# Game theory and Environmental Management

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# Outline of Talk

- Introduction to games and game theory;
- Why is game theory a useful framework for analyzing environmental problems?
- Game theoretic modeling and fisheries;
- Some general comments.

# What is a Game?

- "any activity involving 2 or more "individuals", each of whom recognizes that the outcome for himself depends not only on his own actions but also those of others";
- "A game is a description of *strategic interaction* that includes the *constraints* on the actions that players *can* take".

# What is Game Theory?

- “multi-person decision theory or the analysis of conflicts and rivalry”.
- “a mathematical tool for analyzing *strategic interaction* between and among “individuals” who may be persons, firms, stakeholders, nations, etc.

# Strategic Interaction

- Consider the following situations:
  - (i) a few firms dominate a market, or
  - (ii) a few group of “individuals” have fishing rights to a stock of fish, or
  - (iii) countries have to make an agreement on environmental policy;
- Then each “individual” has to consider the others’ reactions & expectations with respect to their own decision.

# Describing a Game

- The essential elements of a game:
  - *players (agents)*;
  - *constraints, actions and strategies;*
  - *information set*;
  - *outcomes or solutions;*
  - *payoffs*.
- A game's description must include all the above.

# Key Assumption of Game Theory

- "each decision maker is "rational" in the sense that:
  - he is aware of his alternatives;
  - forms expectations about any unknowns;
  - have clear preferences; and
  - chooses her actions deliberately after some process of optimization.
- Comment on evolutionary game theory.

# Types of Games

- Non-cooperative/cooperative games;
- Zero-sum games;
- One-shot/repeated games;
- Static/dynamic games.

# A Non-cooperative Game

- Each player takes the actions of the other as given, and chooses his or her own strategies to maximize own benefits;
  - No lines of communication;
  - No possibility for making binding contracts;
  - Existence of a solution (John Nash);
  - Usually undesirable outcomes emerge.

# A Cooperative Game

- Players seek to maximize joint benefits;
  - Good communication gives players chance to weigh possibility for cooperation;
  - Incentive to cooperate: all may gain;
  - Cooperative with & without side payments;
  - Existence of solutions: Two requirements:
    - Pareto optimality;
    - The individual rationality constraint.

# Why is G.T. Promising for Studying Environmental Problems?

- Environmental resources are usually common pool resources;
- Multi-agent/multi-stakeholder situation;
- Ea. stakeholder has an interest in the use of resource, which it wants to enhance/max.;
- Interest of stakeholders often conflicting;
- Non-cooperation tempting but wasteful;
- There is a need cooperation in the use of environmental resources.

# Why International Agreements often fail: Applying Game Theory

- Let's assume two countries are trying to reach an agreement about whether to ratify the Kyoto Protocol;
- Each country can either:
  - Emit at current level (high emissions);
  - Reduce current emissions by 5% (low emissions).

**Figure 20-3:** Payoffs Received by Two Countries Considering an International Treaty

(a)

| | | B: Low emissions | B: High emissions |
|---|---|---|---|
| A | Low emissions | 4,8 | 1,4 |
| | High emissions | 2,1 | –1,–1 |

(b)

Control costs
A: $3/yr
B: $6/yr

| | | B: Low emissions | B: High emissions |
|---|---|---|---|
| A | Low emissions | 1,2 | –2,4 |
| | High emissions | 2,–5 | –1,–1 |

(c)

Control costs
A: $1/yr
B: $6/yr

| | | B: Low emissions | B: High emissions |
|---|---|---|---|
| A | Low emissions | 3,2 | 0,4 |
| | High emissions | 2,–5 | –1,–1 |

A payoff matrix is shown in a simple game between two countries that are contemplating whether to reduce emissions of GHGs in accord with a commitment under the Kyoto Protocol. In case (a), an agreement to cut emissions is reached when there are no costs of controlling emissions. In case (b), no agreement is reached because if either party deviates to the "high emission" state, the losses to the country that reduces its emissions will exceed its losses if both continue to release high emissions. Case (c) illustrates a situation where Country A has discovered a technology that dramatically reduces control costs. It will now cut its emissions regardless of what Country B does.

