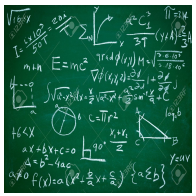
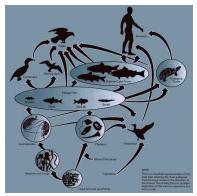
# MESSH
# Mathematics for bio-Economics and Sustainability of fiSHeries

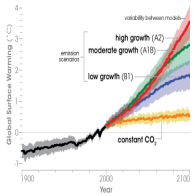
3Days MESSH, Brest, January 2024

**Catherine Rainer, Olivier Thebaud, Pierre Cardaliaguet, Ivar Ekeland, Luc Doyen**

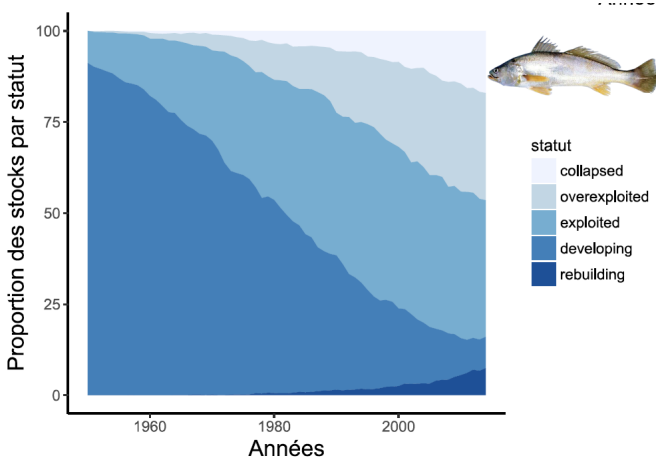


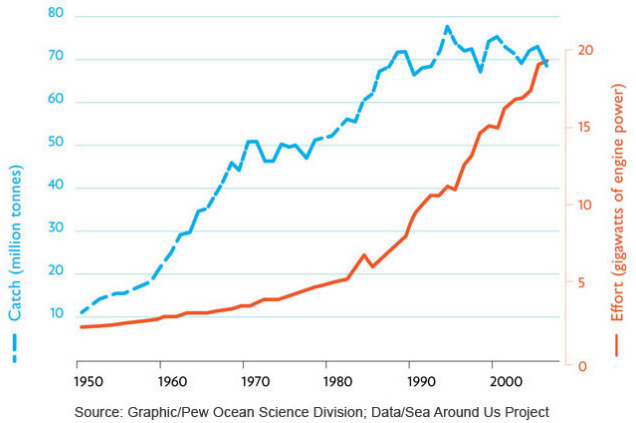






# Marine biodiversity, ecosystems and fisheries under pressure



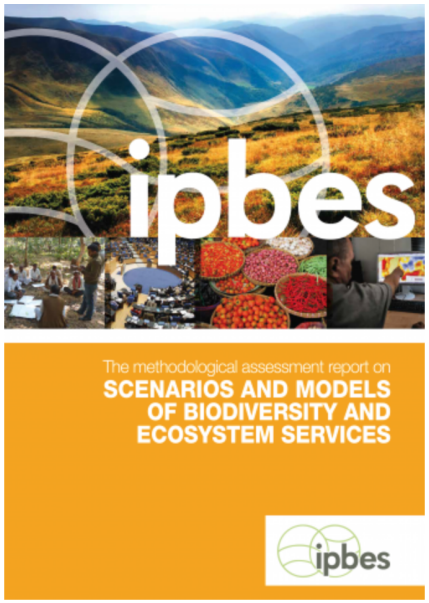



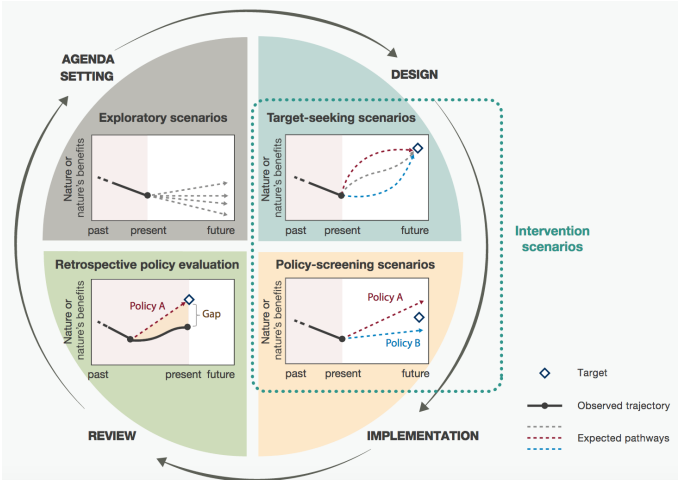

Source: Graphic/Pew Ocean Science Division; Data/Sea Around Us Project

- Global changes in ecosystems
- Ecological vulnerabilities
- Economic vulnerabilities

