Tools to Conduct a Participatory Fishery (ParFish) Assessment Using Bayesian Decision Analysis

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ABSTRACT

Data-deficient fisheries present a problem for management and stock assessment. The Participatory Fisheries Stock Assessment (ParFish) methodology can utilise a wide range of quantitative information including fisher knowledge to overcome this, integrated in a participatory framework. This paper presents the theoretical background to ParFish, outlines the stock assessment models and data types used, how data inform the likely distribution of parameter values in the assessment of the resource, and the tools and approaches for data collection and promoting the involvement of fishers. The theoretical basis for the method is Bayesian decision analysis combined with conventional stock assessment models. Two types of interviews with fishers are used: (i) questions on their current observations and beliefs about the way these experiences might change provide prior probabilities for stock assessment model parameters, where differences in opinion among fishers represent the uncertainty; and (ii) fishers' preferences for different outcome scenarios provide estimates of utility. Other scientific data can be incorporated in the assessment, as well as data from fishing experiments. ParFish contains a number of innovations that make it easier to involve fishers in management decision-making: incorporation of fisher knowledge into the stock assessment; involvement of fishers in the process; and approaches for communicating stock assessment concepts with fishers and discussing management options. ParFish is particularly valuable for initiating greater co-operation with fishing communities. It improves the understanding among scientists, fishers and managers of the fishery and helps with the identification of appropriate management options, which should improve compliance.

KEY WORDS: ParFish, Bayesian decision analysis, methodology

Herramientas para una Evaluación ParFish Utilizando Análisis de Decisión Bayesiano

La metodología de Evaluación Participativa de Stocks Pesqueros (ParFish) puede utilizar un amplio rango de información cuantitativa para proporcionar la posible distribución de valores utilizados en el contexto de evaluación del recurso. Este articulo presenta los antecedentes teóricos de ParFish, explica los modelos de evaluación de stock y los tipos de datos utilizados, y da ejemplos de las herramientas para recoger los datos e métodos para incentivar la participación de los pescadores. La base teórica para el método es el análisis de decisión de Bayes junto con los modelos convencionales para la evaluación de stocks. Dos tipos de entrevista a los pescadores son utilizados: preguntas sobre sus observaciones actuales y sus creencias sobre como dichas observaciones pueden cambiar proporcionan probabilidades a priori para los parámetros del modelo de evaluación de stocks, donde las diferencias en las opiniones de los pescadores representan la incertidumbre; las preferencias de los pescadores por los escenarios de resultado proporcionan estimados de utilidad. Otros datos científicos pueden ser incorporados en la evaluación, así como los datos de experimentos pesqueros. ParFish contiene varias innovaciones que facilitan la participación de los pescadores en la gestión de la toma de decisiones: La incorporación del conocimiento de los pescadores en la evaluación de stocks, la participación de los pescadores en el proceso; y métodos para la comunicación de los conceptos de evaluación de stocks a los pescadores y para la discusión de opciones de gestión. El método ParFish es valioso en especial para la mayor cooperación con comunidades pesqueras. Mejora la colaboración entre cientificos, pescadores y gestores de la pesqueria para la identificación de opciones de manejo apropiadas, mejorando su implementación.

PALABRAS CLAVES: ParFish, análisis Bayesiano, metodología

Outils Utilisant L'analyse de Decision Beyesiénne pour Mener une Évaluation de Pepar (Peche Participative)

La méthodologie d'évaluation participative des stocks de poisson (ParFish) peut utiliser une variété d'information quantitative pour alimenter la distribution probable des valeurs des paramètre utilisées dans l'évaluation de la ressource. Ce document présente le fond théorique de ParFish, décrit les modèles d'évaluation courante et les types de données utilisés, les outils et les approches pour la collecte de données et favoriser l'implication des pêcheurs. La base théorique de la méthode est l'analyse de décision bayésienne combinée avec les modèles conventionnels d'évaluation courante. Deux types d'enquêtes auprès des pêcheurs sont employés: questions sur leurs observations courantes et sur les croyances au sujet de la manière dont ces expériences pourraient changer les probabilités antérieurement fournies pour des paramètres de modèle d'évaluation courante, où les différences dans l'opinion des pêcheurs représentent l'incertitude ; les préférences des pêcheurs pour différents scénarios de résultats fournissent des évaluations d'utilité. D'autres données scientifiques (ex : les captures historiques et les CPUE) peuvent être incorporées dans l'évaluation, aussi bien que des données de la pêche expérimententale. ParFish contient un certain nombre d'innovations et a la flexibilité pour faciliter la participation des pêcheurs dans la prise de décision de gestion: l'incorporation de la connaissance de pêcheur dans l'évaluation courante des stocks; participation des pêcheurs dans le processus ; et les approches pour communiquer les concepts d'évaluation courante des stocks avec des pêcheurs et discuter des options de gestion. La méthode de ParFish est particulièrement valable pour lancer une plus grande coopération avec les communautés de pêcheurs. Elle améliore la compréhension avec les scientifiques, les pêcheurs et les directeurs de pêcheries, et aide avec l'identification des options appropriées de gestion, ce qui devrait améliorer la confiance entre eux.