# How to get Country B to Lower its Emissions

- Employ moral suasion;
- Allow country B to adopt different targets;
- Offer financial incentives or some other side payments to B;
- Threaten to introduce sanctions;
- Try technology transfer.

# Levels of Cooperation in Fisheries

- Will argue that shared fishery resources must be managed cooperatively, if they are to be sustained through time;
- Levels of cooperation (John Gulland, FAO)
  - ***Primary*** - scientific cooperation only;
  - ***Secondary*** - involves cooperation in active management of resources.

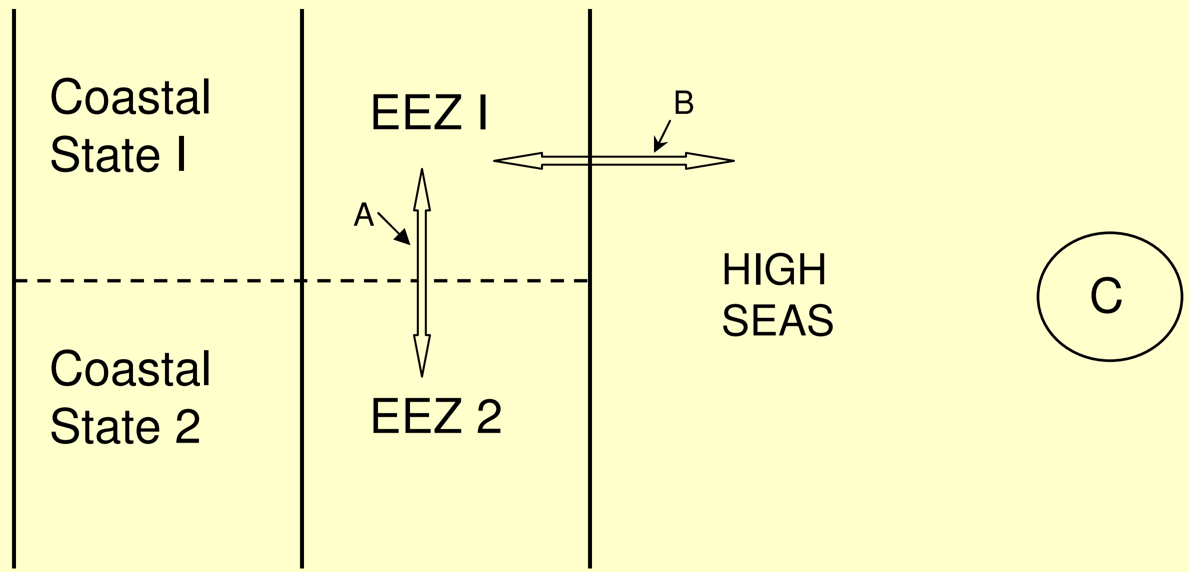
# Secondary Level of Cooperation

- Secondary level of cooperation (argues Gulland) requires:
  - determination of optimal resource management through time;
  - allocation of harvest shares;
  - effective enforcement of cooperative arrangement.
- allocation issue is indeed a key one, BUT
  - has to be addressed simultaneously with the other two issues.

# Categories of Shared Fish Stocks

- What sort of resources are amenable to game theoretic modeling?
  - A. transboundary - EEZ to EEZ;
  - B. straddling (broadly defined) -stocks to be found within the EEZ and adjacent high seas;
  - C. discrete high seas stocks;
  - D. Domestic, shared resources.

# Internationally Shared Fish Stocks




A – Transboundary stocks

B – Straddling stocks

C – Discrete High Seas stocks

# Some Comments

I. Transboundary and straddling stocks are not always mutually exclusive;

II. In terms of difficulty of resource management, domestic, transboundary, straddling and discrete High Seas stocks are in ***strict*** ascending order;

III. I will restrict my talk to transboundary fish stocks from here on.

# Transboundary Stock Management

- Consider simplest case - resources shared by two Coastal States 1 and 2;
- Normal case - harvesting by State 1 fleet has impact on harvests available for State 2 fleet, and vice- versa. Result: *strategic interaction between 1 and 2.*

# Two Fundamental Questions

(a) What are the consequences of coastal states not cooperating in management of shared resource?

