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CLOCK CLIMATE ADAPTATION TO SHIFTING STOCKS

FUTURE OCEANS LAB Universidade de Vigo

MANAGEMENT SOLUTIONS FOR SHIFTING TRANS-BOUNDARY FISH STOCKS UNDER FIXED CATCH SHARES

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HIGHLIGHTS

- We evaluate the potential of a broadly used fisheries management practice for tackling the shifting stocks problem driven by climate change.
- This management practice is based on countries holding catch or quota shares that are constant over the years (as in the European Union).
- We design a model featuring fixed catch shares (FCS) and a quota negotiation process when a stock shifts from one country to another.
- The model suggests that long cooperation can be achieved as long as the stock-losing country is offered a major share in the fishery.
- "Wait and see" strategy is not optimal, negotiation should start sooner rather than later.

1 · INTRODUCTION

Rising temperature is driving many fish stocks to move poleward; e.g., 16 of the 21 key species in the Northeast Atlantic have shown distributional responses to warming [1]. Earlier studies have shown how countries, in absence of a sharing agreement, have little incentive to sustainable harvest a stock that is expected to disappear from their waters [2,3]. The present research investigates to what extent existing trans-boundary fishery agreements that are based on sharing fixed catch quotas can help solving the shifting stocks problem.

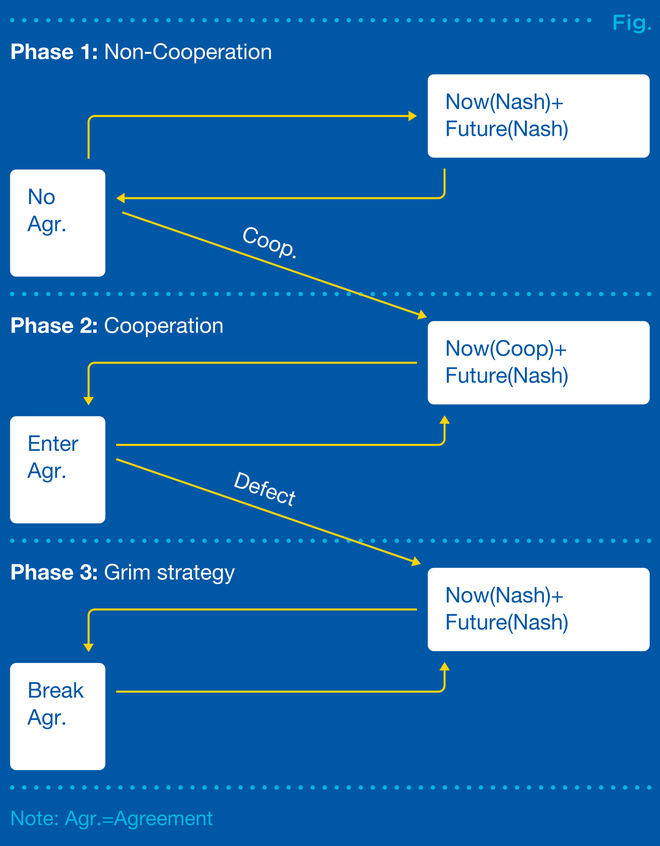
2 · THE MODEL

2.1 The rule of the game

Country negotiations are simulated with a game theoretical bioeconomic model with the following features:

- The two-countries have asymmetric stock ownership ($0 \le \theta \le 1$).
- A self-enforcing fishery agreement.
- Dynamic membership: a country can decide at any step whether to cooperate in stock management, not cooperate, or defect (Fig. 1).

Fig. 1



- Policy options: players negotiate on a fixed catch share (FCS) that remains unchanged for the entire agreement period.
- Grim strategy: once a player defects, non-cooperative game resumes.
- Allow benefit transfer (e.g., access right, monetary transfer) if a player is entitled more catch quota than he can catch optimally in his own water.

2.2 Spatial distributional shift

The fish stock shift is simulated as follows (Fig. 2):

- Split stream migration pattern: a migratory stock moves between spawning and fishing grounds of two countries.
- The stock ownership ($\theta_{i,t}$) depends on sea surface water temperature (SST), which is assumed to be a positive deterministic trend of time t.

