FAO/NORWAY GOVERNMENT COOPERATIVE PROGRAMME

GCP/INT/648/NOR
Field Report F-19 (En)

FISHCODE

MANAGEMENT

REPORT OF THE BIO-ECONOMIC MODELLING WORKSHOP ON THE SMALL PELAGIC FISHERIES OF THE WEST COAST OF PENINSULAR MALAYSIA

Vistana Hotel, Penang

12 – 16 February 2001

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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SUB-PROGRAMME F: ASSISTANCE TO DEVELOPING COUNTRIES FOR IMPROVING THE PROVISION OF SCIENTIFIC ADVICE FOR FISHERIES MANAGEMENT

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PREPARATION OF THIS DOCUMENT

This report presents a summary of the proceedings and the main findings of the Bio-economic Modelling Workshop on the Small Pelagic Fisheries of the West Coast of Peninsular Malaysia, held in the Vistana Hotel, Penang, 12-16 February 2001.

A draft report of the workshop including the first results of the analyses was produced at the workshop. The report was finalized by Rolf Willmann with the editorial assistance of Eric Reynolds.

ACKNOWLEDGEMENTS

Many of the participants of the workshop who are listed in Appendix A have contributed to its preparation and all to its successful conduct. There are some people who should be specifically acknowledged because of their special inputs to this workshop. They are in alphabetical order: Mr Abu Talib Ahmad, Ms Chee Phaik Ean, Ms Lim Chai Fong, Dr Purwito Martosubroto, Mr Per Sparre, Dr Tai Shzee Yew, Ms Tan Geik Hong, and Mr Rolf Willmann, FAO.

FAO/FISHCODE
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FAO/Norway Programme of assistance to developing countries for the implementation of the Code of Conduct for Responsible Fisheries, (FISHCODE). Sub-programme F: Assistance to developing countries for improving the provision of scientific advice for fisheries management.

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SUMMARY

A bio-economic modelling workshop was organized in order to improve the information base for the preparation of a fisheries management plan of the small pelagic fisheries of the West Coast of Peninsular Malaysia. Plan preparation by the Department of Fisheries is supported by the FAO/Norway FishCode Project (see Field Reports F-13 and F-17).

Two different modelling approaches have been applied to these fisheries. The surplus production bio-economic model of the Gordon-Schaefer type suggests that effort at MSY is about 387,000 standard purse seine days producing a MSY of about 109,000 tonnes of small pelagics. At the MSY effort level, however, resource rent is completed dissipated and the fishery incurs an estimated loss of MR 25.6 million. As current effort level (data of 1997) is about 380,000 standardized fishing days, the analysis suggests that fishing effort and capacity are excessive. A resource rent of about MR 77 million might be attainable through the reduction of fishing effort to 180,000 standardized fishing days, i.e. less than half of the current level. This result should be interpreted as providing an order of magnitude only because of the application of a single species model to an assemblage of small pelagic species. One species group, namely *Rastrelliger*, contributes 73 *percent* to the ex-vessel value of these fisheries. This result should also be interpreted cautiously because the shoaling nature of small pelagic species was not explicitly taken into account in the modelling exercise.

The second modelling approach was of a much more ambitious nature because it attempted to model the entire catch of the three main gear types exploiting small pelagics -- namely: purse-seiners, trawlers and driftnetters. The total catch modelled in the base year (1997) amounted to just above one half million tonnes with an estimated ex-vessel value of MR 1727.5 million. The small pelagic catch contributed only about one sixth to the total value.

The newly developed BEAM 5 model was used in the workshop. Its biological component is based on the Thompson and Bell approach while the economic component applies the concepts of economic project analysis. Difficulties were encountered in tuning the model with current estimates of growth and natural mortality for several species. Lower estimates were applied that are not supported by past assessment studies. The results are therefore of a very tentative nature. Not affected by whether low or high values of these parameters are correct is the finding that the fisheries produce a significant net economic cash flow (i.e. resource rent) in the order of MR 500 million. The fact that sizeable resource rents are produced in these fisheries can likely be attributed to the positive impact of the comprehensive limited licensing policy adopted by the country as far back as in the early 1980s.

Determination of the scope for increasing economic benefits from West Peninsular Malaysia's marine fisheries through a reduction of fishing effort, especially of trawling in the inshore zones, is heavily conditioned by the grwoth and natural mortality rates that are assumed, whether high or low. Increased research efforts are recommended in the estimation of critical and sensitive growth and mortality estimates for a range of commercially important species.

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LIST OF ABBREVIATIONS

BEAM	Bio-Economic Analytical Model
DOF	Department of Fisheries of Malaysia
E	Effort
EXCEL	Spreadsheet program produced by Microsoft
GSM	Gordon-Schaefer Model
HP	Horse Power
MCS	Monitoring, Control and Surveillance
MEY	Maximum Economic Yield
MR	Malaysian Ringgit
MSY	Maximum Sustainable Yield
NPV	Net Present Value
R	Recruitment (number of Recruits)
SCF	Standard Conversion Factor
SSB	Spawning Stock Biomass
TC	Total Cost
TR	Total Revenue
Q or q	Catchability coefficient
VPA	Virtual Population Analysis
Y	Yield

1 OPENING

The bio-economic modelling workshop on the small pelagic fisheries off of the West Coast of Peninsular Malaysia was held in the Vistana Hotel, Penang, Malaysia, from 12 to 17 February 2001. The workshop was organized by the Department of Fisheries (DOF) of Malaysia and supported by FAO/Norway Project GCP/INT/648?NOR.[1]

The workshop was attended by 18 staff from the DOF and the State Fisheries Department of Kedah and Penang as well as scientists from the Fisheries Research Institute in Penang. Also attending were lecturers from the University of Putra Malaysia and from FAO. A full list of participants is given in Appendix A. The workshop Agendum appears as Appendix B.

Mr Purwito Martosubroto from FAO highlighted FISHCODE and its activities in the southeast Asia region, especially under Component F, 'Provision of Scientific Advice to Fisheries Management.' He remarked on the active participation of Malaysia in the project as reflected by the two workshops now being conducted back-to-back, i.e. the bio-economic workshop and the stakeholder workshop on development of a fisheries management plan scheduled for the coming week. The present bio-economic workshop is the second in a series, following the one held in Thailand last year, in which the new BEAM-5 (Bio-Economic Analytical Model) software was applied for the first time to tropical fisheries.

Ms. Choo Poh Sze, Director a.i. of the Fisheries Research Institute, expressed sincere appreciation to FAO for its continued interest to Malaysian fisheries and also for its support in strengthening staff capacity of the Institute. She highlighted the importance of small pelagic fisheries to the Malaysian people and further underlined the need to have a good understanding of the dynamics of the fisheries as a basis for strengthening their management and ensuring their sustainability. She expressed the hope that the workshop would be able to expand our knowledge on the economics of the small pelagic fisheries sector and also to generate management options that should be taken to ensure responsible fisheries. She welcomed the participants and wished them success in their deliberations.

2 OBJECTIVES AND PROCEEDINGS OF THE WORKSHOP

Workshop objectives were to investigate the bio-economic and socio-economic effects under current fisheries management regime for the small pelagic fisheries in the west coast of Peninsular Malaysia, to explore options for the future, and to enhance national capacity in bio-economic modelling and analysis.