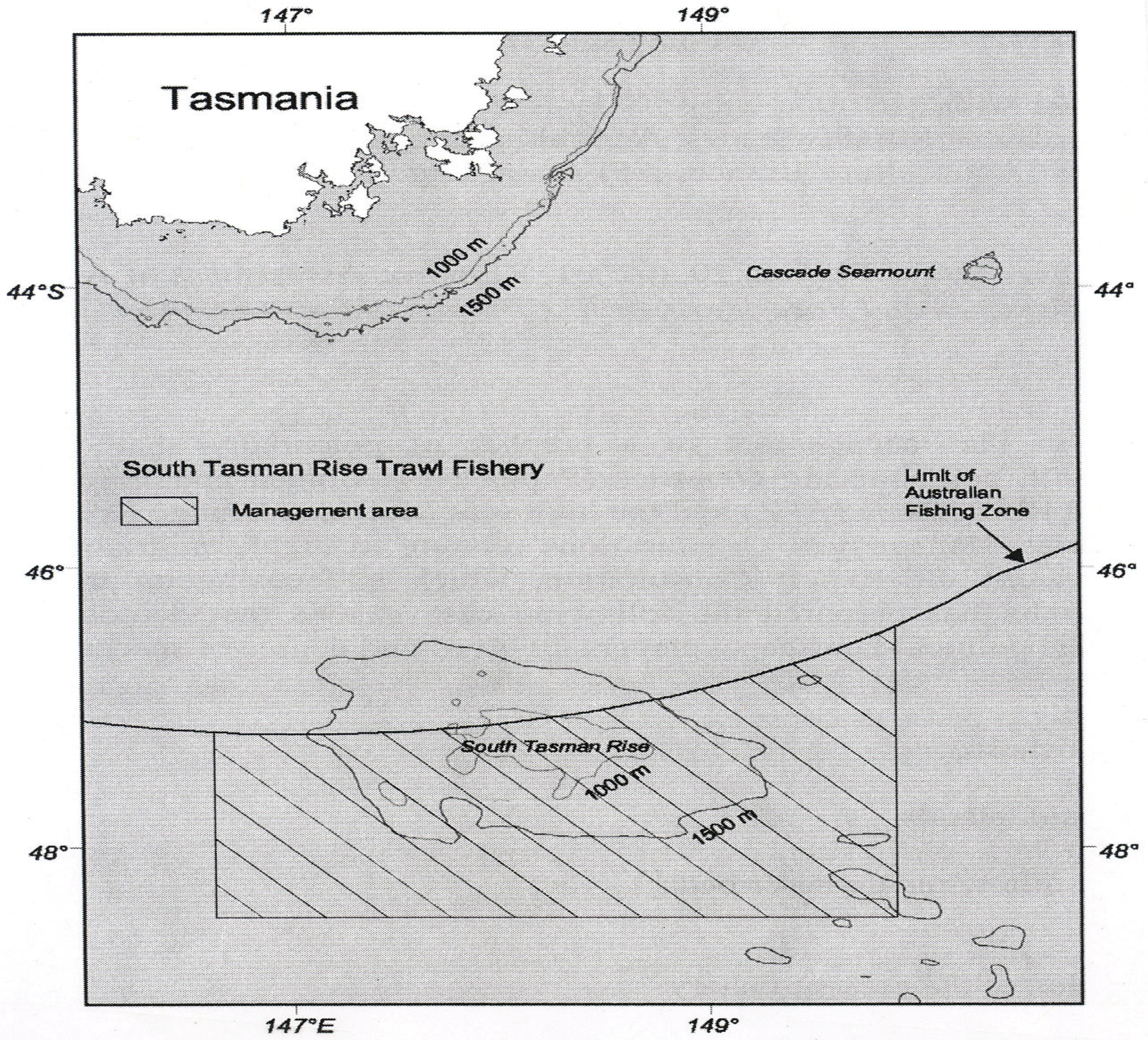
(b) What conditions must be met if cooperative management arrangement is to be sustainable?

