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Reef finfishing pressure risk model for Pacific Island countries and territories

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ABSTRACT

A reef finfishing pressure risk assessment model was developed to predict the status of reef and lagoon fisheries in terms of the current likelihood for sustainable or unsustainable finfishing for any given rural coastal community and its associated reef area in the Pacific Island countries and territories (PICTs). The prediction model aimed at developing a robust system that allows planners to confidently classify any coastal rural site within PICTs with a minimum and relatively easy-to-obtain dataset as being exposed to four classes of low to high finfishing pressure. This model is a response to limitations on data regarding current resource and user status in PICTs that make it difficult to ascertain fish supply for food security and livelihood of coastal communities. The model is based on the latest reef productivity scenarios developed based on a global review of currently known landing data and ecological footprints, reported likelihood of reduced reef productivity in PICTs due to ecological and human factors, and the use of current finfish catch rates collected as a proxy for fishing pressure. The prediction model was developed on the basis of a regional dataset including 63 study sites in 17 PICTs using linear discriminant analysis. The smallest feasible model with a leave-one-out error rate of 14.3% demands nine input variables that can be easily obtained and require only a minimum survey effort. Statistically significant response of decreasing fish length in six fish families important to artisanal fisheries in PICTs (Acanthuridae, Lethrinidae, Mullidae, Scaridae, Serranidae and Siganidae) to increasing catch rates or increasing fishing pressure proxies was used as an independent external factor to validate our hypothesis and the model developed. The reported catch length for Acanthuridae, Scaridae and Serranidae was statistically significantly different between the four finfishing pressure risk groups defined. Due to the lack of data on the natural status and productivity of the coral reefs in question and their historic use, care should be taken in interpretation of current catch rate figures. Classification of sites at low current finfishing pressure risk may reflect catch rates that are adapted to low stocks, either caused by previous depletion or due to natural unfavorable conditions. At the same time, sites classified as being at potentially high finfishing pressure risk may indeed be subject to current overfishing, but may as well feature high natural stock and productivity assets that allow for higher catch rates than elsewhere.

1. Introduction

Fisheries management in Pacific Island countries and territories (PICTs) is faced with declining coastal resources caused by overfishing due to population and socio-economic growth (Adams, 2006; Dalzell et al., 1996; Hickey, 2008; Kronen et al., 2003; Pauly, 1994; Ruddle and Hickey, 2008; Sale et al., 2008; Zann and Vuki, 2000). It has been shown that low-level artisanal fishing can dramatically affect populations of slow-growing, late-maturing animals, deplete stocks (Jennings and Polunin, 1996), and degrade or cause the collapse of ecosystems (Bunce et al., 2008; Jackson et al., 2001; Myers et al., 2007; Pandolfi et al., 2003; Pinnegar and Engelhard, 2008). Determining the degree and exact cause of coastal resource decline and the potential risk imposed by actual resource use remains problematic. First, baseline data and reference points for past resource and user status are insufficiently known (Dalzell et al., 1996), documentation is scattered, and small-scale catches are only partly considered and are generally underestimated in official statistics (Zeller et al., 2007a,b). Second, available data may be incompatible and thus difficult to compare due to the use of different methodological approaches. Third, little is known regarding whether changes documented or obtained by comparing available information are due to natural or anthropogenic factors. The lack of information is not surprising given the high species diversity on the resource side and the multiplicity of fishing gear and craft on the user side (Bundy and Pauly, 2001; Larkin, 1996). The

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complexity of both types of factors requires a wide range of information on the structure and function of reef assemblages (Tsehaye and Nagelkerke, 2008) as well as a wide range of information to capture interactions due to fisheries-induced impact. In addition, small-scale artisanal fisheries in PICTs have their own dynamics, targeting a wide range of different coral reef and lagoon fish species, with high variations between fishing trips concerning objectives (commercial to recreational aspects) (Craig et al., 1993), length of trips (hours to days), the use of boat transport, habitats targeted, fishing gear used, size of fishing party, day or nighttime fishing, and a range of regular and irregular landing sites. Lack of data, or underestimation of the social and economic contributions made by coastal marine resources are thought to add to the marginalisation of small-scale fisheries, often already disadvantaged by their socio-economic, physical, and political remoteness (Pauly, 1997). Today's discussion on possible effects of climate change on coral reefs and their associated resources (Bell et al., 2006; Munday et al., 2008) and the need to ascertain fish supply for food security and livelihood of coastal communities in PICTs (Andrew et al., 2007; Bell et al., 2009) further highlights the dilemma of data limitations for policy-makers and fisheries managers alike. Taking into account Johannes (1998) arguments for taking a precautionary approach for data-less fisheries management, unarguably, assessment of current fishing impact is necessary to prioritise fishing grounds and communities for fisheries management interventions and allocation of limited resources. With limited ecological data, this objective requires development and use of a systematic planning tool (Ban et al., 2009) that is less parameter intensive and that allows ad hoc assessment of the status of fisheries (Bundy and Pauly, 2001; Tsehaye and Nagelkerke, 2008).