3 INTRODUCTION TO BIO-ECONOMIC MODELLING

This session provided participants with an introduction of the two different modelling approaches that were subsequently applied to the small pelagic fisheries. The session also reviewed some of the earlier applications of the Gordon-Schaefer model to these fisheries.

[1] This project is a component of the Inter-Regional Programme of Assistance to Developing Countries for the Implementation of the Code of Conduct for Responsible Fisheries (FishCode), under Sub-Programme F: Assistance to Developing Countries for Strengthening the Provision of Scientific Advice to Fisheries Management.

3.1 INTRODUCTION OF THE GORDON-SCHAEFER MODEL

The presentation was made in two parts. Mr. Martosubroto first provided background on the Schaefer model and its limitations, especially when applied to pelagic species. The shoaling behaviour of pelagic species can result in the violation of model assumptions. These assumptions include the following:

- the equilibrium state of the fish population;
- catch per unit of fishing effort (CPUE) is proportional to stock abundance;
- there is a linear relationship between CPUE and fishing effort; and
- the logistic growth model of a fish stock.F

The model is attractive due to its relatively limited data requirements. Catch and fishing effort are the common data needed. The model generates the estimate of maximum sustainable yield (MSY) and its associated fishing effort.

Mr. Willmann next described the Gordon-Schaefer model (GSM), which takes into account the economic value of the fisheries by incorporating price of fish and cost of fishing effort. The model is able to provide an estimate of the level of fishing effort that produces the maximum economic yield (MEY). 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 cross-checking 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 PRESENTATION OF PAST STUDIES

Dr. Tai Shzee Yew, a lecturer at the University of Putra Malaysia, presented his work on bio-economic modelling applied to the small pelagic fisheries of the north-west coast of Peninsular Malaysia (Tai 1993, 1996, 2001). He described the process of modelling and the dynamic simulation of bio-economic impacts of alternative management policies for the small pelagic fisheries. The presentation was based on a paper distributed to workshop participants (Tai, 2001).

The model developed contains three components, namely the biological, socio-economic, and management sub-models. Surplus production functions specified and estimated in the biological sub-model provide the basis for the other two sub-models. The socio-economic sub-model specifies price, social profits, consumer surplus, crew income, and employment. Effort dynamic equations for various management alternatives are specified in the management sub-model. Simulations were carried out using the Dynamo Program.

The analyses showed that limited entry with non-transferable licenses may be used to curtail fishing effort. However, this policy alone may not be able to reduce effort to the desirable level (about 40% of the existing level) due to the response of fishers to positive rents generated in the rationalised fisheries. Thus, the limited entry licensing scheme has to be supplemented by other policies, including increasing the opportunity cost of fishing effort by providing skill training and encouraging fishers to take up employment outside the fishery sector. In addition, levying of license fees to completely appropriate the resource rent generated in the rationalised fishery is also considered.

3.3 THE BEAM 5 MODEL

BEAM 5, introduced by Per Sparre and Rolf Willmann, is a multi-species, multi-fleet dynamic software implementation of a bio-economic stochastic simulation model. “BEAM 5” stands for “Bio-Economic Analytical Model No. 5”. 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 of them use the Thompson and Bell biological model but with large variations in detail and complexity. BEAM 1 and 2 were single species models. All subsequent models could deal with multiple species fisheries but only at the technological level (i.e. one gear taking several species concurrently). BEAM 4 could account for migration of the animals and incorporated an integrated assessment of the harvesting and processing sectors. Apart from being implemented in Visual Basic with an Excel user interface, the key new features of BEAM 5 as compared to BEAM 4 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; and
- 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 crew members 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. An abbreviated description of BEAM 5 is given in Appendix C.

4 MODEL IMPLEMENTATION AND MODELLING RESULTS

4.1 GORDON-SCHAEFER AND GORDON-FOX MODELS

4.1.1 Background and rationale

Small pelagic resources have long been supporting the fisheries of West Peninsular Malaysia. With development, the fisheries have expanded from subsistence fisheries to a commercial scale fisheries. Three major fleets are currently exploiting the resources –namely: drift-net, trawl and purse-seine. Landings of pelagic fish over the last few years have been over 100,000 tonnes annually, while the number of purse-seines licensed and estimated to be in operation has decreased. It is now timely to know whether the fisheries can be sustained at the current level and whether society could gain from a reduction in fishing effort and capacity.

4.1.2 Model limitations

The original Schaefer model was developed for a single stock fishery and one of its main assumptions is the existence of stable environmental factors. In this workshop the working group used the model for a multi-species/multi-gear fishery.

For the economic framework static analysis is used to determine the optimum level of fishing effort, where resource rent is maximized in each time period. In addition, a fixed price model and a linear cost function were used.

4.1.3 Model description

Both, the Gordon-Schaefer as well as the Fox Model were applied to estimate MSY and MEY. For these models the basic formulae are:

Schaefer Model

$$\mathbf{Y = f\,(E)} \qquad \mathbf{(1)}$$

$$\mathbf{Y = qEk\,(1\text{-}qE/r)} \qquad \mathbf{(2)}$$

where Y = catch
E = effort (standardized)
q = catchability coefficient
r = intrinsic growth rate
k = maximum carrying capacity

Functional form used : $y = aE - bE^2$

Fox Model

$$\mathbf{Y = Ee^{a+bE}} \qquad \mathbf{(3)}$$

where Y = catch
E = effort (standardized)
a,b = estimate parameter

4.1.4 *Catch and effort data*

Data on total catch of small pelagics and total effort were compiled for the three major small pelagic gear types, i.e. purse seines, trawls and drift nets, covering the years 1978 to 1997 (Appendix D). Fishing effort in vessel days for the same years were extracted from Annual Fisheries Statistics. For years prior to 1987, fishing days were estimated from the number of fishing gear in operation in one year and an estimated fishing time of 20 days per month. These data were then standardised to purse seine days (Appendix D) following the method used by Tai (2001). The relative fishing power of these three gears were as follows :

Trawlers = 0.35; Purse seine = 1; Drift net = 0.028.

4.1.5 *Biological analysis*

The constants (a and b) of the Schaefer model ($Yield=a*Effort+b*Effort^2$) were estimated by a linear regression with total CPUE as the dependent variable and total standardised effort as the independent variable. The result of the regression is indicated in Figure 1, where MSY estimate $= a^2/4b$ and its associated fishing effort = a/2b.