# Non-cooperative Management

- The answer to (a): serious risk that the "players" will be driven to adopt inferior, and possibly destructive polices:
  - "The Prisoner's Dilemma" (PD) -world's most famous competitive game;
  - In some cases will lead to results no better than Pure Open Access.

# The Prisoner's Dilemma at Work

- An example: South Tasman Rise Trawl Fishery targeting orange roughy - vulnerable and high valued;
- Actually, a straddling stock - but initially managed by Australia and New Zealand as a transboundary stock:
  - Australia and New Zealand both proud of their fisheries management regimes.


147°
149°
Tasmania
1000 m
1500 m
Cascade Seamount
44°S
44°
South Tasman Rise Trawl Fishery
Management area
Limit of
Australian
Fishing Zone
46°
46°
South Tasman Rise
1000 m
1500 m
48°
48°
147°E
149°

# South Tasman Rise Trawl Fishery

- Cooperative agreement, between Australia and New Zealand, reached at end of 1997 -
  - faulty implementation - official start date March 1, 1998;
  - Australian fleet struck first - gobbled up entire agreed upon TAC before start date; next year NZ fleet deliberately overfished;
  - following year,  fishery plagued by third party interlopers.

# A Bionomic Equilibrium Result

- In 2000, Australia and New Zealand entered into a well crafted cooperative resource management arrangement - but too late!
- Harvests are very low - resource effectively mined out;
- Orange roughy resource may be eventually rebuilt - but only in the distant future.

# Tacit Cooperation: Benguela LME

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- The non-cooperating "players" may be lucky, in that there is tacit cooperation:
  - tacit cooperation is, however, inherently fragile.
- The case of South Africa, Namibia, Angola
  - the three share important fishery resources – hake, in particular;
  - cooperation has not gone beyond the primary level.

# Recommendations from a Study

- We (FERU) did a study for the 3 countries, dealing with the question of whether it was worth their while to move forward to the secondary level of cooperation;
- Our analysis supported such a move for several reasons, an important one being the fragility of tacit cooperation:
  - nagging fear that participants in the fisheries did not yet fully realize the extent of strategic interaction involved.

# True Cooperative Management

- Some preliminaries:
  - Question: what is really to be allocated -shares of TAC among coastal state fleets, or economic benefits from the fisheries? They are not necessarily the same;
  - Proposition: to work, any cooperative management regime has to be *self-enforcing*
    - no participant ("player") has any incentive to defect.

# Recall Conditions for Stability I

- Insights offered by theory of cooperative games (really a theory of bargaining):
  - first condition ***quite obvious***, but often ignored in practice - each "player" must be assured a return from cooperation at least as great as it would get under competition "individual rationality".

# More on the First Condition for Stability

- For the "individual rationality" condition to be satisfied the:
  - scope for bargaining needs to be maximized, e.g. do not restrict allocations only to TAC shares among national fleets;
  - implementation and enforcement of cooperative arrangement must be effective – of ***critical*** importance.

