Fisheries management by a non-cooperative income pooling system as a remedy for the “tragedy of the commons”

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Fishery as a non-cooperative game

- As fish stocks are ownerless entities, any fishery without regulations could be regarded as a non-cooperative game with strong competition and leads a fishing race.

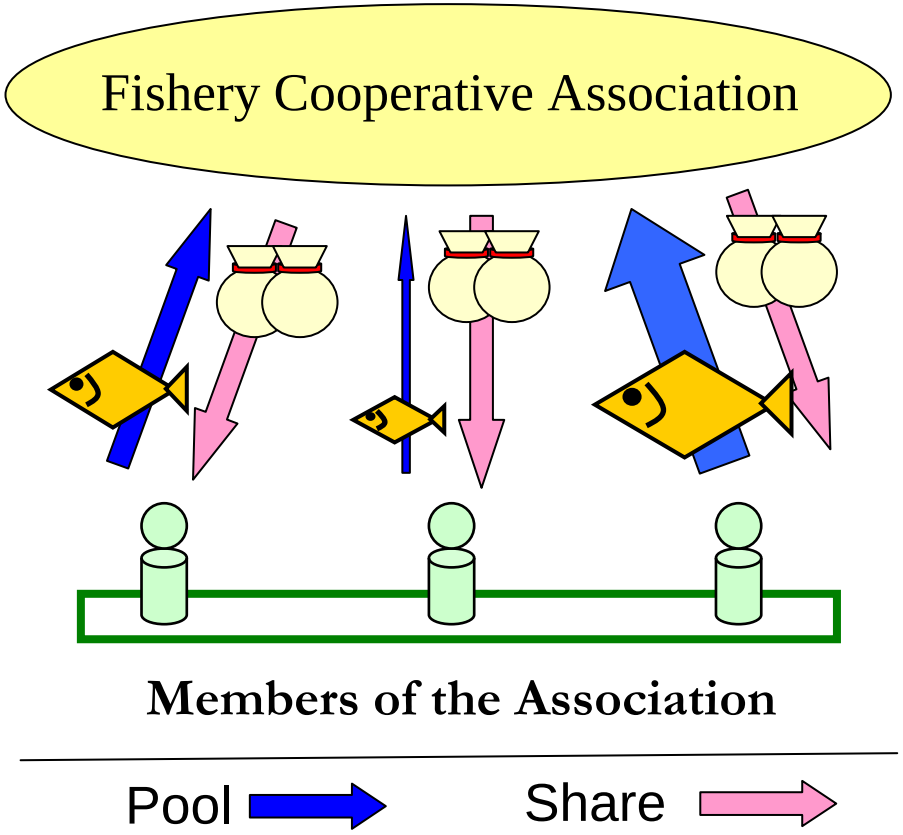
Fisheries essentially could produce an externality of " the tragedy of the commons".

How can we solve this problem ?

Reallocation of income among fishermen might be a solution. An income pooling system could be available for this purpose.

What is the income pooling system ?