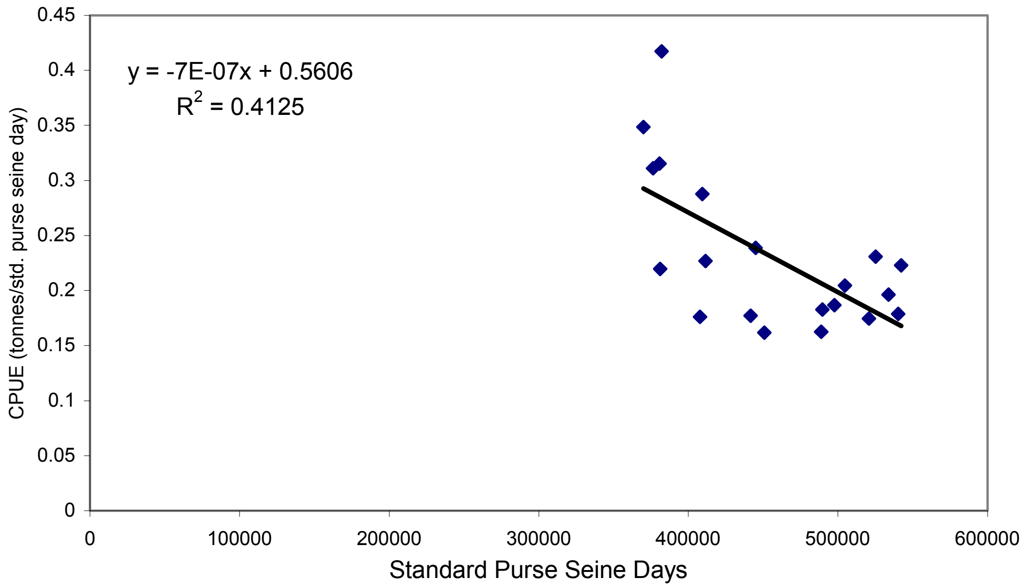

Figure. 1 : Plot of CPUE against effort

A Maximum Sustainable Yield (MSY) of 108,458 tonnes at an optimum fishing effort of 386,952 standard purse seine days was estimated (Figure 2).

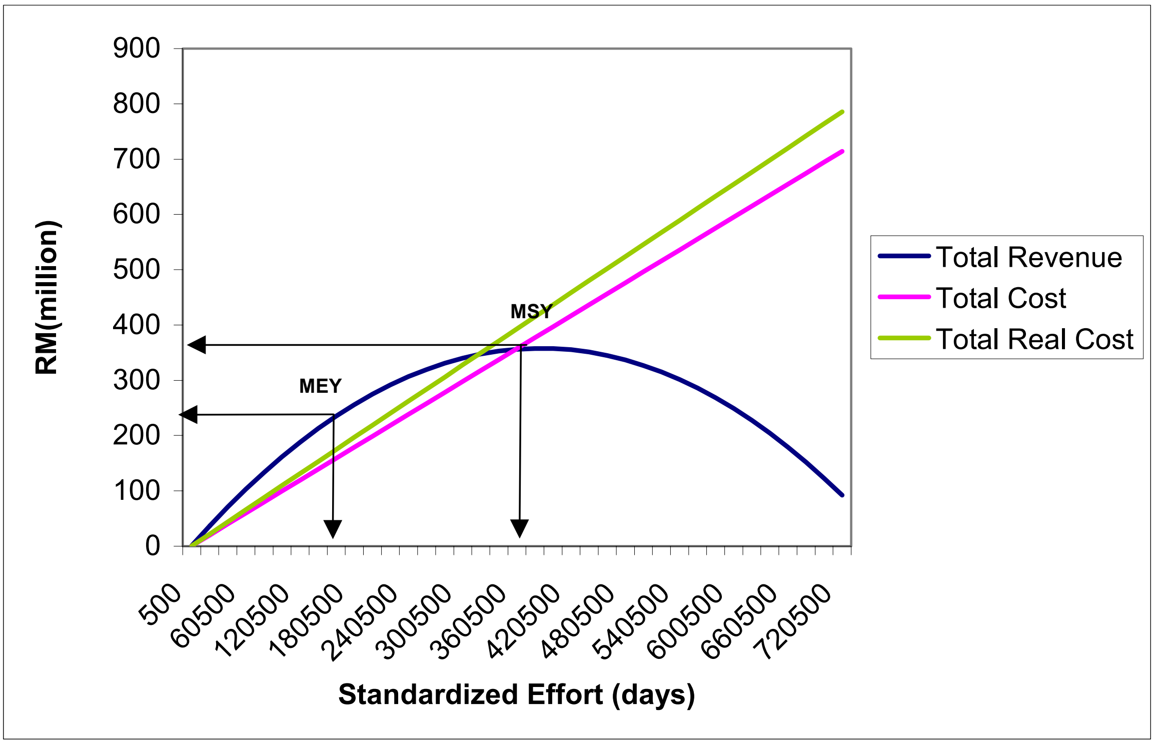

Figure 2: Gordon-Schaefer Model for the small pelagics in West Peninsular Malaysia

The constants (a and b) of the Fox model (Yield=Effort*$e^{a+b*Effort}$) were estimated by a linear regression with logarithmic transformed CPUE as the dependent variable and total standardised effort as the independent variable. The regression results were inferior to those of the Schaefer model (Table 1) which was used in estimating MEY.

Table 1: Regression results of Schaefer's and Fox's Models.

	Schaefer	**Fox**
Regression equation	Y=0.561-0.000000724X	Y=-0.234-0.00000279X
t	(5.995)* (-3.555)*	(-0.638) (-3.490)*
R^2	0.413	0.404

* Significant at 5% or less

4.1.6 Economic analysis

The open access equilibrium occurs where total revenue (TR) equals total cost (TC) and hence resource rent is zero. The maximum economic return is realised at a lower total fishing effort where marginal cost is equal to marginal revenue. Society gains in such a case in the sense that there is efficient use of both the fish resource and the factors of production (i.e. input use: labour, capital asset etc.).

In mathematical terms:

At open access equilibrium: Total Revenue = Total Cost

or TR = TC

$PY(E) = CE$

Where P is fixed price and

C is average cost per one unit of fishing effort

At maximum economic yield:

Marginal Revenue = Marginal Cost

$dTR/dE = dTC/dE$

4.1.7 Economic data

To estimate the value of the fisheries, a fixed weighted average price for small pelagics in 1997 was used. The cost data were determined from fixed cost, operation cost, opportunity costs of labour and capital and cost of fuel subsidy. These data were obtained from a study conducted by the Fisheries Development Authority (Anon, 1995) and Yearbook of Statistics 1997. Costs were converted to the number of standard purse seine days. The total cost was calculated by multiplying the cost per fishing day by the total standard fishing effort. Since this analysis focuses on the small pelagic fishery, the total cost was apportioned using the ratio of the value of small pelagics to the total catch value of each gear.

Figure 3 shows the Gordon-Schaefer equilibrium yield curve and the observed total yield and total standardised effort during the time period. It may be noted that most of the effort observations were beyond the effort at MSY.

