3 INTRODUCTION TO BIO-ECONOMIC MODELLING[2]

This session provided participants with an introduction of the three different modelling approaches to be subsequently applied to the demersal fisheries of the Gulf of Thailand. The session also reviewed some of the earlier applications of the Gordon-Schaefer model to these fisheries.

3.1 GORDON-SCHAEFER MODEL

Dr Mahfuzuddin Ahmed, ICLARM, commenced his presentation with a brief overview of the major causes of biological and economic overfishing and the difficulties that countries face in addressing them. He noted in particular the high exclusion and transaction costs (e.g. enforcement and information acquisition) and inadequate legal and institutional frameworks that hamper developing countries' efforts to achieve effective fisheries management.

He noted that bio-economic modelling was a tool to better inform fisheries management, both at the planning and implementation stages as well as to evaluate management performance. Among the various modelling approaches, the Gordon-Schaefer Model (GSM) has the big advantage of requiring limited data only, but this advantage comes at the cost of needing to make some simplifying assumptions. The GSM is a single-species model and therefore, by necessity, its application to a multi-species and multi-gear fishery would produce only a rough guidance on desirable fleet size and fishing effort. Nevertheless, the GSM has a great value for crosschecking the results of other modelling approaches that rely on larger (and perhaps less robust) data sets and it is well suited for the analysis of single species fisheries.

3.2 BACKWARD-BENDING SUPPLY CURVE ANALYSIS

Dr Rungrai Tokrisna, Kasetsart University, presented Cope's model of the backward-bending supply curve that does not rely on the assumption of fixed output prices, thereby explicitly including an analysis of the impact of changes in fish demand on optimum harvesting effort. As against the GSM, Cope's model is based on average and marginal costs as functions of catch rather than functions of fishing effort.

She then made an exposé of the economics of alternative management measures including taxation, total and individual quotas, licensing and other measures and discussed some pertinent criteria for evaluating management regimes in general.

Regulations should have a fair chance of success, be flexible and should be supported by most of the fishermen. They should achieve efficiency but take full account of management costs, impacts on employment, income distribution and political factors that might impinge on the ability to implement them.

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[2] For detailed expositions on bio-economic modelling, the reader may wish to consult the following publications: Hannesson, R. 1993. Bioeconomic analysis of fisheries. Published by arrangement with FAO by Fishing News Books and Seijo *et al.* 1998. Fisheries bioeconomics – theory, modelling and management. *FAO Fish Tech. Pap.* No. 368. FAO. Rome.

3.3 PAST APPLICATIONS OF THE GORDON-SCHAEFER MODEL TO THE GULF OF THAILAND

In reference to an analysis by Panayotou and Jetanavanich, Dr Rungrai Tokrisna presented the results of past applications of the GSM and Cope's model to the Thai fisheries in the Gulf of Thailand.[3] The base year for the analyses was 1982 when the total number of standardized fishing effort units was estimated at 19.2 million (expressed in standard trawling hours). At that time, the trawl fishery produced a catch of some one million tonnes and yielded an estimated total profit of 1.5 billion Baht. Given the limitations of the GSM model as explained above, it was estimated that effort would have had to be reduced by 46% to 10.4 million effort units to produce the maximum economic yield (estimated at 2.7 billion Baht). A much lower reduction of fishing effort by 18% only would have been required to produce the maximum sustainable catch estimated at 958 000 tonnes. Irrespective of the limiting assumptions underlying these estimates, it is notable that fishing effort and fishing capacity have continued to increase since that time and that catch per unit of effort has further declined.

As would be expected on theoretical grounds, the required reduction in fishing effort under the Cope's model to produce Maximum Economic Yield (MEY) was with 39% somewhat less than with the GSM. The reason is that by accounting for the combined benefit of consumer and producer surplus, the optimal catch is higher. As the GSM assumes fixed output prices, changes in consumer surplus as a result of changes in fish supply (i.e. landed catch) are excluded from the analysis. The total combined producer and consumer surplus at MEY was estimated at 14.2 billion Baht as against 11.5 billion Baht estimated for the reference year.

3.4 FEATURES OF BEAM 5

Mr Per Sparre, Danish Institute for Fisheries Research and Mr Rolf Willmann, FAO, introduced the **B**io-**E**conomic **A**nalytical **M**odel No. 5 or BEAM 5 model (see also Appendix F)[4]. It is a multi-species, multi-fleet dynamic software implementation of a bio-economic stochastic simulation model. It is the fifth in a series of bio-economic models produced by FAO aiming at assisting fisheries researchers and managers to generate improved advice for fisheries management and policy-making. All five models use the Thompson & Bell biological model, but with large variations in detail and complexity.

