Conflict, lobbying and compliance predict the sustainability of biological resource use

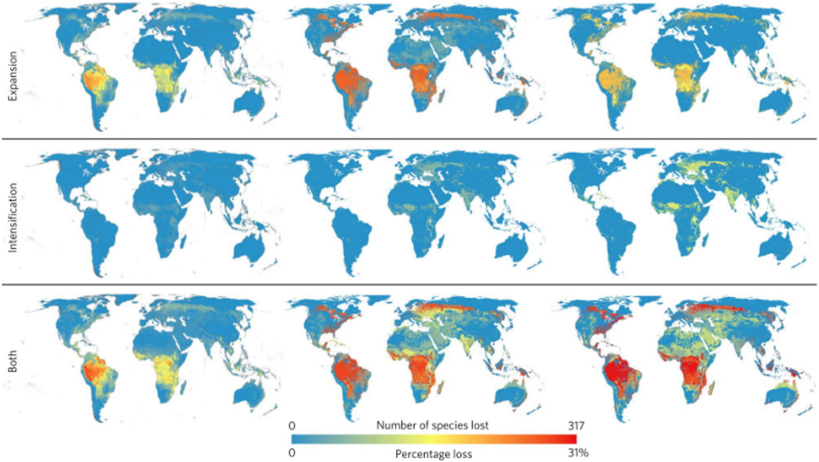
https://bradduthie.github.io/talks/gmse_conflict.pdf

Jeremy Cusack, **Brad Duthie (@bradduthie)**, Rocío Pozo, Steve Redpath, and Nils Bunnefeld

2 October 2019

Conflict between natural resource conservation and use

[1] Richard Crossley. 2010. Barnacle Goose From The Crossley ID Guide Eastern Birds. CC 3.0



[1]Kehoe, L. et al. 2017. *Nat. Ecol. Evol.*, **1**: 1129-1135.

Reframing the Food–Biodiversity Challenge

Joern Fischer,[1,*] David J. Abson,[1] Arvid Berg
Neil French Collier,[1] Ine Dorresteijn,[1] Jan Har
Kristoffer Hylander,[2] Jannik Schultner,[1] and F

Given the serious limitations of production-oriented fra
a new conceptual framework for how to analyze the nex
biodiversity conservation. We introduce four archetyp
, agroec
nservati

REVIEW

The interaction of human population, food production, and biodiversity protection

Eileen Crist,[1*] Camilo Mora,[2] Robert Engelman[3]

Research suggests that the scale of human population and the current pace contribute substantially to the loss of biological diversity. Although technolo and unequal consumption inextricably mingle with demographic impacts on environment, the needs of all human beings—especially for food—imply that population growth will undermine protection of the natural world. Numerous have been proposed to boost food production while protecting biodiversity, bu proposals are unlikely to staunch biodiversity loss. An important approach t biodiversity and human well-being is through actions that can slow and even population growth: investing in universal access to reproductive health services contraceptive technologies, advancing women's education, and achieving gende

chieving high standards of human welfare | through intensification rather than

RESEARCH ARTICLE

Global economic trade-offs between wild nature and tropical agriculture

Luis R. Carrasco[1*], Edward L. Webb[1], William S. Symes[1], Lian P

1 Department of Biological Sciences, National University of Singapore, Repu
2 Environment Institute, School of Biological Sciences, The University of Ade
Australia

† Deceased.
* dbsctlr@nus.edu.sg (L.R.C.); lianpin.koh@adelaide.edu.au (L.P.K.)

Abstract

Global demands for agricultural and forestry products provide ec
estation across the tropics. Much of this deforestation occurs wit
the spatial distribution of benefits and costs of deforestation. To i
land-use policies, we combine geographic information systems (
of ecosystem services (ES) studies to perform a spatially explicit
between agricultural benefits, carbon emissions, and losses of m
because of tropical deforestation from 2000 to 2012. Even thougl
services presents large inherent uncertainties, we find a pattern
that the externalities of destroying tropical forests are greater tha

Biodiversity at risk under future cropland expansion and intensification

Laura Kehoe[1,2*], Alfredo Romero-Muñoz[1], Ester Polaina[3], Lyndon Estes[4,5,6], Holger Kreft[7] and Tobias Kuemmerle[1,8]

