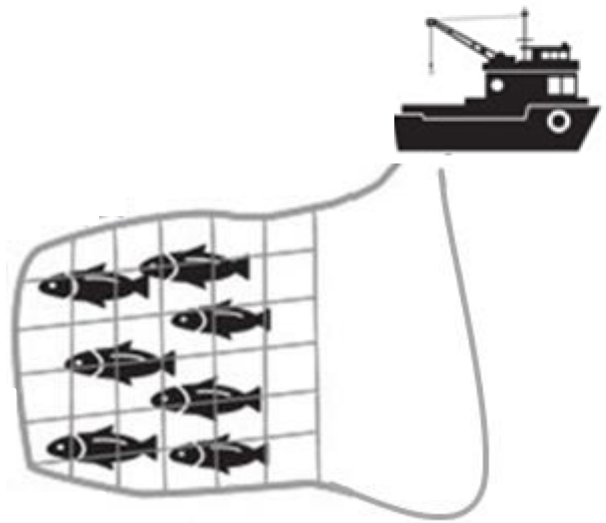
> Considering profit and the emergence of the Maximum Economic Yield (MEY) concept

$$Profit = pC(t) - cE(t)$$

Catch / Income

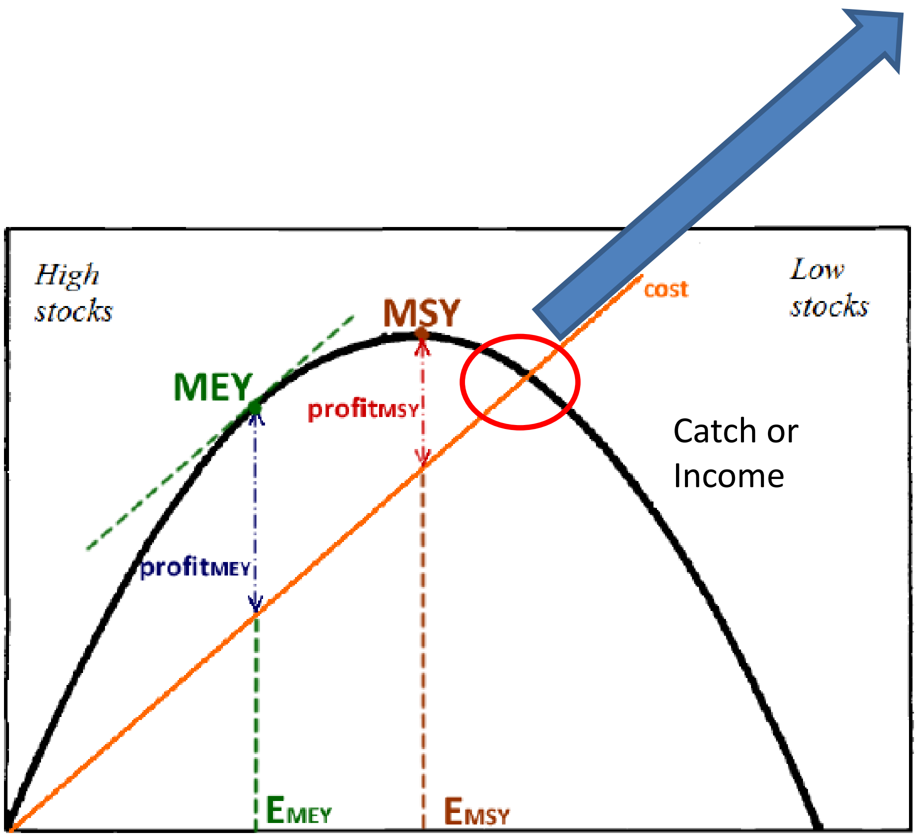


Fishing Effort



Where are we going if nothing is done ?

Catch / Income



Fishing Effort

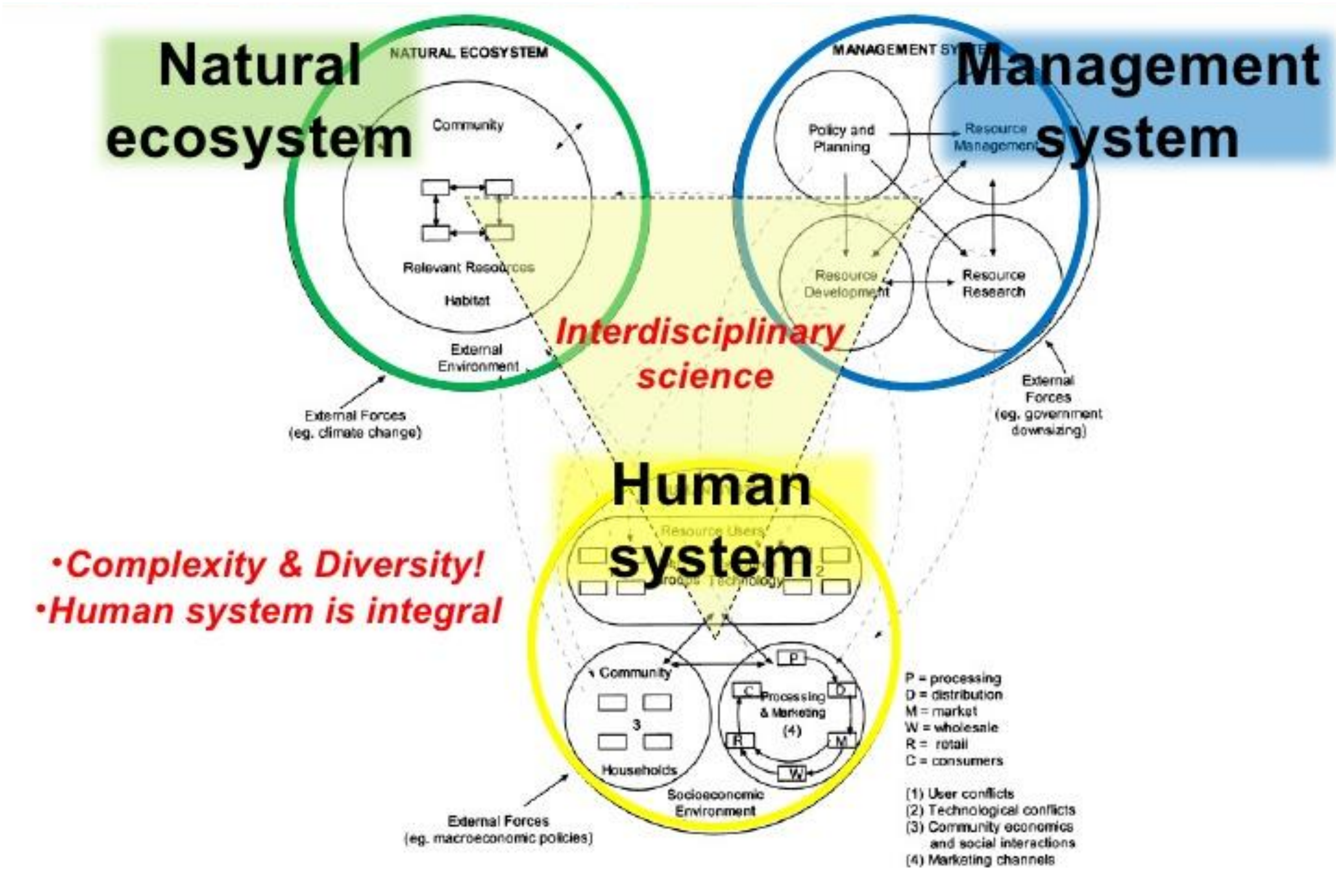
- Open Access equilibrium

As long as each fisherman receives a positive individual profit, new fishermen tend to enter the fishery because the resource is not appropriate (so-called free access regime), regardless of the impact of their action on other fishermen. via the decline of the resource (negative externality).

Too many boats chasing too few fish

2. Fisheries Mangement

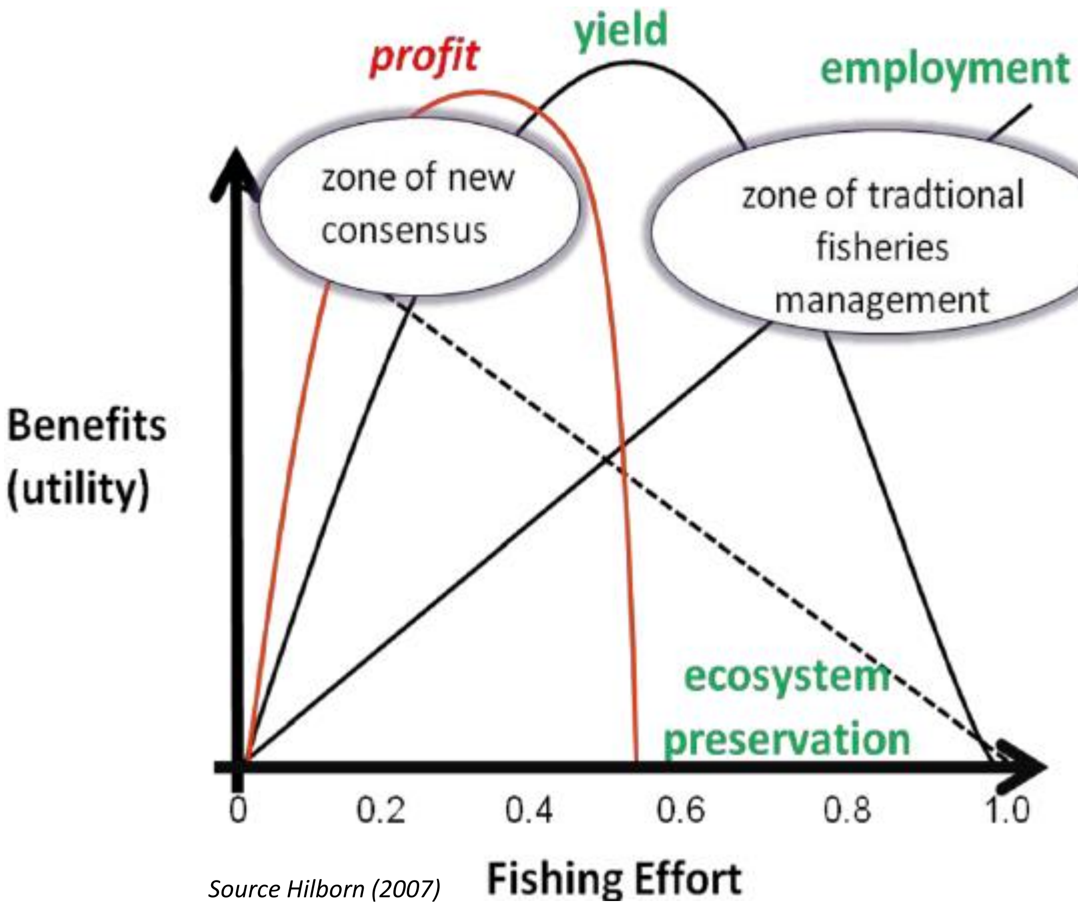
Multiple Dimension of Fishery Management