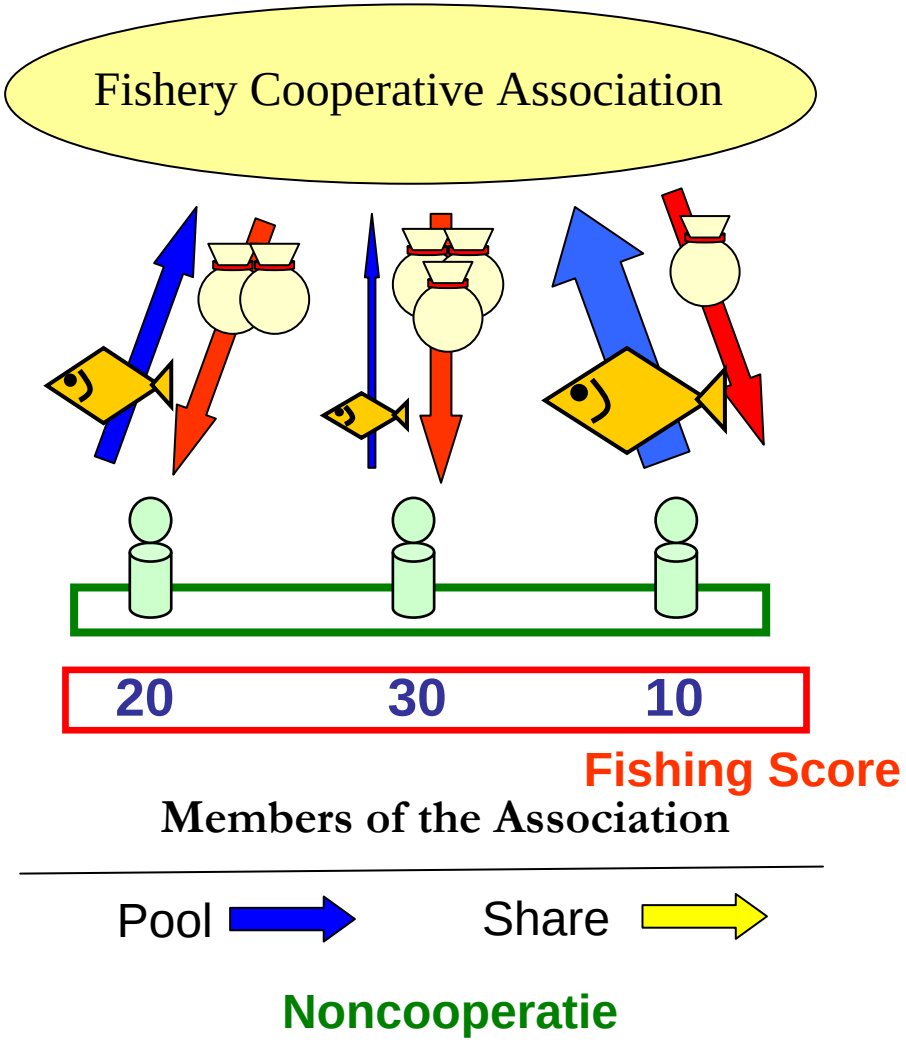
- Income pooling system is introduced in some Japanese coastal fishing communities. (ex. sakura shrimp fishery in Suruga bay.)
- It has some advantages of preventing fishing race and price destruction by oversupply. Therefore, the management of fish stock can be conducted effectively.



Conventional income pooling system

A non-cooperative income pooling system

- This system uses the pooling system as a tool for income reallocation, but by combining with a pre-agreed sharing rule, we could eliminate fishing external diseconomies while keeping competition.
- Without competition, we have to consider other difficult problems, like free-riding problem and feeling of unfairness by ignoring the difference in performance.



Objective

- We propose the concept and the mechanism of a non cooperative income-pooling system and examined its performance as a fisheries management tool by computer simulation.

An example of fishing score and income sharing rule

Tuning parameters for adjusting the magnitude of the two components

Fishing score of fisherman j from stock i in season t

$$\phi_{j,i,t} = CPUE_{j,i,t}^{A} \, INCOME_{j,i,t}^{B}$$

Share of the fisherman Z

$$\Phi_{Z,t} = \frac{\sum_{i}^{I} \phi_{Z,i,t}}{\sum_{j}^{J}\sum_{i}^{I} \phi_{j,i,t}} \sum_{j}^{J}\sum_{i}^{I} INCOME_{j,i,t}$$