Agriculture is the leading driver of biodiversity loss. However, its future impact on biodiversity remains unclear, especially because agricultural intensification is often neglected, and high path-dependency is assumed when forecasting agricultural development—although the past suggests that shock events leading to considerable agricultural change occur frequently. Here, we investigate the possible impacts on biodiversity of pathways of expansion and intensification. Our pathways are not built to reach equivalent production targets, and therefore they should not be directly compared; they instead highlight areas at risk of high biodiversity loss across the entire option space of possible agricultural change. Based on an extensive database of biodiversity responses to agriculture, we find 30% of species richness and 31% of species abundances potentially lost because of agricultural expansion across the Amazon and Afrotropics. Only 21% of high-risk expansion areas in the Afrotropics overlap with protected areas (compared with 43% of the Neotropics). Areas at risk of biodiversity loss from intensification are found in India, Eastern Europe and the Afromontane region (7% species richness, 13% abundance loss). Many high-risk regions are not adequately covered by conservation prioritization schemes, and have low national conservation spending and high agricultural growth. Considering rising agricultural demand, we highlight areas where timely land-use planning may proactively mitigate biodiversity loss.

[1]Kehoe, L. et al. 2017. *Nat. Ecol. Evol.*, **1**: 1129-1135.
[2]Crist, E. et al. 2017. *Science*, **356**: 260-264.
[3]Carrasco, L. et al. 2017. *PLoS Biol.*, **15**: e2001657.
[4]Fischer, J. et al. 2017. *Trends Ecol. Evol.*, **32**: 335-345.

Animal Conservation

ZSL LET'S WORK FOR WILDLIFE

Animal Conservation. Print ISSN 1367-9430

LETTER FROM THE CONSERVATION FRONT LINE

Conservation in a changing world needs predictive models

K. A. Wood[1], R. A. Stillman[2] & G. M. Hilton[1]

1 Wildfowl & Wetlands Trust, Slimbridge, UK

2 Department of Life and Environmental Sciences, Faculty of Science and Technology, Bournemouth University, Poole, UK

Correspondence

Kevin A. Wood, Wildfowl & Wetlands Trust, Slimbridge, Gloucesters

Email: kevin.wood@wwt.org.uk

doi: 10.1111/acv.12371

As conservationists we need to predict how biological systems will respond to environmental change, and how such responses may be affected by conservation interventions (Clark *et al*., 2001). Environmental change can create novel

REVIEW

Ecosystem management as a wicked problem

Ruth DeFries[1*] and Harini Nagendra[2]

Ecosystems are self-regulating systems that provide societies with food, water, timber, and other resources. As demands for resources increase, management decisions are replacing self-regulating properties. Counter to previous technical approaches that applied simple formulas to estimate sustainable yields of single species, current research recognizes the inherent complexity of ecosystems and the inability to foresee all consequences of interventions across different spatial, temporal, and administrative scales. Ecosystem management is thus more realistically seen as a "wicked problem" that has no clear-cut solution. Approaches for addressing such problems include multisector decision-making, institutions that enable management to span across administrative boundaries, adaptive management, markets that incorporate natural capital, and collaborative processes to engage diverse stakeholders and address inequalities. Ecosystem management must avoid two traps: falsely assuming a tame solution and inaction from overwhelming complexity. An incremental approach can help to avoid these traps.