The objective of the present study is to develop a reef finfishing pressure risk assessment model that allows the prediction of the likelihood of sustainable or unsustainable current artisanal finfishing in PICTs for any given rural coastal community and its appropriated reef area. To predict the likelihood of sustainable and unsustainable finfish exploitation rates we applied the major hypothesis that the higher the current finfish catch rate, the higher the likelihood of unsustainable fisheries. This hypothesis is based on the huge range of current finfish catch rates (<0.1 to >50 mt km^{-2} reef $year^{-1}$) identified by the socio-economic and fishery component of the regional coastal fishery and resources database (the first of its kind) across 17 PICTs. This regional database was established by the coastal component of the Pacific Regional Oceanic and Coastal Fisheries Development Programme (PROCFish/C), a European Union-funded project implemented by the Secretariat of the Pacific Community's (SPC)'s Reef Fishery Observatory. Due to the absence of consistent, region-wide coral reef productivity data that could be applied at study site level, we discussed the usefulness of historic reef productivity data available for PICTs as compared to productivity scenarios developed by Newton et al. (2007).

The most exhaustive summary of observed reef finfish yields done by Adams et al. (1997) uses estimates that date as far back as the early 1980s, suggesting a range of 0.3–64 mt km^{-2} $year^{-1}$ (mean = 7.7 mt km^{-2} $year^{-1}$) and a possible sustainable yield of 10 mt km^{-2} $year^{-1}$ where reefs are subject to low human influence (Jennings and Polunin, 1996). Serious doubts about what level of exploitation may in fact be sustainable, and under which conditions, were already expressed in 1999 (Adams et al., 1999). These doubts are consistent with contemporary survey results suggesting much lower estimated yields: 2.3 mt km^{-2} $year^{-1}$ for American Samoa (Craig et al., 2008), and 2.9–3.7 mt km^{-2} $year^{-1}$ for Fiji (Kuster et al., 2005). The fact that coral reefs in the Pacific and elsewhere have been subject to a varying degree of fishing intensity and that degradation has reduced potential productivity is widely accepted (Alcala and Gomez, 1985; Russ, 1991; Hughes, 1994; Jackson et al., 2001; Alacala and Russ, 2002; McClanahan et al., 2002; Hawkins and Roberts, 2004). However, the long-term historic sequence is unknown for any reef (Pandolfi et al., 2003), and little is known about which reefs are overfished (Sadovy, 2005). In view of the existing uncertainties, we opted to apply the productivity scenarios of coral reefs as suggested by Newton et al. (2007) as a proxy to assess the likelihood of sustainable to unsustainable finfisheries, as they take into account current records of landing data, the available reef area, and modeling of historic footprints in 49 island countries, including all of the 17 PICTs we studied. Using the different scenarios described (Newton et al., 2007), we distinguished four possible finfishing pressure risk groups to represent a scale from a pessimistic, low natural productivity scenario of <1 mt km^{-2} reef $year^{-1}$ (A) to a very optimistic productivity scenario of >10 mt km^{-2} reef $year^{-1}$ (D), with two intermediate risk groups, i.e. low to medium productivity of 1–5 mt km^{-2} reef $year^{-1}$ (B) and medium to high productivity of 5–10 mt km^{-2} reef $year^{-1}$ (C). Based on our recent region-wide catch data, applying a precautionary approach, and given the magnitude of pessimistic to optimistic production scenarios, we suggest that current exploitation levels of <1 mt km^{-2} reef $year^{-1}$ have a high likelihood to use resources sustainably, while any catch rate exceeding 10 mt km^{-2} reef $year^{-1}$ is regarded as having a high likelihood of being unsustainable. Further to Newton et al.'s (2007) scenarios, the lower intermediate group (1–5 mt km^{-2} $year^{-1}$) uses a loss of 50% of the assumed sustainable reef productivity in PICTs (Adams et al., 1997; Jennings and Polunin, 1996) over the past 25–30 years as the upper threshold. Based on the same argument, the upper medium risk group (5–10 mt km^{-2} reef $year^{-1}$) is not regarded as likely to sustainably use finfish resources but instead is considered to represent a high probability of overfishing. We used our finfish catch rates expressed in mt km^{-2} reef $year^{-1}$ fished to classify each of our sites studied into any of the four finfishing pressure risk groups accordingly.

To validate our hypothesis we selected from our regional database average fish size by family of target species collected from respondents as best indicator for fishing impact. While other variables from finfish resource and socio-economic fishery surveys may also proof our hypothesis, average reported catch size by family is the easiest to collect information and therefore best suited for application of our model elsewhere. The proposed indicator of average fish size is based upon numerous observations and studies showing that increasing fishing pressure results in smaller fish sizes (Roberts, 1995; Pet-Soede et al., 2001; Halpern, 2003; Amand et al., 2004; Hawkins and Roberts, 2004; Ashworth and Ormond, 2005; Jennings, 2007; Craig et al., 2008; Stallings, 2009), or growth-overfishing (Alacala and Russ, 2002; Froese, 2004).

The prediction model aimed at developing a robust system that allows planners to confidently classify any coastal rural site within PICTs with a minimum and relatively easy-to-obtain dataset as being exposed to low, low to medium, medium to high or high finfishing pressure, corresponding to a likelihood of increasingly unsustainable use from groups A to D.

2. Methods

2.1. Study sites

During the period 2003 to 2008 usually four study sites were selected and surveyed in each of the 17 PICTs that belong to one of the three major cultural groups Melanesia, Micronesia and Polynesia, i.e. Cook Islands, the Federated States of Micronesia (Yap and Chuuk), Fiji Islands, French Polynesia, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Palau, Papua New Guinea, Samoa,