A review of bioeconomic and sociological FAD modelling, with recommendations for future research projects

by Jim Anderson

In the first issue of the SPC FAD Information Bulletin, we presented abstracts from the first two documents of Jim Anderson's work on 'The assessment of the interaction between fish aggregating devices and artisanal fisheries'. *The following is extracted from Document 5,* 'A review of bioeconomic and sociological FAD modelling, with recommendations for future research projects', *in which Jim Anderson briefly reviews the history of FAD research and gives directions and recommendations for future research.*

Recommendations for future research

In this section recommendations are made for the specification of projects or project components which would contribute meaningfully to FAD research and its application to fisheries development and management problems. The philosophy behind these proposals is that we should build upon the FAD work that has already been done, in ways that specifically address the most pressing open questions about the nature and use of FADs.

Dissemination of information

There should be regular projects to interpret and disseminate information related to FADs to fisheries managers.

Multi-criterion and decision making (MCDM), and expert systems

Develop MCDM based expert system to assist with all decision making relating to FAD development and planning. This could be based on the FAD Handbook and report accompanying this document. Sociological analysis using the systemic approach should be included. The system should not operate as a 'black box' but rather provide a framework within which all relevant questions are addressed while showing clearly how answers are derived and how goals and priorities affect decisions.

Analytical methods

- Develop software to do sensitivity analyses on:
  - parameters in biomass exchange models for estimating yields and optimal effort levels;
  - assumptions on which cost-benefit analyses are based; or
- Write a thorough, step-by-step description of how to implement such a sensitivity model in a spreadsheet.

Investigation of the aggregation effect

It is important to quantify how fish aggregate and disperse, so that models can be applied in fisheries management. In the process, clues as to why they behave in this way may also emerge. Two approaches are recommended here—one to examine the relationships expressed in the biomass exchange models of FADs and another to look for the effects predicted by diffusion and optimal foraging models.

The first approach would be to try to determine at what rate fish accumulate at FADs, and what relation this rate has to the biomasses of fish at the FADs and in the underlying stock. This would include quantifying the loss of fish from the FAD to determine whether it is a constant- or density-dependent proportion of the biomass at the FAD. Seasonal effects would have to be accommodated. Different age / length classes may well aggregate in different ways, and this should be quantified.

For a start, where possible, use should be made of the data sets that exist, e.g. the data from the Solomon Islands industrial purse-seine fishery. Further data would have to be collected by monitoring a number of FADs and measuring how the number of fish (in various length-classes) at each FAD changes over time.

A good pre-FAD dataset would be useful. Measurements could be made by visual survey, sighting counts, or by taking acoustic soundings at the FADs. Water samples, plankton net samples, climatological and oceanographic data should be collected so that any correlations that exist can be detected. A series of experimental, unfished FADs would be ideal but expensive. Whether experimental or commercially exploited, the FADs should be chosen / placed so as to cover as many of the following categories as possible.

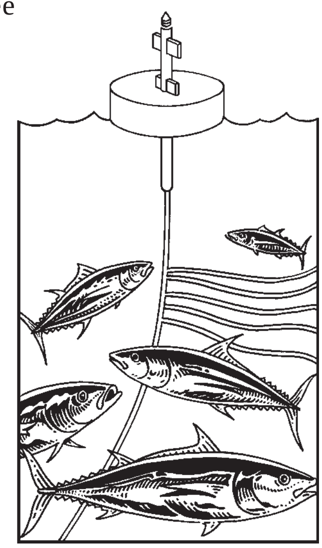
- Deep water FADs that are fished by purse seiners are regularly stripped of most of their fish. The manner and rates at which those FADs are repopulated could be measured. Length and age composition of the catch could also be correlated with the number of days since it was last fished, to see what patterns emerge.

- FADs that are fairly lightly used by artisanal fishermen would be interesting because they are more likely to be close to equilibrium. Catches as well as population movements would have to be monitored.

- Neritic (shallow water) pelagics such as bonito and frigate mackerel seem to be less migratory than others. In such positions it might be possible to estimate population biomass of the base stock. Measurements of migration to and from FADs in such areas could be correlated to the base stock and FAD biomass. The FAD and species would have to be chosen carefully because the aggregation effect is likely to be weaker in these areas.

- Sites where FADs are fairly densely placed would be particularly interesting if tuna were also tagged in order to watch them move between the FADs. Commercial FADs are generally placed further apart than the 'safe distance' of about 10 miles. To measure movement between FADs that are closer than that, an experimental setup would be needed. The ideal would be to observe a matrix of FADs about four to five miles apart, and then to remove intermediate FADs and monitor the effect on distributions.

