

EVALUATION OF MANAGEMENT STRATEGIES IN NINGALOO MARINE PARK,  
WESTERN AUSTRALIA

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ABSTRACT

The spatial, multi-species nature of coral reef fisheries makes them notoriously difficult to manage. We have developed a simulation modeling approach to examine the effect of management options on the recreationally important tourist destination of Ningaloo Reef in Western Australia where a recreational fishery targets Spangled Emperor (*Lethrinus nebulosus*). The approach brings a broad range of physical, biological and socio-economic information and process understanding into an integrated framework. It also provides an effective interface with management. Model results show the effects of historical fishing mortality, localized depletion of Spangled Emperor, and the potential effect of the sanctuary zones that are closed to fishing. They also show expected recreational catches and catch rates under different projected management strategies and future scenarios regarding the evolution of the fishery. Results from the model will provide a means to assess, test and ultimately improve the effectiveness of management and monitoring strategies in the region.

**Keywords: reef line fishery, recreational fishing, management strategy evaluation, Ningaloo Marine Park, Western Australia**

INTRODUCTION

One of the big challenges for contemporary societies is the management of competing human uses of, and impacts on, natural and transformed ecosystems. In meeting this challenge, there has been an increasingly prominent role for science in providing information and analytical methods for supporting policy and management decisions. This has led to a need for scientists to communicate with an ever increasing range of stakeholders. This in turn has induced a search for decision support frameworks allowing active participation of stakeholders (including management agencies) and facilitating the generation of ideas, identification of problems and approaches for solving them, as well as anticipation of real-world impacts. Such frameworks necessarily span diverse fields ranging from biophysical, social and economic sciences, to jurisdictional, political, institutional and managerial processes. Integrated management strategy evaluation (MSE) frameworks have been developed with such a purpose. While they have been largely applied to commercial fisheries (Sainsbury et al. 2000, Mapstone et al. 2008), MSE approaches have only rarely been applied to the explicit assessment of recreational fisheries management or to Marine Protected Area (MPA) regulations (Little et al. 2007). In this paper, we present the preliminary results of an application of the MSE approach to the regulation of recreational fishing in the context of a marine protected area.

Ningaloo Marine Park is located along the coast of Western Australia. Its Commonwealth (i.e. federally managed) component was established in 1987, with the objective to protect the marine biodiversity of the longest fringing barrier reef in Australia, as well as to favor the development of sustainable recreational uses, education and research. Current management objectives, strategies and targets for the Ningaloo Marine Park are documented in CALM and MPRA (2005). These address a broad range of ecological, social and conservation issues. Measures implemented include: sanctuary zoning for 34% of the park; facilitation of comprehensive research and monitoring programs; implementation of education and information programs; regulation of recreational use to ensure sustainability; and integration of management of the marine environment and the adjoining coastal lands.

In this paper, we focus on the management of the recreational line fishery which operates within and outside the boundaries of the Park. Recreational fishing is by far the main extractive activity in the park, and as such, has the potential to be a major factor affecting the overall conservation value and, ultimately, the ecological integrity of the park. Within the park this is currently the activity most directly controlled and influenced by new multiple use zoning regulations. We present preliminary results obtained as part of a research project aimed at developing a modeling framework that integrates key ecological, social and economic considerations for evaluation and simulation testing of the current and potential future management arrangements for the fishery, within the broader set of park management strategies. The paper is structured as follows. In the first section, we describe the approach taken to develop an MSE for the Ningaloo recreational fishery for Spangled Emperor (*Lethrinus nebulosus*), which is the main species targeted by recreational fishers in the area, based on the ELFSim modeling platform. The second section presents a description of management objectives, management strategies and scenarios selected through consultation with the key stakeholders involved in the regulation of this activity in the park. Preliminary results of the simulations are illustrated in the third section, and section 4 discusses these results and concludes.

## **DEVELOPING A MSE FOR THE NINGALOO RECREATIONAL FISHERY**

Management strategy evaluation (MSE) is a process that attempts to evaluate the effects of management actions in a computer simulation framework so that trade-offs can be identified among management objectives, specified by stakeholders. MSE is comparative rather than prescriptive, seeking to compare likely outcomes from a range of management strategies rather than just prescribe an optimal strategy or decision that should be taken under an existing regulatory framework. The approach thus uses a simulation based framework consisting of a representation of the resource dynamics and exploitation, within which management actions are implemented and compared.

