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# Improving management of coral reefs fisheries in data limited situations: Experiences from the ParFish methodology

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**Abstract.** Coral reef fisheries are complex systems. This is due primarily to the multi-species, multi-gear and high labor mobility that often occurs within the fisheries sector. Since many small-scale fisheries operate in remote areas and/ or in developing coastal states, the quality and quantity of data necessary to undertake basic fisheries management, including robust stock assessments, are often lacking. It is becoming more widely acknowledged that local stakeholder participation is an essential pre-requisite to improve overall management of the resource, but this has rarely engaged them directly within a stock assessment framework to provide information on the status of the resource. This study presents a summary and comparison of three pilot studies undertaken in Turks and Caicos Islands, Zanzibar and Puerto Rico. Through the development of a participatory fish stock assessment (ParFish) methodology, fishers are engaged at the beginning of an ongoing adaptive management process to contribute their valuable knowledge about the fishery. Using a Bayesian statistical model, information obtained from fishers help inform prior statistical distributions that are used to estimate parameters in the stock assessment model. The results have shown that this approach can be used successfully to establish preliminary results of stock status in data limited situations.

**Key words:** Reef fisheries, Data limited, Stakeholder participation, Stock assessment, ParFish

## Introduction

The future health and status of coral reefs are threatened from many sources, including environmental and anthropogenic impacts such as climate change, pollution and fisheries (Carpenter et al. 2008). Coral reef fisheries provide a valuable source of income and source of protein for many coastal communities, although the status of reef fisheries has been exacerbated by poor management (Munro 1996).

One important pre-requisite for effective fisheries management is information on the status of the resource. However, in many regions of the world, fisheries data are often lacking due to limited funding and capacity within fisheries management agencies. A lack of quantitative fisheries information has prohibited the use of traditional stock assessment models to assess the status of the stocks, without which sustainable catch control limits cannot be determined. Moreover, without effective monitoring, control and surveillance, illegal, unreported and unregulated fishing is likely to undermine existing management measures.

Fisheries management has now recognized the importance of stakeholder participation, and the potential benefits of co-management initiatives are well documented (Wilson et al. 2004). Until recently, however, fishers and key stakeholders have not been directly involved in the assessment of the stock.

This paper describes the results from three pilot studies that have been used to test a rapid assessment technique that uses fishers' knowledge and information to parameterize traditional stock assessment models without need of a long time-series of data. The results of the Participatory Fish Stock Assessment (ParFish) methodology (Medley 2006) are described in an attempt to determine if it can be used successfully in the field.

## Material and Methods

The ParFish methodology was developed under the Fisheries Management Science Programme (FMSP) (www.fmsp.co.uk) funded by the UK Department for International Development (DFID). It is an adaptive process that includes six key stages to (i) understand the context of the fishery (ii) agree objectives of the study with stakeholders (iii) undertake the ParFish

stock assessment (iv) give feedback of the results and initiate management planning (v) assist with the implementation of the management plans, and (vi) evaluate the ParFish process.

The ParFish approach is supported by two main components: a toolkit that provides guidance on the process outlined above and the ParFish software. The software enables the analysis of the data, based on Bayesian statistics and decision analysis. Quantitative data used to develop statistical probability distributions (or priors) of parameters used in the stock assessment are obtained from interviews with fishers. In addition, preference interviews are used to score individual fishers' utility (i.e. risk seeking or risk averse) to selecting different management options based on changes in fishing effort (cost) and expected catch (benefit). A full description of the ParFish methodology and toolkit can be found in Walmsley et al. (2005).

Development of ParFish is ongoing, and this study presents a summary of the results obtained from pilot studies occurring within the Caribbean region (Turks and Caicos Islands and Puerto Rico) and Africa (Zanzibar Island, United Rep. Tanzania).

*Turks and Caicos Islands*

A pilot study funded by DFID was conducted to assess the status of the queen conch (*Strombus gigas*) on the islands of Provenciales and South Caicos (Fig. 1). This fishery provided a useful test for the value of the fisher interviews since a long time series of catch and effort data is available for comparison.

The fishery is targeted by small day boats with fishers who free dive to 10m depth to collect conch that is shelled at sea. The meat is landed and recorded at processing plants. These data, available since 1974, are used to record catch and effort information and have subsequently been used to estimate stock size from a logistic biomass model (Medley and Ninnes 1999). The data collected from processing plants are used by the government to set catch quotas for landings and exports (Taylor and Medley 2003a).

With the assistance of the Department of Environment and Coastal Resources (DECR), a total of 46 stock assessment and 38 fisher preference interviews were conducted between 3rd and 21st July, 2003.