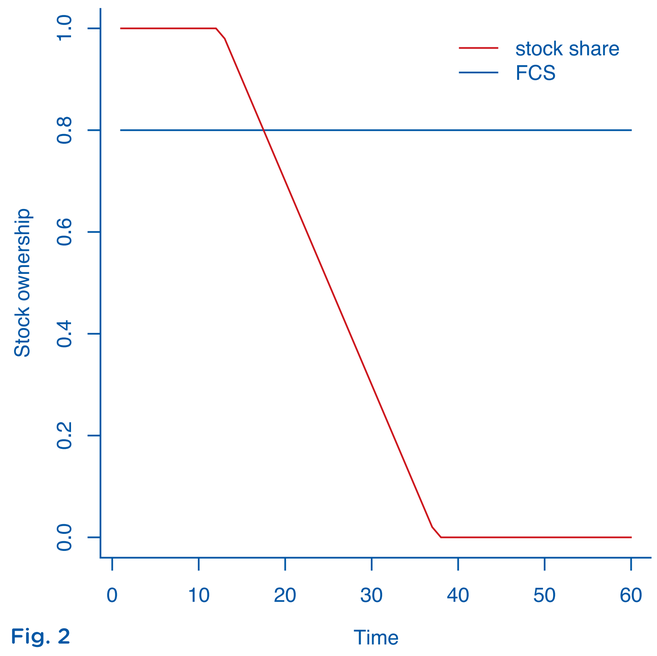


Fig. 2

2.3 Biological model

$$R_t(N_t) = aN_t(1 - N_t) + N_t + \varepsilon, \quad (1)$$

$$\frac{dC}{dt} = \tilde{q}E\rho\,, \rho = N^b \quad (2)$$

where R-recruitment, N-normalized abundance, a-growth parameter, C-catch, ρ-stock density, b-schooling parameter.

- Discrete time logistic growth;
- Stochastic recruitment ($\mathcal{E}$ follows a beta distribution)
- Define instantaneous catch rate in terms of stock density (ρ) rather than abundance (N).

2.4 Economic model

The specific choice of the FCS level depends on the goal of fisheries management:

$$V_t^i(.) = \max_{p_t^i, G_t^i} \left\{ \overbrace{v_t^i(p_t^i, R_t, G_t)}^{\text{Current payoff}} + \overbrace{\sum_{k=t+1}^{t_{max}} \frac{E_k[v_k^i(p_k^i \mid p_k^{-i*}, R_k, G_k)]}{(1+\gamma)^{k-t}}}^{\text{Expected discounted future payoff}} \right\}$$

where p is escapement proportion, and G game strategy.

- Playing cooperative or non-cooperative is an endogenous process.
- The optimal harvest policies are closed-loop equilibria that can be adjusted according to stock size, game strategy and time.
- Dynamic programming algorithm, consisting of backward iteration and forward iteration.

3 · RESULTS AND DISCUSSIONS

3.1 Optimal game strategy

Figure 3 shows the number of years countries cooperate (dots) at different combinations of Fixed Catch Shares (y-axis) over the time period (x-axis). Light blue area is the period of stock transition, this is when the stock is moving from country 1 to country 2. We found that:

- Both countries have incentive to cooperate at least for some periods;
- Long cooperation can be achieved if the stock losing country (country 1) is offered high FCS (e.g., 80%);
- Cooperation can not be achieved near the end of stock transition;
- Countries have asymmetric bargaining power;
- The countries shall enter the agreement relatively early during the stock transition.

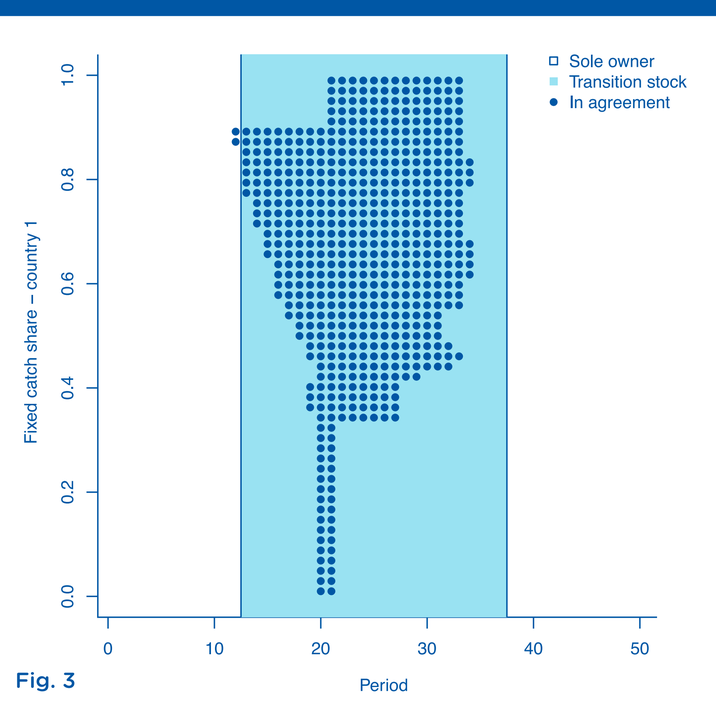


Fig. 3

3.2 Harvest trajectories

Figure 4 shows the amount of harvest for each country over the time period at a low (1%) and high (79%) FCS scheme and the resulting stock level.