CPUE : catch per unit effort, *INCOME* : yiled * price

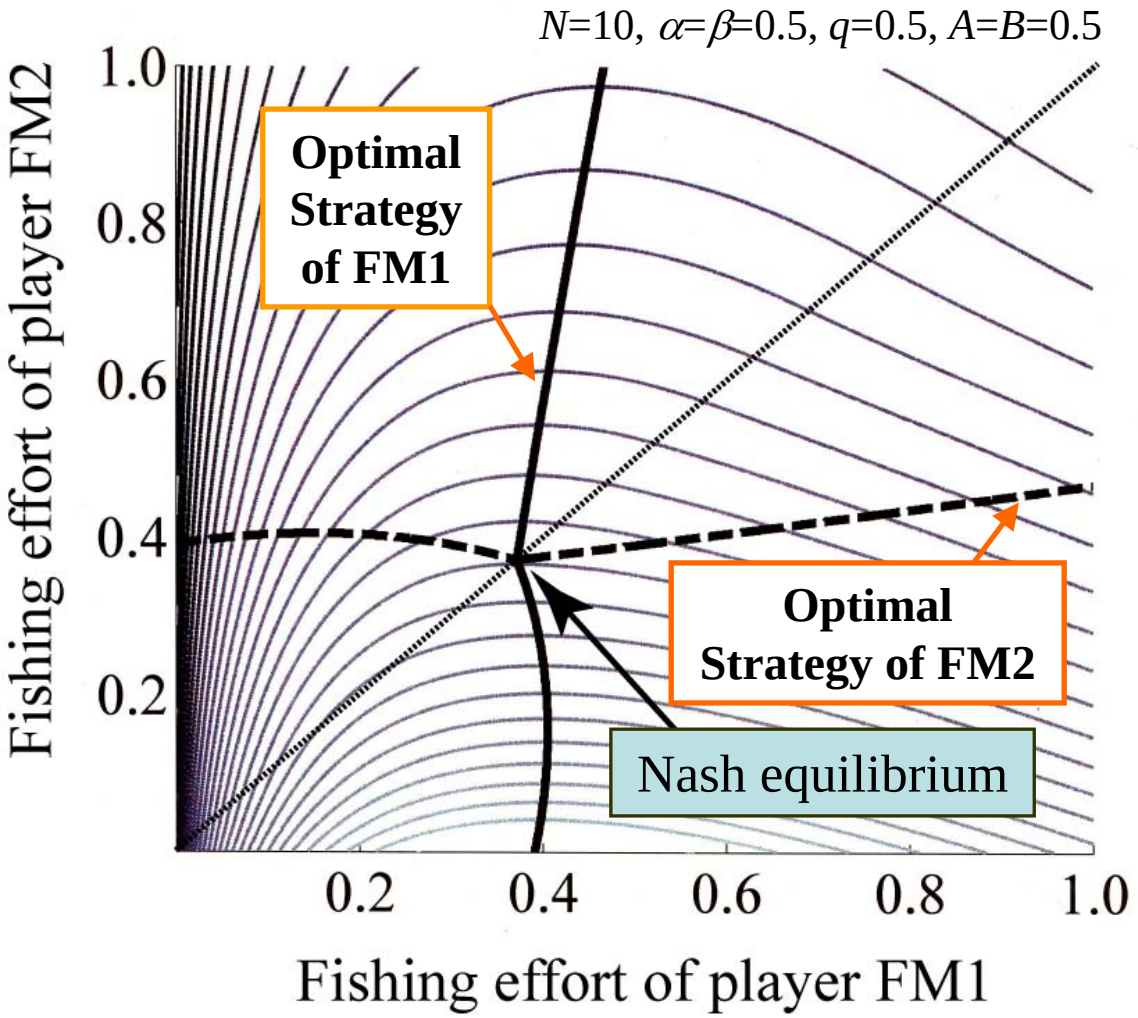
In this rule, fisherman has to care about his CPUE

Each fisherman has to compete intensively for his share, and as a result, a pre-agreed goal will be automatically attained.(e.g. prevention of a decline of CPUE)

Game theoretic mechanism of the non-cooperative income poling system

Each fisherman would take his optimal strategy to maximize his fishing point.