The central part of MSE is the computer representation of reality on which to impose the various management activities including regulations, monitoring and assessment procedures. The operating model in this study, ELFSim (Little et al. 2007), provides the MSE framework to examine the trade-offs associated with the performance of alternative management strategies. ELFSim captures the dynamics of the underlying resource and its exploitation.

The framework is able to deal explicitly with a range of sources of uncertainty when showing the consequences of alternative management strategies, including structural and parameter uncertainty, errors in data, estimation uncertainty and management implementation uncertainty. Transparency and recognition of sources of uncertainty in assessing trade-offs between alternative strategies are essential to the approach and acceptance of outcomes from stakeholders.

Stakeholder engagement in MSE is essential to the acceptance of credible management objectives and strategies that represent the divergent interests of the different user groups. A key element of MSE involves turning broad conceptual objectives into quantifiable and measurable operational management objectives and related performance indicators. Fundamental to this approach is the identification and representation of stakeholder objectives. In specifying operational management objectives three things are needed: a performance indicator that specifies the quantity of interest, a target for the performance indicator, and a measure of tolerance or acceptance that the indicator must achieve, usually specified as a probability.

In addition, central to a MSE approach are the identification of management strategies and of scenarios for the resource system under consideration. In this paper, we define a management strategy as a deliberate existing or planned course of action by one or more people. It may be a management strategy that constrains human use in order to achieve environmental, social and economic objectives. It may be a monitoring strategy (or program) designed to observe and measure the state of the ecosystem through time and space in order to build a set of environmental, social and economic indicators. It may be a business or private strategy aimed at achieving business outcomes or personal advantage. It may be a particular set of policy instruments or governance arrangements. It may also be a combination of these and other types of strategies. A scenario is a hypothesized future trajectory of external forces on either the system itself or a computer representation (or model) of the real system. Uncertainty in knowledge usually leads to several alternative scenarios of the system, which include the natural ecosystem and relevant components of human society. These scenarios represent alternative hypotheses about current state of nature and how the system evolves in response to natural events and human actions.

For each combination of a strategy and scenario, the MSE provides output data in the form of GIS layers (maps and images) and indicator variables chosen with stakeholders to reflect the management objectives. The display of these data may then be used to compare and contrast similar displays for different combinations of strategies and scenarios.

### **The ELFSim modeling platform**

ELFSim (“Effects of Line Fishery Simulator”) was initially developed for the assessment of management scenarios for the commercial line fishery operating on the Great Barrier Reef of Australia (Mapstone et al. 2008). It includes the following key components (see Little et al. 2007 for a detailed presentation of the model):

- a (meta) population dynamics model of target species that captures their full life history (including larval dispersal, reproduction, development, and habits);
- a spatial fishing effort allocation model that captures the exploitation pattern due to fishing behavior;
- a management model that simulates the implementation of management strategies;
- an output visualization and run management tool, for easy scenario testing and interpretation of results.

The biological component permits several local populations of the same species. Each is associated with a single reef and has a specified age, sex, and size-structure, which may be linked to other reefs through larval dispersal. The number of animals settling each year is determined by the annual egg production, the assumed larval distribution pattern and density-dependence in first-year survival. The biological model also allows for variability in natural mortality and larval survival among different reefs and at different times, as well as monthly variation in the relationship between fishing effort and fishing mortality. Larval dispersal is controlled by reef-to-reef migration data, and a self-seeding parameter that specifies the proportion of larvae spawned on a reef that settles on it.

The model explicitly represents the spatial allocation of fishing effort in the projection period across individual reefs at each monthly time step. Several harvest models have been developed for ELFSim (e.g. Little et al. 2004). For the application to the Ningaloo Marine Park, a module was developed to simulate the movement, reef selection processes, and fishing activities of both charter and individual recreational vessels, using an agent-based model. Agent-based models attempt to determine the combined behaviour of a collection of individuals (Uchmański and Grimm 1996, Grimm 1999, Lempert 2002). In the ELFSim platform, the agents are vessels with heterogeneous characteristics, such as location and boat ramps from

which they sail, and different fishing efficiencies. These agents make decisions on effort allocation based on rules, learn from past experiences and may use information from a range of external sources.