BEAM 1 and BEAM 2 are very simple single-species models.

BEAM 3 is a stochastic model that can handle up to four species, but only at one technological level (i.e. one gear taking several species concurrently).

BEAM 4 is a much more general program that accounts for migration of the animals and incorporates an integrated assessment of the harvesting and processing sectors.

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[3] Panayotou and Jetanavanich 1987. The economics and management of Thai marine fisheries. Manila, ICLARM. *ICLARM Studies and Reviews*. No. 14.

[4]. For a detailed description of BEAM 5, the reader should consult the following: Sparre P. and R. Willmann. (in preparation). BEAM 5 - A multi-species, multi-fleet dynamic software implementation of a bio-economic stochastic simulation model. FAO. Rome.

In BEAM 5 the new key features are as follows:

- Non-equilibrium dynamic biological model;
- Optional stock-recruitment relationship;
- Optional stochastic variability of selected biological parameters;
- Dynamic economic model based on the concepts applied in project analysis;
- Inclusion of fisheries management costs and analysis of the impact of fisheries management and fiscal measures on government budget;
- Optional modelling of a buy-back or decommissioning scheme with compensation payments for boat-owners and fishing crew;
- Optional behavioural rules of fishing firms governing fishing effort and investment;
- Optional flexibility of ex-vessel prices in response to changes in fish supply (i.e. landings).

These new features allow the use of BEAM 5 in the analysis of the bio-economic and socio-economic effects of the transition process from a poorly managed fishery with excessive fleet sizes, depleted stocks and low or negative returns on investment to a well managed fishery where stocks are recovering and fleet sizes and fishing effort are being adjusted to desirable levels. The adjustment process would usually entail certain up-front transition costs for a buy-back or decommissioning scheme of redundant fishing vessels and compensation for displaced crewmembers that would often have to be financed by government. Moreover, investments may be needed to upgrade the fisheries management capacity at various levels for improved research, monitoring, control and surveillance and educational and organizational activities in the promotion of effective co-management arrangements between government and fishing communities and fishing industry.

BEAM 5 uses the Net Present Value (NPV), i.e. the sum of the discounted future stream of net benefits (i.e. benefits minus costs) to evaluate the desirability of alternative adjustment paths and management and fiscal measures. A discount rate (or factor) is applied to the benefits and costs that arise in the future to account for the fact that a dollar earned (or spent) today is worth more than a dollar earned (or spent) in a future year. In the evaluation, a distinction is made between the financial performance of the fishing firms and the performance of the fishery from a point of view of the economy as a whole.

The financial analysis estimates how well the fishing industry will be doing over a series of future years. It is based on estimates of the likely revenues and costs of the fishing firms. The economic analysis, on the other hand, includes certain costs that are usually not paid for by the fishing firms and are thus excluded from their financial calculations. These include fisheries management costs such as research, administration and Monitoring, Control and Surveillance (MCS). Another important difference is that the economic analysis uses shadow prices of inputs whenever there is a discrepancy between the prices paid by fishing firms or the government and the economy wide opportunity costs of such inputs.

BEAM 5 also allows an analysis of the impact of the adjustment or transition process on the government's budget. The fishing industry contributes to the government budget through the payment of taxes (e.g. on fuel), duties (e.g. on imported equipment) and fishing licence fees. On the other hand, the government incurs various expenditures in support of the fishing industry including fisheries management costs, subsidies and eventual payments under a buy-back programme for vessel decommissioning and compensation of displaced crew.

3.5 THE ECOPATH APPROACH

Dr Villy Christensen, ICLARM, introduced the ECOPATH approach to ecological modelling. The first ECOPATH program was developed at ICLARM from the original ECOPATH model developed by J. Polovina, National Marine Fisheries Service, Hawaii, USA. Subsequently ECOPATH with ECOSIM, a Windows-based software, was developed jointly by ICLARM and the Fisheries Centre, University of British Columbia, Canada. ECOPATH with ECOSIM is an approach for construction and analysis of mass-balance models and feeding interactions or nutrient flows in ecosystems.

The software is designed to help construct a (simple or complex) model of the trophic flows in an ecosystem, to analyse the system and to study interactions in the system. Its successful application represents a move towards sustainable management of ecosystems. Aquatic ecosystems are emphasized because the approach presented initially was applied to marine and freshwater ecosystems, but it has also been applied to a number of terrestrial ecosystems, such as farming systems, as can be seen in the publications list and published ECOPATH models.