$\Longrightarrow$ Bio-economic challenges

# The need for bio-economic models, scenarios, policy



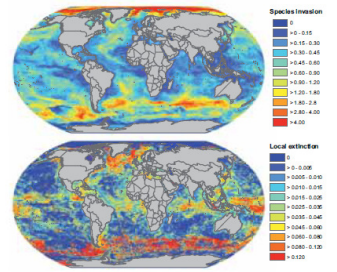
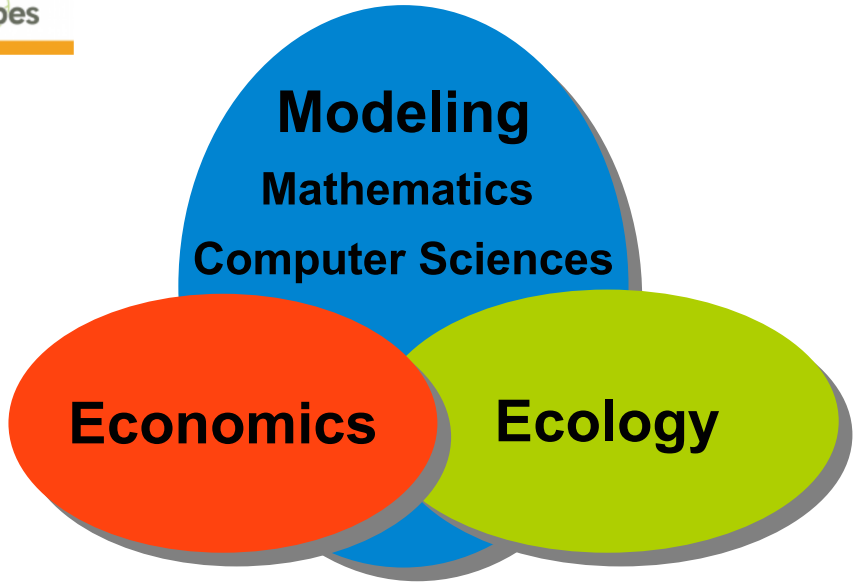



FIGURE 19 PROJECTED CHANGES IN MARINE BIODIVERSITY DUE TO CLIMATE CHANGE.

Biodiversity impact in 2050 under the IPCC SRES A1B scenario expressed in terms of: number of new species moving from other regions (top) and local extinction intensity (bottom). The projections are based on bioclimate envelope models for 1,066 species of fish and invertebrates. Source: redrawn from Cheung et al. 2009.



# Existing and applied bio-economic models in fisheries

## Verlhust dynamics + equilibria (*Gordon-Schaefer, 1954*)

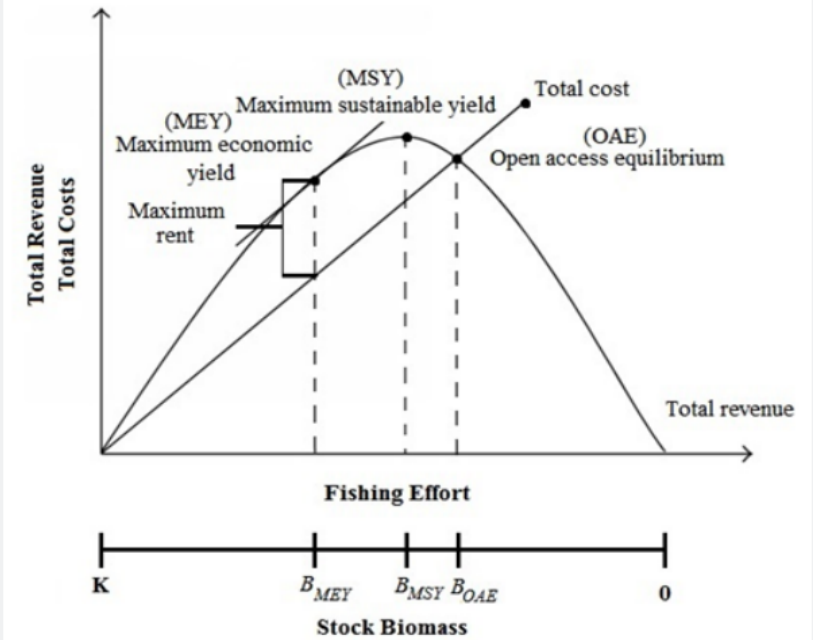
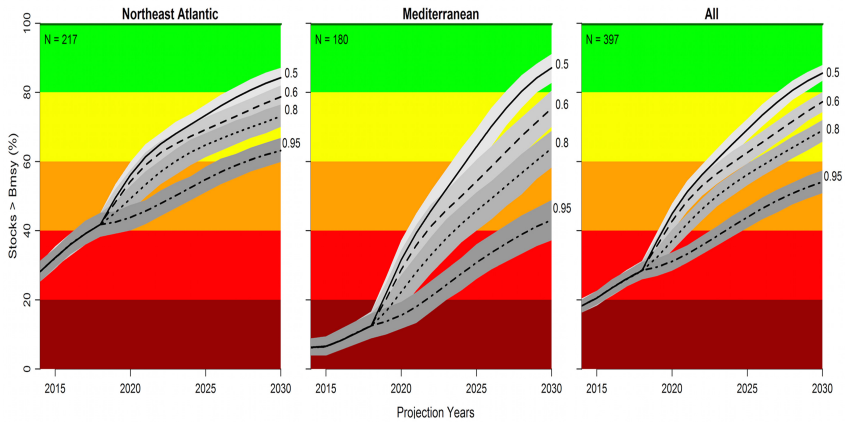