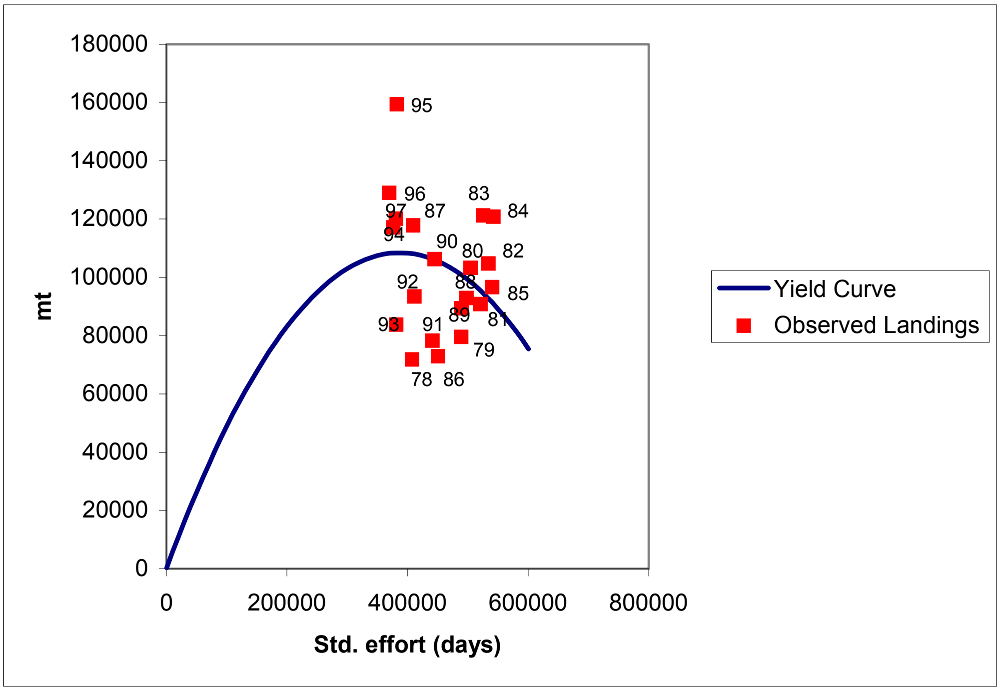

Figure 3: Schaefer Model and actual small pelagic catch in West Peninsular Malaysia

Table 2 shows the optimum level of effort and catch derived from the Schaefer Models. The Schaefer Model shows the Effort at MSY at 386,952 standard purse seine days with a respective catch of 108,458 tonnes, which results in a negative resource rent of MR 25.6 million. Effort at MEY is at 179,618 standard purse seine days with a respective catch of 77,320 tonnes which results in a resource rent of MR 77.1 million.

Table 2: Model results for the MSY, MEY, and open access situation

Situation	Effort (standard purse seine days)	Catch (tonnes)	Resource rent (MR million)
MSY	386,952	108,458	–25.6
MEY	179,618	77,320	77.1
Open access	359,237	107,901	0

4.2 BEAM 5

4.2.1 Objectives

The overall objective of the BEAM 5 working group was to make predictions about the financial, economic and social implications of a change in the structure and level of fishing effort and fishing capacity in the small pelagic fisheries of West Peninsular Malaysia.

4.2.2 Biological and technical data

This was the first attempt to make a multidimensional simulation of the fisheries of West Peninsular Malaysia, and the exercise to be described below therefore is also to be considered as a training exercise. It was thus decided not to include too many components in the simulations, as this would make them less suitable as a teaching tool. Future simulations with BEAM 5 will probably contain more species groups, more areas and more fleets.

The BEAM5 simulation was set up to cover all landings by the involved fishing fleets, so that all major sources of income to the fleets could be accounted for. The only component excluded from the analysis was the purse seine fishery for anchovies, as this fishery catches (almost) only anchovies, which are not caught be the other fleets.

Emphasis was placed on the fishery for small pelagics; other groups of fish, crustaceans and cephalopods, etc., were lumped into larger groups. For example, all demersal fish were lumped into one single group “Demersals”, whereas the most important small pelagic species, Indian mackerel, was treated as a real fish stock.

The time allocated to make a multidimensional simulation of a fisheries system was only one week and there was little prior experience in this type of modelling. It should be noted that a group of, say, 25 experienced model workers (e.g. a fish stock assessment working group of ICES) would need two weeks and several months of preparatory work in order to execute a similar multidimensional simulation. The exercise at the present workshop must thus be seen as a very first step towards the implementation of a multidimensional description of West Peninsular Malaysia fisheries.

Considerable preparatory work on the biological input parameters remains to be done before a model implementation for direct use in fisheries management can be advised.

4.2.3 Basic model structure and dimensions

Table 3 shows the dimensions selected for the present implementation of the BEAM 5 model.

The choice of fleets and areas were chosen to reflect the fisheries regulations of Malaysia. These are based on zoning by gear type and vessel size category as outlined in Tables 4 and 5. In 1981, Malaysia introduced a Fisheries Comprehensive Licensing Policy (FCLP). The FCLP divides Malaysian waters into four fishing zones, namely Zones A, B, C and C2. Zone A (shoreline to 5 nm) is reserved exclusively for the traditional fishery, and Zone B (5 to 12 nm) is reserved for commercial fishing gear vessels (trawlers and purse seiners) using vessels of below 40 GRT. Zone C (beyond 12 nm) is for commercial gear operated by fishing vessels of below 70 GRT, while Zone C2 is for deep-sea fishing vessels of 70 GRT and above.

In the BEAM 5 simulation, the "in-shore area" comprises zones A and B and "off-shore area" zones C and C2. The choice of fleets reflects the composition of the fleet relative to the vessel size limit of below and above 40 GRT as applies in the FCLP (Tables 4 and 5). Driftnetters and "other gear" are almost exclusively comprised of small vessels of less than 40 GRT. Thus, only one size group was defined for these gear.

Licenses issued for the inshore zones A and B recognize also a geographical division by state. However, this was not taken into account as the West Coast was treated as one unit. Furthermore, only the 5 northern states of the West coast were considered in the BEAM 5 simulation. These states include: a) Perlis; b) Kedah; c) Penang; d) Perak; and e) Selangor. The waters of these states are naturally separated from the southern states by the so-called "one-fathom bank". The stocks south of this border appear to be separated from those to the north. Furthermore, catches of small pelagics are taken almost entirely from the northern area.

A time step of 0.25 years for the simulation is sufficiently short to model resources with a life span of 2 or more years. (Shrimps have a life span of only one year, but are not a focus of interest for the present exercise.) The life spans assumed for the respective species groups were based on overall perceptions from literature on life spans of tropical fish.

The choice of species groups reflects biological features as well as value (price/kg), with an emphasis on small pelagics (see further details in Table 6). Shrimps were separated from other demersal catches, due to their high commercial importance. The group "Trash fish" applied here is only 30 *percent* of the amount reported in the official annual statistics. The remaining 70 *percent* of trash fish, were allocated to the demersal group, as this percentage is believed to represent the juveniles of commercial species found in the "trash fish". The pomfrets were given a separate group because of their high value and relative large part of the total landings.

Table 3: Dimensions of West Peninsular Malaysia fisheries, with focus on small pelagics.

BEAM 5 SYSTEM DIMENSIONS	
Time steps/year	4 (Time step = 0.25 year)
Number of Stocks	7
Number of Fleets	6
Number of Areas	2
First year	2001

	Stock Names	**Number of age groups**		**Fleet Names**	**Number of Vessel ages**		**Area Names**
1	Rastrelliger	3	*1*	Small Trawlers	15	*1*	In shore
2	Large Pelagics	5	*2*	Large Trawlers	15	*2*	Off Shore
3	Pomfret & Threadfin	3	*3*	Medium Purse seines	15		
4	Other Pelagics	3	*4*	Large Purse seines	15		
5	Shrimps	1	*5*	Drift netters	15		
6	Demersal fishes	5	*6*	Others	15		
7	Trash fish	2			15		

Table 4: Zones and vessel groups of the Malaysian fisheries regulation system.