The harvest model operates on a daily time-step within each monthly time-step at which the remainder of ELFSim operates. Through the model effort can respond dynamically to daily changes in fishing conditions (e.g. catch rates on individual reefs) and management arrangements (e.g. area and seasonal closures). The model incorporates progressive discounting of historical catches, with more recent experiences and personal information being more important than historical information or fleet-wide experience when making decisions. Catch expectations therefore are specific for each vessel, for each reef for each month of the year; and are ‘learnt’ by the fishers or ‘forgotten’ if a reef is not visited for some time. It is assumed that at the start of each day the vessels start from a particular port/boat ramp (e.g. Exmouth, Tantabiddi Creek, Coral Bay).

The model is based on the idea that fishers will endeavour to fish in locations where they would expect to obtain the highest catch rates. At each daily time step a decision is made of where to fish. This is done by selecting a location (reef) based on the (normalised) distribution of expected CPUE, i.e. the probability of vessel  $b$  fishing on reef  $r$ , in any day is given by

$$P_{b,r} = \frac{p \overline{CPUE}_{b,r} - cd_{b,r}}{\sum_r p \overline{CPUE}_{b,r} - cd_{b,r}}$$

Where  $\overline{CPUE}_{b,r}$  is the historical average CPUE experienced by boat  $b$  on reef  $r$ , and is calculated as

$$\overline{CPUE}_{b,r} = \delta \overline{CPUE}_{b,r,\text{exp}} + \frac{C_{b,r}}{E_{b,r}}$$

with

$\overline{CPUE}_{b,r,\text{exp}}$  is the past experienced catch rates

$p$  is the price of fish per kg

$c$  is the cost of moving to fish per unit distance

$d_{b,r}$  is the distance between the location of boat  $b$  and reef  $r$ ,

$\delta$  is the parameter used to discount past CPUE value.

Based on this formulation the vessels are constrained to fish at locations they have fished in the past. We have also introduced the ability of boats to explore new fishing locations (reefs). With a 1% probability a vessel will choose a reef location based only on distance from port, and not on catch rate. We assume the probability of choosing a location declines exponentially with distance from port. The probability that a vessel will choose a reef in this manner is calculated as,

$$P'_{b,r} = \frac{e^{-5d_{b,r}}}{\sum_r e^{-5d_{b,r}}}$$

Each vessel allocates fishing effort on a daily basis,  $E_{y,m,b,d}^r$ , by selecting a location at random from either  $P_{b,r}$  with 99% probability or  $P'_{b,r}$  with 1% probability. Since fishing varies from day to day, however, the daily effort is assumed to be influenced by stochastic fluctuations. Thus, an effective effort  $\tilde{E}_{y,m,b,d}^r$  is determined as:

$$\tilde{E}_{y,m,b,d}^r = \varepsilon_d E_{y,m,b,d}^r$$

where  $\varepsilon_d$  represents the daily variability in fishing expressed as a log-normal random variable

$\varepsilon_d \sim e^{N(0, \sigma^2) - \sigma^2/2}$ , and  $\sigma^2$  is equal to 1. This effective effort is used to calculate fishing mortalities.

ELFSim operates at a monthly time scale and each simulation consists of two parts. In the first, the biological component uses information from the physical characteristics of individual reefs to determine the population size (and its age-, sex- and size-structure) on each reef given the documented amount of past fishing. In the second part, which projects the reef populations forward in time, the biological component is subjected to simulated fishing pressure, which is subject to management measures imposed by the user. The user is then able to evaluate various management options by examining performance indicators that are produced from the model.