**Figure 1:** Total revenue of the fishery with constant price.




*Froese et al., Marine Policy, 2018*

# New bio-economic (and MESSH) challenges

- **Axis 1**: Operationalizing the ecosystem-based fishery management ?
- **Axis 2**: Operationalizing sustainability for fisheries?
- **Axis 3**: Operationalizing resilience for fisheries ?
- **Axis 4**: Which gouvernance for bio-economic public policies ?

$\longrightarrow$ **Need of**

- dynamic systems theory,
- control of systems (optimal, viable),
- stochastic approaches,
- game theory

# MESSH interdisciplinary and international consortium

- Co-coordinator: **Environmental Economics** Montpellier (CEEM, UMR CNRS - U. Montpellier - INRAE):
- Co-coordinator: Centre de **Mathématiques de la Décision** (CEREMADE, UMR CNRS - U. Paris-Dauphine)
- Centre de Droit et d'**Economie de la Mer** (AMURE, UMR IFREMER - CNRS - U. Bretagne Occidentale).
- **Marine Biodiversity,** Exploitation and Conservation (MARBEC, IRD - IFREMER - CNRS - U. Montpellier)
- Observatoire des **Sciences de l'Univers** (OSU) PYTHEAS (UMS CNRS - U. Aix-Marseille - IRD - INRAE)
- Labo. **Ecologie,** Evolution, Interactions Systèmes Amazoniens (LEEISA, IFREMER - CNRS - U. Guyane)
- Labo. de **Mathématiques** de Bretagne Atlantique (LMBA, UMR CNRS - UBO - UBS)
- **Centre Modélisation Mathématique (CMM, IRL CNRS - U. Santiago, Chile)**
- **IRL PIMS Fishery Department U. British Columbia (Canada) CNRS**
- **Australian National University - CSIRO (Australia)**

# Results

- Symposium 3Days Sete, January 2023

- A perspective paper:

Mathematical Bio-Economics 2.0 for Sustainable Fisheries

L. Doyen*[,1], M. Smith[2], U. R. Sumaila[3], G. Zaccour[4], I. Ekeland[5], P. Cury[6], C. Lett[6], O. Maury[6], O. Thebaud[7], J.-C. Poggiale[8], A. Moussaoui[9], J.-M. Fromentin[6], S. Gourguet[7], P. Guillotreau[6], H. Gomes[11], P. Courtois[1], R.-J. Schaap[1], F. Blanchard[7], C. Rainer[10], M. Tidball [1], M. Cuilleret[1], T. Villain[8], F. Menard[8], S. Tewfik[8], P. Cardaliaguet[2], and P. McCartney[20]

Upcoming preprint CEEM
Submission 'npg Ocean Sustainability'

# **Complexity** in bio-economics of marine fisheries

# 3Days Brest Results

- Symposium 3Days Brest, January 2024




- Finalize the MESSH perspective paper:

Mathematical Bio-Economics 2.0 for Sustainable Fisheries

L. Doyen*,[1], M. Smith[2], U. R. Sumaila[3], G. Zaccour[4], I. Ekeland[5], P. Cury[6], C. Lett[6], O. Maury[6], O. Thebaud[7], J.-C. Poggiale[8], A. Moussaoui[9], J.-M. Fromentin[6], S. Gourguet[7], P. Guillotreau[6], H. Gomes[11], P. Courtois[1], R.-J. Schaap[1], F. Blanchard[7], C. Rainer[10], M. Tidball [1], M. Cuilleret[1], T. Villain[8], F. Menard[8], S. Tewfik[8], P. Cardaliaguet[2], and P. McCartney[20]