Zone	**Distance from shore**	**5 N. States (nm^2)**	**Area of Operation**	**Mode of operation**	**Gear**	**Max GRT**	**Ownership**
A	0-5 Nm	9652	Adjacent to state	Traditional	Small scale , No trawling or purse seining	<40	Owner-Operated
B	>5 Nm	10605	Adjacent to state	Commercial	Trawl, purse seine	<40	Owner-Operated
C	>12 Nm	37887	All	Commercial	Trawl, purse seine	>40	All
C2	>30 Nm	4026	All	Commercial	All	>70	All

Table 5: Fleet names in fisheries of West Peninsular Malaysia.

	Fleet names	**Vessel size**
1	Small Trawlers	< 40 GRT
2	Large Trawlers	> 40 GRT
3	Medium Purse seines	< 40 GRT
4	Large Purse seines	> 40 GRT
5	Drift netters	All sizes
6	Other gears	All sizes

Table 6: The seven species groups selected to represent total catch from the seven fleets

Common name	**Scientific name**	**Representing species groups**
Indian mackerel	Rastrelliger brachisoma	Mackerels
Spanish mackerel	Scomberomorus guttatus	Small tunas, Spanish mackerel, Dorab wolf-herring
Pomfret	Parastromateus niger	Threadfin & Pomfret
Scad	Atule mate	Other pelagics
White prawn	Peneaus merguiensis	Shrimps & Squids, High value short lived non-fish species.
Threadfin bream	Nemipterus japonicus	Demersal fishes
Pony fish	Leiognathus bindus	Trash fish

The scientific names given in Table 6 show the “representative species” for each group. The biological parameters of these stocks were used to represent the groups of stocks. The inclusion of cephalopods into the “white prawn” group may appear strange from a taxonomic point of view, and in future BEAM 5 applications it is recommended to separate the two groups. They are not so different, though, in terms of growth rate (high), and life span (short). Furthermore, both fetch a high price (although there are considerable price differences within the groups).

Thus, from a pure modelling point of view, there is some justification for merging them together.

4.2.4 Growth, maturity and natural mortality

Growth rates and natural mortality rates are very important parameters for the management of fisheries. If these values are high, the productivity of the stock is high and the stock is rather resilient to heavy fishing pressure. As a consequence, the influence of fishing on the dynamics of the stock is relatively small and biological over-fishing may not easily arise (if natural mortality is high, the fish not dying from being caught by the fishery will die anyway, so one may as well catch them before they die.) If on the other hand natural mortality is low, it will pay to let the fish live longer (for example, by using large mesh sizes in fishing gear, banning of fishing in nursery areas, and reducing fish effort). Thus, the outcome of the model simulation is quite sensitive to whether small or large parameter values for growth rate and natural mortality are used. The two parameters "go together" in the sense that if one is large the other one must also be large, and vice versa. For example, if natural mortality was high and growth rate low, too few fish would survive to become mature (reproductive) specimens. On the other hand, if growth rate was high and natural mortality low, the stock would rapidly grow to an astronomic size.

The parameters estimated for Malaysia by the so-called "FISAT" package of computerised estimation-methods gave very high values of K (the parameter which determines the growth rate) and M (the natural mortality). The values reported were about an order of magnitude higher than those reported by Mr. P. Sparre for the North Atlantic species. He would accept higher values of K and M for tropical species, but questioned that they should be an order of magnitude higher (recall the report on the North Atlantic horse mackerel given above).

The two graphs in Figure 4 show how the yield from fisheries is related to size of growth (K) and mortality parameters (Z). The total mortality is the sum of fishing and natural mortality ($Z = F + M$).

As can be seen, there is a very pronounced maximum on the yield curve when parameter values are low, whereas for the high parameter values fishing can continue for a large range of effort values and still provide a high catch. Thus, it is very important to obtain good estimates of these biological parameters.

The graphs in Figure 5 show the exponential decay curve for number of survivors of a cohort (fish born in the same year) and the body growth curve (in length). The two curves with the lowest parameter values (K=2.-.4 and Z = 0.4 - .8) apply to most North Atlantic fish stocks. Z of around 1.0 is the maximum observed for the North Atlantic stocks.

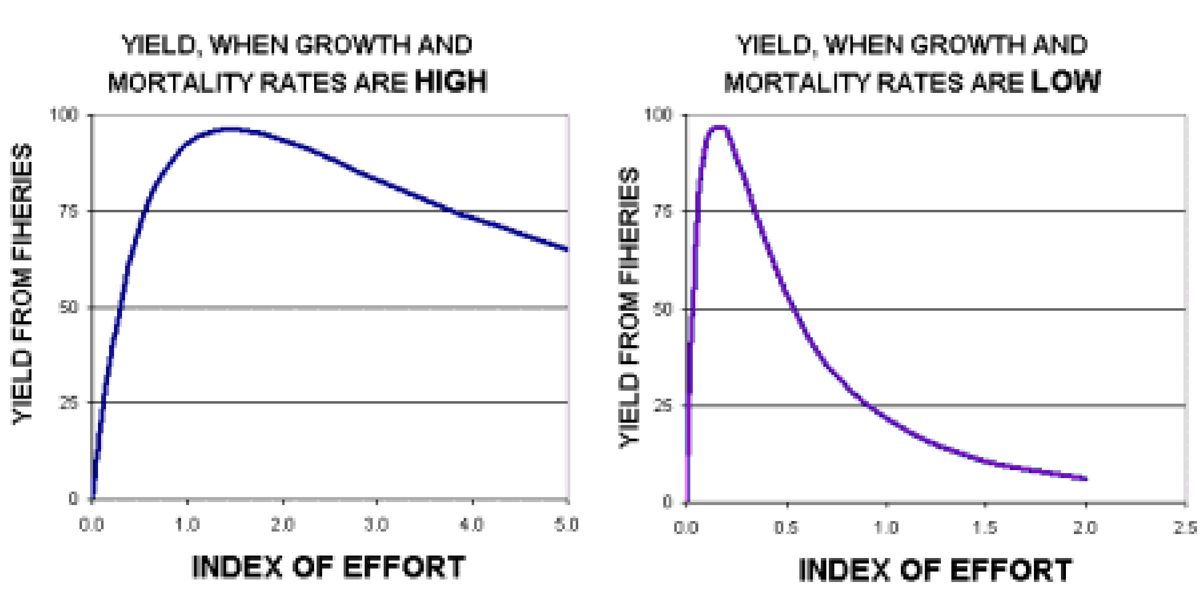

Figure 4. The principal relationship between biological parameters and yield as a function of fishing effort (Left: M=1.6, K=1.6, Right: M =0.2, K =0.2).