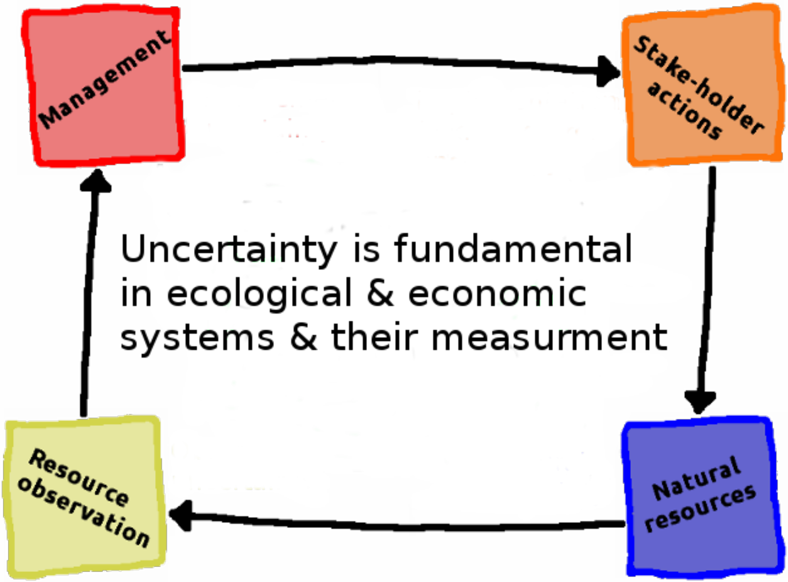
People modify and manage ecosystems to | try officials to farmers, fishers, and foragers. They

---

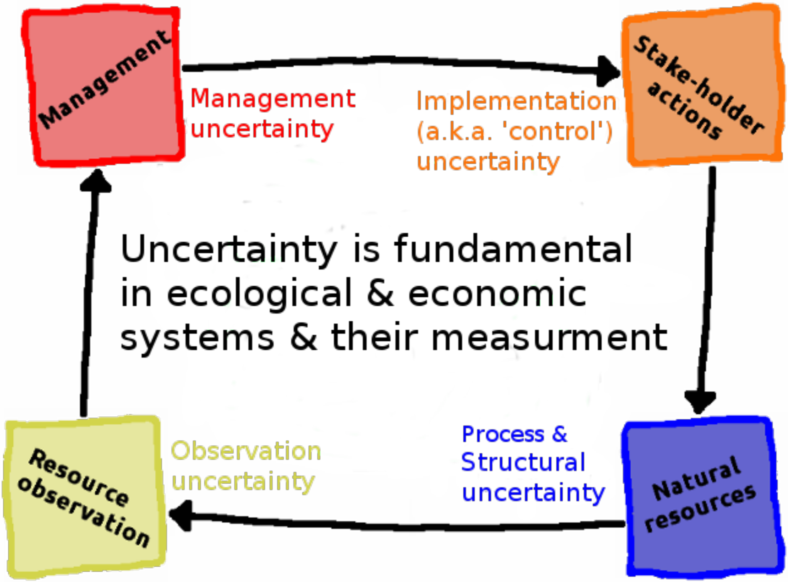
[1]Wood, K. A. et al. 2017. *Anim. Conserv.*, **21**: 87-88.

[2]Defries, R. & H. Nagendra. 2017. *Science*, **356**: 265-270.

[1]Bunnefeld, N. et al. 2011. *Trends. Ecol. Evol.*, **26**: 441-447.
[2]Chadès et al. 2017. *Theor. Ecol.*, **10**: 1-20.



[1]Bunnefeld, N. et al. 2011. *Trends. Ecol. Evol.*, **26**: 441-447.
[2]Chadès et al. 2017. *Theor. Ecol.*, **10**: 1-20.

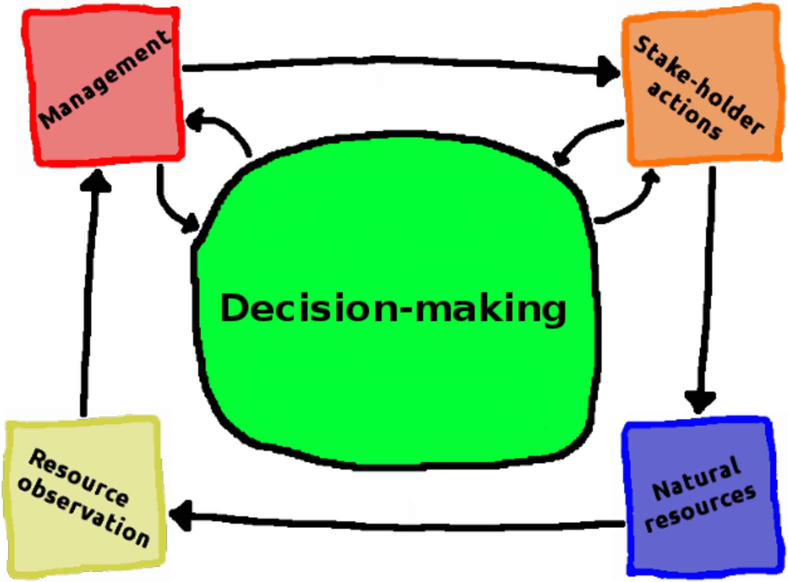


[1]Bunnefeld, N. et al. 2011. *Trends. Ecol. Evol.*, **26**: 441-447.
[2]Chadès et al. 2017. *Theor. Ecol.*, **10**: 1-20.