MOTS CLÉS: ParFish, analyse de décision bayesienne, méthodologie

INTRODUCTION

It has long been recognised that fishers possess information about the stocks they fish which would be useful for scientists (e.g. Ruddle *et al*. 1992, Pomeroy and Williams 1994, MRAG 1999, Townsley 1998). This information has tended to be qualitative rather than quantitative and has not been used directly in stock assessments. For data-deficient fisheries, the primary target of the ParFish methodology, this information is of particular importance.

Bayesian decision analysis, with subjective prior probabilities, provides a framework in which quantitative information from stakeholders might be used with standard fisheries data (Press 1989). Decision analysis has been applied with success to many simple problems, and has been discussed a great deal in the fisheries literature (Punt and Hilborn, 1997), but concentrating only on using the Bayesian approach within a strict scientific framework avoiding subjectivity. A more general approach applicable to small-scale fisheries and implementing participatory management requires the ability to use subjective information as well as being rapid and inexpensive.

Within the Bayesian decision-making framework, some measure of preference between different potential outcomes is required, which is referred to as utility (Berger 1985). While utility can have a clear meaning as a theoretical quantity, measuring it for an individual or a community is in practice more difficult.

This paper sets out a summary of the methods used by a new technique, ParFish, to capture stakeholder knowledge about the resource and identify what outcomes the stakeholders want from the management of the fishery.

MODELLING FRAMEWORK

ParFish uses a standard modelling framework, which is widely used in fish stock assessment. An operational fishery dynamics model describes how the fishery changes over time. The dynamics model should have parameters, which decide its quantitative behaviour, and fishery controls, which management is able to manipulate to improve the fishery. Typical fishery controls include effort and total catch quotas, closed areas, seasons or minimum size and so on. The uncertainty surrounding the model is encapsulated in the parameter probability density functions. Random draws of parameters from the probability density functions can be used to project the population forwards and estimate the outcome of the fishery in response to different controls. These random projections can be used to carry out a Monte Carlo integration and find the expected values for parameters of interest, such as the population biomass, spawning stock biomass, and catch under different management controls.

Bayesian analysis provides a framework for combining a number of different information sources as priors and likelihoods to produce posterior probability density function for the model parameters (Gelman *et al.* 1995). Priors represent subjective belief of the values in question, and are not based on observations. Likelihoods are probability densities built from observational data only. As long as separate sources of information can each be converted to probability density functions, Bayes' theorem can be used to combine them into a single "posterior" probability density function which represents the final result, including uncertainty.

In practice, only the simplest of models are likely to have parameters estimable for data-deficient fisheries. A logistic biomass dynamics model (Schaefer 1954) has been developed and used in ParFish, and an alternative length-based assessment method is under development and testing. The methodology surrounding the former is described in detail below to illustrate the approach. It should be noted however, that ParFish could be adapted to many different fishery models.

The biomass dynamics models possess an advantage in their simple demands for data (catch and effort) and in their basic assumptions. They provide advice on a limit reference point, the maximum sustainable yield (MSY), which can be used to restrict the risk of unsustainable fishing to an acceptable level.

In the difference equation form, the multi-gear logistic fisheries model is written as an equation describing how the population changes through discrete time (usually annual), as:

$$
\begin{aligned}
B_{t+1} &= B_t + rB_t\left(1-\frac{B_t}{B_\infty}\right) - C_t \\
C_{gt} &= \frac{F_g}{\sum_g F_g}\left(1-e^{-\sum_g F_g}\right)B_t \\
F_g &= q_g f_{gt}
\end{aligned}
\qquad (1)
$$

Where:

B_t is the stock biomass at time t,
C_t is all catches combined in the fishery
F_g = fishing mortality
q_g = catchability, and
f_g = effort for gear g.

The model requires three population parameters: B_{now} = state at the start of the projection ($B_0 = B_{now}*B_\infty$), r = the rate of population growth, B_∞ = unexploited stock size, and as many catchability parameters as there are gear types.

The state of the stock is defined as the biomass (B_t) divided by the unexploited biomass (B_∞). If the stock state falls below that required for the maximum sustainable yield (0.5), the stock is overfished.