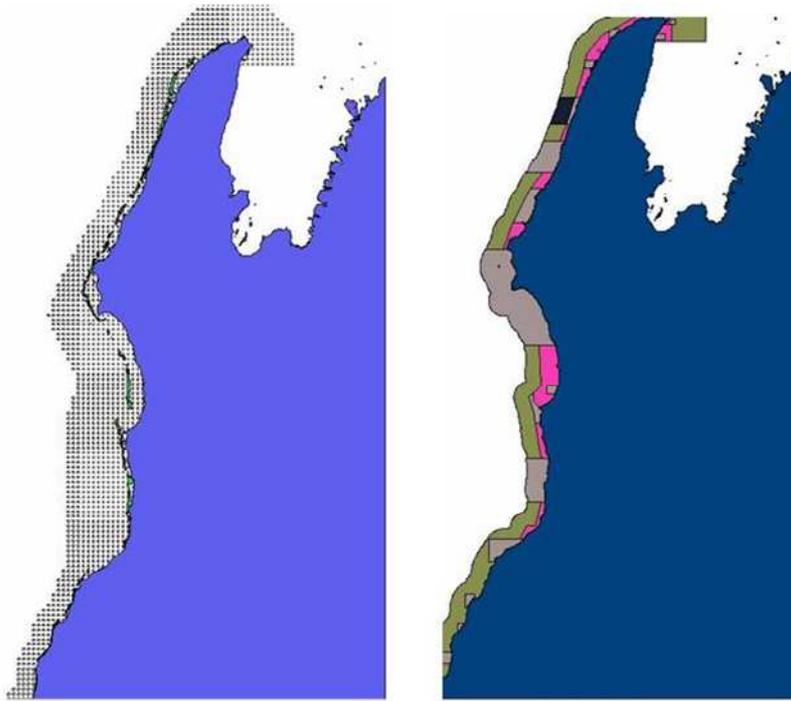
### *Infringement*

Whether a reef  $r$ , is open or closed to fishing by vessel-class  $v$  is defined by its ‘management status’,  $L^{r,v}$ , which ranges between 0 (open to fishing) and 1 (closed), with intermediate values representing closed reefs that experience some level of infringement. Effort assigned to reefs is calculated by multiplying the probability of fishing on a particular reef by  $(1 - L^{r,v})$ . Allowance can be made for spatial (edge effects) and temporal changes to infringement into MPAs (Little et al. 2005).

### **Data**

Biological data were obtained from Marriot et al. (2010) for growth rates, length-weight relations, maturity, sex-change and selectivity relationships, as well as natural mortality of Spangled Emperor.

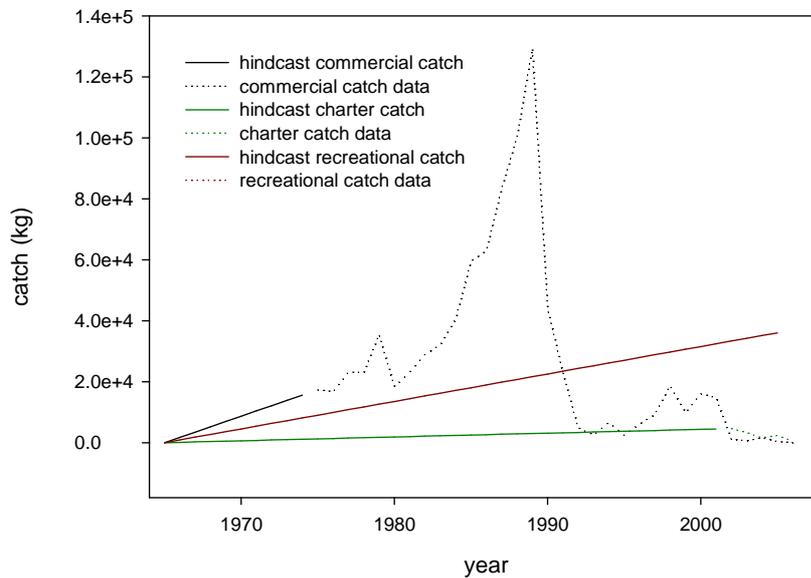
The spatial domain of Ningaloo Marine Park was spatially segregated into a 1x1 minute grid (Figure 1). The spatial distribution and putative amount of habitat for Spangled Emperor, for each grid, was assigned based on GIS intersections with mapped inter-tidal coral reef habitat. The model contains 1544 sub-populations. Although Spangled Emperor are generally considered reef associated species, they are assumed in the model to occur in locations other than the inter-tidal area in the marine park, where they are known to exist from fish catch records. Nevertheless, inter-tidal habitat is used to derive an indicator of habitat, which determines the population carrying capacity for each local population associated with a 1 minute grid. For those grid cells not associated with inter-tidal habitat, an initial value for the amount of habitat and carrying capacity of the local population is determined by selecting a value randomly for the ten closest inter-tidal locations.