They reach Nash equilibrium and they exploit the target stock by this effort level.



Model settings and computer simulation

- We modeled Income-pooling system and other three types of fisheries and compared the management performance by computer simulation.

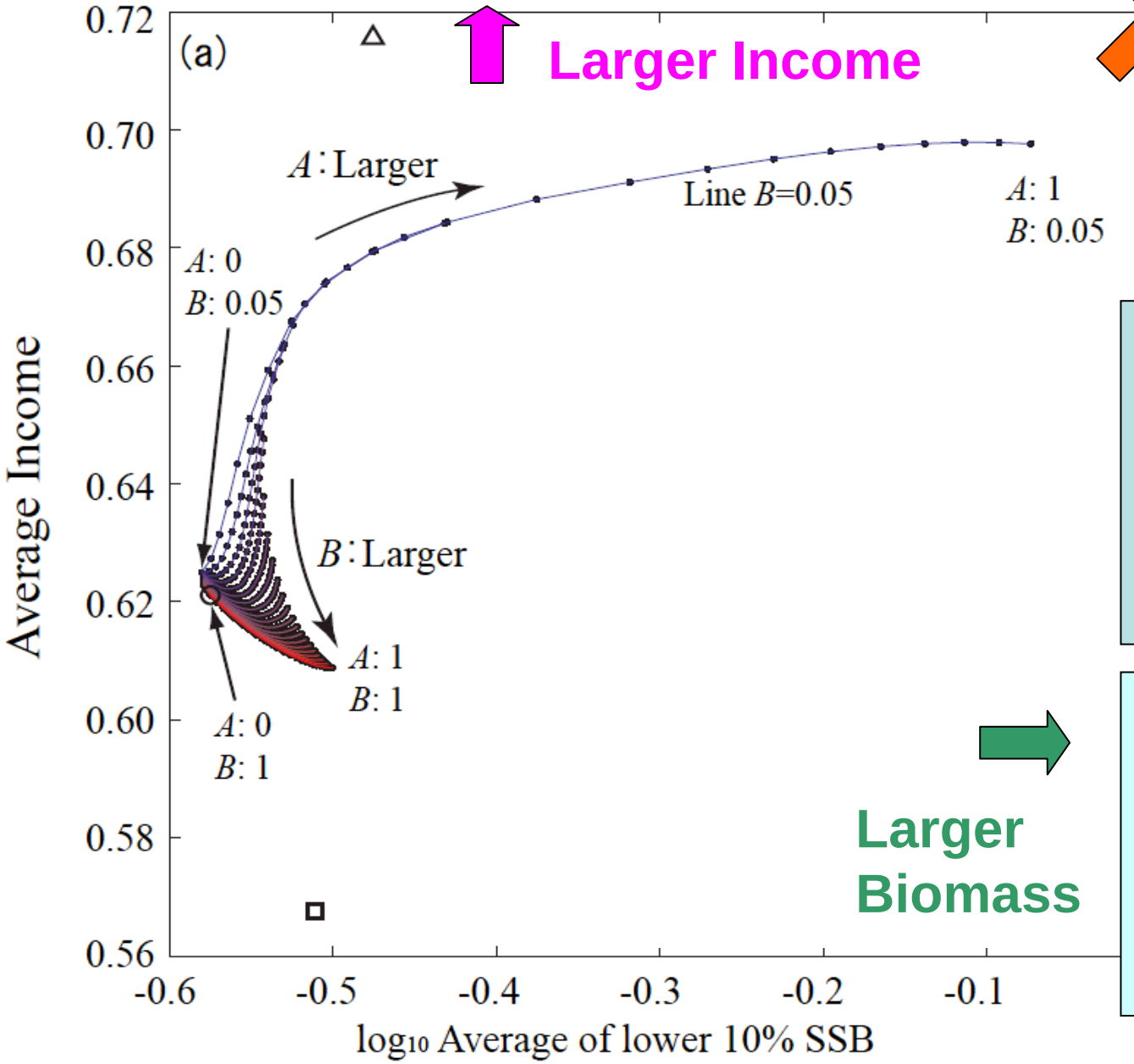
- The fixed-effort fishery is a fishery which exploits the target stocks every season at a constant effort level regardless of the stock abundance.
- The normal income pooling fishery is a fishery in which fishermen share the optimal effort to maximize the total annual income from the target stocks. (It did not consider the long-tem benefit in this comparison)
- The general competitive fishery is a fishery where each fisherman competitively exploits the target stocks to maximize his annual income under a given effort limit.