Source : Charles (2008)

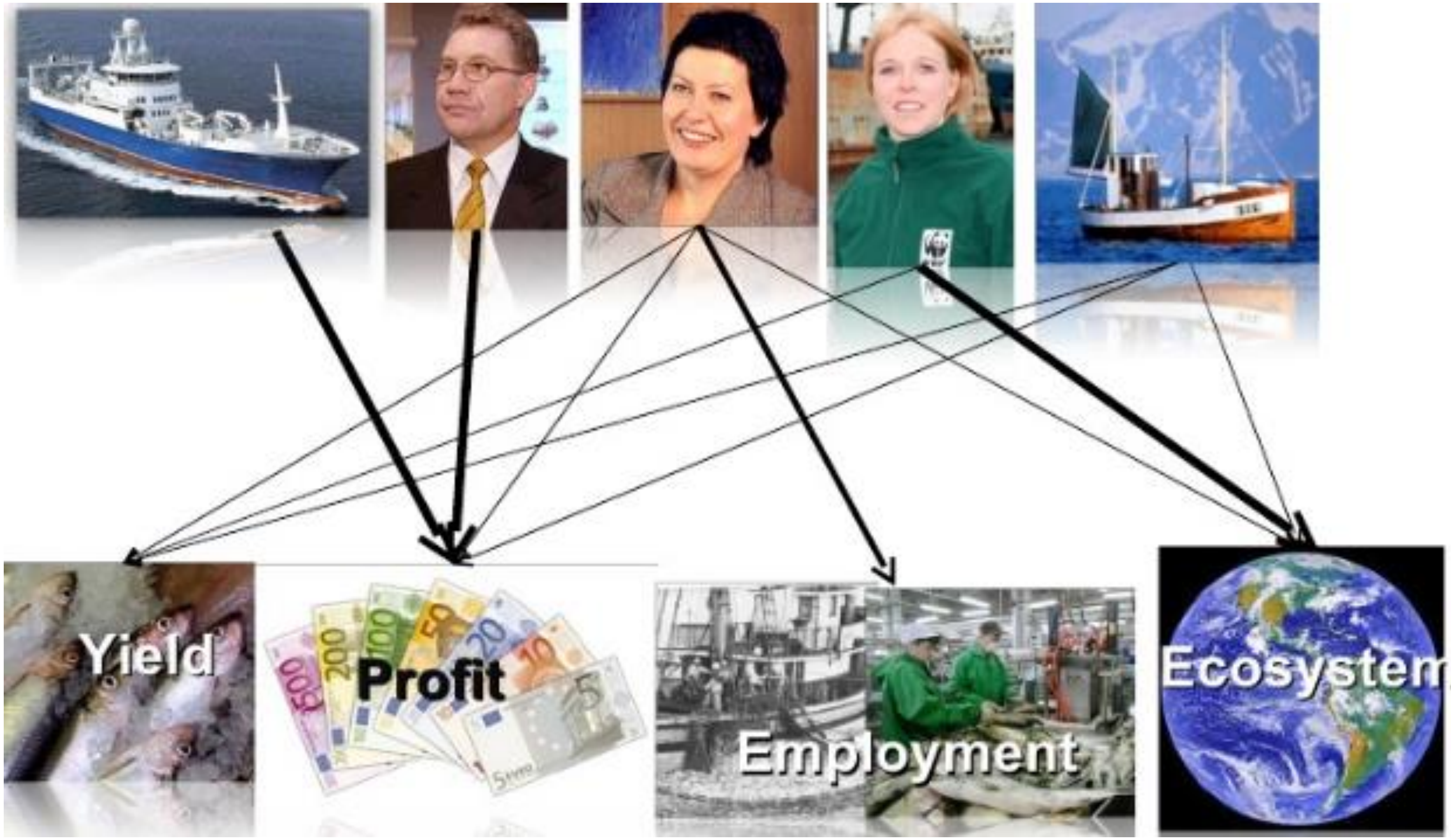
2. Fisheries Mangement

Multiple Dimension of Fishery Management = Multiple conflicting Objective

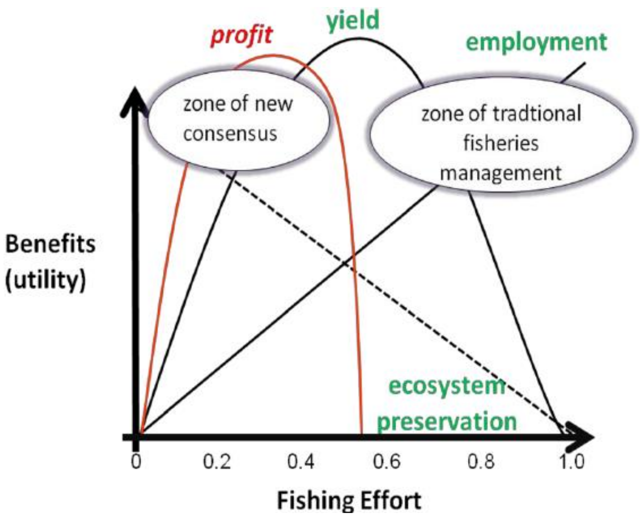


Source Hilborn (2007)

Stakeholders preferences



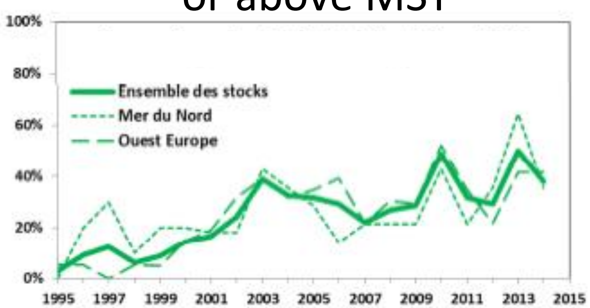
2. Fisheries Mangement



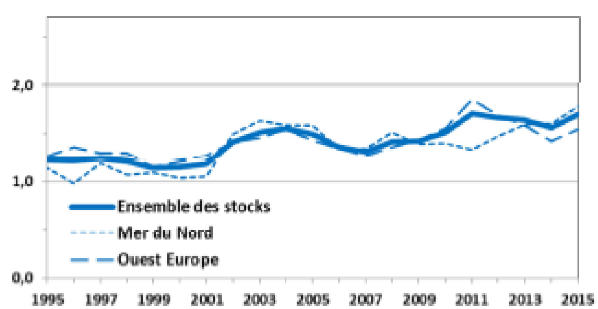
MSY as fishery management objective/target failed

The case of EU fisheries

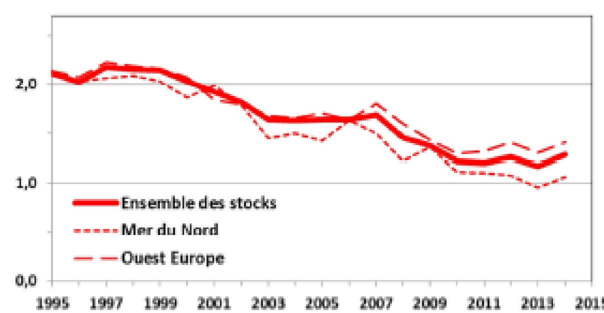
% Stocks evaluated at or above MSY



Relative fish biomass



Relative fishing effort



Outlines

1. Fisheries: what are we talking about
2. Fisheries Management
3. Risk Management: Precautionnary Approach
   - Base Concept / Implementation
4. Defining Management Strategy
5. The case of Atlantic Bluefin tuna

Risk Management

> Risk entails the ideas of uncertainty and loss, the Food and Agriculture Organisation (FAO) refers to average forecasted loss.

> Uncertainty refers to the incompleteness of knowledge about the state or processes (past, present, and future) of nature.

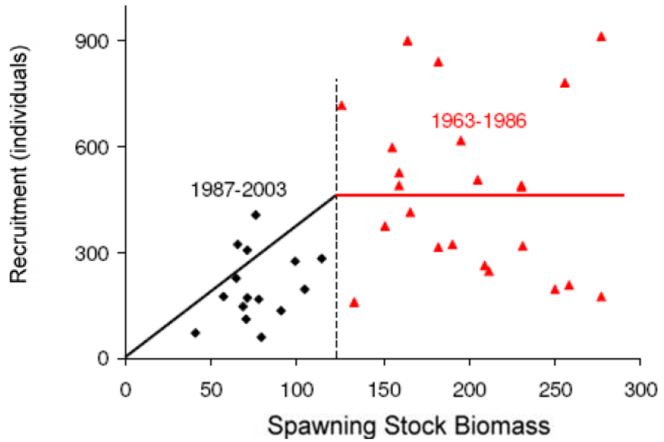
It is agreed that it is a lack of knowledge that causes risk

Biological Risks

Natural populations can exhibit dynamical behaviors broadly described as nonlinear, including multiple equilibria (regime shifts).