Once an ECOPATH model has been built it can be used directly for simulation modelling using the ECOSIM model. ECOSIM, fully integrated with ECOPATH, is a relatively simple simulation model for evaluating the impact of different fishing regimes on the biological components of ecosystems. ECOSIM also incorporates some economic variables on fish prices, harvesting costs and discount rate that allow for the assessment of the economic performance of alternative management strategies.

One interesting, if somewhat unexpected aspect of the availability of ECOSIM in combination with ECOPATH is that ECOPATH parameterizations can be evaluated quickly in terms of the dynamics they imply. For example, one can quickly identify over-aggregated groups, whose ability to consume a wide range of preys enables them, through this ‘unfair competition’, to drive other groups into extinction.

3.6 SCOPE AND LIMITATIONS OF THE MODELS

The workshop draws on three different model types in order to address the questions posed in the objectives. This is not to find the ‘right’ model for the workshop purpose, but because the models have different strengths and weaknesses and they address different aspects: effort, ecology and economy. It is also reflective of the fact that modelling is ‘cheap’ – the expensive part is to get the data required for the analyses, therefore the more use can be made of expensive data, the better (less uncertain) will be the results when it comes to addressing the questions at hand for the management of the demersal fisheries of the Gulf of Thailand.

Models should be seen as simplifications of reality. Adding complexity may, as is well known from multiple regression analysis, lead to a better data fit but may also decrease a model’s capability for making predictions. Therefore, it is often advisable to use as simple a model as possible to capture the essence of the challenges posed. There are several angles to this: Firstly, one should not generally expect that the construction of a very detailed model aimed at addressing all issues related to bio-economic (including ecological, economical and social) aspects of the fisheries of the Gulf of Thailand would be feasible or desirable. Even if such a model could be constructed, there would be no certainty that its predictions would be reasonable. Therefore, the direction taken by this workshop has been to utilize several models, which show some overlap in the predictions they make, but which are based on independent approaches for obtaining their results. If such different models come up with similar results, there is greater confidence that the results are robust. If not, the properties of the models can be investigated in search of explanations for the differences.

Some aspects of the three models applied at the workshop are described in Table 3.1. It is apparent that each of the models contributes towards addressing the workshop’s objectives, and that they together encompass the chief bio-economic, social and ecological aspects of interest for management of the demersal fisheries of the Gulf of Thailand.

Table 3.1. Overview of the three models used in the bio-economics workshop on the Gulf of Thailand, Hua Hin, Thailand, May 2000*

	Gordon-Schaefer & Fox models	**ECOPATH with ECOSIM**	**BEAM 5**
Model type	Surplus production	Ecological	Bio-economic
Model assumptions	Equilibrium	Dynamic	Dynamic
Number of biological resources	Single	Multiple (45 here, demersal and pelagic)	Multiple (10 here, demersal only)
Fish population dynamics	Not included	Included	Included
Biological interactions	Not included	Included	Not included
No of fleets	Single	Multiple (6 here)	Multiple (8 here)
Cost function relation to effort	Linear	Linear	Non-linear
Cost function relation to catch			Non-linear
Fisheries management costs	Not included	Not included	Included
Fleet adjustment costs	Not included	Not included	Included
Information utilized for present application * ('TS' indicates a time series, often 1973-1997)	Total effort (TS) Total catch (TS) Total value of catch (TS)	Research vessel CPUE (TS) Catch by fleet (TS) Effort by fleet (TS) Prices by fleet Costs by fleet Mortality rates Consumption rates Diet compositions	Catch by fleet (recent av.) Effort by fleet (recent av.) Mortality rates Prices by fleet Costs by fleet Fisheries management costs Fleet adjustment costs
Spatial model	Single area	Multiple areas (5 here)	Multiple areas (2 here)
Predictions	Catch as a function of fishing effort MSY MEY Yield at open access	Biomasses, catches, and profit as a function of fishing effort Spatial distribution of resources and effort	Financial and economic net present value of different adjustment paths
Issues addressed (see pages 1 and 2):			
a-Pushnet fishery	NO	**YES**	**YES**
b-No-trawl zone	NO	**YES**	**YES**
c-Season and area	NO	**YES**	**YES**
d-Mesh size	NO	**Yes**, but indirectly	**YES**
e-Fleet reductions	**YES**	**YES**	**YES**
f-License fees	NO	NO	**YES**