In addition to the comparison between the stock assessment and the ParFish results, a simple retrospective analysis was performed to see if the interviews alone might have improved the management of the fishery, had that information been used to set effort control back in 1974.

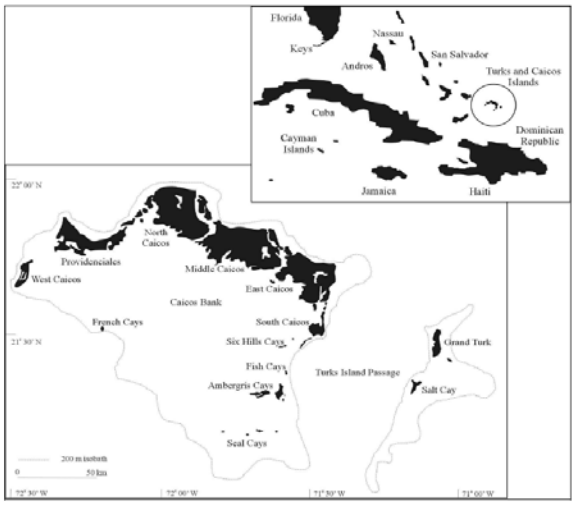


Figure 1: Location of ParFish assessment in Provenciales and South Caicos within Turks and Caicos Islands during ParFish assessment.

*Zanzibar*

A pilot study funded by DFID was conducted to assess the status of a multi-species fishery on both the offshore patch reefs (Dimbani) and inshore fringing reefs (Mkunguni and Mtende) in the Kizimkazi region of southern Zanzibar (Fig. 2). The field sites also fall within the boundaries of the Menai Bay Conservation Area which was listed as a multiple-use management area in 1997 (ref here). To date, no restrictions are placed on the minimum size of capture or catch limits.

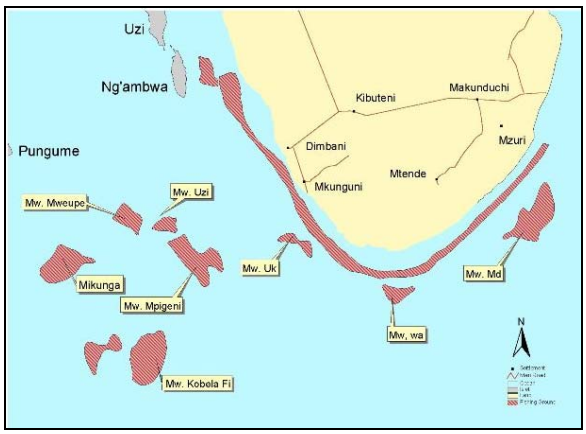


Figure 2: Location of ParFish assessment in Kizimkazi, southern Zanzibar Island during ParFish assessment.

The fishery provided a further opportunity to develop the ParFish interview technique and develop the participatory process but also included a range of auxiliary information from research experiments. This included fishing experiments, underwater visual census (UVC) and mark and recapture of fish within the experimental area (Taylor and Medley 2003b).

With the collaboration of the Institute of Marine Science, University of Dar es Salaam, a total of 92

stock assessment and 67 preference interviews were completed between April and June, 2003.

Fishing Experiments

Depletion techniques reduce the population size through fishing to provide parameters necessary to estimate stock size (Hilborn and Walters, 1992). An important assumption of depletion methods is that no immigration or emigration occurs in the population during the experiment, and thus would preferably be conducted over a short time period. In Dimbani (offshore reef), the fishing experiment was conducted over an area of 600 x 500m during an eight day period with approximately 55 fishers while in Mkunguni and Mtende (inshore reef), this was conducted within an area of 800 x 100m with an average of 43 fishers during a nine day period. Log books were provided to all fishermen to record fishing duration and catch by species.

Underwater Visual Census (UVC)

A UVC, using similar methods to Gaudian et al. (1995), was conducted at Mkunguni and Mtende (inshore reef sites). Six permanent monitoring stations were established in the study area: two within the fishing area for the depletion experiment and two on either side of the experiment area. Each transect (200 x 10m belt) was conducted by two pairs of divers, each recording the target species within the transect boundaries. These sites were monitored at random (as far as possible) before, during, immediately after, and one month after the fishing experiment.

Mark and Recapture Studies

The use of mark and recapture techniques in the ParFish experimental design was investigated at Mkunguni and Mtende (inshore reef sites). Following the demarcation of the fishing experiment, an intensive tagging program was conducted during eight days within the same area. During the tagging phase 566 fish from 35 different species were marked and released within the boundaries of the fishing area. The depletion experiment was then used to recapture the tagged fish, in addition to recording tagged fish during the UVC.