Upcoming preprint CEEM
Submission 'npg Ocean Sustainability'

- Draft of a new paper: '**Of Mice, Fish and Fishermen**'

# MESSH objectives and deliverables

MESSH general goals:

- **Structure an international and interdisciplinary network** to advance the 4 research axis and 'A New Mathematical Bio-Economics'
- Attract **young mathematicians** on these topics

MESSH specific tasks:

- **Task (i)**: two symposiums;
- **Task (ii)**: a summer-school;
- **Task (iii):** supervision of 12 internships of master students;
- **Task (iv)**: Inclusion in Mathematics Curricula.

# 3 Days program

## Wednesday January 25, 2023

**Mathematics of ecosystem approach for fisheries**

09:00 - 9:30 **Opening**
*Luc Doyen (CNRS); Ivar Ekeland (CEREMADE, UBC), Pierre Cardaliaguet (CEREMADE); Laurent Dagorn (IRD, MARBEC)*

09:30 - 10:30 **Keynote lectures 1 Part I : Ecosystem-based approach for fisheries**
*Olivier Maury, Christophe Lett, Philippe Cury (IRD, MARBEC)*

Coffee break

11:00 - 12:00 **Keynote Lecture 1 Part II : Ecosystem-based approach for fisheries**
*Olivier Maury, Christophe Lett, Philippe Cury (IRD, MARBEC)*

Lunch

13:30 - 14:00 *Jean-Christophe Poggiale (Institut Pytheas, Un. Aix-Marseille)*

14:00 - 14:30 **Small pelagics fisheries crisis in the the Gulf of Lion: a consequence of ecosystem shift due to climate change?**
*Jean Marc Fromentin (IFREMER, MARBEC)*

14:30 - 15:00 **Assessing the viability of socio-ecosystems subject to fisheries-predators conflicts: a bio-economic modelling approach**
*Sophie Gourguet (IFREMER, AMURE)*

Coffee break

15:30 - 16:00 **A MICE model for the small-scale fishery in French Guiana facing global changes**
*Hélène Gomes, Fabian Blanchard, Abdoul Cissé (IFREMER, Un. Guyane)*

16:00 - 16:30 **Mathematical modeling of natural resource management**
*Ali Moussaoui (Un. Tlemcen)*

16:30 - 17:15 **Discussion on ecosystem models and complexity**

Social event **Wine tasting**

## Thursday January 26, 2023

**Mathematics of criteria for sustainability and resilience "for fisheries"**

09:30 - 10:30 **Keynote Lecture 2 Part I: Criteria of sustainability and resilience**
*Martin Smith (UCLA, USA)*

Coffee break

11:00 - 12:00 **Keynote Lecture 2 Part II : Establishing Causality in Coupled Human-Natural Systems: Insights from Numerical Modeling of Fisheries Policy Interventions**
*Martin Smith (UCLA, USA)*

Lunch

13:30 - 14:00 **Speaking for the seventh generation: the classical growth model with intergenerational justice**
*Rashid Sumaila (UBC, Canada) & Ivar Ekeland (CEREMADE, Un. Paris-Dauphine)*

14:00 - 14:30 **An eco-viability approach for the management of mixed fisheries under output controls**
*Olivier Thébaud (IFREMER, AMURE)*

14:30 - 15:00 **Developing alternatives to resource extraction: A developmental and environmental win-win?**
*Robbert-Jan Schaap (INRAE, CEEM)*

Coffee break

16:00 - 16:30 **Taking into account habitat in fishery models**
*Mabel Tidball (CEEM, INRAE)*

16:30 - 17:00 **Resilience management for coastal fisheries facing with global changes and uncertainties**
*Mathieu Cuilleret (CEEM, Montpellier)*

17:00 - 17:45 **Discussion**

19:30 **Dinner Sete : Le Quai d'en face**

## Friday January 27, 2023

**Mathematics of governance and strategic interactions "for fisheries"**

09:30 - 10:30 **Keynote Lecture 3 Part I : Governance, strategic interactions and game theory**
*Georges Zaccour (HEC Montreal, GERAD)*

Coffee break

11:00 - 12:00 **Keynote Lecture 3 Part II : Governance and game theory**
*Georges Zaccour (HEC Montreal, GERAD)*

Lunch

13:30 - 14:00 **The tragedy of open ecosystem**
*Luc Doyen (CNRS, CEEM)*

14:00 - 14:30 **When fisheries management may increase uncertainty**
*Patrice Guillautreau (MARBEC)*

Coffee Break

14:30 - 15:30 **Perspectives and closing**

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