From fork to fish: The role of consumer behaviour on the sustainability of fisheries

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Framework

- Introduction
- Bio-economic model
- Analytical results for sustainable consumer behaviour
- Example: the coastal fishery in French Guiana
- Conclusion and perspectives

Consumption

- Increased consumption of seafood products (FAO, 2022).

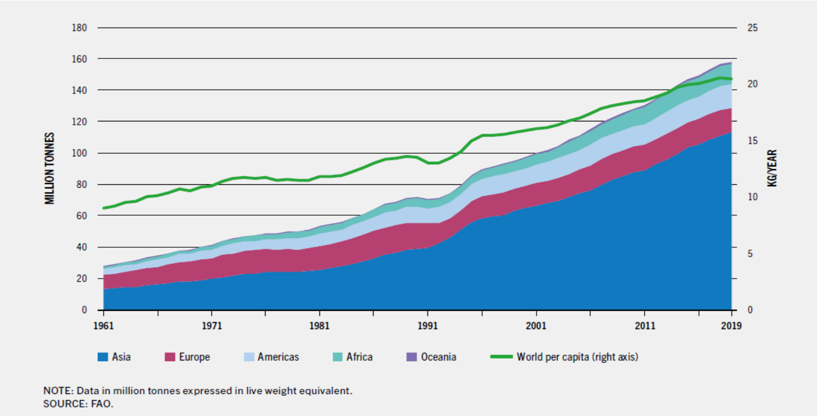

Figure 1: Aquatic Food consumption by continent, 1961-2019 (FAO, 2022)

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- The necessity of a worldwide dietary transition (Tilman and Clark, 2014; Fischer and Garnett, 2016).
- The role of fish (Béné et al., 2015; Loring et al., 2019; De Boer et al., 2020).
- The interest of the (sea)-food system approach (Béné et al., 2019).

Objectives

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- Quantify the role of consumer behaviour in the sustainability of marine ecosystems, fisheries, and seafood systems.
- Sustainability of seafood systems ?
- Determine the analytical conditions for consumer behaviour that make it possible to combine the maintenance of biodiversity with positive catches and profits.

Method

- Demand and Supply, Market equilibrium, long-run equilibrium and multi-species resource based dynamics.
- Viability goals
- Intermediate complexity model for ecosystem assessment (MICE) (Plagányi et al., 2014).

Demand side

- **Maximisation with CES utility function** (Quaas and Requate, 2013):

$$\max_{Q_i} \left(\sum_i a_i Q_i(t)^\sigma \right)^{\frac{1}{\sigma}} - \sum_i p_i(t) Q_i(t)$$

with a_i: consumer behaviour for a species i,
$Q_i(t)$: quantity of species i consumed at time t,
σ: is related to constant elasticity of substitution and $p_i(t)$: price of the species i.

- Using optimality conditions, **Inverse demand function**:

$$p_i(t) = \left(\sum_j a_j Q_j^*(t)^\sigma \right)^{\frac{1}{\sigma}-1} a_i Q_i^*(t)^{\sigma-1}$$

Supply and market equilibrium

- **Profit maximisation**, π, through fishing effort:

$$\max_{e(t)\geq 0} \pi(x(t), e(t))$$

with

$$\pi(t) = \sum_i p_i(t) H_i(t) - C(e(t)) \text{ with } C(e) = c_0 + c_1 e + \frac{c_2}{2} e^2$$

with $C(e)$: operating costs.

- **In a situation of market equilibrium**:

$$H_i^*(t) = Q_i^*(t)$$

The optimal fishing effort depends on behaviour levels a:

$$e^*(x, a) = \frac{U\Big(Cpue(q. * x), a\Big) - c_1}{c_2}$$

Resource based-model (Exclusion principle) (Tilman, 1982).

- **Species stock dynamics**, $x_i(t)$:

$$x_i(t+1) = x_i(t)\Big(1 - m_i + g_i y(t)\Big) - \sum_f q_{i,f} e_f(t) x_i(t).$$

m_i: natural mortality rate, g_i: the resource-based per capita growth of species i, $y(t)$: the state of the resource, $q_{i,f}$: catchability, $e_f(t)$: fishing effort.

- **Resource dynamics**, $y(t)$:

$$y(t+1) = y(t)\Big(1 - \sum_i s_i x_i(t)\Big) + I(t).$$

s_i: the consumption rate of the predator i on the resource y,
I: is the external input (source) for this resource

Bioeconomic viability goals

- Objective : Identification of the conditions on consumer behaviours that will enable:
  - Biodiversity (number of species at equilibrium ≥ 2)
  - Viable catches (> 0)
  - Viable profits (≥ 0)

Consumer behaviours: analytical conditions for sustainability

- Sufficient analytical conditions on consumer preferences for sustainability:

$$a^*_{i^*} q^\sigma_{i^*} + a^*_{j^*} q^\sigma_{j^*} = \left(\frac{y^*(s_{i^*} + s_{j^*})(c_2 e^* + c_1)}{I} \right)^\sigma$$

where

$$\begin{cases} y^* = \min_{i,j} \frac{m_i q_j - m_j q_i}{g_i q_j - g_j q_i} = \frac{m_{i^*} q_{j^*} - m_{j^*} q_{i^*}}{g_{i^*} q_{j^*} - g_{j^*} q_{i^*}} > 0 \\ e^* = \frac{g_{i^*} y^* - m_{i^*}}{q_{i^*} > 0} \end{cases} \quad (1)$$

Specie i^* and j^* coexists.

Calibration

- Data: SIH Ifremer.
- Least Squares: Scilab genetic algorithm.