The biomass dynamics model supports three types of control:

i) Effort control: this is applied through the catch equation used in the simulation models. A new effort is set as the new control and the stock is projected forward from its current state under the new fishing mortality. More complex changes to effort, as might be used in a management strategy evaluation are not supported.
ii) Catch quota control: this is applied as a future limit to catches. A new effort must also be supplied as the maximum effort, which is used to calculate catches. If catches exceed the quota, this maximum effort is scaled back to a level where the catches are met. This allows effort to change, but catches remain fixed if the effort is high enough to reach it and if the stock is not overfished. Setting the quota above the MSY means it will have no effect and the maximum effort control will apply.
iii) Closed areas: these provide a refuge for fish from fishing by establishing no-take zones. This is modelled by defining the proportion of the unexploited stock which is protected and sharing biomass growth in this same proportion. This rather crudely models the argument that no take zones protect part of the spawning stock, while trying to take into account the impact on the fishery of reducing the area for exploitation. Such zones may provide many benefits beyond those dealt with in this assessment model, for example, maintaining unexploited habitat, biodiversity and ecosystem for purposes other than fishing.

The models not only report probabilities for catches, CPUE and so on, but also provide specific advice in the form of target and limit fishing controls. In most cases, uncertainty is the dominating factor in data-poor fisheries. The models and results need to be robust to this uncertainty and yet provide specific advice. This is achieved by defining target and limit reference points as the fishery controls which maximise the expected preference for the catch and fishing effort, or have some acceptable maximum probability of depleting the resource below a biomass limit.

The simulation model calculates the overall catch and effort for the fishery projection. These can be converted to the relative change in CPUE and effort from the current CPUE and effort. These relative changes are assumed to apply equally to all fishers, so that if CPUE is 85% and effort 80% of the initial CPUE and effort, then each fisher's new CPUE and effort will also be 85% and 80% of his/her current CPUE and effort, respectively. The main assumption is that any effort or other control is applied proportionally to all fishers.

The optimum Bayesian decision is to choose the action that maximises the expected preference. Using the preference data and model, the discounted preference score can be summed for each simulation leading to a relative measure of how much that outcome would be preferred over the others. The expected preference score is the average of the simulations where the simulation parameters are drawn at random from their posterior probability distribution.

The limit reference point is designed to identify the level of the chosen control that would limit the chance of the stock being overfished to some acceptable level. An overfished stock is defined here as the stock biomass being below some limit state defined as the proportion of the unexploited biomass. The limit state may be set by the user, but a generally-accepted value for the logistic model is 0.5 of the unexploited stock. The probability is calculated as the chance that a scenario state taken at random from all scenario states combined over time and simulations, is below the limit state.

STOCK ASSESSMENT INTERVIEWS

ParFish captures stakeholder knowledge on the stock dynamics using 'stock assessment interviews'. The methodology is based on that suggested by Press (1989), who tried to estimate the probability of a nuclear war — a hopefully unobserved event — by interviewing a large number of experts and building a probability density function from the individual point estimates. This approach was adapted for ParFish by making the questions both clear and simple, and designing questions that would be within the sphere of knowledge of the fishers. The values on which opinions are sought can not usually be obtained directly (e.g. f_{MSY}, MSY), but through the interpretation of a model. The model will not be known by the fishers, so there are implications to their answers which they would not necessarily understand or agree with. For this reason, results need to be discussed with stakeholders to confirm them.

The interviews for the logistic biomass model are based on four key questions outlined below. Although there are only a few questions, it is recognised they are not easy to answer. Other questions are required to provide a foundation for the interview and some explanation for the approach is also needed. In particular, the time, catch and effort units need to be clearly defined and used consistently for all interviews. This applies both to the stock assessment and preference interviews. Although an obvious point, this has sometimes proved to be a problem for both interviewers and interviewees.

The key questions obtain the following information for each fisher:

i) The fisher's main gear, last year's CPUE (qB_{t-1}) and this year's CPUE (qB_t) for this gear. These are assumed to be proportional to the biomass.
ii) A CPUE range for the unexploited stock (E_l, E_k).

iii) The time needed for the stock to recover to its unexploited state (E_l), if fishing were to cease (T).
iv) The total effort in this fishery over the last year (f_{t-1}), which must be obtained from other sources.

The individual answers from fishers are then used to estimate the four parameters for the logistic model for each fisher. This identifies a set of parameters most consistent with the views of the fisher, but conforming to the requirements of the model.

The individual catch rates are regressed towards the mean of the sample. This is necessary as they are used as an estimate for the mean catch rate in the fishery. For the j^{th} fisher:

$$\left[\hat{q}B_t\right]_j = \left(\left[qB_t\right]_j + \left(\sqrt{N}-1\right)\overline{qB_t}\,\right)\Big/\sqrt{N} \tag{2}$$

Where: $\overline{qB_t}$ = mean catch of the sample.