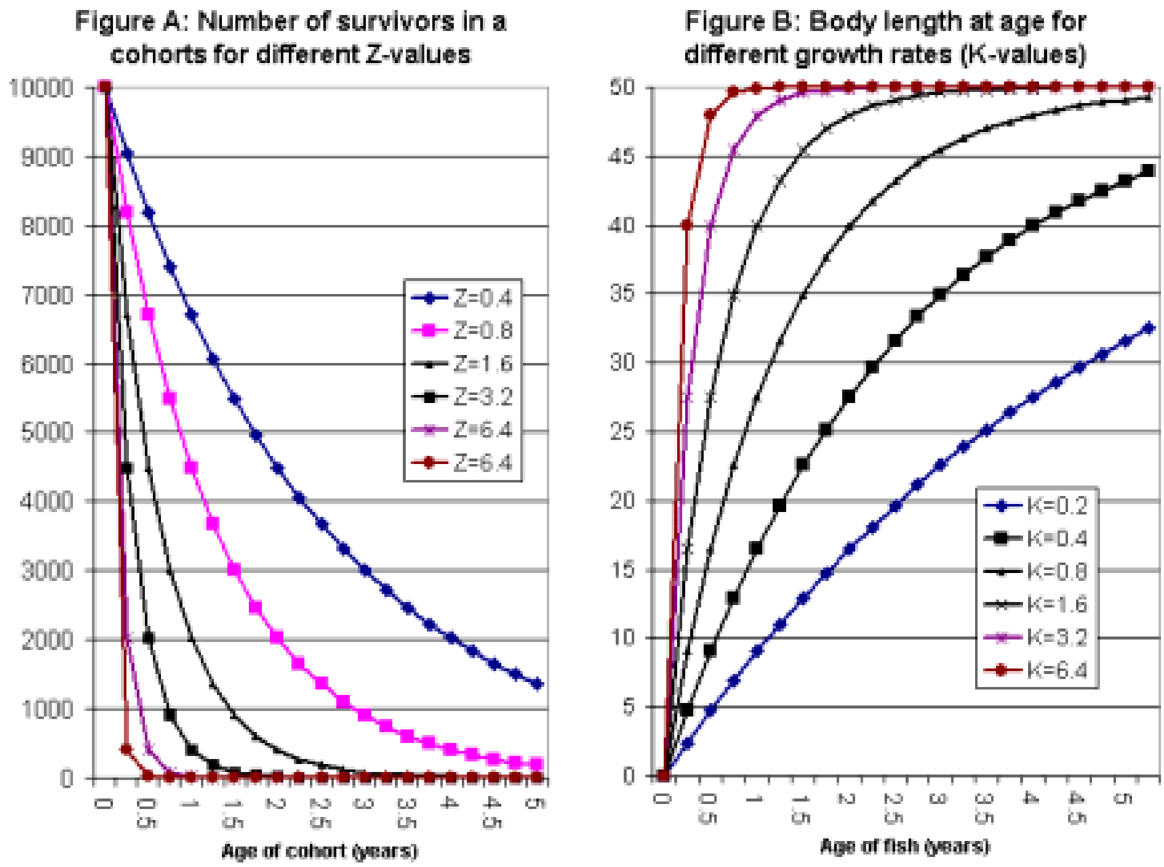

Figure 5. Growth and survival curves for various values of the growth (K) and total mortality rates (Z).

As a result of the discussion it was agreed to test two sets of biological parameters. The high value parameters were selected from the literature and from local experiments (Table 7).

Table 7. Two alternative sets of growth and mortality parameters (L_{oo} = Maximum body length of species).

Species Groups		Large Size Parameters		Small Size Parameters	
	Loo	K	M	K	M
Rastrelliger	23.0	.80	0.8	.30	0.2
Large pelagic	128.0	.18	0.5	.18	0.2
Pomfret	33.0	.80	1.0	.30	0.2
Other pelagics	34.4	.80	0.7	.20	0.2
Shrimps	10.0	2.00	1.5	.70	0.5
Demersal	31.5	.53	0.8	.20	0.2
Trash fish	19.0	.85	1.0	.30	0.3

As can be seen the, the parameter "maximum body length" (L_{oo}) was kept at the same values in both cases. Also the K for large pelagics found in Malaysia, was considered so low that no further reduction could be justified. The low values used for shrimps (peneaid shrimps) are higher than values for any shrimp in temperate waters, but these temperate species (e.g. pandalus) of shrimps are quite different from the tropical shrimps.

Table 8 shows other (non-controversial) biological parameters, which were given the same value in both parameter sets.

Table 8: Other Growth parameters and maturity ogive used as input for the BEAM 5 simulation.

Growth	Indian mackerel	Large Pelagics	Pomfret	Other Pelagics	Shrimps	Demersal fishes	Trash fish
t_o year (growth param.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
a in $W = a*L^b$ (kg)	0.000041	0.0057	0.0073	0.00002	0.0034	0.029	0.018
b in $W = a*L^b$ (kg)	3.20	3.13	3.32	2.89	2.00	2.70	2.90
Maturity Ogive :							
$L_{50\%}$ (cm)	6.0	38.4	9.9	10.3	5.6	9.5	5.7
$L_{75\%}$ (cm)	7.0	51.2	13.2	13.8	7.5	12.6	7.6

4.2.5 Gear and discard selection ogives

The gear selection parameters L50 *percent* and L75 *percent* (the length at which 50 *percent* and 75 *percent* of the fish are retained by the gear, respectively, upon encounter) are shown in Table 9. Table 10 shows the sizes and selection factors used as input to BEAM 5 (note that $L_{50\%}$ = Mesh size * Selection Factor)

The value of 1.1 for the selection ranges (=$L_{75\%}$ / $L_{50\%}$) was used for all combinations of gear and species groups.

Table 9: Gear selection parameters used as input to BEAM 5.

Fleet	Indian mackerel		Large Pelagics		Pomfret		Other Pelagics		Shrimps		Demersal Fishes		Trash fish	
	$L_{50\%}$	$L_{75\%}$	$L_{50\%}$	$L_{75\%}$	$L_{50\%}$	$L_{75\%}$	$L_{50\%}$	$L_{75\%}$	$L_{50\%}$	$L_{75\%}$	$L_{50\%}$	$L_{75\%}$	$L_{50\%}$	$L_{75\%}$
Small Trawlers	8.0	8.8	8.0	8.8	6.0	6.6	8.0	8.8	4.0	4.4	6.0	6.6	6.0	6.6
Large Trawlers	10	11	10	11	7.5	8.3	10	11	5.0	5.5	7.5	8.3	7.5	8.3
Medium Purse seines	10	11	10	11	7.5	8.3	10	11	5.0	5.5	7.5	8.3	7.5	8.3
Large Purse seines	10	11	10	11	7.5	8.3	10	11	5.0	5.5	7.5	8.3	7.5	8.3
Driftnetters	10	11	10	11	7.5	8.3	10	11	5.0	5.5	7.5	8.3	7.5	8.3
Others	10	11	10	11	7.5	8.3	10	11	5.0	5.5	7.5	8.3	7.5	8.3

Table 10: Mesh size and selection factors corresponding to Table 9.

