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Effects of social factors on fishing effort: The case of the Philippine tuna purse seine fishery

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ABSTRACT

High fishing effort remains in many of the world's fisheries despite a variety of policies that have been implemented to reduce it. These policies have predominantly focused on models of cause and effect that ignore the possibility that the intended outcomes are altered by social behavior and bounded rationality of autonomous agents. This paper presents a spatially explicit agent-based model for the Philippine tuna purse seine fishery that specifically includes social factors and bounded rationality in the decision making of agents. The model has been informed by interviews, and is verified and validated against data. Sensitivity analysis is used to determine the effects of social factors and bounded rationality on macro-level outcomes (fishing effort, fish stock and industry profit). Three social factors are identified to have considerable effect on these outcomes. These factors are a culturally and personally motivated resistance to exit the business, a social norm regarding the spatial distribution of vessels, and the use of imperfect information by potential entrants in their investment decisions. Existing fishery policies do not explicitly consider these social factors. The results suggest that both research and the management of fishing effort could be improved by viewing fisheries as Complex Adaptive Systems, in which social factors and bounded rationality have a considerable effect on the decision making of fishers (fishermen and fishing companies) and on the macro-level outcomes.

1. Introduction

Overfishing has received considerable attention in many of the world's fisheries (Anticamara et al., 2011; Froese and Proelß, 2010). However, many policy-makers and researchers continue to consider the allocation of effort, and fisheries in general, in simple terms of cause and effect and commonly at a macro industry level (see Van Putten et al., 2012; Fulton et al., 2011; Schlüter et al., 2012). Such an approach generally ignores the existence of feedbacks and nonlinear relationships between agents, which in this case are the fishers (fishermen and fishing companies), and their economic, social, and ecological environment. It also often assumes that agents, operating at different scales, are perfectly rational actors who obey conventional economic rules (economic rationality), resulting in predictable linear relationships (Van Putten et al., 2012; Fulton et al., 2011).

There are at least three problems with this view. First, it is often assumed that perfect information exists and that fishers can and will calculate the future costs and benefits of all alternative effort choices with absolute certainty. However, especially in developing world fisheries, this assumption is problematic given that a fisher's information set is often limited to what he/she can observe and that future conditions can change due to economic and ecological changes and the actions of other fishers (Allen and McGlade, 1987). Second, there exist many social norms that may play a relevant role in fisheries and thus cannot simply be ignored (Pollnac et al., 2001; Salas and Gaertner, 2004; Salayo et al., 2008; Fulton et al., 2011). Third, fishers can display adaptable behavior, which either intentionally or unintentionally changes their response to policy measures or to other social, economic or ecological changes in the fishery. As increasingly argued (Schlüter et al., 2012; Van Putten et al., 2012), neglecting these characteristics of agents, and relying on economic drivers alone to change behavior related to complex issues, such as fishing effort decisions, can produce unwanted results.

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To address these concerns, it has been suggested that in the analysis of fisheries should recognize that fisheries can be considered as Complex Adaptive Systems (CAS) (Mahon et al., 2008). The term CAS is used to describe real world systems that include "heterogeneous subsystems or autonomous entities, which often feature nonlinear relationships and multiple interactions such as feedback, learning and adaptation" (An, 2012). The complexity in CAS arises from the multiple agents and interactions between them (An, 2012, and references therein), while the adaptivity refers to the capacity of agents to change their behavior in response to the current states of themselves, of others, and of their environment (Railsback and Grimm, 2011; p.10). Recognizing that fisheries are CAS means that we consider the interactions between the different parts of the system—agent internal decision making, agent influence, and ecological parts—at a more fundamental level then what is done in simpler models of cause and effect. Decision making is also not necessarily according to well-defined economic objective functions: agents have imperfect and limited knowledge of their surroundings and limited cognitive abilities (bounded rationality), and can change their decision making (i.e., can display adaptivity) based on the interactions they have (which includes social behavior), changes in their internal state and changes in the environment. That means that, unlike in models of cause and effect, input and output are not considered to be directly coupled, and also that these couplings can change. Outcomes at the macro-level (such as industry profit and fish stocks) may seriously deviate from what is predicted by simpler models of cause and effect if bounded rationality and social factors have clear effects. Policies that do not adequately address the complex, adaptive nature of fisheries may thus not achieve their objectives (Mahon et al., 2008).