The intrinsic rate of increase (r) can be calculated by solving the non-linear projection equation for the unknown r based on the logistic population model:

$$X_1 = X_0\left(1 + r\left(1 - X_0\right)\right) \quad \cdots \quad X_T = X_{T-1}\left(1 + r\left(1 - X_{T-1}\right)\right)$$
$$X_0 = \frac{\hat{q}B_0}{\hat{q}B_\infty} = B_{now}, \quad X_T = \frac{E_l}{\hat{q}B_\infty}, \qquad \text{and} \quad \hat{q}B_\infty = \frac{E_l + E_h}{2} \tag{3}$$

A value of r is found for which the population will rise from the current stock state to the unexploited state over the time specified by the stakeholder. The value for r, however, is limited to the range 0–2, as outside this range the logistic difference model becomes unstable and biologically unrealistic. Catchability (q) can be estimated from the current catch rate and effort adjusted for the stock change due to production and catch:

$$\hat{q} = \left(\frac{\left(\hat{q}B_{t-1} - \hat{q}B_t\right)}{S} + r\,\hat{q}B_{t-1}\left(1 - \frac{\hat{q}B_{t-1}}{\hat{q}B_\infty}\right)\right)\Big/ f_{t-1}\,\hat{q}B_{t-1} \tag{4}$$

This assumes a linear relationship between catch and effort, but should be an adequate approximation unless fishing mortality is high. The time S allows the time unit to be altered. For example, converting from a year to a month S is set to 12. This allows r to be rescaled between 0 and 2.0.

The point estimates of the parameters from the fishers are converted to a smooth probability density using a kernel function (Silverman 1986). This involves fitting a smoothing parameter to each of the principle components generated by the data using least squares cross validation, which together produce a smoothing matrix for the multivariate normal kernel. The smoothing matrix is important in that it defines the weight given to the interview data within the Bayesian analysis. In general, the more agreement there is among interviewees, the higher the weight given to the interview data.

PREFERENCE INTERVIEWS

The 'preference interview' aims to elicit peoples' preferences for various potential catch-effort scenarios. Interviews are based on households as the fundamental economic unit. A random selection of household representatives should be interviewed. Preference interviews are based upon relative changes of two variables: fishing effort, representing economic inputs such as labour; and catch, representing the economic outputs such as income.

In the case of fishers, who have usually been the target of the preference interviews, scenarios represent possible changes in the catch and effort as they relate to the fisher. Changes are represented as combinations of +/-25% and 50% of catch and effort relative to the present situation (scenario I), for each respondent, and are constructed to maximise the information obtained from an interview. The scenarios, which are given a letter for easy identification, can be laid out in relation to the current catch and effort (Figure 1).

The objective is for the interviewee to rank these scenarios in order of preference, then score them relative to each other. This is used to calculate a preference score for each scenario, which can be used as a measure of utility. Ranking uses a combination of two techniques:

i) Comparisons between pairs of scenarios make the process as simple as possible. Pair-wise comparisons have the advantage that they are relatively easy for people to do and contain an internal consistency check to ensure the answers given make sense (Saaty 1995).
ii) The number of comparisons is minimised by using dominance and a binary tree to organise the scenarios as the interview progresses. Dominance occurs where one scenario clearly is better than another without having to ask the interviewee. For example, a rational fisher is almost certain to prefer a scenario with the higher catch between two scenarios with the same effort.

Once the scenarios have been ranked, each one is scored relative to the scenario immediately above and below in the ranked list. For each pair of consecutive scenarios, a score from 0 (no difference) to 4 (large difference), is elicited from the interviewee. The score for each scenario is calculated as the cumulative sum of these difference scores between the ranked scenarios, starting with the least-preferred scenario. This assumes that scores between ranked scenarios are additive, as they are assumed to measure the relative distance along a single utility variable.

Bayesian analysis uses the preference score as measure of utility, to choose between alternative outcomes. The ranking alone represents utility to a certain extent. A scenario clearly has a higher utility if it is preferred to another. Quantifying the distance between scenarios is more difficult and probably not very accurate. However, the ranking itself provides considerable information on the relative value of changes in catch and effort in the fishery.

The preference score needs to be calculated from these 17 points derived from the interview scenarios. The rapid nature of the interview prevents detailed evaluation of the scores in any particular case, and individual preferences, while potentially of interest, are unlikely to be reliable by themselves. Errors are reduced in two ways: firstly as many interviews as possible should be conducted; secondly, for each interview, a simple polynomial is fitted to the scores based on an assumed underlying quadratic utility:

$$U = \alpha_1 c + \alpha_2 f + \alpha_3 c^2 + \alpha_4 f^2 + \alpha_5 cf \qquad (5)$$

Where f = relative change in effort, c=relative change in catch and α_i = fitted parameter. This allows smooth calculation of preference between 50% and 25% catch and effort scenario points (Figure 2).