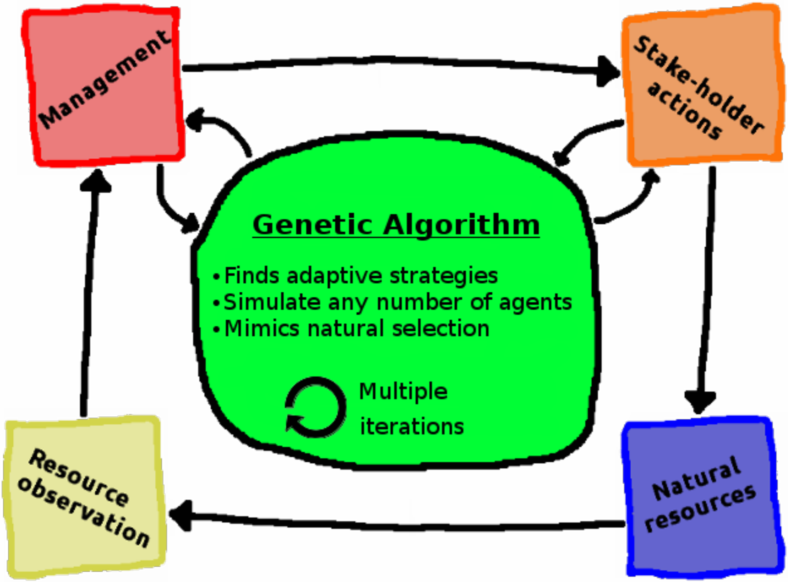
Generalised Management Strategy Evaluation (GMSE)

- Model biodiversity dynamics & realistic human decision-making
- Predict resource & land-use changes in social-ecological systems
- Integrate flexibly with existing ecological models
- Default models individual-based (IBMs) on a spatially explicit landscape
- Open-source on CRAN & GitHub

[1] Duthie, A. B. et al. 2018. *Method. Ecol. Evol.*, **9**: 2396-2401.



Management
Stake-holder actions
Decision-making
Resource observation
Natural resources


Management
Stake-holder actions
Genetic Algorithm
•Finds adaptive strategies
•Simulate any number of agents
•Mimics natural selection
Multiple iterations
Resource observation
Natural resources

GMSE: modelling decision-making

Multiple options can be run using gmse in R.

```
sim <- gmse(time_max = 30, land_dim_1 = 100,
            land_dim_2 = 100, observe_type = 1,
            res_death_K = 4000,
            manager_budget = 2000, user_budget = 500,
            scaring = TRUE, land_ownership = TRUE,
            tend_crops = TRUE, stakeholders = 7,
            res_consume = 1, RESOURCE_ini = 600);
```

One function shows the general results of simulation dynamics.

```
plot_gmse_results(sim);
```

Another function shows manager permissiveness, and stakeholder effort, for each action.

```
plot_gmse_effort(sim);
```

Custom sub-models with gmse_apply

Custom models can be integrated into GMSE with `gmse_apply`, which takes the arguments `res_mod`, `obs_mod`, `man_mod`, and `use_mod`.

```
sim <- gmse_apply(
          res_mod      = custom_resource_model,
          obs_mod      = custom_observation_model,
          man_mod      = manager, # GMSE default
          use_mod      = user,    # GMSE default
          stakeholders = 5,       # GMSE option
          custom_arg   = 200      # Custom arg.
          );
```

The `gmse_apply` function needs to be looped for modelling more than one time step (e.g., using the `old_list` argument).

How does conservation conflict affect management?