Model settings and computer simulation

- We make one (or two) stock dynamics by the delay-difference model and each type of fishery exploits them for 200 seasons. Then, we compared each fisheries' long-term performance (average income and minimum stock level in latter 150 seasons).
- In income-pooling system, we changed its tuning parameters (A and B) from 0 to 1and examined how it works.
- We also changed the fisheries' surroundings (*e.g.* price function, constraint on the maximum fishing effort, or the number of target stocks) and examined how it effect.

Result 1

Fishing Point $\phi_{j,i,t} = CPUE_{j,i,t}{}^{A} INCOME_{j,i,t}{}^{B}$



Dot and Line : Performance of non-cooperative income pooling system with different values of tuning parameters

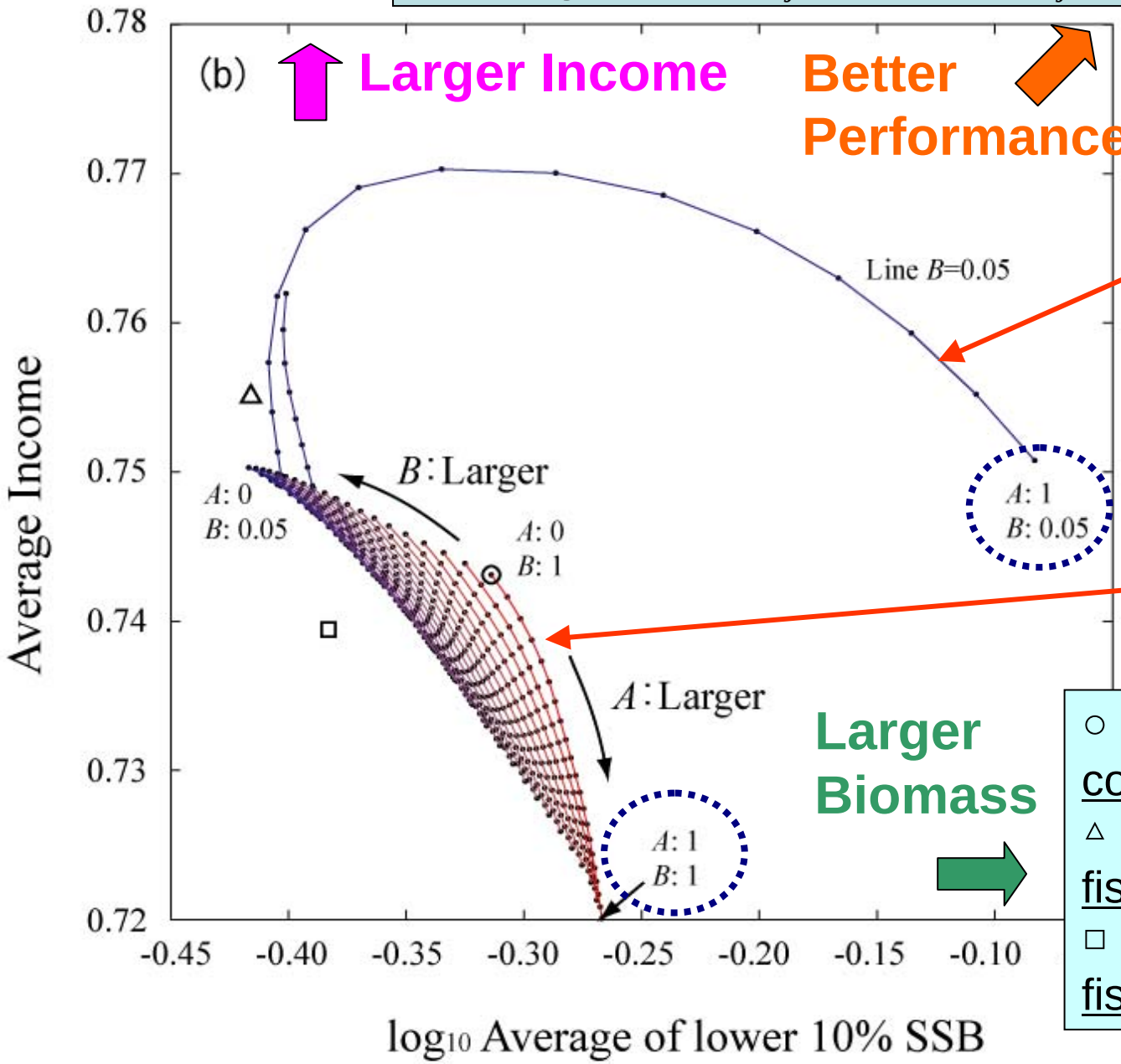
○ General competitive fishery

△ Normal pooling fishery

□ The fixed-effort fishery

Result 2

Fishing Point $\phi_{j,i,t} = CPUE_{j,i,t}{}^{A} INCOME_{j,i,t}{}^{B}$



Decrease in total fishing effort

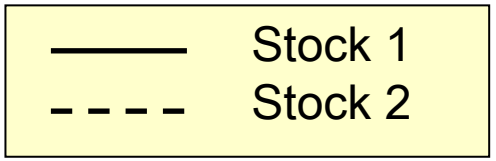
Emergence of "switching effect" (This holds only in exploiting two fish stocks simultaneously.)