- It has been reported that tuna schooling behaviour is different in different oceans. Old fish tend to school around mammals in the Indian and Atlantic oceans whereas younger ones (and often mixed schools) are found around FADs in the West Pacific. Differences between the oceans, such as quantity of floating objects or behaviour of currents, should be investigated; any correlations could possibly provide insights into aggregation behaviour.



The second approach is aimed at testing diffusivity models and should begin with a study to estimate which of the predicted effects would be observable at all, given statistical variation. If the results are favourable, one could:

- determine whether heavy fishing in an area enhances immigration to that area i.e. whether FAD recruitment is density dependent. This could be added to the first approach, by including FADs that are heavily but continuously fished, rather than pulse fished.

- look to see whether there are fewer fish in the regions adjacent to a FAD catchment area than there are in the open ocean. This would require estimates of abundance at various distances from the FAD. Either research catches or sonar would have to be used, since fishermen will not fish in areas of known lower abundance.

- estimate deviation from constant diffusivity at certain times. The first group of biomass studies could be extended to include seasonal variation in the aggregation effect.

- determine whether there is a component of migration that is simply the result of diffusion combined with seasonal movement of the tolerable environment. This would require investigation of the oceanographic and climatological changes that take place along the known migration routes of tuna. If correlations exist, a diffusion model could be set up to try to imitate known tuna migratory behaviour using only diffusivity.

- if the structure of the model seems correct, estimate the diffusivity constant empirically for particular fisheries. Estimates of diffusivity have been reported in the literature. Methods for making such estimates should be investigated and applied adaptively to real fisheries.

Selecting figures of merit for FAD effectiveness analysis

Most bioeconomic models of conflict between user groups use optimisations based solely on the goals of economic efficiency. Other goals are harder to formulate and vary greatly between fisheries. It is recommended that an interdisciplinary team of biologists, economists, social scientists and mathematicians investigate this issue. Goal programming, which can handle multiple goals, may be more useful than single-criterion optimisation techniques. The possibility of using multi-criterion decision-making techniques, game theory or the systemic approach as a procedure for determining goal functions should be investigated.

An adaptive research phase to implement developed techniques in specific fisheries would be important. It is possible that a weighting of objectives which is revised iteratively according to observed data may be more useful than a fixed framework.

Biological modelling

There are a number of ways in which existing biological models could be expanded to make them more representative of FAD fishing.

- Develop a bioeconomic model along the lines of the existing biomass exchange models (Samples and Sproul, Hillborn and Medley) but accounting for multiple cohorts where specific year classes are preferentially attracted to FADs. This sort of age-linked behaviour is considered very likely. The project should examine management implications of such a differentiation.
- Expand on Hillborn and Medley's model by including the spatial distribution of FADs and allowing for boats to search for the largest schools before making a set. Include a stochastic arrival and departure model, for example assuming fish come and go in schools that are small subsets of the stock population. It would be interesting to include a diffusion or optimal foraging model and see how this influences biomass equilibria.
- Look at the dynamics of games between multiple boats placing FADs with more subtle decision criteria than the ones used previously, for example each one deciding when it would be advantageous to place more FADs.
- Refine existing spatially-distributed models to include ideas and concepts which have been successfully incorporated in other types of models, such as density-dependent diffusivity, schooling and pulse fishing.

Many of these modelling projects would benefit from contributions from many disciplines. Research directions which span more than one field of technical expertise are usually the slowest to mature, but it is from such fields that whole new directions of scientific endeavour often emerge.

Fishing for tuna around floating objects

by Alain Fonteneau & Jean-Pierre Hallier

This article was published in the French magazine La Recherche *in 1992, following the IATTC annual meeting. It is interesting to note that the ecological consequences of an extensive use of FADs started to be questioned at this time.*

One distinguishing feature of tunas is their habit of aggregating under floating objects. A new fishing technique capitalises on this surprising and as-yet unexplained habit.

Industrial fisheries in all the world's oceans are now beginning to take the advantage of an unusual event long known to artisanal fishermen in the Philippines. Schools of tunas and other fish species tend to gather under objects floating on the ocean. In order to study this behaviour, a group of scientists, including the authors of this article as representatives of ORSTOM, met at La Jolla in the United States in February 1992 at the invitation of the Inter-American Tropical Tuna Commission (IATTC). The meeting report, just published (Annual IATTC report, Tunas and floating objects: a worldwide review, 1992), is the first world review of knowledge on this topic.

The annual industrial tuna fishery catch worldwide amounts to over 2.5 million tons. The three main tropical species, yellowfin (*Thunnus albacores*), bigeye (*T. obesus*) and skipjack (*Katsuwonus pelamis*) are open-ocean fish and account for the vast majority of tuna landings. The skipjack is a small tuna weighing between one and five kg, while yellowfin and bigeye can weigh as much as 100 kg. Tuna is chiefly caught with the purse seine, a 1,800m-long net, which is drawn