**Figure 1 – Left: The spatial extent of the modeled area, including the 1 minute grid cells representing *Lethrinum nebulosus* populations, and the inter-tidal habitat; Right: The zoning on Ningaloo Marine Park used by the management model of ELFSim to constrain vessels in the harvest model (pink: no-take sanctuaries; green: recreational zones; grey: general purpose; black: special purpose)**

Since the actual unexploited state of the species is not known but is generally expected to be explored through model sensitivity analysis by the user, the actual values of the species carrying capacity of the different local populations is less important than the relationship among the location populations. As a result, in the current model the spatial distribution of the resource (Figure 1) is calculated as a function of inter-tidal coral reef habitat area and catch records.

Charter fishing catch and effort data were obtained at a 5 minute spatial grid scale for the period from 2002 to 2006 (Dept. of Fisheries, Western Australia). These data were disaggregated to the 1 minute spatial scale of the sub-populations based on the amount of assumed habitat distributed among the 1 minute grid cells embedded in each 5 minute grid cell datum. For each grid cell, catch and effort data were hindcast linearly back to zero in 1965, the year in which fishing was assumed to have started (Figure 2). Recreational fishing catch and effort data were obtained for 5 minute blocks in 2006. These data were similarly disaggregated to 1 minute grid cells based on the amount of habitat assumed to exist in each grid cell, and hindcast linearly back to zero in 1965. Commercial catches were obtained for 1 degree blocks from 1975 to 2005 and disaggregated to the 1 minute spatial scale of the sub-populations based on the amount of assumed habitat distributed among the 1 minute grid cells. These data were also hindcast back to 0 in 1965 (Figure 2).



**Figure 2 - Spatially aggregated catch data, by fleet over the historical period**

These data allow the model to run historically, capturing the spatial pattern of historical fishing. Assuming that there was no or little fishing before 1965, and with an assumed relationship between habitat and reef (grid cell) population size, the model derives the state of the local reef populations in 2006. After 2006 the harvest model operates to project the population under different management conditions. For simulation of management strategies involving the zoning of the marine park (Figure 1), ELFSim prevents fishing from occurring in the protected (sanctuary) zones in this projection period (pink areas Figure 1).

**Table 1 - Number and distribution of fishing vessels in the harvest model, fishing in the different fleets (charter and recreational) from different ports (boat ramps).**

Port	Fleet	
	Charter	Recreational
Exmouth	8	18
Tantabiddi Creek	4	12
Coral Bay	0	10
<b>Total</b>	<b>12</b>	<b>40</b>

At the start of the projection period all vessels start with the same perceived CPUE across different locations (reefs), based on the historical data used in the historical period of the model. As the projection period in the model progresses however, these perceptions diverge under stochastic influences, and the behaviour of individual vessels becomes conditioned on recent individual fishing experiences. For the

current simulations, a number of vessels were selected for each fleet so that the aggregate effort of the vessels, each operating consistently over the period of a year, would match the aggregate effort that has actually occurred in the fishery. A distribution of fishing vessels across different ports, or boat ramps, was also necessary, based roughly on the calculated effort distribution in different areas of Ningaloo Marine Park (Table 1).

## **MANAGEMENT OBJECTIVES, MANAGEMENT STRATEGIES AND SCENARIOS**

Identification of management objectives, management strategies and scenarios to be considered in the simulation runs was carried out in consultation with the stakeholders involved in the regulation of the fishery. Five workshops were held to this intent, 3 early on in the process (in May, August and September 2006), one in November 2008 and one in March 2010.

### **Management objectives**

The management objectives identified fall into two broad categories of ecological and social objectives.