The population models commonly used to project stock rebuilding are generally single species (i.e., no interactions among species), assume continuation of historical conditions in the ecosystem (including variability) into the future (i.e., stationarity assumption), and calculate the biomass reference points under stable equilibrium assumptions.

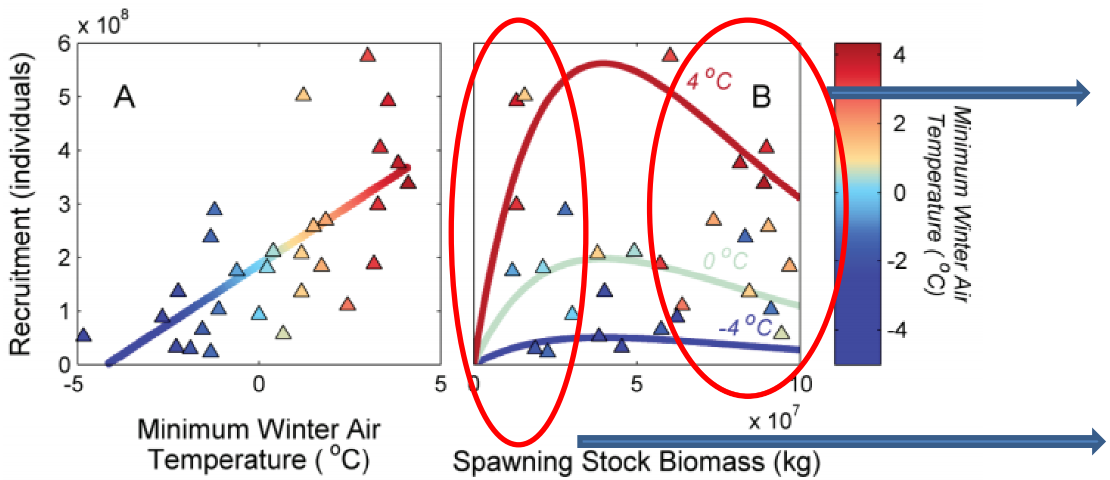
> e.g. Stock - recruitment relationship: a highly variable process



Relationship between cod (*Gadus morua*)) recruitment and spawning stock biomass.

Biological Risks

Density-dependent process



Relationship between Atlantic croaker (*Micropogonias undulatus*) recruitment, temperature, and spawning stock size (Hare et al. 2010).

>Compensatory Phenomena:

Density-Dependent regulatory mechanismeon adult fecundity or during the pre-recruited phase.

> Recruitment over exploitation:

Decreased fertility of females in relation to intraspecific competition;
Increased cannibalism of pre-recruits by adults;
Decreased pre-recruit survival (intra-specific competition).

Precautionnay Approach

Dealing with uncertainties and avoid risk through applying Precautionary Approach

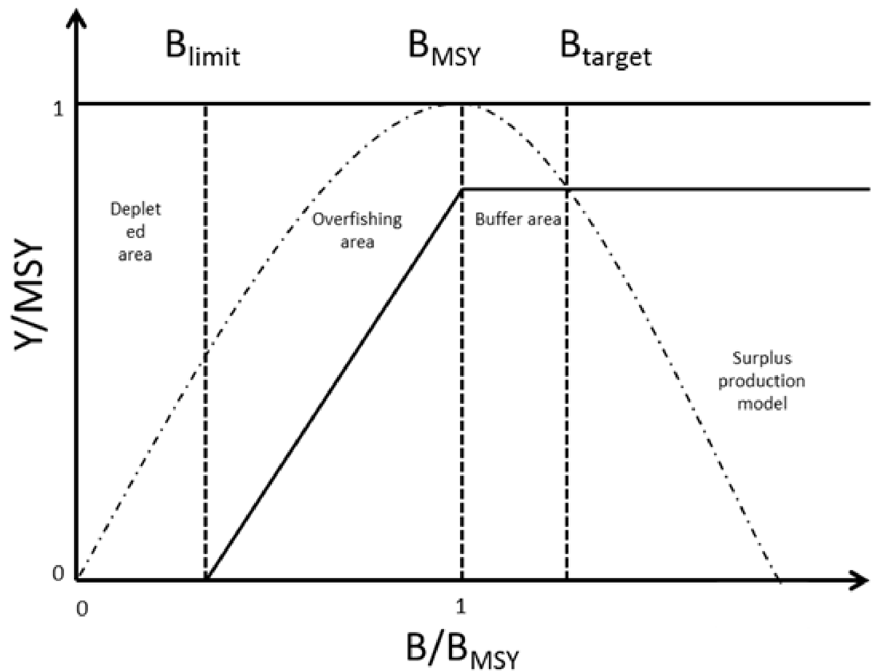
> Involves the application of prudent foresight by taking account of the uncertainties in fisheries systems and the need to take action with incomplete knowledge.

One way of reducing risk is by reducing fishing pressure in order to have larger average stock sizes, which would serve as a buffer for natural fluctuations.

Target and limit references points

Reference points are used as a guide for fisheries management.

A reference point indicates a particular state of a fishery indicator corresponding to a situation considered as desirable (‘target reference point’), or undesirable and requiring immediate action (‘limit reference point’ and ‘threshold reference point’).

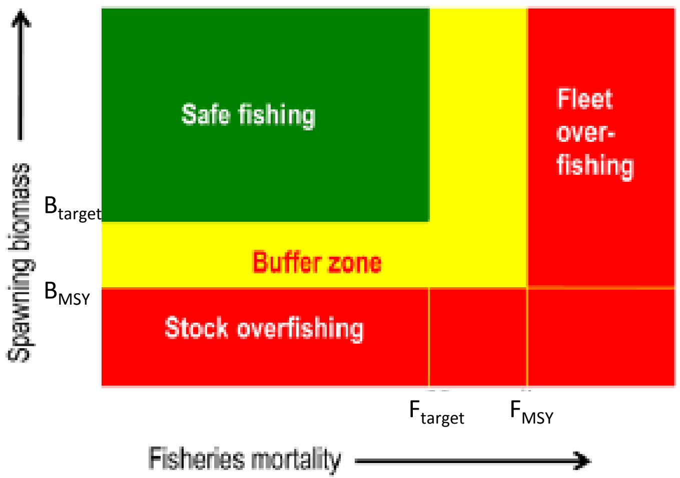


Target and limit references points

> Fishing mortality rate which generates MSY should be regarded as a standard for limit reference points.

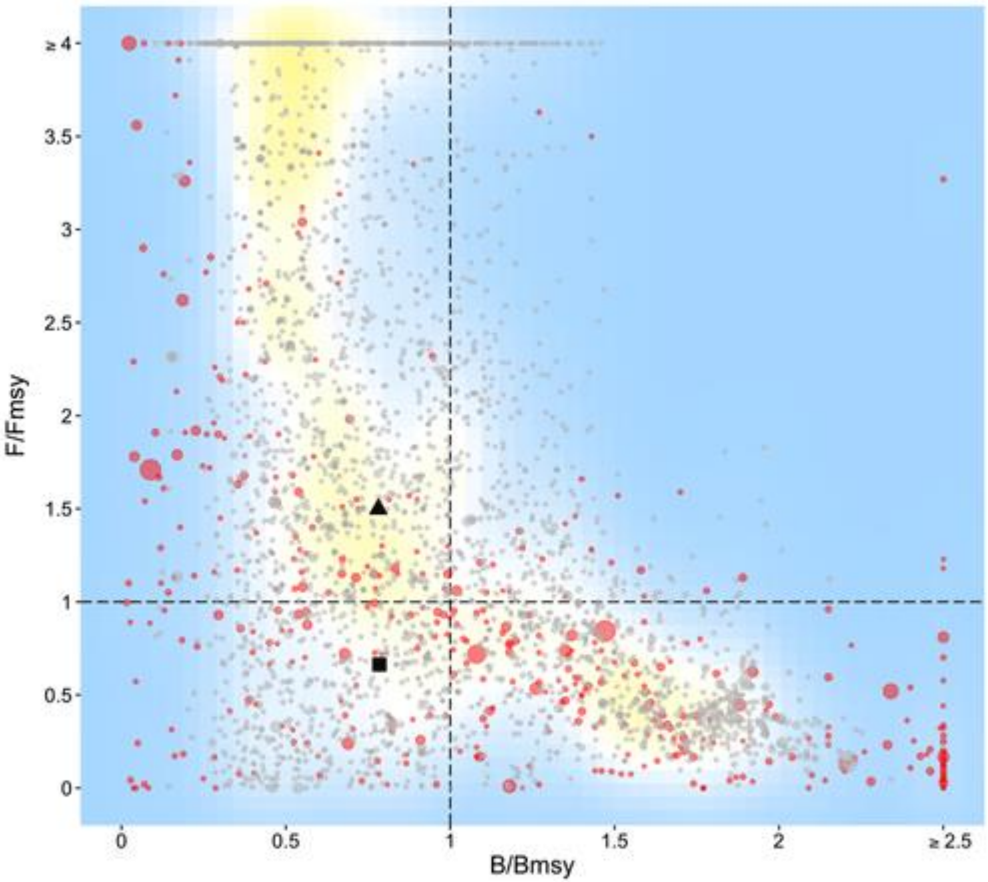
$$F(t) = \frac{C(t)}{N(t)}$$

> Implementing the Precautionary Approach, we defined MSY as a limit reference point instead of target reference point.