In order to account for unrealistic preference scores resulting from extrapolating beyond the interview ranges of catch and effort, maximum and minimum catch rates, minimum catches and maximum effort are obtained during the interview. This restricts scores to a realistic range, and in particular prevents the model calculating scores too far away from the current level, which could lead to inappropriate advice.

Because the fishery model projects over time, the preference score also needs to be discounted. Either a national bank rate can be used, or a discount rate can be elicited as part of the interview. ParFish includes a technique to do this based on a type of widely-used saving scheme where savers put money into the scheme in sequence, while one person in each time interval receives all the money.

Given a time series of projected catch and effort as proportional changes from the initial catch and effort, the time series of preferences can be obtained based on equation (5). The discounted mean preference score is calculated as:

$$U = \left(\sum_{i=1}^{n} \sum_{t=0}^{T-1} P_i U_{it} e^{-\delta t} + \frac{U_{iT} e^{-\delta T}}{1 - e^{-\delta}} \right) \Big/ n$$

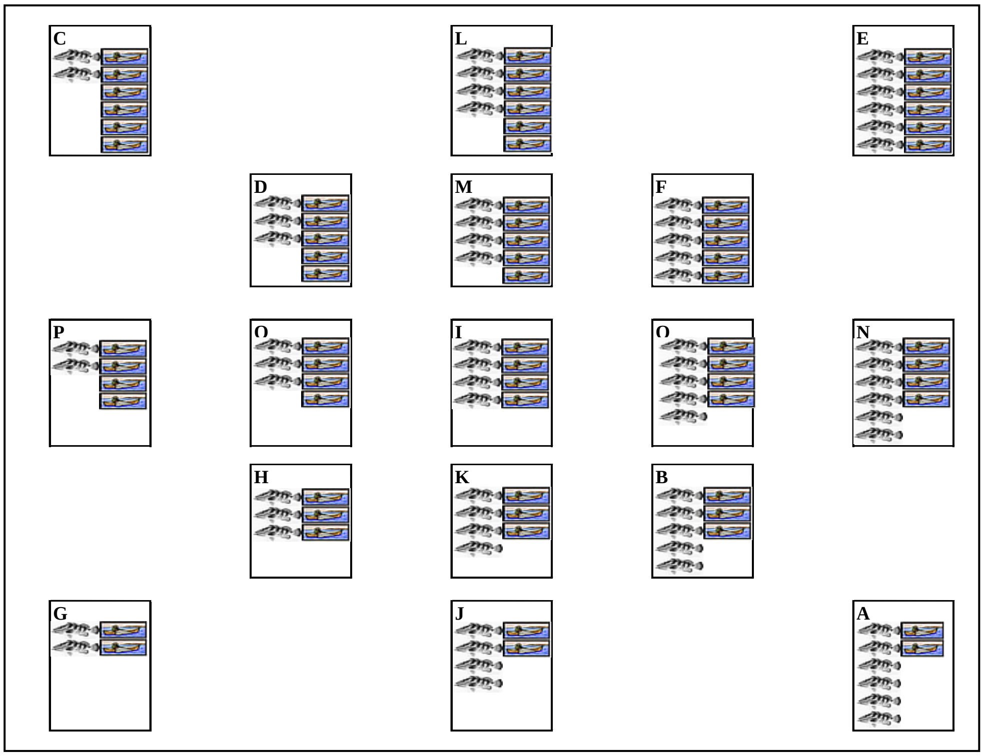


Figure 1. The different scenarios used to assess fisher preference. The central scenario I represents the current situation with 4 fish and 4 boats representing the current catch and effort respectively. Effort and catch is decreased by 25% and 50% around this current value. There are 17 scenarios which need to be ranked from the best, Scenario A to the worst Scenario C.

Where:

U_{it} is the preference score of fisher i at time t,

P_i = the fishers importance (if used), and

d = discount rate. Importance weights a fisher's score, and could represent the importance of the fishery to his/her household income and the size of the household, which are optional questions in the interview.

Note the projection only has to be continued until an equilibrium state is attained (i.e. catch and effort longer change) at some time T, where after the infinite sum can be calculated as in equation (6). The mean score is the total divided by the number of fishers (n).