Ecological management objectives on which stakeholders agreed pertained to:

- the capacity for spawning biomass of the target species to be restored to high levels in the sanctuaries. Quantitatively, this was taken to imply a spawning biomass above 90%, or at least above 75%, of pre-exploitation spawning biomass, 75% of the time;
- the length distribution and the age distribution of the population in the sanctuaries, which should approximate those of an unexploited population. Quantitatively, we interpreted these objectives as the mean of the age and length distributions of the population in the sanctuaries to be within the tenth percentile of the unexploited values, 75% of the time;
- the status of the stock outside of the sanctuaries and the desire that it not decline below the current state. Quantitatively, this was taken to mean that both the spawning biomass and the biomass available to fishers outside sanctuaries should be greater than what they were in 2007, 75% of the time;
- the status of spawning biomass at the scale of the entire marine park. This specified that the spawning biomass should be more than 40% of the pre-exploitation spawning biomass, 75% of the time.

Social objectives on which stakeholders agreed pertained to:

- maintaining a good recreational fishing experience in terms of catch rates. This was interpreted as the total catch rate (including landed and released catches) , CPUE, be greater in the future than the most recent value 75% of the time;
- improving recreational fishing experience by ensuring that there should be a good chance of catching trophy fish (considered as fish of body size > 50cm). This was interpreted as ensuring that each fisher would catch one trophy fish on each trip, or that trophy fish would constitute 25% of a fisher's catch on any given trip 75% of the time;
- reducing the variability in catch (assumed to be the day-to-day variability in total catch), and the number of days, or trips in which zero fish are caught. Because the functional relationship between catch and effort assumed in the model, a non-zero effort will never result in a zero catch. Also, because the main form of catch is weight, not numbers, it is possible to get catch in numbers that is fractional, e.g. 1.5 fish. As a result we developed an indicator that represents the chance of not catching a fish, as the proportion of days or trips during which the average number of fish in the catch is less than 1, 75% of the time.

## Management Strategies

Several management strategies were considered during the workshops, under current conditions. These include:

- use the current or an increased network of marine sanctuaries;
- allowing or not allowing fishing to occur from shore in sanctuaries;
- maintaining the current recreational effort, or increasing it, presumably through a licensing platform or implementing a TAC;
- implementing an educational program, which would be expected to reduce infringement in closed areas, and informally reduce the bag limit through the development of a catch and release plan;
- implementing an enforcement monitoring program by having a monitoring vessel patrol the coast, to reduce fishing in the sanctuaries, and over-catches of the bag limit.

Although other management options are included in the modeling platform, such as bag limits and minimum legal sizes, changes to these regulations were thought to be less likely to be adopted in the near future, and were thus not implemented in the first set of simulations considered here.

## Scenarios

The scenarios that were thought to be likely conditions experienced in the future included:

- environmental pressures as a result of climate change or similar global effect;
- increased fish catchability, which would result from technological development;
- development of fishing effort in relation to the increase in population and economic activity currently experienced in Western Australia;
- wider footprint of the fishery, which would result if fishers moved to bigger boats, or relative costs decreased, such that their operational range per unit cost increased;
- boat ramp / road upgrade, which would allow more vessels originating from Coral Bay, and thus would be expected to have an effect on localized depletion of the resource.

The table below illustrates a combination of management strategies and scenarios which were considered for the presentation of preliminary simulation results in this paper. Across all scenarios, catchability was assumed to increase by 1% a year for 10 years, and overall recreational fishing effort was assumed to double, which was thought to be likely outcome under increasing mining activity in the region.

**Table 2 – Combination of management strategies and scenarios tested**

Management strategy	Climate Change (CC)	Fishing footprint (foot prt)	New boat ramps (b ramp)	All (all)	None
Status Quo	SQ <sub>1</sub>	SQ <sub>2</sub>	SQ <sub>3</sub>	SQ <sub>A</sub>	SQ <sub>N</sub>
Modified Sanctuaries	MS <sub>1</sub>	MS <sub>2</sub>	MS <sub>3</sub>	MS <sub>A</sub>	MS <sub>N</sub>
No inshore fishing	NIF <sub>1</sub>	NIF <sub>2</sub>	NIF <sub>3</sub>	NIF <sub>A</sub>	NIF <sub>N</sub>
Increased Sanctuaries	IS <sub>1</sub>	IS <sub>2</sub>	IS <sub>3</sub>	IS <sub>A</sub>	IS <sub>N</sub>

Management strategies considered individually were: a modification in the spatial distribution of sanctuaries in the Park; a ban on inshore fishing in the sanctuaries; or the extension of the area of existing sanctuaries. Key indicators considered in this analysis to assess the capacity of Management Strategies to achieve the objectives pursued in the fishery include the spawning biomass relative to un-fished levels

(ecological objective), catch rates (fisher satisfaction) and the probability of catching trophy fish (fisher satisfaction and population structure).