3. Risk Management: Precautionnary Approach

Status of World fisheries

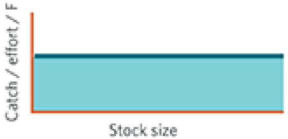
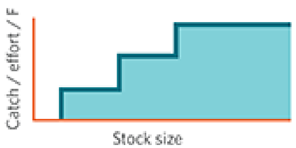
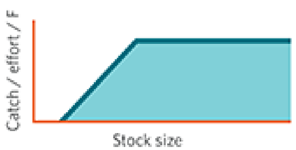
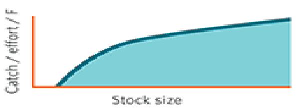


Source Costello et al. (2016)

Legend: Dot size scales to fishery MSY. Shading is from a kernel density plot. The triangle is the median and the square is MSY-weighted geometric mean.

How to define quotas?

> Harvest control rules (HCRs) are the operational component of a harvest strategy, essentially pre-agreed guidelines that determine how much fishing can take place, based on indicators of the targeted stock's status.

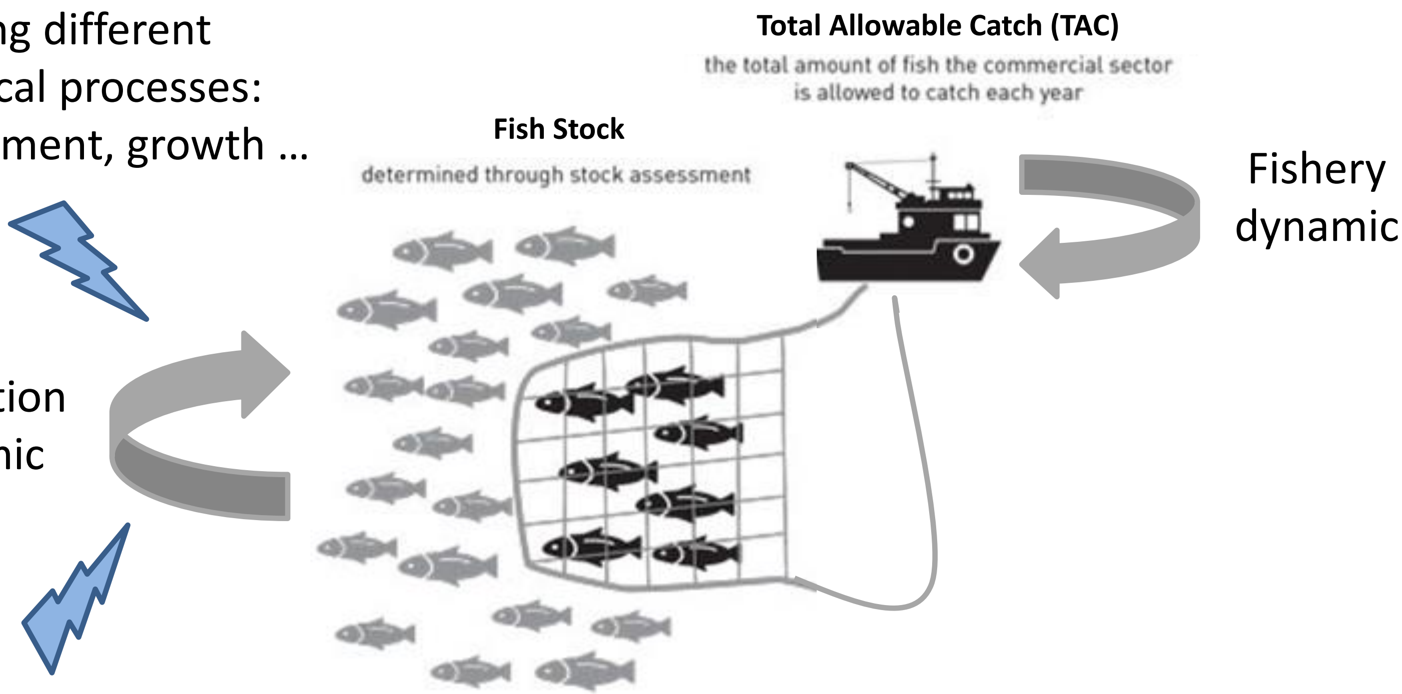
HCR type	Description	What it looks like
Constant	Allows for a constant level of fishing based on one value, regardless of stock status. The single value could be mortality (F), total allowable catch, days at sea, etc.	
Threshold	Fishing is allowed at a single target level until a limit is reached, at which point fishing is stopped.	
Step	Incorporates steps so higher fishing levels are permitted as the stock's status improves.	
Sliding (simple linear)	A sliding rule allows for a continuous adjustment in fishing controls. Higher fishing levels are permitted with improved stock status.	
Sliding (nonlinear)	Similar to the sliding forms, but the adjustments are nonlinear. This may be logarithmic (i.e., a smooth increase in fishing levels as stock status improves, as shown) or logistic (more S-shaped—i.e., a smooth increase up to a constant control measure at larger stock sizes).	

Outlines

1. Fisheries: what are we talking about
2. Fisheries Management
3. Risk Management: Precautionnary Approach
   - Where do uncertainties come from?
4. Defining Management Strategy
5. The case of Atlantic Bluefin tuna

Where do uncertainties come from?

Environmental shocks and fluctuation affecting different biological processes: Recruitment, growth …

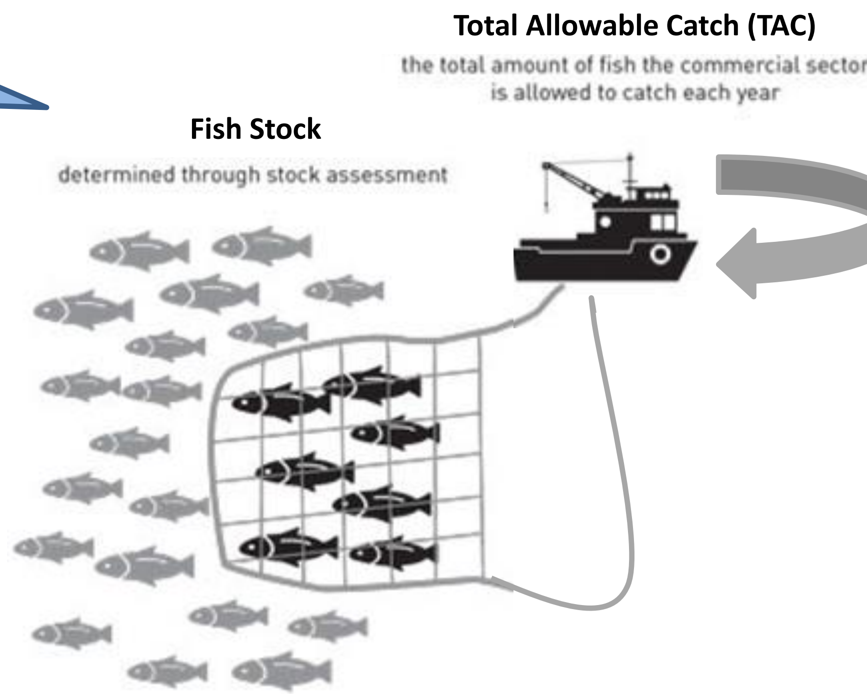


Environmental and Anthropogenic impact on the ecosystem: Fishing practise, climate change …

Where do uncertainties come from?

Uncertainties related to the assessment of the ressource :

> Observation : catch (IUU fishing), CPUE…
> Model and parameter uncertainties are the upshot of an incomplete, and potentially misleading, representation of system dynamics.