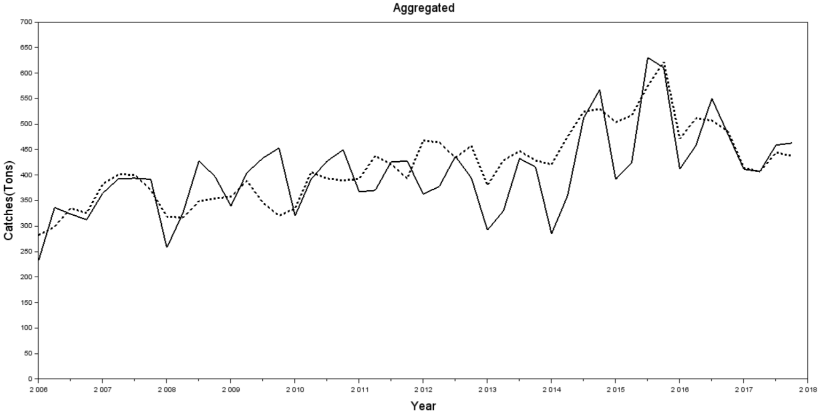

Figure 2: Comparison of catches from the first quarter of 2006 to the last quarter of 2017. The black line represents the catches derived from the model. The black dotted line represents the historical data.

Three consumer behaviour scenarios

- Three consumer behaviour scenarios from 2018 to 2100 :
  - BAU behaviour, a_i^{BAU}
  - Sustainable behaviour, a_i^*
  - Sustainable progressive behaviour, $a_i(t)$

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	Species $i = 1$	Species $i = 2$	Species $i = 3$
	Acoupa weakfish	Green weakfish	Catfish
BAU scenario a_i^{BAU}	100755	88464	63645
Sustainable scenario a_i^*	5462	78503	63645

Viable species $i^* = 1$ **and** $j^* = 2$

: Sustainable behaviour : Progressive sustainable behaviour
: BAU behaviour

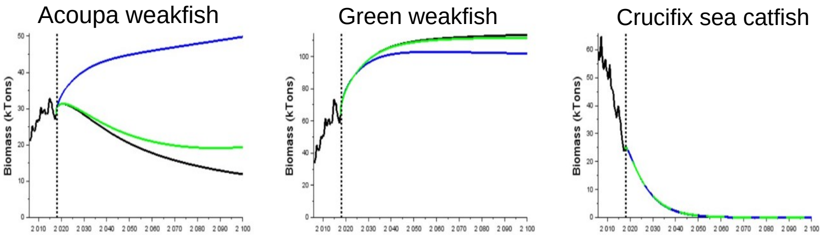

Figure 7 - **Biomass**

: Sustainable behaviour : Progressive sustainable behaviour
: BAU behaviour

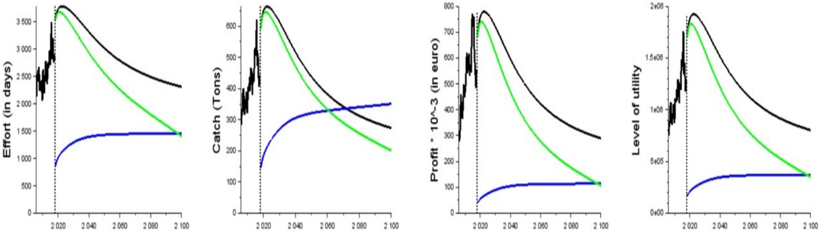

Figure 8 - **Effort, Catch, Profit and Utility**

Conclusion and perspectives

- The key role of consumer behaviour
- Conditions for sustainable consumer behaviour
- Food system sustainability through market-based strategies
- Methodological originality: bio-economic viability thresholds

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- The key role of consumer behaviour
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- Food system sustainability through market-based strategies
- Methodological originality: bio-economic viability thresholds
- Application of the model and the analytical findings to the French Guiana coastal fishery: alleviating the dominance of AW on the local food system
- Refine the shape of the utility function (Van't Veld, 2020) and the supply chain (The role of power and market structure.)

Thank you for your attention!

If you have any comments, please do not hesitate to contact me at c.kersulec@uw.edu.pl

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Calibration

Table 1: Parameters of the bioeconomic model for the case study in French Guiana.

Parameters	Unit	Species $i=1$ AW	Species $i=2$ GW	Species $i=3$ CsC
Interaction species - resource $s_i * 10^6$		2.5	7.6	7.0
Catchability $q_i * 10^6$		3.4	0.7	0.6
Natural mortality $m_i * 10$		0.9	1.4	1.6
Growth efficiency $g_i * 10$		5.5	1.15	5.5
Initial stock $x_i(t_0 = 2006)$	Ktons	21.4	34.7	59.2
Initial catches $Q_i(t_0 = 2006)$	Ktons	156	50	75
Initial Prices $p_i(t_0 = 2006)$	€/Kilo	3.4	1.9	1.6
Initial Resource $y(t_0)$	Ktons		282.6	
Resource input I	Ktons		318.9	
Utility parameter (elasticity) σ			1.4	
Risk aversion proxy c_2	$(€/Days)^2$		0.109	
Variable costs c_1	$€/Days$		95	
Fixed costs c_0	€/Quarter		1640	

Value of consumer behaviour estimated on the basis of analytical results

Table 2: BAU consumer behaviour a_i^{BAU} and the fixed sustainable behaviour a_i^*.

	Species $i = 1$ AW	Species $i = 2$ GW	Species $i = 3$ CsC
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Prices

▬ : Sustainable behaviour ▬ : Progressive sustainable behaviour
▬ : BAU behaviour