Simulated synchronisation and emergence of a fishery complex

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Abstract: A multi-agent simulation model of the small-scale fishery sector in Senegal is presented. The aim of the study is to formalise the diversity of interactions and evaluate their effect on the coordination and overall functioning of the fishery sector. Fishermen, traders, boats, trucks, consumers, fishing zone, markets, landing sites and fish products are formalised on the basis of observations in the real sector. Simulations show that, given an associated 'selection/creation' process for the working communities, the fishery system reaches a steady state regime optimally organised in terms of production, wealth, working population size and activity (four indicators are presented in this respect). The role of diversity and history in the adaptation and synchronisation of the integrated functional process is highlighted.

Keywords: multi-agent simulation, synchronisation, self-organisation, complex adaptive system, fishery sector, modelling

Introduction

Self-organisation may be defined as the internal structuration of the elements composing a given entity (Camazin et al., 2001). This process leads to various phenomena including synchronisation (Strogatz, 2003). In systems composed of heterogeneous components, co-evolving subsystems may appear (Kauffman, 1993, Solé and Bascompte, 2006) adding further complexity to the coordination problem.

Fishery sectors are typically characterised by coordinated sets of heterogeneous elements such as diverse types of fishermen, fish traders (with interdependency between and within the subsectors), marine resources and consumers. Managing such intricate systems may thus appear difficult.

To study the nature, strength and effect of these links, a multi-agent simulation model has been developed with the aim of accounting for component diversity and interactions and studying the global system dynamics. To achieve consistency, the model is developed in accordance with the small-scale fishery sector of Senegal (West Africa).

Model description

The model simulates types behaviours related to a diverse set of professions and the means available to achieve them. The simulated space formalises fishing areas, landing sites and markets. The inputs of the model are resource abundance and consumers demand in the major cities of the simulated country. Fishermen and fish traders are the simulated agents and are able to deliberate, act and negotiate. They can move between sites as a function of various objectives such as fishing, selling and buying fish. Behaviour may vary as a function of information (vehicles, transportation costs, fishing gear, location, destination, profits, losses, flow capacity, fishing yields, and consumer demand) stored by the agents during their previous actions. Interactions between agents consist mostly of negotiations and transactions for selling of fish (Le Fur, 2006). Fishermen are also able to make choices and to take various courses of action when fishing. The time step considered for simulations is 15 days.

Preliminary analyses showed that externalities had a linear effect on the internal dynamics of the model and that the model is mainly sensitive to the sequence of actions of the various agents (fishermen, traders).

Four synthetic indicators were used in the analysis: population size as an employment indicator, wealth (amount of money available), production (amount of circulating fish products) and activity. This last indicator was calculated by summing the numbers of activities (deliberation, action, negotiation, transaction) carried out by the different agents. These indicators were studied at different scales (local, global) in the simulated system.

Simulations were carried out with a scenario based on a very coarse categorisation of the small-scale fishery sector in Senegal. It consisted of 14 markets, 4 ports, 13 marine areas, 4 species, 4 fishing gears, 6 vehicles (trucks and canoes), 13 communities of consumers, 5 of fishermen and 5 of fish traders representing 612 activity units.

We introduced a mechanism for 'selection/creation', according to which agents generating a deficit leave the system and are replaced by new agents of the same type but created with a random set of known localities, types of vehicle, etc. Simulations were conducted on 600 time steps to allow for the possible establishment of a steady-state regime.

Simulation results

The model simulates an open fishery sector linked to fish stocks and consumers. The local activities of the agents result in a flow of fish from the sea to consumers and a flow of money diffusing from consumers throughout the entire fishing sector. Fishing and trade are conducted in accordance with expectations: prices normally fluctuate as a function of supply and demand and are synchronised between the ports and markets (Le Fur, 2006)

The simulations generated a wide range of agent behaviour. At fishery level, a structured and stable pattern arose, with seasonal production dynamics closely synchronised with resource abundance, a stable workforce and steadily growing wealth. The activity indicator displayed stable fluctuation ("tonus") with a steady pulse (polarisation/depolarisation kind) at the end of each fishing season.

The removal of the selection/creation mechanism renders this configuration unviable and resulted in gradual deterioration with declining production, wealth and employment. The regularity of the activity curve also deteriorated until the fishery ceased to function altogether.

Discussion

Within the model, the fishery sector appeared as an integrated whole (tonus, pulse) with self-organisation dependent on the entire set of components and their interactions. The selection/creation principle yielded an optimised system. In this framework, the only way to achieve the observed improvement was a medium term historical construction encompassing each and every component.

Synchronisation in this model thus requires a combination of *(i)* external forcing, *(ii)* a diversified set of objects and interactions, *(iii)* an improvement process and *(iv)* a sufficiently long time span for the progressive construction of synchronisation.

Conclusion

Within the simulation context, the fishery sector aims to establish a set of fluxes between living marine resources and consumers. Appropriate management should involve maintenance of both the requisite diversity (Ashby, 1958) and the existing adaptive forces as well as the time span required for development of the integrated functional scheme. Within this framework, the modification of a single component or sub-system (resources, fisheries, trade) includes the risk of the sector as a whole becoming destructured.

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