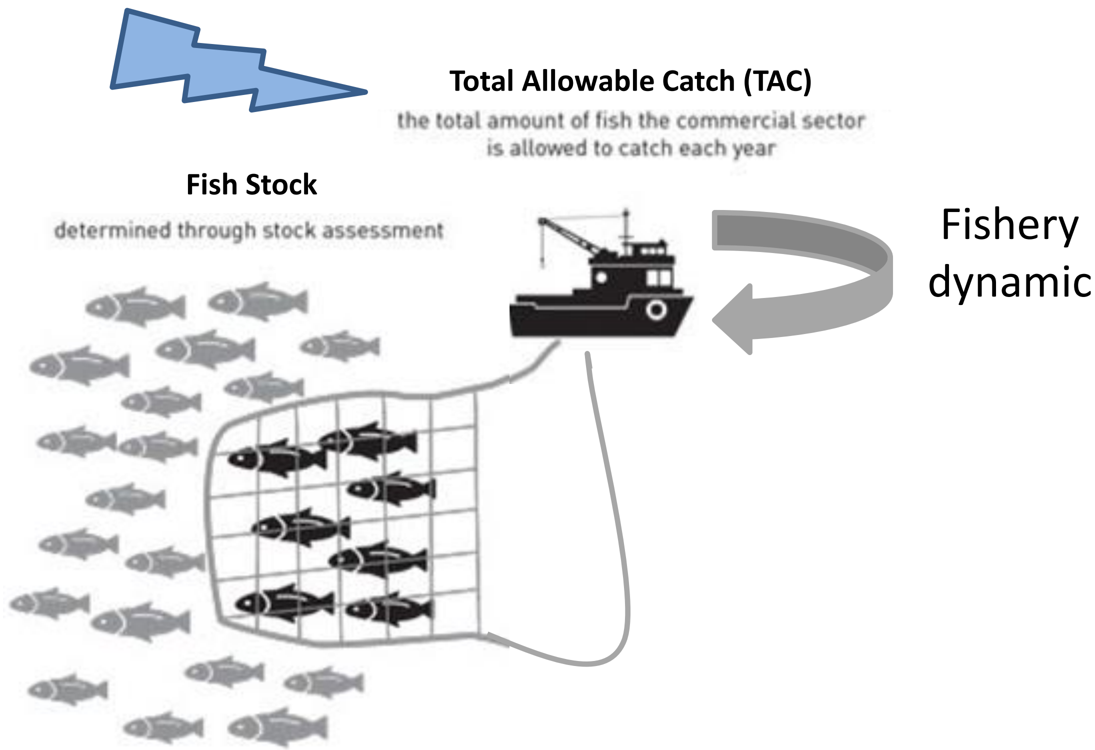


Fishery dynamic

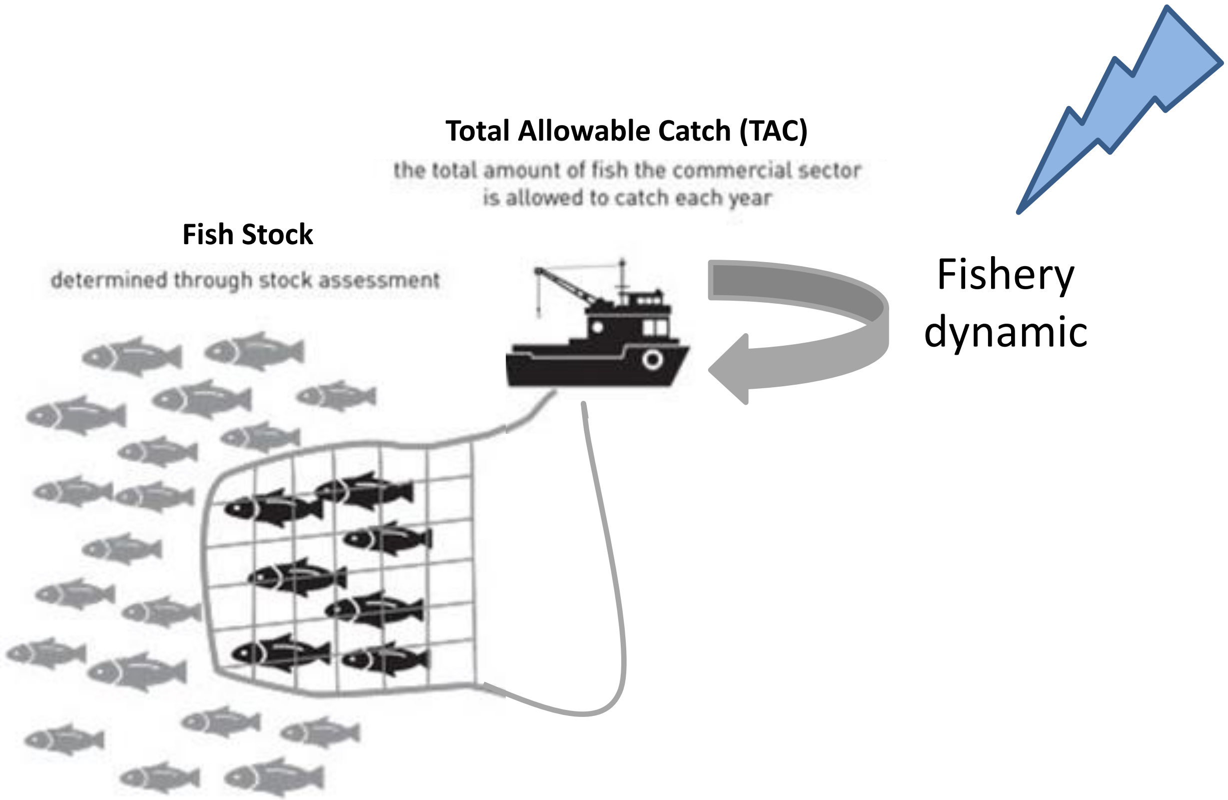
Where do uncertainties come from?

Decisional uncertainty:

> Uncertainty in decision, changes in management objectives (resulting from an unpredictable behaviour of the political authority) and the existence of multiple and conflicting objectives constitute another important source of uncertainty.



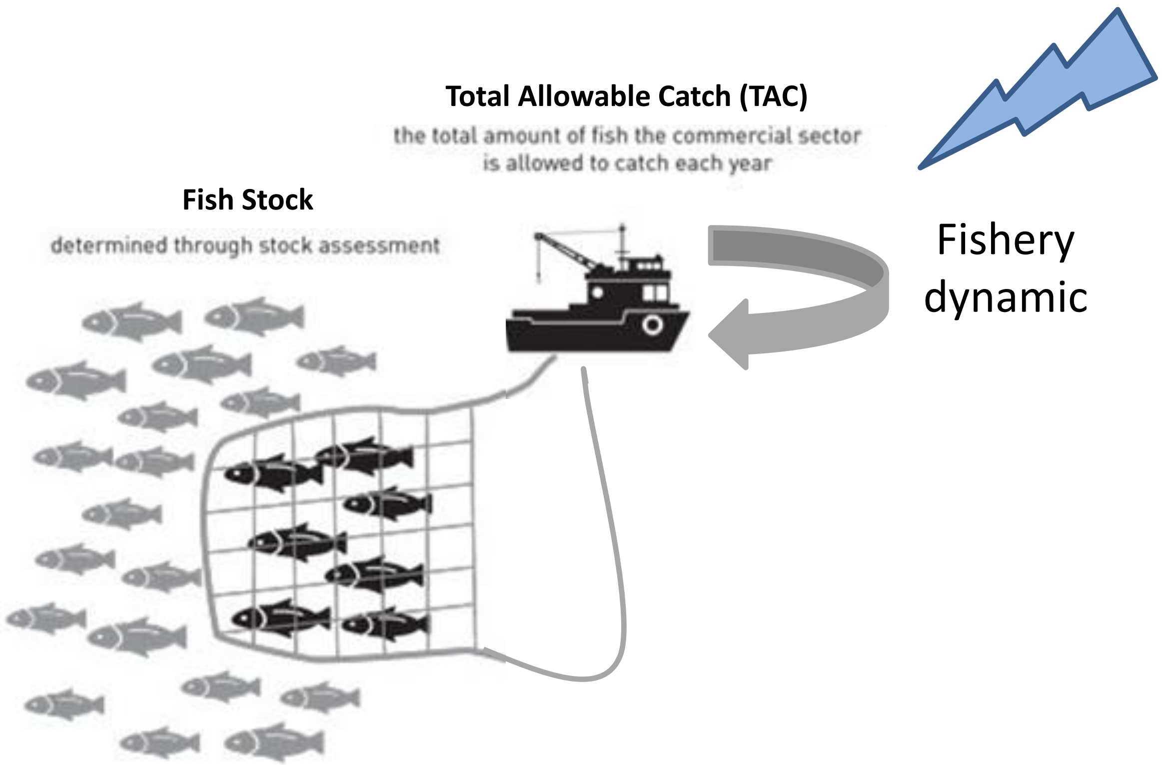
Where do uncertainties come from?



Behavioural uncertainty:

> Uncertainty in the behaviour of resource users is the consequence of complex interactions between economic and social drivers which can lead fishers to act as free-riders and undermine the intent of management actions.

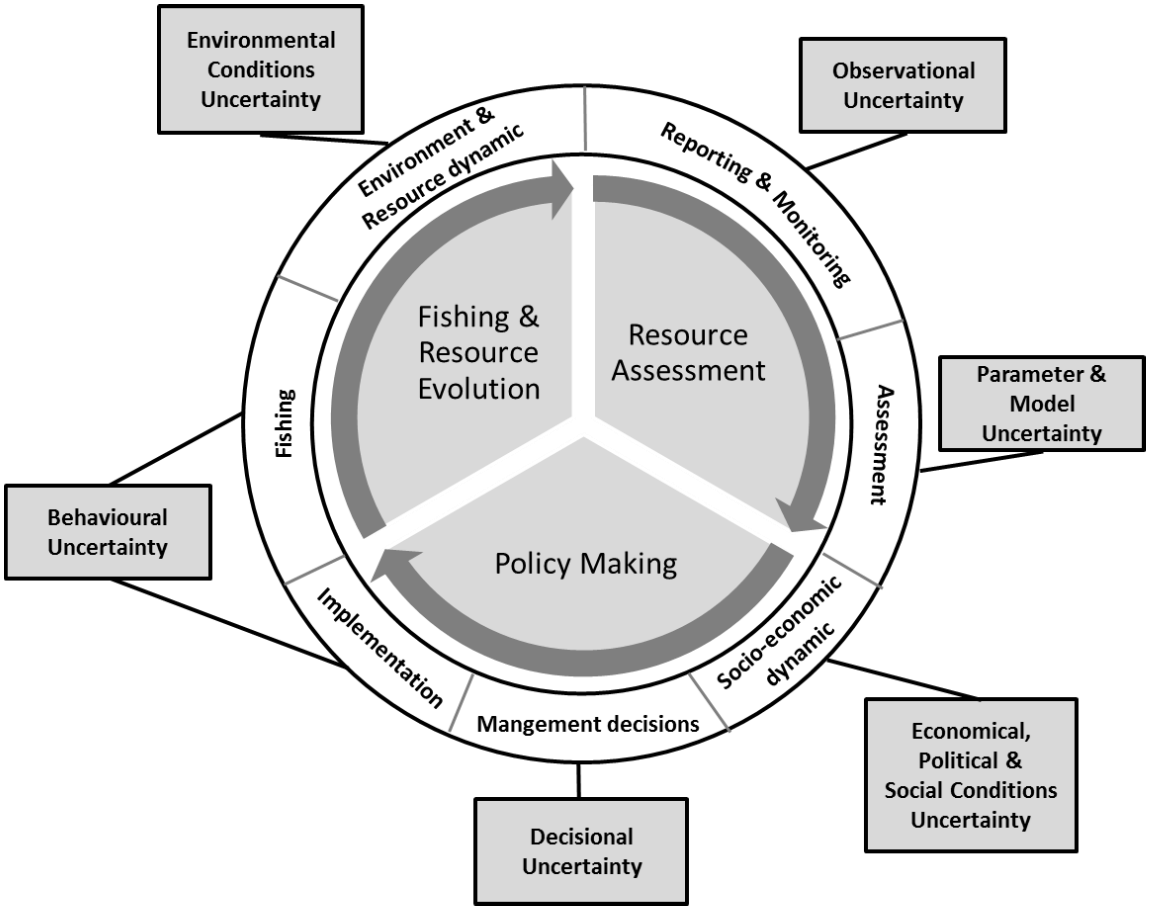
Where do uncertainties come from?