Investigate how disagreement over target population size affects natural resource management

- Divergent conservationist & harvester goals
- Modified `gmse_apply` to allow for policy lobbying and illegal harvesting
- Varied manager 'impartiality' (bias toward lobbying pressure)
- Compared population dynamics given conservationist and resource user disagreement over population target

Jeremy Cusack
@jeremyjcusack

Natural resources submodel

Simple discrete logistic growth model,

$$N(t+1) = \frac{N(t)Ke^{r(t)}}{K + N(t)(e^{r(t)} - 1)} - H(t).$$

- $N(t)$ is resource population at time t
- K is carrying capacity
- $r(t) =$ is intrinsic growth rate at time t
- $H(t)$ is total harvest at time t

Natural resources submodel

Simple discrete logistic growth model,

$$N(t+1) = \frac{N(t)Ke^{r(t)}}{K + N(t)(e^{r(t)} - 1)} - H(t).$$

- $N(t)$ is resource population at time t
- K is carrying capacity
- $r(t) =$ is intrinsic growth rate at time t
- $H(t)$ is total harvest at time t

For simplicity, we assume no error in resource observation.

$$\hat{N}_{t+1} = N_{t+1}$$

Natural resources submodel

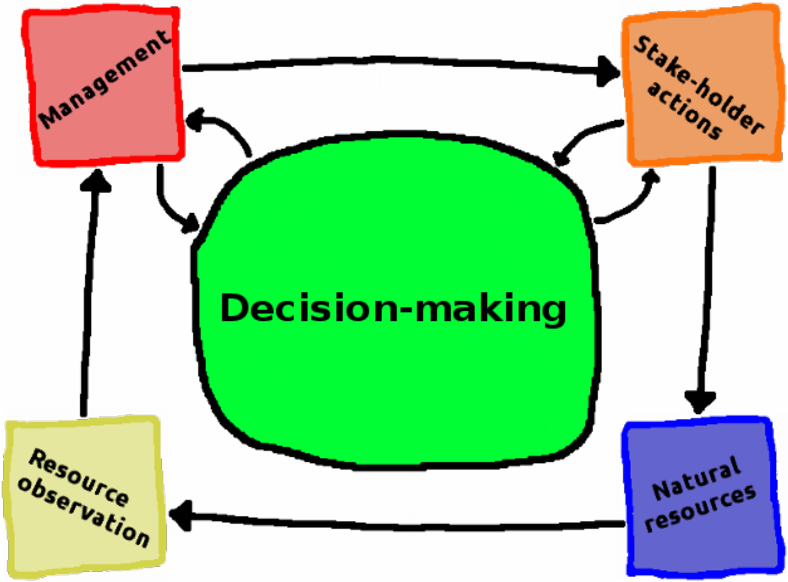
Simple discrete logistic growth model,

```
pop_mod <- function(N, K, r, H){
                top <- (N * K * exp(r));
                bot <- (K + N*(exp(r) - 1);
                New <- (top/bot) - H;
                return(New);
}
```

- $N(t)$ is resource population at time t
- K is carrying capacity
- $r(t) =$ is intrinsic growth rate at time t
- $H(t)$ is total harvest at time t

For simplicity, we assume no error in resource observation.

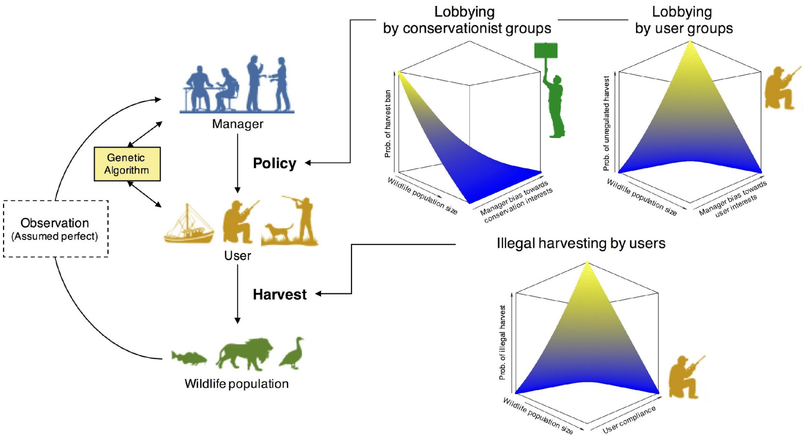
```
obs_mod <- function(N) return(N);
```