○ General competitive fishery

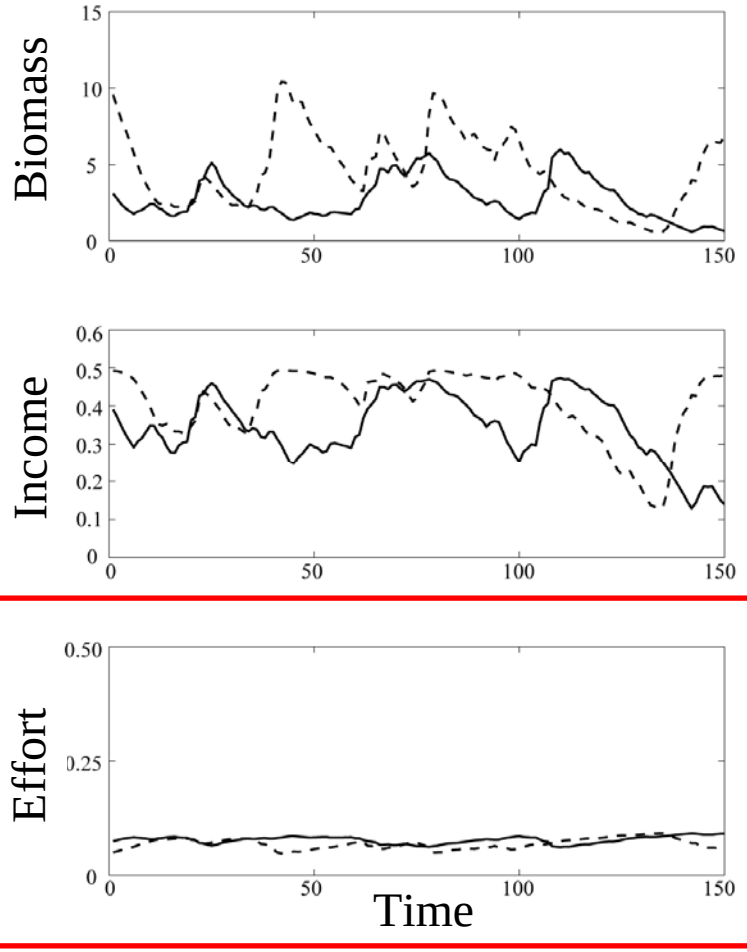
△ Normal pooling fishery

□ The fixed-effort fishery

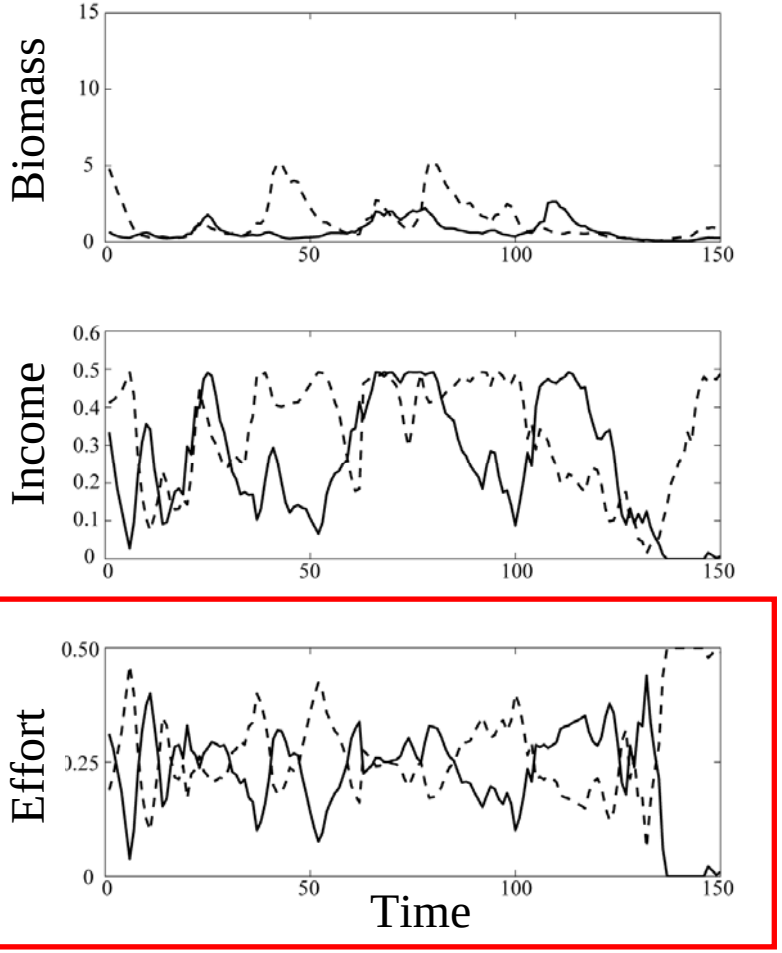
Results 2 (detail)



A=1,B=0.05



A=1,B=1



Decrease in total fishing effort

Switching effect

Summary of the results

- When fishermen target only one stock, …

  the non-cooperative income pooling system with emphasis on CPUE obtain better performance. While other three types of fisheries tend to exhaust its spawning stock biomass.

- When fishermen target multiple (two) stocks, …

  1) the non-cooperative income pooling system could keep its spawning stock biomass high, even in such cases where the limit on the maximum fishing effort of each fisherman is high.

