A Causal Relationship between Resource Levels and User Effort drives Sustainable Behaviour

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A causal relationship between resource levels and user effort drives sustainable harvest behaviour

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Introduction

- The **Tragedy of the Commons (ToC)**
  - Situation in a shared-resource system where individual users end up depleting the resource through their collective action;
  - Incentives are such that each individual is better off if everyone else cooperates and they “free ride”.

  The outcome predicted by non-cooperative game theory for such situations is a Nash equilibrium in which no one cooperates.

- **Common Pool Resource Experiments**
  - Standard tool to study the ToC
  - Create an environment in which a number of participants make decisions in a controlled setting mimicking the CPR exploitation;
  - The rules (institutional arrangements, information,...) of the experiment define the payoff structure.

Introduction (2)

Myriads of CPREs were run since then –> ToC can be avoided if users cooperate.

==> Cooperation maintains resource levels at higher levels, and certain institutional arrangements provide the forum for cooperation to emerge.

- **1st generation**: contest the non-cooperative game theoretical normative solution (Ostrom et. al, 1994; Gardner et al., 1997; Ostrom, 1998);
- **2nd generation**: policy implications - how to maintain/force cooperation (Cardenas, 2000; Cardenas et al., 2000; Hill & Gurven, 2004; Carpenter & Seki, 2011; Gurven & Winking, 2008);
- **3rd generation**: gain insights on the reasons behind users' harvesting decisions ==> intercultural comparisons.

Introduction (3) - The Case of Fisheries

In the meantime, the state of marine fishery resources continues to decline...

↓

There is something that the CPREs are not capturing CPRE in discrete time are taken for granted. They worked so far, but they are not enough any longer.

Our Contribution

We incorporate the dynamic of the resource into the design of the CPR (Janssen (2014), and Petit et al. (2014)) to study the interaction between resource levels, effort levels and cooperation in real time.

How?

- Schaefer model
- Real-time

Experimental Design

- Leibniz Centre for Tropical Marine Ecology, in Bremen (DE);, betwen August 2015 and February 2016;
- 70 participants recruited from a small jobs online platform;
- Two treatments and 8 sessions (4 each)

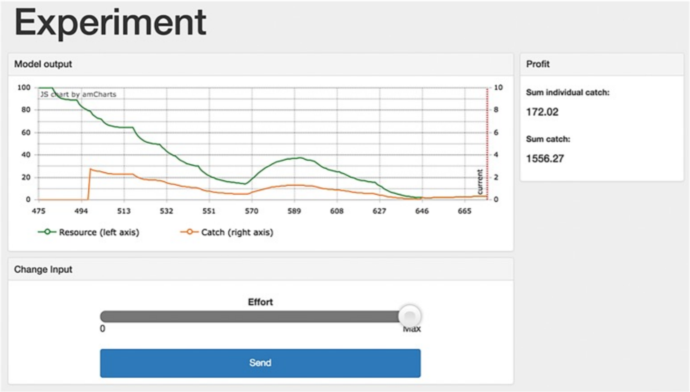
Treatment	Nr. of participants	Age	Gender
		(m $\pm$ sd)	(males, females)
communication	32	35 ± 16	(22, 10)
no communication	38	35 ± 14	(16, 22)

OGUMI

Experiments were conducted with OGUMI (https://www.ogumi.de/)

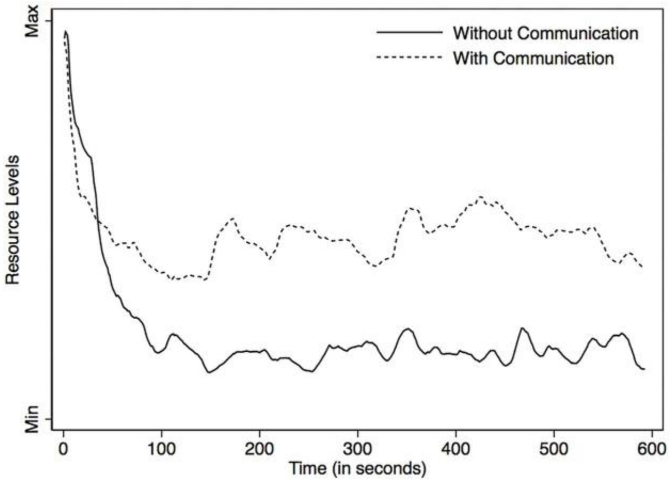
- Mobile application specifically designed to conduct CPRE in Continuous Time;
- Captures real-time changes in extraction behaviour in response to a dynamically varying resource;
- Is very flexible – we can specify any model for the resource dynamics.

OGUMI

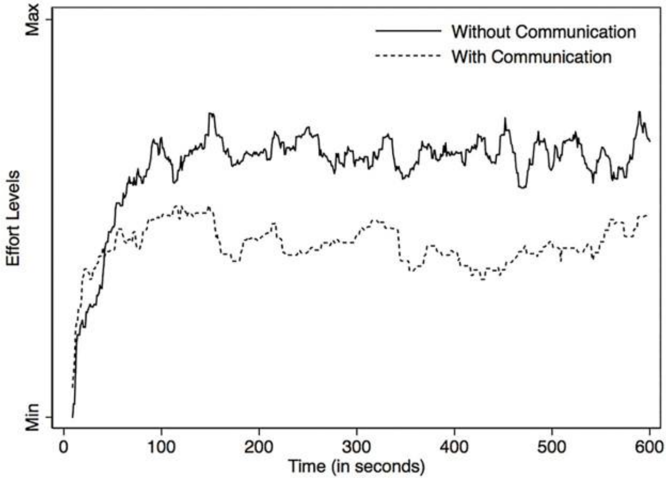


Experiment
Model output
JS chart by amCharts
100
80
60
40
20
0
10
8
6
4
2
0
current
475
494
513
532
551
570
589
608
627
646
665
Resource (left axis)
Catch (right axis)
Profit
Sum individual catch:
172.02
Sum catch:
1556.27
Change Input
Effort
0
Max
Send

