Outline

March 29, 2017

1 Title

Optimal harvest strategy for fishing prawns according to a Markov Decision Process

2 abstract

- We applied a Markov Decision Process to determine the optimal strategy to harvest sustainably one of Qld natural marine resource taking into account its biological and ecological characteristics.

3 Why are we doing this work ? what are MDPs ? Think about the key question you and your audience might have

Background on Markov Decision Processes

- Markov Decision Process is a method to determine optimal decisions in an uncertain environment
- Rational decision making requires reasoning about uncertainty in the system under consideration.
- Previous application to fisheries ? Previous applications of MDP in fisheries (Mendelssohn; Walters) have focused on actions to control the number of spawners which is difficult and costly to quantify precisely. We opted instead to condition the MDP to evaluate policies regarding the fishing effort expanded by the industry as it natural reflects the action of the fishing industry on a wild fish populations, links directly to the rewards they are seeking fishing and the fish removal effect it has on the stock. This approach was rendered possible because a complete model of environmental and fishing effects on the stock pre-existed the present analysis (kienzle, 2014).

Background on fisheries and particularly the case study

- Fisheries production varies through time, often in unpredictable ways
- Fishing increase mortality and deplete the biomass of fish left to spawn, decreasing the capacity of a population to reproduce. This relationship is modeled through a stock-recruitment function.

- The abundance of young fish contributing to replenish a stock every year highly variable: besides of spawning biomass, it depends on many other, often unknown, factors including difficult to predict environmental conditions. The relative importance of spawning stock versus other causes of recruitment variability is debated.
- In fisheries management, the largest source of uncertainty is recruitment variability. This uncertainty arises from practical and theoretical limitations in our ability to predict recruitment.
- In the case of short-lived species (lifespan 1year), the biomass of fish available for harvest in each fishing season is directly determined by the magnitude of recruitment. Hence the abundance of fish avaible for catching varies substantially from year to year.

It's almost a tautology to say that fisheries dynamics are driven in part by the economic rewards of fishing. But one could be excused to miss completely that point if she/he was to focus only on ecological aspects. To exists, a fishery must target an abundant population as well as generate sufficient profits to sustain its activity.

What did we do ?

- We applied a Markov Decision Process to determine the optimal strategy to harvest sustainably brown tiger prawn (*Penaeus esculentus*) in Moreton Bay taking into account its biological and ecological characteristics.
- The single species stock assessment was adapted into a Markov Decision Process framework calculating the probability this natural resource transiting from one state to another every year according to the magnitude of fishing effort expanded in the fishery. A profit reward function was used to quantify the benefit of fishing at the scale of the entire industry.

4 Detailed content of the article

1. Introduction

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2. Materials and methods

2.1 The tiger prawn fishery model

- Calibration of the delay-difference model
- Stock-recruitment relationship
- Simulated dataset. Calculating MSY.

2.2 Casting the problem into a Markov Decision Process framework

- Actions: fishing is rewarded by catch. Fishing impacts on future productivity.
- State and transition matrices. yearly timesteps.
- Reward. Economic data

3. Results

- Simulation using the stock assessment taken as a black box shows that the probability of transitioning between years from one state of the system to another is almost even when there is no fishing pressure (show bubble plot figure). On the other extreme of the spectrum of actions, the highest fishing pressure (45.000–50.000 boat-days) alters the system towards ending up into the lowest level of production with highest probability irrespective of the initial state it was in.
- Parametrizing the MDP reward function with fishing profits results in optimal policies that are monotic increasing function of abundance. This result is qualitatively similar to observed characteristics of the fishery (the decline of fishing effort over time thought to be induce by economic factors, correlation between recruitment and effort). Quantitatively the level of effort observed at a given level of recruitment are in the region of optimal fishing effort provided by the MDP using a profit function (comparison of observed recruitment and effort values to MDP optimal policy) but not a catch or catch per unit of effort function
- The optimal strategy is to fish harder the more abundant the resource. It maximizes industry profits allowing it to extract as much as 2.5 M$ at 12$/kg for a cost of 200$ per boat-day (Show a table giving maximum profit as a function of prices and costs).
- The MDP provides a mechanism to explain the dynamic of effort observed in the last 20 years: fishing ceases as it becomes unprofitable. Adverse economic conditions reduce fishing effort expanded in this fishery. Economics explains in part the fluctuations of effort in this fishery.
- The optimal fishing strategy from a profitability point of view is to fish the stock harder the more abundant it is
- The optimal fishing effort is always below effort at Maximum Sustainable Yield (MSY): in the current economic conditions, it is economically un-profitable to fish this stock at MSY. Economics acts as a safe guard against biological over-exploitation.

- Assuming fishing effort expanded by the entire industry guided by profit behaves according to the optimal strategy, fishing ceases at low prawn abundances because each small business involve in the extractive process cannot incure losses for a long period of time. Profitability effectively acts as a mechanism that protects the stock at low level of abundance.

4. Discussion

- The large amount of latent effort is perceived in some sector of the government as a threat to sustainability and requires priority intervention in the form of a buyback program. The fact that these effort allocation have been unused for many years suggests that some factors prevent owner to use them. The present study suggests that in the current economic context, the optimal strategy is to use only a portion of the available effort. The perceived threat will not eventuate until economic condition evolve into a new situation that reverses the declining trend in fishing effort observed since 2000. This work also highlight that capping effort to a level equal or below that currently expanded is economically counter productive as it will limit the industry to a sub-optimal condition.
- The profit function provides a mechanisms to explain the declining trends in fishing effort observed over the last 20 years.
- Tactical decision to fishermen, strategic decisions to government.
- The optimum fishing policy are quantitatively similar to the total amount of fishing effort expanded at a given recruitment level suggests that a MDP representing the fishing fleet as a whole can represent the behaviour of fishing decisions made in reality at the level of each individual boats.
- It is possible that a more detailed knowledge of the values of economic quantities that influenced this fishery over time would provide a detailed model capable of reproducing the observed trends in fishing effort over time. This level of details is, for now, beyond our reach. Nevertheless, MDPs provided a framework to think about management of this fishery economics above and beyond biological and ecological aspects of the dynamic of this fishery.
- A government interested in maintaining and improving employment opportunity for its constituent could address the decline in fishing effort by influencing fishing profit either increasing income by for example allowing fishermen to commercialise by-catch species or reducing costs by giving tax incentives as it is done for other industries.
- The quality of results of MDPs depends on the quality of the transition matrix. The transition matrices were calculated from the population model that best fitted reported catch and effort data selected from a range of models using likelihood based methods (CITE Kienzle, 2014, 2016). Improvement to the outcome of MPDs by improving the transition matrix belongs to the phase of calibrating the stock assessment model not applying an MDP.

5 Citations

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