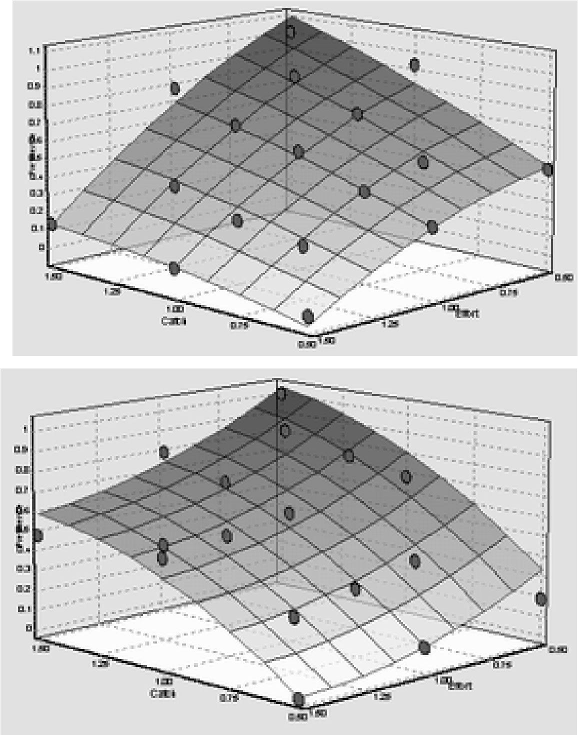


Figure 2. Example preference curves fitted to interview data. In cases of point outliers, the interviewer could check back with the interviewee that the scenarios are in the right order if this were possible.

OTHER DATA

A Bayesian approach to the analysis of data (Gelman *et al*. 1995) allows inclusion of any data for which there is a likelihood including at least one of the parameters for the simulation model. For the logistic model, biomass surveys, catch and effort time series and fishing experiments can all be used. For example, in the ParFish software the logistic model can be fitted to a catch-effort time series to generate a likelihood for all parameters in the standard way (Haddon 2001). The ParFish software also has provision for fishing experiments, as these are particularly valuable in encouraging stakeholder participation in the data collection and assessment.

Fishing experiments, where a small area is intensively exploited over a short time, can be valuable for estimating catchability (Gaudian *et al.* 1995) and current stock size. The area fished needs to be scaled up to the whole area, and, because the current state of the stock is unknown, it can be difficult to interpret the estimate of stock size. However, the catchability estimate is informative and helps provide a reasonable assessment of the total biomass. Perhaps more importantly, fishers can be involved in the experiment, which demonstrates in a practical way the impact of fishing on the stock.

COMMUNICATION

ParFish is not only a stock assessment tool, but also a method to try to initiate monitoring and control without waiting for research (FAO 1995). Within a participatory framework, management decisions are made by stakeholders. For this to work, stakeholders must be able to make informed decisions, and in particular need to understand the scientific information they are being presented with.

In fisheries, population dynamics and uncertainty are key concepts. However, understanding the science can be difficult because of the dominant role of uncertainty. ParFish includes techniques which help to explain the issues and concepts to stakeholders and develop a common language to communicate among the group.

In population dynamics, stakeholders need to understand that stock size is finite, can be depleted and can recover dependent on its size and productivity, and its productivity is reduced if it is over-exploited. It is also necessary to consider the assumptions of the model and the concept of MSY and the catch rate associated with this. Visual aids can be used to illustrate these ideas, and have been used successfully in various fisheries, including a 'bau' game and scenario cards (Figure 1). Using concepts that were also used during interviews helps develop a common language.

Most of the results from the assessment can and should be presented as probability density functions (Figure 3). These can be difficult to understand, but can be explained based on the same assumption as used to estimate the probability density function from the stock assessment interviews, where uncertainty is represented as differences of opinion (Figure 4).

The Bayesian concept of uncertainty can be illustrated using a simple technique involving a large jar containing a number of oranges or similar objects which stakeholders are required to estimate (Fiure 4). Participants provide their estimates independently of each other first with and then without the clear jar being covered in paper. When estimating the number of oranges, the group mean can be guaranteed to be a consistently better estimate than any individual's estimate. The estimates tend to converge when the paper is removed. This conceptually represents the role of science — introducing accepted information among stakeholders should increase agreement, effectively decreasing uncertainty.

This same approach can be used to explain some results. In an assessment in Tanzania and using information only from the fisher stock assessment interview, results indicated a 70% probability that the stock was overfished. This can be represented as 7/10 fishers or 70 people out of 100 believing the stock is overfished. Including scientific information from a fishing experiment, this probability was reduced to 50%, which can be represented as 5/10 fishers or 50 out of 100 people believing that the stock is overfished. This is clearly not a definitive result even with the scientific information. The discussion in this case revolved around possible options to firstly stabilise the fishery by controlling effort to the current level, and secondly collecting information to decrease the uncertainty.

The type of information required is that which would change the participants' view on the fishery status. In this context, science has an important role in reducing disagreement among stakeholders, and therefore stakeholders should be involved in designing and implementing any data collection and research programme. Routine catch and effort data collection, and adaptive management using closed areas and fishing experiments have important roles to play in on-going improvements to management.