The application of a CAS perspective is relevant to economically impoverished countries with poor records of state sponsored fisheries management and high levels of societal dependence on valuable fisheries resources (Bailey and Pomeroy, 1996; Christie et al., 2007; McClanahan et al., 2015). Here, we focus on the Philippines tuna purse seine fishery. Located in the Western and Central Pacific Ocean, the Philippines are one of the top ten suppliers of tuna in the world (WCPFC, 2012). Tuna is the country's top fish export commodity, and fishing, in general, is a culturally significant occupation (Muallil et al., 2011; Pollnac et al., 2001), which provides livelihood for an estimated 1.6 million Filipinos (Barut and Garvilles, 2013). Recent stock assessments display a decreasing trend in stock levels of skipjack tuna (*Katsuwanus pelamis*) in Philippine waters, corresponding to declining catch per unit effort for purse seine vessels (BFAR, 2012). Additionally, high purse seine fishing effort has resulted in high mortality among juvenile bigeye (*Thunnus obesus*) and yellowfin (*T. albacares*) tuna, which are caught along with adult skipjack (WCPFC 2012). In spite of a decline in catch and a number of regulations, including a moratorium on commercial vessel licenses and gear restrictions, high tuna fishing effort remains a problem in the Philippines. This appears to go beyond what is expected based on economic rationality. However, it may be explained by social factors and bounded rationality that affect the decision making processes of fishers, including those on entry and exit.

The objective of this paper is to view fisheries as CAS to evaluate the effects of social factors and bounded rationality on macro-level outcomes of fisheries, including the number of vessels, total fishing days (the measure of fishing effort), fish stock, and industry profit. We consider the Philippine tuna fishery as a case study. We first identify what social factors exist that may affect the decision making processes of fishers in the Philippine tuna fishery. Then, we implement these in a modeling tool to reveal the effects of the social factors on the macro-level outcomes. A common way of modeling CAS is by using agent-based models (ABMs, Railsback and Grimm, 2011). ABMs involve a bottom-up modeling approach, which is well-suited to describe agents and their decision making processes. The agents have imperfect information and bounded rationality, and interact with each other and their environment (Fulton et al., 2011; Schlüter et al., 2012). This research thus involves two stages: model development, for which we use interviews to inform the modelling, and then model analysis. The interviews (Section 2) provide information on Philippine purse seine operations and decision-making by fishers, which is used in the model. Section 3 is a description of the model including the methods used for verification, validation, and analysis of the model. Section 4 presents the results of the validation and sensitivity analysis of the model. We then proceed with a discussion (Section 5) and conclusions (Section 6) on how a CAS approach of fisheries can contribute to the understanding of how social factors affect fisheries.

2. Purse seine operations, and effort decisions

This section presents an overview of the Philippine tuna purse seine fishery, describing the operational decisions made by master fishers of catcher vessels and the strategic decisions made by company managers. Information was obtained from interviews of fishing company owners, master fishers, captains of carrier vessels, and industry representatives (see Table 1 for the profile of informants, and online supplement for the interview guide) and from literature. The companies of informants were based in General Santos city (the Philippine's 'tuna capital'), Davao Oriental (with purse seiners with fishing practices similar to the smaller purse seine companies of General Santos), and Manila (home port of other large tuna purse seiners). To complement the interviews, reports and previous studies from the Philippine Bureau of Fisheries and Aquatic Resources, and WCPFC were used.

2.1. Overview of the Philippine purse seine fishery

The Philippine purse seine fishery uses anchored fish aggregating devices (FADs) to attract and capture fish. Purse seiners target skipjack tuna but also catch juvenile yellowfin and bigeye tuna, which are attracted to the FADs along with schools of skipjack tuna (Dagorn et al., 2013). Tuna purse seiners' catch comprises of, on average, 56% skipjack, 13% juvenile yellowfin, 1.5% juvenile big-eye, and 29.5% other small pelagic fishes (BFAR, 2012).

The purse seiners fishing in the Celebes and Sulu seas (Fig. 1) operate with catcher vessels that stay at sea for an average period of six months, continually monitoring and catching tuna, and carrier vessels that transport the fish caught from the fishing site to the port. The average maximum fish capacity of carrier vessels is 60 tons. One fishing site of one catcher vessel is comprised of a cluster of around 40 FADs, spaced at 3 to 5 miles apart over a total area of approximately 900 square miles. The use and clustering of FADs minimizes fuel cost, which constitutes around 60% of a vessel's operating cost. Clustering is also the fishing companies' way of creating informal ownership to minimize conflict between companies. A social norm among companies is that no other companies are allowed to fish within another company's cluster of FADs.

Sites can be identified by the location of a company's FADs, which is based on 60-by-60 square mile latitude-longitude coordinates on a map used by the fishermen. Information about catch per site is generally kept secret to avoid competition with other vessels. If other companies learn that a site is abundant with fish, they tend to place their FADs around the same area leading to an increase in the number of vessels operating in adjacent areas and to a decrease in the catch per vessel. There are thus two opposing tendencies that affect the selection of sites and hence the spatial distribution of FADs: on the one hand there is a tendency to aggre-