Using an Agent-Based Model to study the Effects of Enforced Quota for Sustainable Tuna Fishery

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May 17, 2013

Fishing overcapacity threatens both economic and ecological sustainability and produces significant economic waste, and is a pressing concern in the tuna fisheries of the Western and Central Pacific Ocean ([2]). Specifically, bigeye (Thunnus obesus) and yellowfin (Thunnus albacares) populations are threatened because of bycatch in skipjack tuna (Katsuwonus pelamis) fisheries. Various tuna management schemes have been implemented or are being considered for implementation with the goal of influencing tuna fishers towards more ecologically and economically sustainable practices. However, the results of implemented tuna management thus far is a mixture of successes and failures.

Generally it is found that conventional fishery management seldom successfully deals with overfishing ([3]). An important reason for this seems to be, that policy does not or only mildly consider the sociological aspects of fishery systems. Yet, fishery systems are composed of several types of actors (including fishers), and subject to ecological, economic, social and political factors ([1], [3]). In order for any management aimed at ecological and economic sustainability to work, it is important to view fisheries as complex adaptive systems.

To better understand which management schemes are successful or not and why, an Agent Based Model (ABM) is used to model the behaviour of fishery system agents, in an environment containing ecological, economic, social and political processes. The use of an ABM is sensible, as interactions among agents, and between agents and their environment, can lead to emergent outcomes which are of importance when considering various management schemes.

The spatial environment in the model operate is a square 2D lattice with a length of 100 sites. This corresponds to a region of 1500 × 1500 km², which is equivalent to an area the size of the seas around the Philippines and some of the high seas surrounding them, for which data on fishing vessels and catch sizes are available. The ecological part of the model consists of densities of skipjack, bigeye, and yellowfin assigned to the lattice sites, which are updated
in time through movement and reproduction. Movement is described by diffusion of tuna between lattice sites. Reproduction is captured by updating the densities according to growth functions. Both of these processes operate on daily timescales and are coupled to the time and distance scales of the model to obtain realistic movement speeds and reproduction rates.

Fishing vessels move and harvest tuna on the same daily timescale. Vessels are influenced by mutual interactions, economic factors and policy mechanisms. Quotas are imposed, determining their maximum allowed catch. However, vessels can decide to catch beyond these quotas ("cheating"). Adapting the trust-reputation-cooperation likelihood framework of [4], the probability of each vessel cooperating (i.e., keeping their quotas) is affected by the level of trust they have towards other vessels. In turn, this trust is influenced by the reputation vessels acquire through past actions. The probability of cooperation and cheating is also influenced by the state of the ecological environment, institutional factors and cultural factors.

An important part of this model-based study is model verification and validation, and model analysis. Interviews and experiments involving stakeholders are planned to validate the decision-making processes of the actors in the model. Sensitivity analysis is applied to quantify the effect of different parameters on model output. As ABMs are time-dependent complex systems, sensitivity analysis methods need to be tailored (Van Voorn et al., ESSA2013 poster 64). Model analysis is furthermore aimed at evaluating possible resilience regimes and tipping points in the model. An initial analysis of a preliminary version of our model shows that tipping points exist in the model, which correspond to a collapse of the fishery system under certain levels of cheating.

The model will be used to examine the effects of different existing tuna fisher incentives and policy schemes on tuna population levels and economic profitability. The aim is to investigate why existing policies have not shown intended effects, and if possible also to explore new alternatives.

References