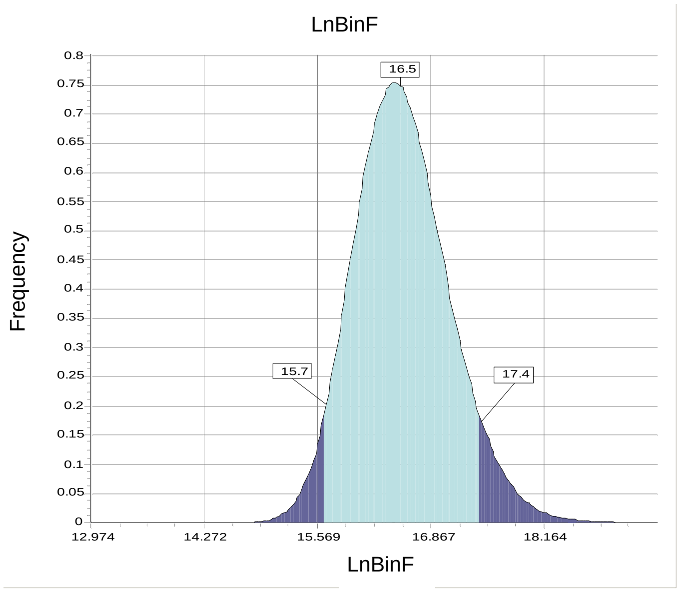


Figure 3. Probability density for the logarithm of the unexploited stock size estimated as a smoothed frequency of random draws from the posterior probability density function. The graph is one of the standard outputs from the ParFish software. The 90% confidence interval and median values are also indicated.

DISCUSSION

The ParFish approach has four distinct advantages over other stock assessment approaches:

i) The fishers are involved through interviews. Even if individual stakeholder beliefs are unreliable, the collective view on stock status and behaviour is likely to be broadly correct. There is also considerable advantage in involving fishers, since they can see that their views are being taken into account and they are therefore more likely to comply with the resulting decisions.

ii) Data from many sources can be combined, and in particular, rapidly-collected data can be used and so can provide a start point for an adaptive management system. Depending on the model, published information from Fishbase for example, might be used as the basis for additional probability density functions for parameters, which can be easily incorporated into the posterior.

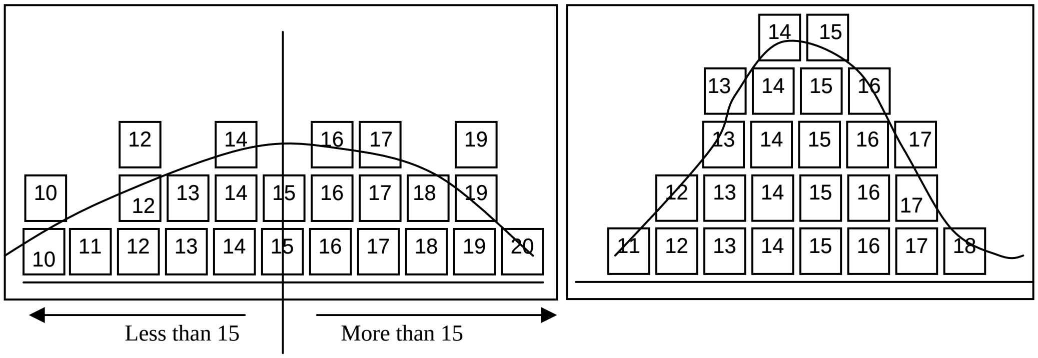
iii) The method applies decision analysis, making use of utility and risk to help in deciding the most appropriate management actions. This means that the method can be used even when only a little information is available.

iv) Combining sources also allows information to be built up for quite complex models. For example, breaking down complex models into simpler building blocks could make multispecies assessments easier.

The ParFish software implements procedures described in this paper using a general robust numerical approach. This software is not a requirement, but should help implementation for those unfamiliar with technical aspects of fitting Bayesian models.

For most small-scale fisheries, no stock assessments exist because it is too expensive to apply standard methods. Management might still be introduced, but without scientific advice, there is no guarantee that it will protect or improve the fishery. Science has an important role in improving management, but should not be used as a reason for postponing or failing to take measures to conserve the fishery (FAO 1995).

The role of science in fisheries needs to be clearly delineated. Science is necessary to minimise the number of poor management decisions, build real knowledge of the resource over time and arbitrate between conflicting views on how the resource should be managed. However, uncertainty will always exist in all management decisions and needs to be taken into account. Presenting scientific results as absolute certainties is misleading and undermines scientific evidence. As scientists cannot assess the stakes at risk themselves, they cannot and should not directly advise on which decision to take, only the likely consequences.



Points to note:
Larger range of estimates (10 – 20)
More spread out, flatter curve – less agreement about the number of oranges

Points to note:
Smaller range of estimates (11 – 18)
Higher curve – more agreement around middle values

Figure 4. Using the orange jar concept to describe the uncertainty surrounding the state of the stock. In this example just under half of a room full of people believed that there were less than 15 oranges in the jar (the true number). When there was a piece of paper covering the jar (left), and the curve is relatively flat showing a higher level of uncertainty than when the paper was removed (right).