Management
Stake-holder actions
Decision-making
Resource observation
Natural resources

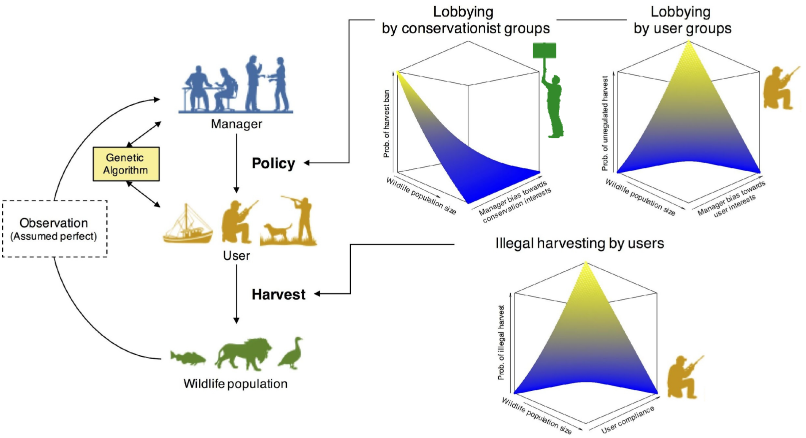
Social dynamics: Goals and Power

	Conservationist	Manager	Harvester
Target	$N(t) \geq N_c$	$N(t) = N_m$	$N(t) \leq N_u$
Power	Lobbying	Set harvest cost	Lobbying, harvesting

Policy, lobbying, and illegal harvesting



Policy, lobbying, and illegal harvesting



Separate simulations for conservationist or user lobbying.

How lobbying works

Conservationists lobby for a total harvesting ban:

- Distance of resource $N(t)$ from N_c
- Manager bias toward conservationist $(0 < I_c < 1)$

$$\Pr(ban) = \left[(2 - I_c)^{\frac{N_c - N(t)}{N_c}} \right] - 1.$$

How lobbying works

Conservationists lobby for a total harvesting ban:

- Distance of resource $N(t)$ from N_c
- Manager bias toward conservationist $(0 < I_c < 1)$

$$\Pr(ban) = \left[(2 - I_c)^{\frac{N_c - N(t)}{N_c}}\right] - 1.$$

Harvesters lobby for unregulated harvesting:

- Distance of resource $N(t)$ from N_u
- Manager bias toward harvester $(0 < I_u < 1)$

$$\Pr(unregulated) = \left[(2 - I_u)^{\frac{N(t) - N_u}{K - N_u}}\right] - 1.$$

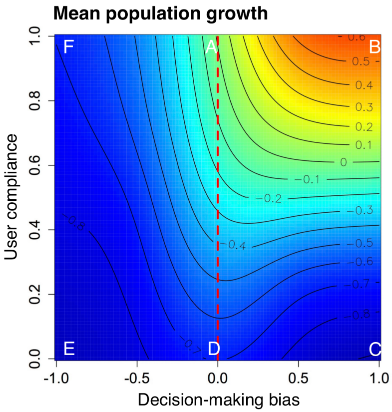
How illegal harvesting works

Harvesters decide whether to harvest illegally:

- Distance of resource $N(t)$ from N_u and K
- User compliance with harvesting rules ($0 < E < 1$)

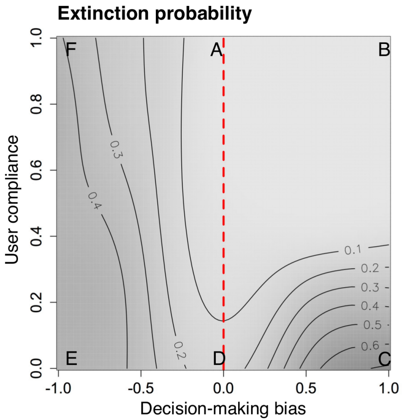
$$\Pr(illegal) = \left[(2 - E)^{\frac{N(t) - N_u}{K - N_u}} \right] - 1.$$