**SIMULATION RESULTS**

Preliminary simulation results are presented in Figure 3 (for each scenario and management strategy listed in Table 2).

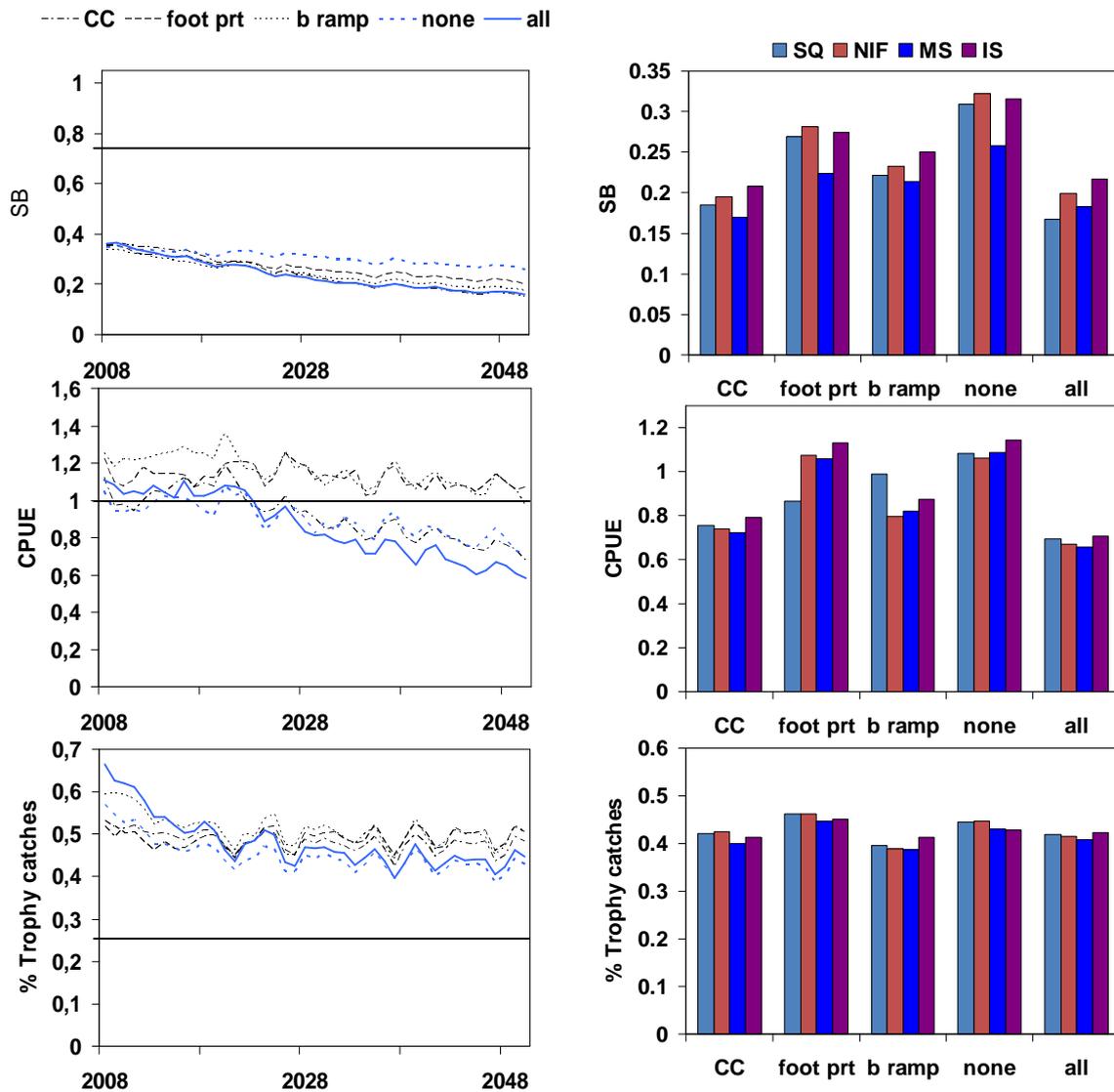


Figure 3 – Simulation results for key indicators. Top: Spawning biomass (SB) relative to unfished spawning biomass in open and closed areas; Middle: Catch rates (CPUE) relative to 2007 catch rates; Bottom: Proportion of trophy catches. Left quadrants: trends in the Status Quo management strategy; Right quadrants: status of the indicators at the end of the simulation period

The left quadrants illustrate the evolution over the projection period of the key indicators selected, in the status quo management strategy, under the different scenarios considered. With no new management measures adopted, there is a decreasing long term trend in biomass which is stronger if the climate, extended footprint and new boat ramp scenarios occur. Catch rates also tend to decrease throughout all scenarios, although they do less so under the wider footprint and the boat ramp scenarios, as these entail new fishing possibilities for the fleets. Over time, there is also a decrease in the proportion of trophy catches. The results in the right quadrant illustrate the effectiveness of alternative management strategies at achieving the objectives pursued by the stakeholders, based on the same set of indicators measured at the end of the simulation period. Overall, under the scenarios considered, none of the strategies considered manages to achieve the ecological objective of restoring spawning stock biomass. Increased sanctuaries and a ban on inshore fishing produce the strongest effects towards this objective, whereas the modification of sanctuary distribution considered in these runs performs less well. Maintaining catch rates is only achieved if none of the foreseen scenarios occurs, or if either the extended footprint of fishing scenario or the boat ramp scenario occurs. In the latter case, alternative management strategies to the status quo tend to degrade the performance of management towards this objective, while in the former, they tend to improve this performance. Trophy catches is the only indicator which appears to be satisfied over the projection period, and is relatively unaffected by the scenarios or the alternative management strategies.