Even if it is accepted that local people might be better-placed to make decisions for their own welfare, it is possible that interviews do not gather accurate data representing their views. For the preference interview, people may not know what they want, and individual preferences should not be over-interpreted. However, by accumulating a number of interviews and using these to evaluate the relative preference between possible future outcomes, it is hoped that some true overall preference is approached. Furthermore, the preference cards and scores can be used to explore with stakeholders the potential impacts that management actions might have.

The interview questions help fishers think more about possible outcomes for the fishery. If participatory, community- or co-management is to be successful, it is important fishers understand possible management outcomes and can weigh up the impact of these on themselves and the community. This assessment approach not only obtains data for assessment, but starts fishers thinking about what might happen and what they would prefer to happen.

However, it is likely if ParFish is used, decisions might be based on interview data alone. Given that interviews may not necessarily contain good information, it is possible that the method could lead to poor decisions, worsening the status of the stock. In theory, interviews could lead to poor results due to bias and prejudice among stakeholders. In practice, it seems less likely these problems will make using the method worse than doing nothing.

The method has been tested on a fishery with good catch and effort data, so that the accuracy of the interview information could be compared with the standard stock assessment. In particular, it was of interest to see how well management would do if actions were based only on the interview data. The Turks and Caicos Islands conch fishery was identified as a suitable location because of its long catch and effort time series.

The fishery is managed through a quota, so this is the appropriate control. A standard stock assessment using the logistic model fitted to the catch-effort time series which is currently used to set the quota has suggested a safe level would be around 1.5 million pounds landed weight (Medley and Ninnes 1999). Using the preference information, the stock assessment based upon both the combined interview and catch-effort model and the catch-effort model alone suggested quotas of around 1.53 and 1.38 million pounds, respectively (Table 1). Interviews by themselves were much less accurate (as indicated by the much lower limit control), but nevertheless recommended a target of 1.68 million pounds, reasonably close to but above the other target controls.

Pretending that the fisher interviews were conducted in 1974 as opposed to 2002, the interview-only target control of 1.68 million lbs was applied in the simulation instead of the actual catch series over the same period. The actual total catch over the period 1975 - 2002 was 45.47 million pounds. Had the 1.68 million pound quota been applied in 1974, the results suggest a total catch of 47.00 million pounds. This quota would realise higher catches in the longer term by foregoing higher catches in the late 1970s.

A discount rate of around 5% yields approximately the same net present value between the two options.

The real gain, however, would have been the rise in catch rate (Figure 5). The catch-effort model suggests the stock was in an overfished state in 1974 and an enforced quota would have led to stock recovery. In other words, the catch would be met with much less work and costs than is now applied (from 3,300 boat days down to 2,500 boat days to realise the same catch) (Table 1). This case indicates considerable benefits to using just interviews in the absence of other data, but would need more testing to make the case as a general statement. In particular, in cases where it turns out the logistic is not the best model, it needs to be shown that interviews may still have value in setting initial targets. However, with ParFish also helping to initiate long-term monitoring and research programmes, it is difficult to believe any initial problems would prevent a fishery from moving towards a sustainable and profitable fishery in the longer term.

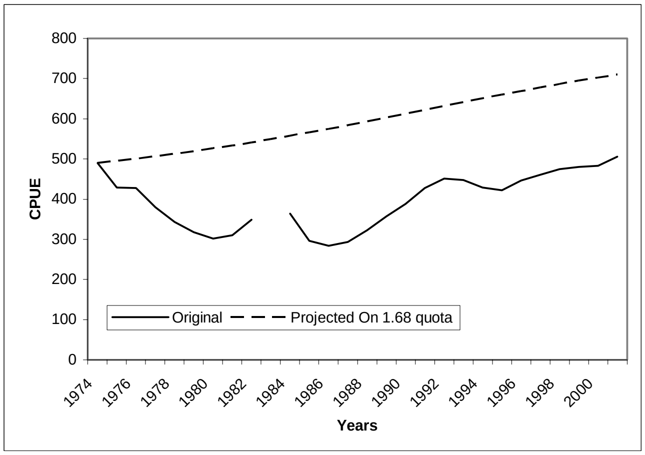


Figure 5. Expected catch per boat day (CPUE) from the fitted logistic model including the observed catches and the projected CPUE using the same model but with a 1.68 million pound quota.

Table 1 Target and limit controls (landed TAC lbs) for the Turks and Caicos Islands onch fishery based on the ParFish method using catch-effort and interview data.

Scenario	Target Control (lb)	Limit Control (lb)
Combined interview and catch-effort model	1,531,254	1,580,855
Catch-effort data only	1,384,883	1,432,696
Interview data only	1,678,103	791,651

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