*Puerto Rico*

A pilot study funded by the NOAA Cooperative Research Program was conducted to assess the status of the two most important deepwater snapper: queen snapper (*Etelis oculatus*) and silk snapper (*Lutjanus vivanus*) in western Puerto Rico. The study enabled the ParFish software to be further developed to include a yield-per-recruit analysis in addition to the existing logistic production model.

Deepwater snapper are targeted by a small-scale hand line fishery using electric reels and multiple baited hooks. Approximately 30 to 40 full-time commercial fishers operate from two main fishing centers, Rincón and Cabo Rojo. Standardized catch and effort data are available through SEAMAP surveys (Rosario Jimenez 1989), although these have been shown to be of limited use for the assessment of the snapper complex (Ault and Rothchild 1991). To date, management of the fishery employs a closed season for silk snapper and minimum size limits for both species. There are no catch limits placed on either species.

With the assistance of the Department of Natural Resources and the Environment, a total of 31 stock assessment and 29 preference interviews were conducted between March and June 2008.

**Results**

*Turks and Caicos Islands*

The results of the ParFish stock assessment are associated with high uncertainty in the status of the conch stock, although overall there is a greater tendency to indicate the stock is overfished. The scientific data from the catch and effort time series supports the fishers' view that the fishery is in an overfished state. When interview and scientific data are combined the posterior opinion is that the fishery is overfished (Fig. 3).

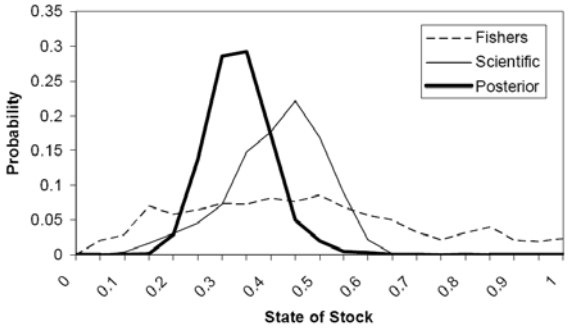


Figure 3: State of stock (current biomass / initial biomass) estimated from ParFish interviews, scientific catch and effort time series data and combined analysis (posterior distribution).

Similarly, the ParFish assessment showed high uncertainty in the level of fishing effort although overall there was a higher probability that overfishing was occurring, or at the very least fishing at the maximum (status greater than 1). Again, the scientific data supports the fishers' view that the stock is overfished. When interview and scientific data are combined, the posterior opinion shows that the stock is either currently overfished or very close to being in an overfished state (Fig. 4).

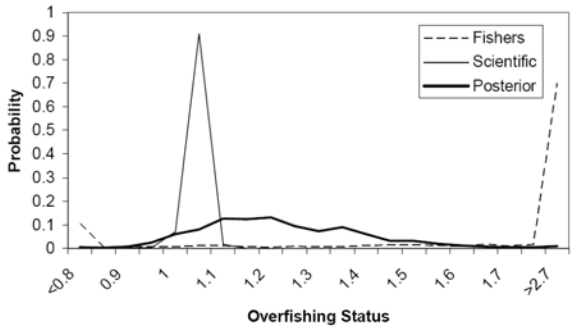


Figure 4: Overfishing status of stock (current fishing mortality / fishing mortality at MSY) estimated from ParFish interviews, scientific catch and effort time series and combined analysis (posterior distribution).

Since the fishery is managed on a catch quota system, the results from the ParFish stock assessment and preference interviews were used as part of a retrospective analysis (Fig. 5) to evaluate the impacts if an appropriate catch level had been applied back in 1974.

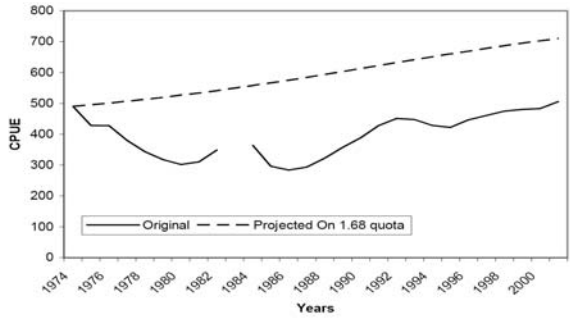


Figure 5: Expected catch per boat day (CPUE) from the fitted logistic model (original) and the projected CPUE from the annual catch quota (1.68 m pound) estimated from ParFish interviews.

Assuming the logistical model can represent the dynamics of the fishery, the results show that the total catches over the period 1975-2002 were very similar (approx. 46 million pounds; not shown). There was, however, a marked increase in the catch rate. This suggests that far less effort (and costs) would have had to be exerted than is now applied (from 3,300 boat days down to 2,500 boat days).