## **DISCUSSION**

The results reported above demonstrate both the variability and trends in depletion and recovery of target species and, by implication, a critical component of the Ningaloo marine ecosystem under different management strategies and a range of bio-physical and human-usage scenarios. A striking feature of the results is the relatively slow recovery of fish stocks from a state of high depletion. This is the result of the biological parameters for the species, which include a productivity parameter (steepness), for the stock recruitment relationship, which was set to 0.5. This parameter usually varies between about 0.4 and 0.75, and we chose 0.5 as an approximate mid-point.

Equally revealing is the rapid human response in the harvest model to changes in extractive use permitted in the marine park, and to modified fishing conditions under the alternative scenarios considered. Depending on the combination of scenarios and strategies, large differences are observed in the spatial distribution of fishing effort, as well as in its variability in time. These key aspects of the results are currently being analyzed with the aim to identify the implications of these responses in the evaluation of management strategies.

Such model-based results may not only agree with public perceptions, but they also help to pinpoint the most important features of the biology and human exploitation that give rise to the changes, and how management agencies might best set their strategies in order to achieve their stated objectives. In these simulations, some management strategies clearly perform better than others with respect to the social objectives pursued in the fishery, although none manages to improve the ecological status of the system.

Further evaluation of alternative management strategies will be pursued, to assess their capacity to achieve the objectives which have been identified as key via the stakeholder consultation. This will involve testing alternative combinations of management approaches, under a wide range of scenarios regarding the conditions under which the fishery will evolve over the next few decades. In particular, we will examine the trade-offs between the levels at which the threshold values for objective indicators are set, whilst ensuring that given management strategies remain successful. Such analysis is akin to the application of viability analysis in ecological-economic modeling (Béné et al, 2001; Martinet et al., 2007;

Martinet et al., 2010), and should better inform the stakeholders involved in determining the regulations of recreational fishing in Ningaloo Marine Park, about the options they face to ensure viable management strategies for reef line fishing in Ningaloo.

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