Economic, political and social uncertainty :

> Uncertainty in economic, political and social conditions results from market fluctuations which affect species price, as well as the fixed and variable costs of fishing effort.

Adaptative mangement cycle



> Large uncertainty is common in most fisheries management activities. To embrace uncertainties, fishery management can be viewed as an adaptive management cycle. Uncertainty emerges at each step of the management cycle and can act to undermine effective fishery management.

Source Fulton et al. (2011)

Outlines

1. Fisheries: what are we talking about

2. Fisheries Management

3. Risk Management: Precautionnary Approach

4. Defining Management Strategy

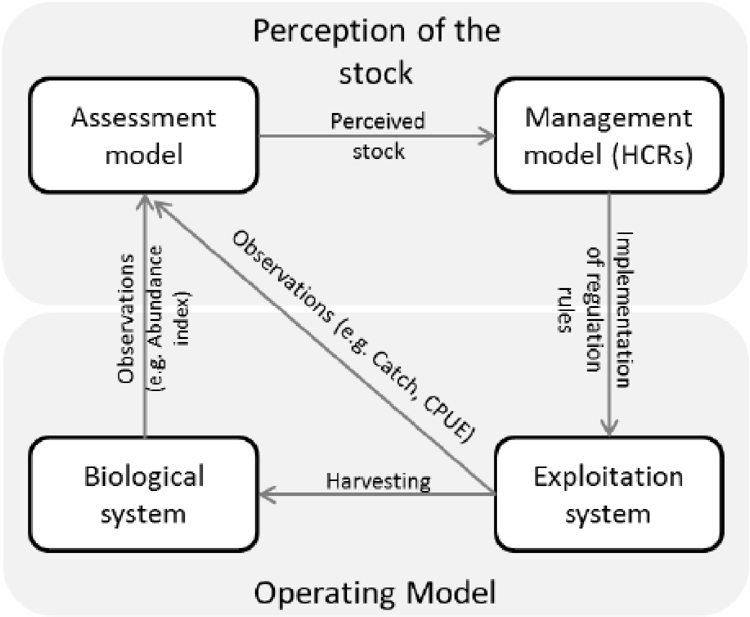
> Management Strategy Evaluation

5. The case of Atlantic Bluefin tuna

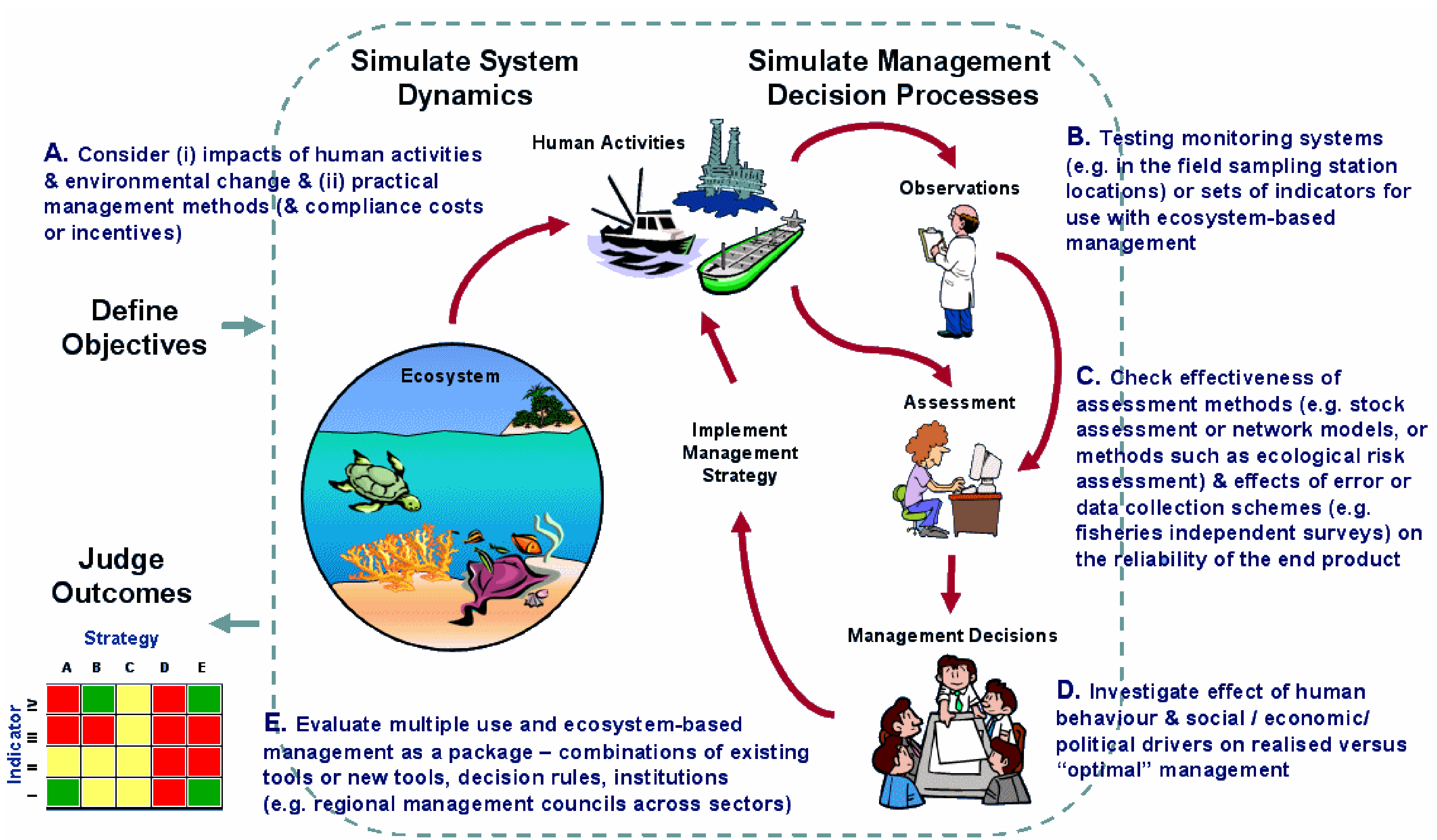
Management Strategy Evaluation

> Management strategy evaluation (MSE) in the broad sense involves assessing the consequences of a range of management strategies or options and presenting the results in a way which lays bare the tradeoffs in performance across a range of management objectives.

> MSE is a simulation technique based on modelling each part of the adaptive management cycle to test the effectivemess of HCRs.



4. Risk Management: Precautionnary Approach



Outlines

1. Fisheries: what are we talking about

2. Fisheries Management

3. Risk Management: Precautionnary Approach

4. Defining Management Strategy

> Optimization model - Feedback solutions

5. The case of Atlantic Bluefin tuna

Optimal Harvest strategy

> Searching for optimal strategy for a given objective while accounting for uncertaintes.

> Feedback solutions through the application of optimal control theory extensively used in fishery economics studies have the ability to translate biological or ecological indicators (e.g. stock biomass) into harvest advice.

> When stochasticity is integrated in a such system, the decision problem is called a of Markov decision process (Puterman 2004) and solved using stochastic dynamic programming techniques (Marescot et al. 2013).

Optimal Harvest strategy

A typical discrete optimal dynamic management problem is defined as a social planner, a hypothetical fishery manager who could be a corporation, a cooperative, a government agency, or a regulatory body, someone who owns the rights to the exploitation of the fish stock and who seeks to maximize the expected net present value of the resource stock.

$$max_{\{y_t\}} E[\sum_{t=0}^{\infty} \delta^t \pi(x_t, y_t, \varepsilon_t^{\pi}, \theta_t^{\pi})]$$

Subject to $$x_{t+1} = f(x_t, y_t, \varepsilon_t^f, \theta_t^f)$$

> Objective function: $\pi(x_t, y_t, \varepsilon_t^{\pi}, \theta_t^{\pi})$
> State transition function from period *t* to *t+1*: $f(x_t, y_t, \varepsilon_t^f, \theta_t^f)$
Each function depends on a set of variables, the state variable xt (i.e. the stock) and control variable yt (i.e. the yield).
> Vectors of stochastic terms $\varepsilon_t=(\varepsilon_t^{\pi}, \varepsilon_t^f)$ applied on the objective function (e.g. stochastic prices) or the transition function (e.g. stochastic shocks to the resource stock).
> Vectors of parameters $\theta_t=(\theta_t^{\pi}, \theta_t^f)$ relating to the state transition and objective functions.