Resources


Max
Min
Resource Levels
Without Communication
With Communication
0
100
200
300
400
500
600
Time (in seconds)

Resources


Without Communication
With Communication
Max
Min
Effort Levels
0
100
200
300
400
500
600
Time (in seconds)

Model - VAR

$$R_t = \alpha_1 + \sum_{i=1}^{m} \beta_{1,i} R_{t-i} + \sum_{i=1}^{m} \gamma_{1,i} E_{t-i} + u_{1,t} \quad (1)$$

$$E_t = \alpha_2 + \sum_{i=1}^{m} \beta_{2,i} R_{t-i} + \sum_{i=1}^{m} \gamma_{2,i} E_{t-i} + u_{2,t} \quad (2)$$

where R, E represents resource and effort, respectively; m is the lag-length ; α_1, α_2 are constants; $\beta_{1,i\cdots1,m}$, $\gamma_{1,i\cdots1,m}$, $\beta_{2,i\cdots2,m}$, $\gamma_{2,i\cdots2,m}$, are coefficients; and $u_{1,t}$, $u_{2,t}$ are white noise error terms.

Model - VECM

$$\Delta R_t = \sum_{i=1}^{m-1} \beta_{1,i}\, \Delta R_{t-i} + \sum_{i=1}^{m-1} \gamma_{1,i}\, \Delta E_{t-i} - \lambda_1\, ECT_{t-1} + u_{1,t} \quad (3)$$

$$\Delta E_t = \sum_{i=1}^{m-1} \beta_{2,i}\, \Delta R_{t-i} + \sum_{i=1}^{m-1} \gamma_{2,i}\, \Delta E_{t-i} - \lambda_2\, ECT_{t-1} + u_{2,t} \quad (4)$$

where Δ is the difference operator; ECT is the error-correction term; and λ_1, λ_2 are the error-correction coefficients. The optimal lag length m of the model was chosen based on the Schwarz Information Criterion (?).

Model - IRF

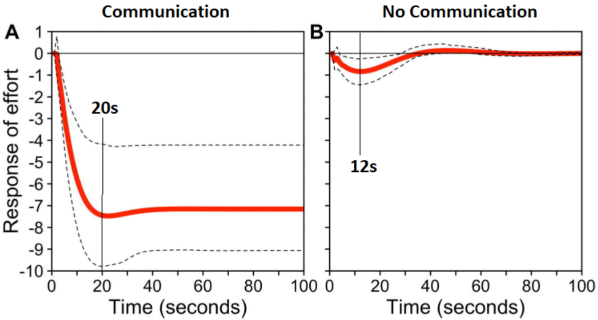
$$R_t = \alpha_1 + \sum_{i=1}^{k=m+d_{max}} \beta_{1,i} R_{t-i} + \sum_{i=1}^{k=m+d_{max}} \gamma_{1,i} E_{t-i} + u_{1,t} \quad (5)$$

$$E_t = \alpha_2 + \sum_{i=1}^{k=m+d_{max}} \beta_{2,i} R_{t-i} + \sum_{i=1}^{k=m+d_{max}} \gamma_{2,i} E_{t-i} + u_{2,t} \quad (6)$$

where d_{max} is maximal order of integration of the variables.

Results - IRA

- The temporal relationship between the variables show that an unanticipated resource shock...
- The Toda-Yamamoto Granger causality test: lagged values of the resource levels significantly predict effort levels for TC and have no impact in TNC.



Conclusions

- Effort constantly and significantly respond to dynamic changes in Resource Levels when Communication is allowed;
- Variations are not exclusively related to the human sphere, but are a result of the coupled dynamics of the user-resource system.Cooperation mediates the last.
- Set the basis to predict (thus, to measure) the dynamics of future effort levels based on the dynamics of the resource (e.g. DC funds and individual extractions.)

Extra Slide

The standard user-resource model

The user-resource model that runs in the background is the classic Schaefer model [31, 32]. In spite of its simplicity, this model has proven very powerful for studying exploited fish stocks. A logistic term describes the growth of the resource R, while the harvest is a bi-linear function of the resource level and the cumulative effort $\sum E$ that N users invest in the harvest. Hence,

$$\frac{dR}{dt} = \mu_R R\left(1 - \frac{R}{K}\right) - qR\sum_{i=0}^{N} E_i \quad (1)$$

with K representing the carrying capacity, μ_N representing the maximum resource growth rate, and q representing the catchability per unit effort and resource unit.

The resource productivity is highest at $K/2$, while the harvest scales linearly with both effort and resource levels. The maximum sustainable yield, MSY, is achieved at

$$E_{MSY} = \sum_{i=0}^{N} E_i = \frac{\mu_R}{2q} \quad (2)$$

Assuming a specific cost c per unit of effort and a price p per resource unit, the return for an individual user i is given by

$$B_i = pH_i - cE_i \quad (3)$$

with the individual harvest $H_i = qRE_i$.

Individual efforts of all users E_i are summed up and Eq 1 is then integrated forward in time with the cumulative effort of all users. The calculated future dynamics are valid as long as the cumulative effort remains unchanged. Whenever a user alters the effort E_i, a new integration is carried out from that time with the updated $\sum E_i$. While at constant effort the Schaefer model approaches a steady-state in R, repeated user intervention typically perturbs the dynamics of the system and displaces it from equilibrium.