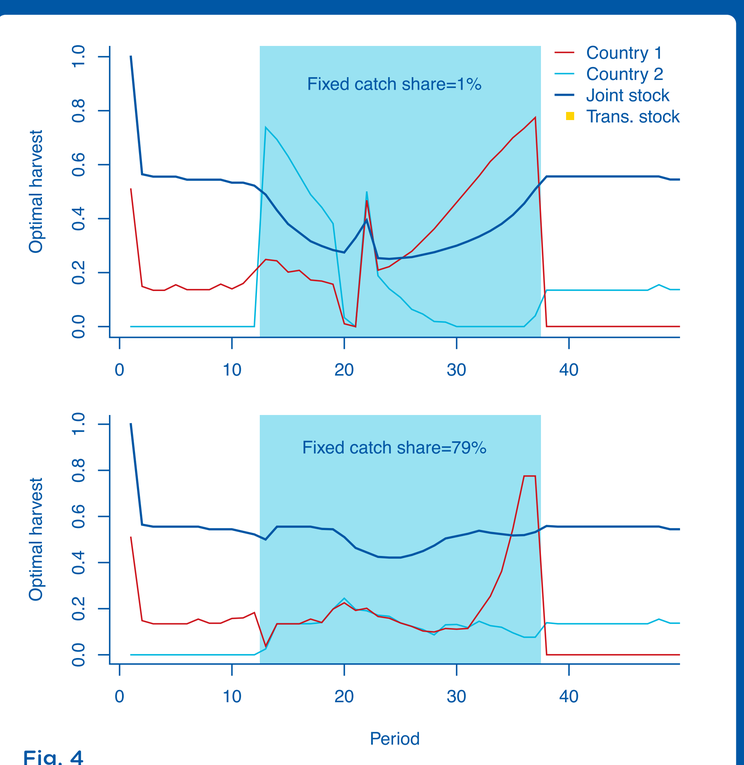


Fig. 4

- In the absence of agreement, the minor stock owner always harvests more aggressively than the major one, driving the stock down.
- Agreement restricts the over-exploitation by the minor owner.
- Countries in agreement adopt common but non-constant harvest strategies, due to expectations about distribution change.

3.3 Policy selection criteria

The specific choice of the FCS level depends on the goal of fisheries management (Fig. 5)

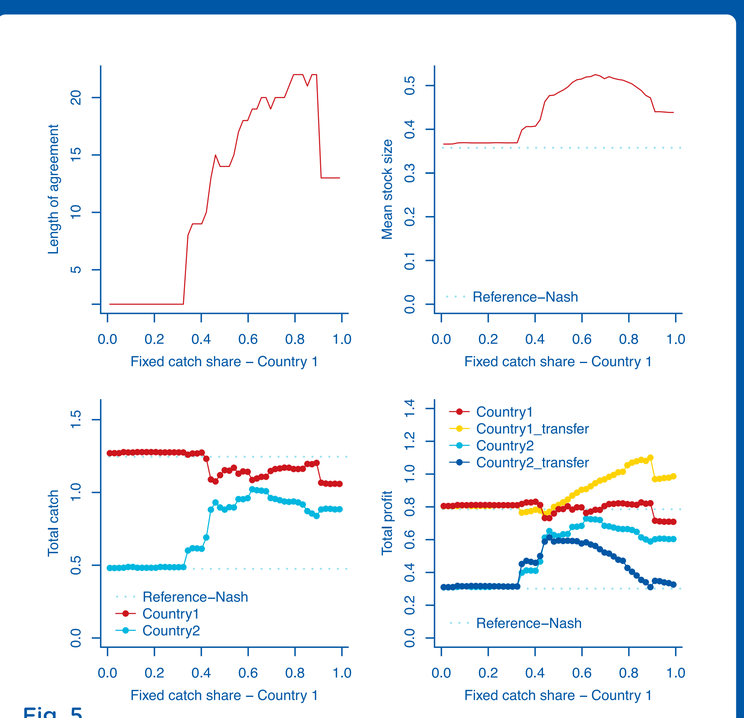


Fig. 5

- to maximize the duration of agreement, the stock losing country can demand fairly high FCS, up to 80% of the total catch;
- to maximize the mean transition stock, an optimal FCS is found at an intermediate level (e.g., 60%);
- this intermediate level of FCS can also minimize the difference in total catch during the transition and require a moderate level of benefit transfer between the countries.

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