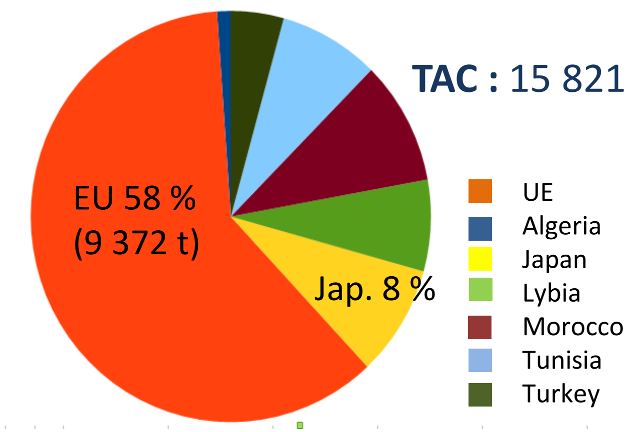
Outlines

1. Fisheries: what are we talking about
2. Fisheries Management
3. Risk Management: Precautionnary Approach
4. Defining Management Strategy
5. The Atlantic Bluefin tuna fishery

5. The Atlantic Bluefin tuna fishery

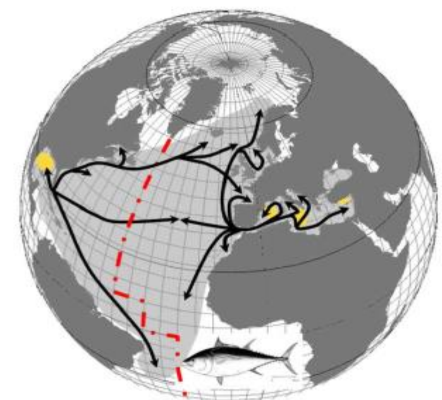
2015 Fishery state

TAC : 15 821 t



> More than 15 nations involve in the fishery using 5 kind of gear;

> International market dominated by Japan;



Fromentin et al. 2005

High market value:

A total landing value evaluated to more than 150 million $ USD and end value evaluated to more than 700 million $USD in 2014.

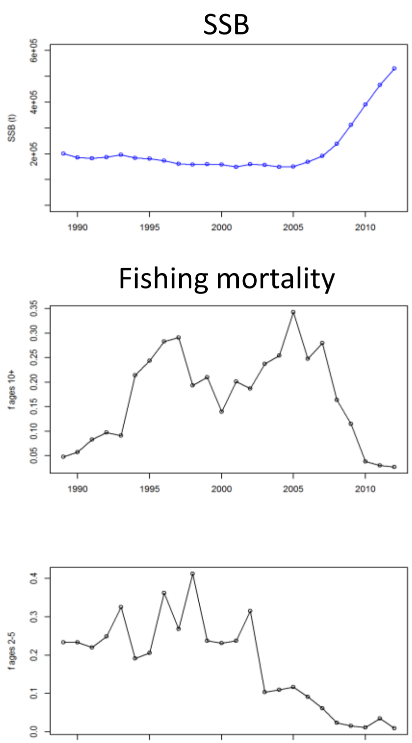
Graeme Macfadyen & Vincent Defaux 2016

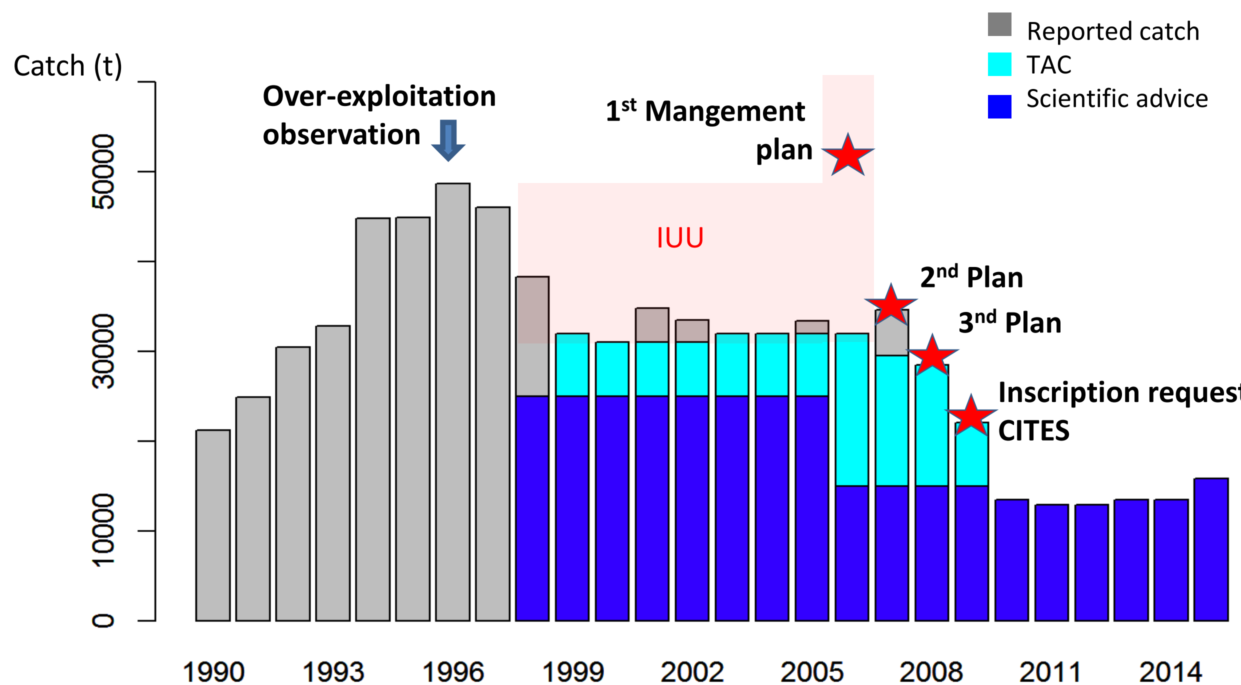
- Longevity: 20 to 40 years old;
- Length > 3 m for 700 Kg;
- Sexual maturity around 4 years old (1,3 m and 30 Kg);
- 15-20 years: 45 million eggs per female;
- Thermo-regulation.

High incertitude on biological process (growth, reproduction, recruitment…) and on data gathering quasi-exclusively from fishing activities.

Exploitation and Management

> Failure to cooperate (e.g. IUU, failure to agree on agreement respecting the scientific advice);
> Rivalry and incentives to catch more (e.g. overcapacity associated with non maleability of capital, notably after fishing effort ajustment, high international demand).





OPTIMAL BIOECONOMIC MANAGEMENT OF THE EASTERN ATLANTIC BLUEFIN TUNA FISHERY: WHERE DO WE STAND AFTER THE RECOVERY PLAN?

The problem: $max_{\{H_t\}} \sum_{t=0}^{\infty} U(H_t)\delta^t$

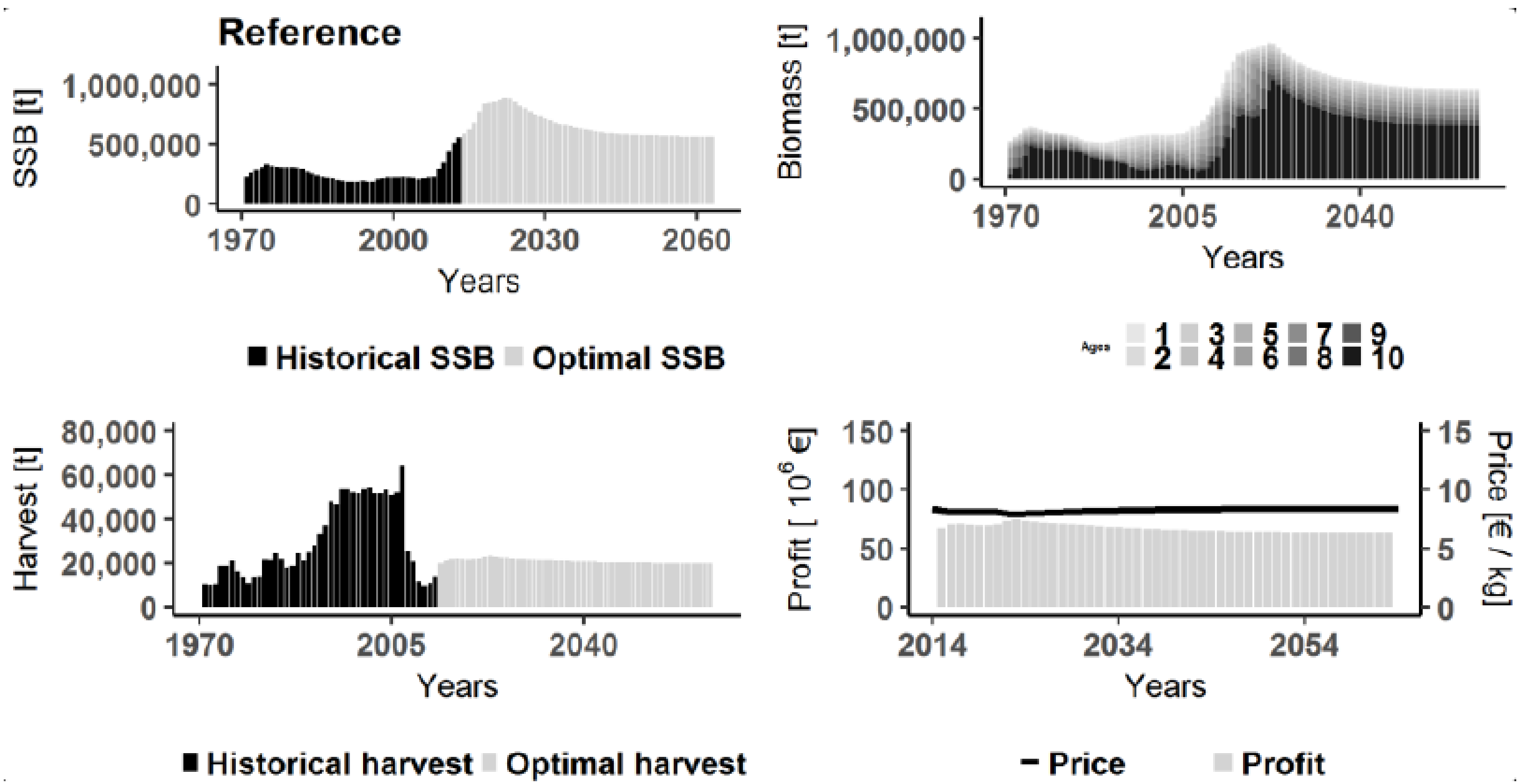
With $U(H_t, B_t) = R(H_t) - C(H_t)$

$R(H_t) = P(H_t)H_t$: revenues depend on the price of Bluefin tuna which is formulated as an overall iso-elastic downward-sloping demand function.