# Conditions for Stability II

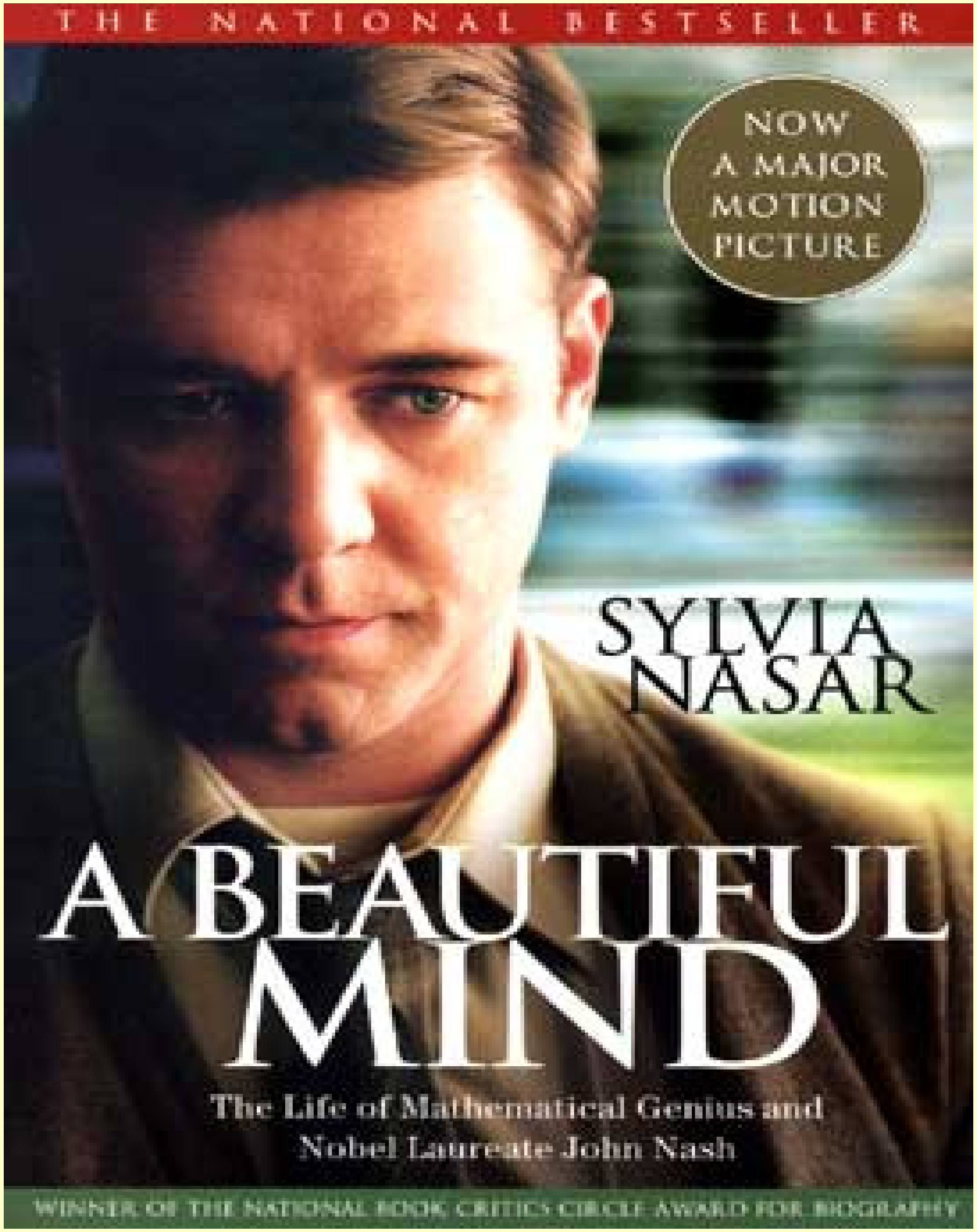
- Second major condition: “resiliency”of the arrangement:
    - cooperative arrangements subject to unpredictable shocks, which will undermine arrangements lacking flexibility – the example of Pacific salmon.
  - Both conditions for stability will be more difficult to achieve:

    i. the larger the number of “players” ***-the curse of large numbers;***

    ii the greater the difference in management objectives among the players.

# G.T. Fertile Ground for Nobel Prize

- 2005 Nobel Prize in Economics:
  - T. Schelling;
  - R. Auman.
- 2002 Nobel Prize in Economics:
  - Vernon L. Smith.
- 1994 Nobel Prize in Economics:
  - John Nash;
  - John Harsanyi;
  - Reinhard Selten.


THE NATIONAL BESTSELLER
NOW A MAJOR MOTION PICTURE
SYLVIA NASAR
A BEAUTIFUL MIND
The Life of Mathematical Genius and Nobel Laureate John Nash
WINNER OF THE NATIONAL BOOK CRITICS CIRCLE AWARD FOR BIOGRAPHY

# General Information on Literature

- Kowero, G., B. M. Campbell and U.R. Sumaila. (Editors), 2003. Policies and governance structures in woodlands of Southern Africa. CIFOR Press, Indonesia;
- www.feru.org;
- www.seaaroundus.org;
- Google scholar.


Thanks for your attention