Results given manager bias and harvester compliance



- Mean population growth over 10 years
- User compliance range from guaranteed illegal harvesting (0) to total compliance (1)
- Manager decision-making bias from guaranteed unregulated harvest (-1) to guaranteed ban on harvesting (1)

Results given manager bias and harvester compliance



- Mean population growth over 10 years
- User compliance range from guaranteed illegal harvesting (0) to total compliance (1)
- Manager decision-making bias from guaranteed unregulated harvest (-1) to guaranteed ban on harvesting (1)

Five key model predictions

1. In the absence of lobbying, stable populations require high harvester compliance.

Five key model predictions

1. In the absence of lobbying, stable populations require high harvester compliance.
2. As compliance decreases, manager bias toward conservation is required for stable populations.

Five key model predictions

1. In the absence of lobbying, stable populations require high harvester compliance.

2. As compliance decreases, manager bias toward conservation is required for stable populations.

3. As compliance decreases further, bias towards conservation can cause extinction:
   - Banning on harvesting becomes more likely
   - Resource abundance increases, followed by illegal harvesting

Five key model predictions

1. In the absence of lobbying, stable populations require high harvester compliance.
2. As compliance decreases, manager bias toward conservation is required for stable populations.
3. As compliance decreases further, bias towards conservation can cause extinction:
    - Banning on harvesting becomes more likely
    - Resource abundance increases, followed by illegal harvesting
4. Minimal compliance always leads to population decline.

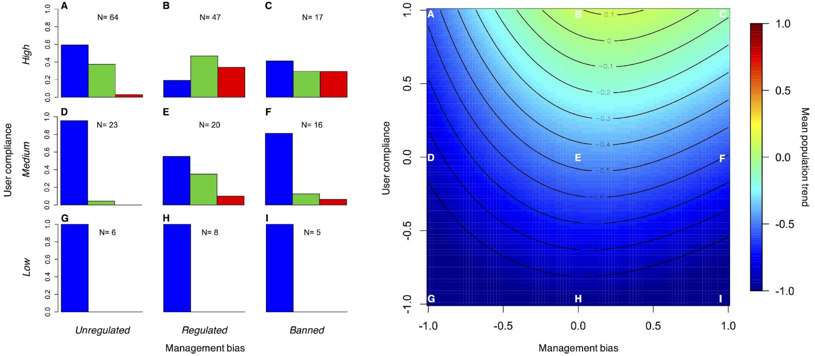
Five key model predictions

1. In the absence of lobbying, stable populations require high harvester compliance.
2. As compliance decreases, manager bias toward conservation is required for stable populations.
3. As compliance decreases further, bias towards conservation can cause extinction:
    - Banning on harvesting becomes more likely
    - Resource abundance increases, followed by illegal harvesting
4. Minimal compliance always leads to population decline.
5. Populations decline when managers are biased toward harvester interest

Application of model to harvested species

- Compared model predictions to data from 206 harvested species from IUCN Red List
- Anseriformes, Cetartiodactyla, Carnivora included
  - Commonly hunted globally
  - Least Concern or Near Threatened
- Assessed manager bias and user compliance
  - Bias: unregulated, regulated, or banned
  - Compliance: low, medium, or high reported illegal harvesting
- Assessed if population is decreasing, stable, or increasing

Application of model to harvested species




Nils Bunnefeld
@bunnefeld


Sarobidy Rakotonarivo
@SarobidyRakoto


Erlend B. Nilsen


Jeroen Minderman
@jejoenje


Jeremy Cusack
@jeremyjcusack


Rocío Pozo
@RocioPozo5


Bram Van Moorter


Isabel Jones
@_Isabel_Jones

erc
European Research Council
Established by the European Commission

LEVERHULME
TRUST

ConFooBio

Five key model predictions

1. In the absence of lobbying, stable populations require high harvester compliance.
2. As compliance decreases, manager bias toward conservation is required for stable populations.
3. As compliance decreases further, bias towards conservation can cause extinction:
   - Banning on harvesting becomes more likely
   - Resource abundance increases, followed by illegal harvesting
4. Minimal compliance always leads to population decline.
5. Populations decline when managers are biased toward harvester interest