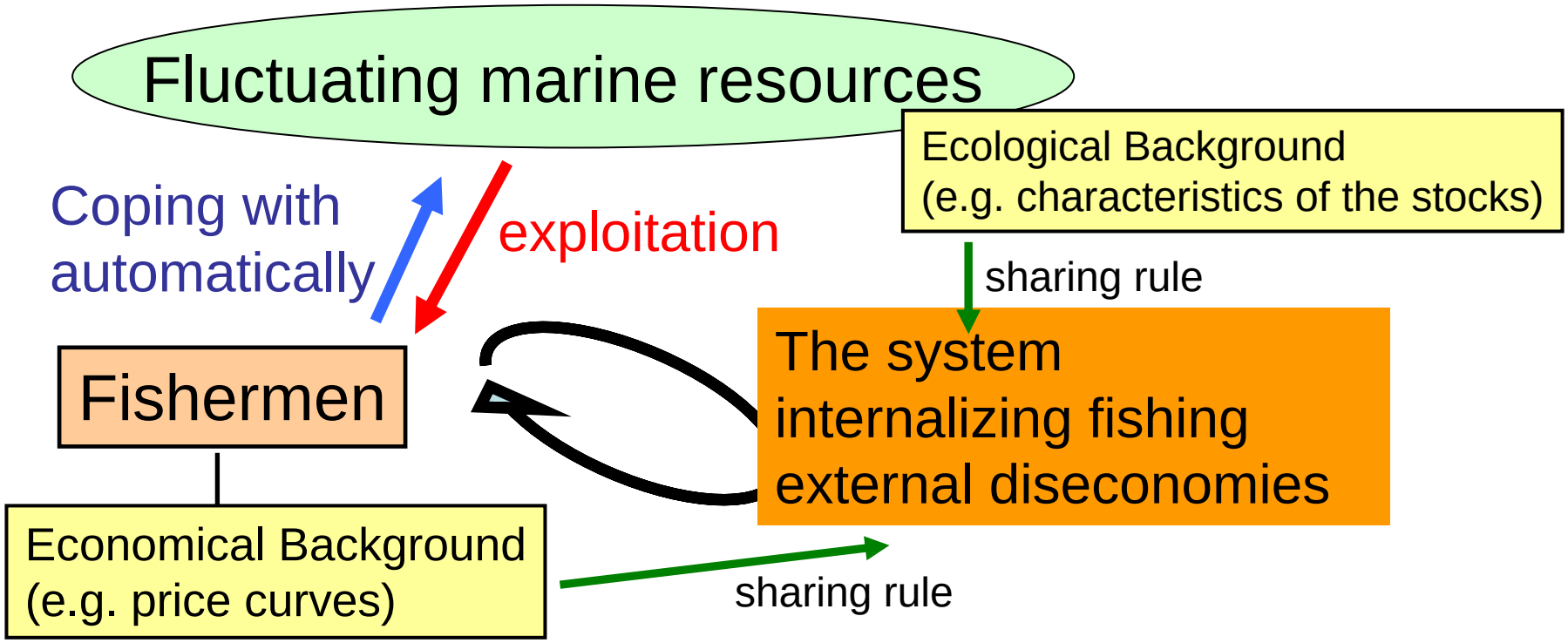
  2) if the limit on the maximum fishing effort is low, normal income pooling system also showed a high performance.

  3) if fish price did not collapse so dramatically by oversupply, the general competitive fishery could also produce high average of annual income under a low limit on the maximum fishing effort.

Discussion

- Non-cooperative pooling system could eliminate short-term external diseconomies and achieve long-term benefit by its income-sharing rule. Tuning parameters in this sharing rule allows us to decide the management goals more flexibly.
- We defined the normal income pooling fishery as a fishery which maximizes the total annual income without any consideration of the long-term benefit. In actual cases, as they consider the long-term benefit and stock conservation, stock does not collapse like this simulation. However they require more rigid agreements among fishermen about management goals according to fluctuation of target stocks.

In the context of topic session



This research is just only a theoretical analysis. Therefore, there remain much more issues to be considered for practical application. However this research could provide a clue to consider how to internalize external diseconomies of fisheries.