Fleet	Mesh size (cm)	Selection factor						
		Indian mackerel	Large Pelagics	Pomfret	Other Pelagics	Shrimps	Demersal Fishes	Trash fish
Small Trawlers	20	0.4	0.4	0.3	0.4	0.2	0.3	0.3
Large Trawlers	25	0.4	0.4	0.3	0.4	0.2	0.3	0.3
Medium Purse seines	25	0.4	0.4	0.3	0.4	0.2	0.3	0.3
Large Purse seines	25	0.4	0.4	0.3	0.4	0.2	0.3	0.3
Drift netters	25	0.4	0.4	0.3	0.4	0.2	0.3	0.3
Others	25	0.4	0.4	0.3	0.4	0.2	0.3	0.3

4.2.6 Number of vessels, effort and capacity

Table 11 shows the number of vessels, the number of fishing days and the maximum number of sea-days per year. These data were derived from annual Malaysia fisheries statistics, and refer to the "number of active boats" estimated from samples collected by fisheries inspectors. Thus it does not refer to the number of licensed vessels, which may be slightly different.

Table 11: Effort and number of vessels by area in 1997 for West Peninsular Malaysia.

Effort (1000 days)	Small Trawlers	Large Trawlers	Medium Purse seines	Large Purse seines	Drift netters	Other Gear	Total
In shore effort	191,621.3	6808.6	2327.4	355.5	19559.4	20700.0	241372.00
Off shore effort	0	27234.2	581.9	1422.1	0	0	29238.20
Total Effort	191,621.3	34042.8	2909.3	1778	19559.4	20700.0	270610.20
Number of vessels	3180	540	37	120	10725	4140	18742
Max Number of days/year/boat	240	240	240	240	240	240	1440

4.2.7 Fishing mortality

There was a discussion on the values of fishing moralities estimated by the FISAT package. Compared to the values of fishing mortalities found in temperate waters the fishing mortalities estimated by FISAT were very high. Mr. P. Sparre again commented on the North East Atlantic Horse mackerel. The fishing mortality of this species is small, and it is known to have a long life span (at least 18 years and probably more). The fishing mortality is proportional to the fishing power of the fishing vessels. It is not related to the biological features of the fish. It appears that the maximum fishing mortality the North European fishing fleets can produce is around 1.0 per year (that corresponds to removing 63 % of the fish every year). The table below shows the number of survivors each year from a "cohort" of 1000 fish born at the same time, when they are exposed to a fishing mortality (F) of 1.0. Here we have ignored the natural mortality, so actually they will die out faster than indicated in the table.

Table 12: 1000 fish cohort survivors by year under F = 1.0 condition

Year (age of cohort)	0	1	2	3	4	5	6	7	8
Number of survivors	1000	368	135	50	18	7	2	1	0

When F approaches a high value of 1.0 it may cause a halt of the fishery, as has happened for the cod in the North Sea in these days. Now the question is whether the Malaysia vessels are many times more efficient and numerous than the North sea fleets. There is general consensus in EU countries that there is a severe overcapacity in the North Sea, and governments are in the process of implementing a new round of vessel decommission schemes. There was a first decommission scheme in the early nineties, implemented by the EU. Thus, there are good reasons to believe that the fishing mortality observed is the maximum one will ever observe in the North Sea. The question is if the Malaysia vessels are more powerful (in numbers and fishing efficiency) than the North Sea vessels. A comparative study could be made, to check if it is realistic to assume that fishing mortalities are so much higher in Malaysia (and other East Asian countries). That the Malay vessels are two times more efficient than the North sea vessels is not entirely impossible, but it is doubtful that they could be 5 times more efficient.

One reason for the high apparent fishing mortalities observed in Malaysia could be bias in the method (the FISAT-package) used to estimate mortality rates from length frequency data. It starts with an overestimate of the growth rate which in turn leads to an overestimate of the mortality rates. Is there a reason to believe that fish grow 5-10 times faster (achieve their maximum size) than temperate species? A comparative study based on physiological and bio-chemical considerations should be made to throw light on the question. If an animal achieves its maximum size in 2-4 months it must have a short life-span (a large natural mortality), as it would otherwise soon take over the entire ecosystem, and there would be insufficient supply of food.

High growth rates and consequent high estimates of natural mortality (estimated by Pauly's formula) are of concern because of their implications for fisheries management. As noted earlier, if the natural mortality is high, it does not matter so much for the biomass dynamics if fishing mortality is high too. (If fish are not caught in the fishery they will die anyway from natural causes.) High estimates of growth rates and high estimates of natural mortalities imply that a reduction of fishing effort would hardly lead to a better exploitation of the resources from a biological point of view. In economic terms, though, it still would pay to take the same or only a slightly smaller catch at lower harvesting costs of a smaller fleet.

The fishing mortality, F, given as input to BEAM 5 is used to "tune" the model to reproduce observed landings. One set of tuning Fs is shown in Table 13. These high fishing mortalities were used in conjunction with the high growth rates and high natural mortalities (see Table 7). These F-values were obtained from the so-called catch curve method of FISAT. For the simulation with low growth rates, fishing mortalities were given values corresponding to the maximum values observed for the North Sea, that is, values of around 1.0 per year.

Table 13: Mortality rates (per year) used as input to BEAM 5 in conjunction with high natural mortality and growth rates.

Mortality	Indian mackerel	Large Pelagics	Pomfret	Other Pelagics	Shrimps	Demersal Fishes	Trash fish
Fishing mortality, F / year	2.42	1.52	3.00	2.12	4.50	2.41	3.02
Natural mortality, M /year	0.80	0.50	1.00	0.70	1.50	0.80	1.00
Total mortality, Z / year	3.22	2.02	4.00	2.82	6.00	3.21	4.02

4.2.8 Stock numbers, migration and stock biomass

The stock numbers were back-calculated to reproduce the observed landings for year 1997, which was the most recent data year available in the Annual Fisheries Statistics. Thus, estimates of biomasses and stock-numbers should be considered parameters in the model rather than actual estimates of stock sizes.

The migration coefficients were given some plausible values, allowing for the fish to move gradually to deeper waters as they grow larger.

4.2.9 Catches (observed landings)

The observed landings total landings (Table 14) given as input to BEAM 5 were used for "tuning" the model to reproduce the observed landings, as will be explained below. The landings refer to year 1997, the most recent data year of the Annual Fisheries Statistics.

The split between in-shore and off-shore areas (Table 15) was based on the assumption that large trawlers and medium-sized purse seiners got some 20 *percent* of their catches from inshore-waters. All catches were assumed to be landed – i.e., were assumed not to involve any discarding.

Table 14: Total landings (tonnes) of the seven groups of fish on the West Coast of Peninsular Malaysia in 1997 (source: Annual Fisheries Statistics of Malaysia).

Fleet	Indian mackerel	Large Pelagics	Pomfret	Other Pelagics	Shrimp	Demersal fishes	Trash fish	Total
Small Trawlers	9315	2435	3630	7931	39752	91552	27333	181948
Large Trawlers	8070	1594	1757	12137	14223	71040	16508	125329
Medium Purse seines	5668	2435	61	6702	535	1432	476	17309
Large Purse seines	9134	1594	398	13052	142	2535	896	27751
Drift netters	32891	2607	2056	2006	8847	24719	959	74085
Others	1508	2155	67	4417	29264	34975	3530	75916
Total	**66586**	**12820**	**7969**	**46245**	**92763**	**226253**	**49702**	**502338**

Table 15: Landings from the West Coast of Peninsular Malaysia (tonnes) in the year 1997 by fleet and by area.