*Zanzibar*

The results of the ParFish assessment indicate that the current states of both the offshore and fringing reef multi-species fisheries are unknown, although the balance of probabilities suggests that the offshore fishery is overexploited. The results from the interviews suggest that too little is known about the initial state of the stock, which has been exploited for generations and is likely to provide unreliable estimates of unexploited biomass. In addition, there is no evidence to indicate overfishing is occurring in either fishery, although further increases in fishing effort should be capped until more information on the state of the stock can be determined.

The results of the fishing experiments showed that fishers were able to deplete the population on a local scale for both offshore and fringing reef populations sufficiently to estimate initial biomass that could be used in the ParFish assessment (Fig. 6).

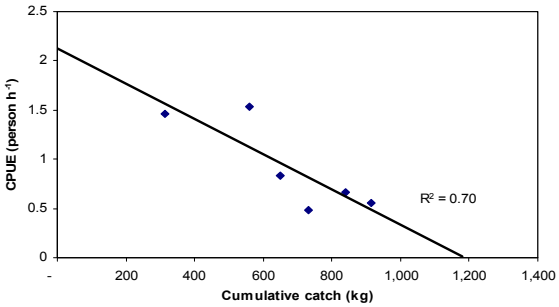


Figure 6: CPUE against cumulative catch to show depletion of population on a local scale for fringing reef fishery. Data represents days 4 -9 of the experiment.

The results of the UVC demonstrated that the abundance of the selected target species was reduced by the fishing experiment (Fig. 7). The increase in number of fish reported one month after the experiment indicates the population may experience immigration on a small scale.

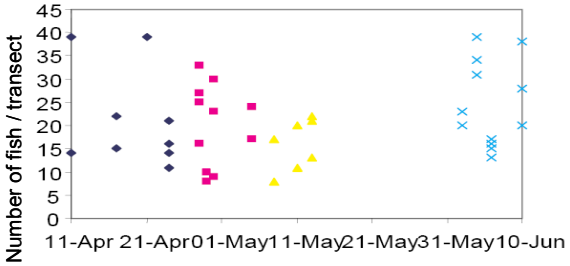


Figure 7: Density of fish observed at monitoring station on fringing reef, before (diamonds), during (squares), immediately after (triangles) and 1 month after (crosses) the fishing experiment.

During the fishing experiment, 56 tagged fish were recovered and provided a fishery-independent estimate of population size for the fishery. The mark and recapture data could also be used for estimating the population sizes of individual species for inclusion in multi-species assessments.

*Puerto Rico*

The assessment is still in process and the results show a high uncertainty associated with the parameters but that the probability of the current level of biomass for queen snapper being below the MSY level is slightly higher than 50% (i.e. possible overfished). In addition, the current yield from the analysis suggests that overfishing is not occurring.

## Discussion

The results of the pilot studies have demonstrated that the ParFish methodology can be used to collect quantitative information from small-scale fisheries sufficient to parameterize traditional stock assessment models such as the logistical production and yield-per-recruit models using a Bayesian statistical framework. The methodology provides a rapid assessment of the stock, which does not require a long time-series of catch and effort data.

The robustness of the assessment results can depend on the quality and quantity of interview data obtained. It is therefore important to develop a good rapport with fishers and key stakeholders at the beginning of the study. This may require considerable outreach, but can help manage expectations and indicate the likely benefits of the results. Furthermore, it can lead to more effective involvement of fishers in the management process and development of regulations.

In comparison with more formal stock assessments, the initial ParFish results can exhibit high levels of uncertainty. This is to be expected however, given the diverse array of opinions and level of fisher experience. Options to help reduce the overall level of uncertainty in the results may include (i) ensuring that all fishers fully understand the questions being asked (ii) re-interviewing fishers with different questions that lead to the same answer, and (iii) asking very specific questions about a fixed attribute (e.g., closed area/ season etc.) that can be compared among fishers to measure sampling variability.

ParFish should not be viewed as a single one-off assessment, but part of an ongoing participatory adaptive learning and management process. To further help reduce the level of uncertainty in the results, information gathered from fisher preference interviews can be used to establish a consensus of opinion with management agencies to develop alternative levels of fishing effort. For example, fishers in Zanzibar have recognized that a reduction in fishing effort can be implemented by better enforcement of existing regulations to prevent illegal fishers from entering the fishery. Within a ParFish full assessment, these would become re-evaluated with new research and data collection programs to ensure catch rates can be improved by lowering fishing effort.

In conclusion, the ParFish methodology may be used where little or no previous data are available to conduct more formal stock assessments. It can be a useful tool in helping to establish initial catch limits and develop management options in collaboration with the fishers. A full ParFish assessment would include ongoing adaptive learning and management to further improve catch rates within the fishery and reduce the level of uncertainty in the results.


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