$C(H_t, B_t) = cH_tB_t^{-\chi}$: harvesting costs are proportional to fishing mortality.

Does economic objective can meet the precautionary approach principle ?

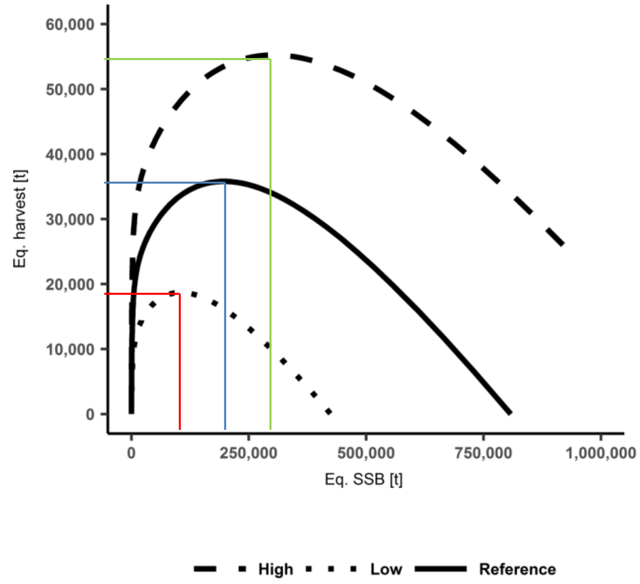
The optimal path

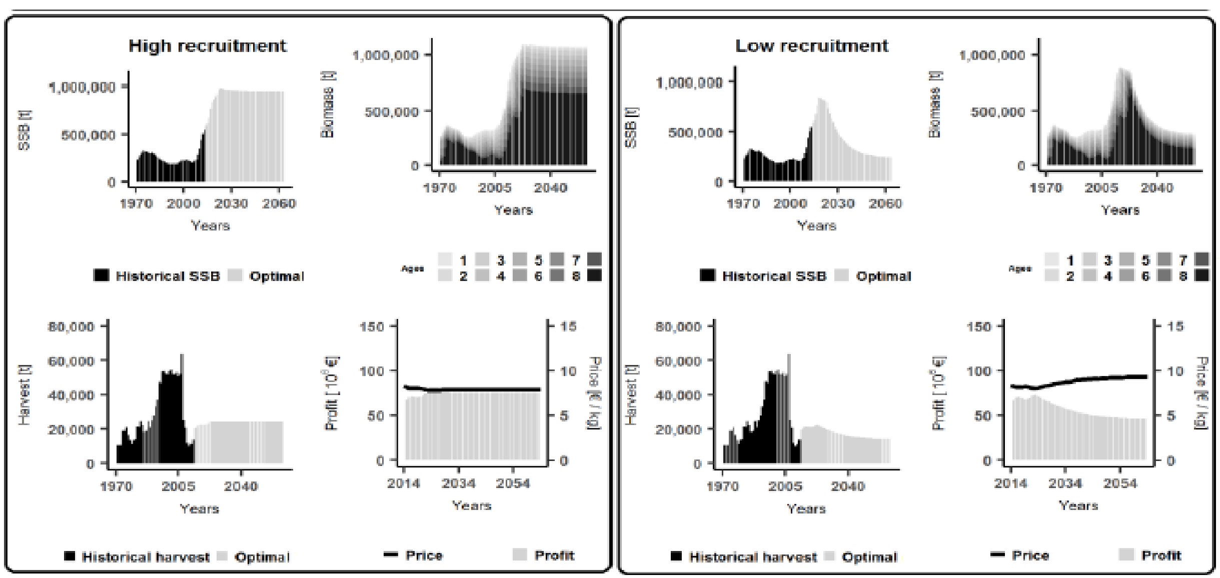


5. The Atlantic Bluefin tuna fishery

Alternative recruitment hypothesis

> Adopting a more cautious target, such as MEY, should smooth potential errors in the stock estimation and the productivity of the EABFT

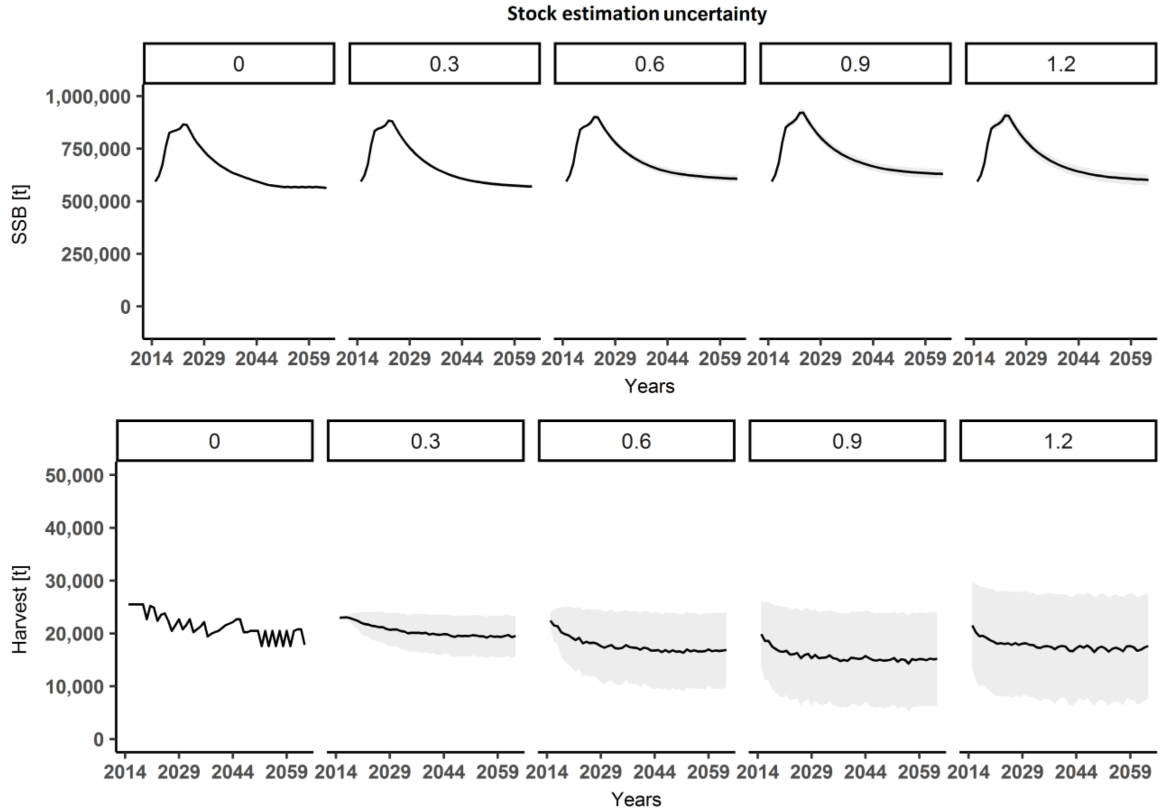




Observation uncertainty

$$Xobs_t = Z_t X_t$$

Where $X_t = \sum_{s=1}^{n} x_{s,t}$. and $Z_t\ U(1\text{-}\sigma_m, 1 + \sigma_m)$.



> This result exacerbates the need for a cautious target, such as MEY, in face of potential high stock estimation uncertainties affecting the Atlantic bluefin tuna.

Conclusion

> Conservation and economic objectives are still aligned if we consider age structured models, especially when the considered species is a long-lived species.

> MEY as a new management reference point has the advantage to be robust to high stock estimation uncertainty and foster balanced harvesting. These characteristics are crucial if we consider the management of the EABTF at the scale of its ecosystem.

> Keeping low catch rate has both the advantage to maintain ecosystem resilience, and smoothing stock variation over time. MEY policy has the potential to create confidence in the future of fishery and promote consistency between RFMOs to maintain a high price on the global market.

Thank you for you attention !!

Interested ?

- Selles, J. (2018). Fisheries management: what uncertainties matter? Working papers, retrieved from: https://hal.archives-ouvertes.fr/hal-01824238/document.
- Selles, J., Bonhommeau, S., & Guillotreau, P. (2018). Optimal bioeconomic management of the Eastern Atlantic Bluefin tuna fishery: where do we stand after the recovery plan? In press.
- Selles, J., Bonhommeau, S., Vallée, T., & Guillotreau, P. (2018). Influence of tipping points in the success of international fisheries management: an experimental approach. Working papers, retrieved from: https://hal.archives-ouvertes.fr/hal-01719101/document.

References

> Charles, A. T. (2008). *Sustainable fishery systems*. John Wiley & Sons.
> Costello, C., Ovando, D., Clavelle, T., Strauss, C. K., Hilborn, R., Melnychuk, M. C., ... & Rader, D. N. (2016). Global fishery prospects under contrasting management regimes. *Proceedings of the national academy of sciences*, 201520420.
> FAO (2018). The state of the world fisheries and aquaculture, 227 pages. FAO, Rome.
> Fromentin, J.-M., & Powers, J. E. (2005). Atlantic bluefin tuna: population dynamics, ecology, fisheries and management. *Fish and Fisheries*, *6*(4), 281–306.
> Hilborn, R. (2007). Defining success in fisheries and conflicts in objectives. *Marine Policy*, *31*(2), 153-158.
> Marescot, L., Chapron, G., Chadès, I., Fackler, P. L., Duchamp, C., Marboutin, E., & Gimenez, O. (2013). Complex decisions made simple: a primer on stochastic dynamic programming. *Methods in Ecology and Evolution*, *4*(9), 872-884.
> Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., & Torres, F. (1998). Fishing down marine food webs. *Science*, *279*(5352), 860-863.
> Puterman, M. L. (1994) Markov Decision Processes: Discrete Stochastic Dynamic Programming, 684 pages. John Wiley & Sons, New York.