IN-SHORE AREA	Indian mackerel	Large Pelagics	Pomfret	Other Pelagics	Shrimps	Demer-sal Fish	Trash fish	Total
Small Trawlers	9315	2435	3630	7931	39752	91552	27333	181948
Large Trawlers	1614	3198	351	2427	2845	14208	3302	25066
Medium Purse seines	5668	2435	61	6702	535	1432	476	17309
Large Purse seines	0	0	0	0	0	0	0	0
Drift netters	32891	2607	2056	2006	8847	24719	959	74085
Others	1508	2155	67	4417	29264	34975	3530	75916
Total	50996	12830	6165	23483	81243	166886	35600	374324
OFF-SHORE AREA								
Small Trawlers	0	0	0	0	0	0	0	0
Large Trawlers	6456	1275	1406	9710	11379	56832	13206	100263
Medium Purse seines	0	0	0	0	0	0	0	0
Large Purse seines	9134	1594	398	13052	142	2535	896	27751
Drift netters	0	0	0	0	0	0	0	0
Others	0	0	0	0	0	0	0	0
Total	15590	2869	1804	22762	11520	59367	14102	128014
GRAND TOTAL	**66586**	**15700**	**7969**	**46245**	**92763**	**226253**	**49702**	**5022338**

4.2.10 Tuning of BEAM 5

The task of the tuning is to select recruitment-numbers and catchability coefficients to reproduce the observed catches, as illustrated in Figure 6. The result becomes the "reference simulation" to which all other simulations are compared. The reference simulation re-creates the situation of "today." However, as the most recent data year for the present exercise was 1997, the reference simulation here refers to that year. The reader is referred to the BEAM 5 user's manual on details of the tuning procedure.

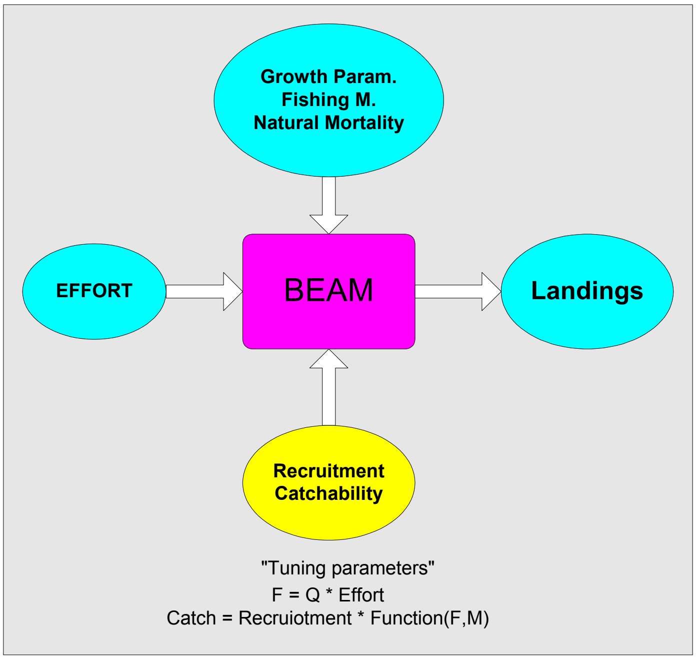

Figure 6: Tuning of BEAM5.

All simulations with BEAM 5 were made for a time series of 15 years, that is from a hypothetical year 2001 to 2015. The reference simulation was an "equilibrium simulation," or a simulation where all parameters were kept constant, and biomasses were given initial values which were reproduced every year.

The principal biological output from the reference simulation with low values of growth and mortality parameters is shown in Table 16a. The table shows the landings, values, CPUE and catch value per unit of effort, for all combinations of gear and species groups. The results are shown for the starting year (2001) and ending year (2015) of the simulation time span.

As can be seen, the results are identical for the years 2001 and 2015 for this equilibrium simulation.

Table 16b shows the same results as Table 16a, but with the number of vessels (in all fleets) and the number of effort units (fishing days) doubled. The system is no longer in equilibrium, and the results for year 2015 are all less than those of year 2001. In this case not only have catch rates declined (they always go down when effort is increased), but total landings as well. Had high parameter values for growth and mortality been used, BEAM 5 would not have predicted a long term loss, and the reduction in CPUE would be much smaller.

Table 16a: Reference simulation with set of low mortality and growth rates.

Reference variable	Small Trawler 2001	Small Trawler 2015	Large Trawler 2001	Large Trawler 2015	Medium purse seiner 2001	Medium purse seiner 2015	Large purse seiner 2001	Large purse seiner 2015	Drift nets 2001	Drift nets 2015	Other gear 2001	Other gear 2015
Landings Rastrelliger	15421	15421	13740	13740	5999	5999	10895	10895	32284	32284	1619	1619
Landings Large pelagic	3908	3908	2779	2779	2576	2576	1947	1947	2534	2534	2291	2291
Landings Pomfret	6182	6182	2716	2716	65	65	431	431	2122	2122	76	76
Landings Other pelagics	11151	11151	21604	21604	6149	6149	16276	16276	1571	1571	3784	3784
Landings Shrimps	34223	34223	79137	79137	316	316	759	759	16182	16182	21052	21052
Landings Demersal	56310	56310	40666	40666	617	617	284	284	7486	7486	27086	27086
Landings Trash fish	29997	29997	13478	13478	495	495	731	731	1067	1067	3931	3931
Total Landings	**157191**	**157191**	**174119**	**174119**	**16216**	**16216**	**31322**	**31322**	**63245**	**63245**	**59839**	**59839**
Value Rastrelliger	52.440	52.440	49.519	49.519	21.326	21.326	39.265	39.265	114.151	114.151	5.725	5.725
Value Large pelagic	17.748	17.748	14.128	14.128	12.120	12.120	9.898	9.898	11.537	11.537	10.432	10.432
Value Pomfret	47.757	47.757	21.252	21.252	.511	.511	3.372	3.372	16.598	16.598	.592	.592
Value Other pelagics	20.524	20.524	45.059	45.059	12.342	12.342	33.946	33.946	3.092	3.092	7.447	7.447
Value Shrimps	175.363	175.363	410.577	410.577	1.636	1.636	3.936	3.936	83.708	83.708	108.901	108.901
Value Demersal	146.632	146.632	114.804	114.804	1.699	1.699	.803	.803	20.232	20.231	73.205	73.205
Value Trash fish	9.056	9.056	4.209	4.209	.156	.156	.228	.228	.336	.336	1.239	1.239
Total Value	469.52	469.52	659.55	659.55	49.790	49.790	91.448	91.448	249.65	249.65	207.54	207.54
Mean Value/kg	.0029869	.0029869	.0037879	.0037879	.0030703	.0030703	.0029196	.0029196	.0039474	.0039474	.0034683	.0034683
Number of Crew	9540	9540	2160	2160	555	555	1800	1800	21450	21450	8280	8280
Number of boats	3180	3180	540	540	37	37	120	120	10725	10725	4140	4140
C.P.U.E Rastrelliger	.0217	.0217	.1060	.1060	.6756	.6756	.3783	.3783	.0229	.0229	.0027	.0027
C.P.U.E Large pelagic	.0055	.0055	.0214	.0214	.2901	.2901	.0676	.0676	.0018	.0018	.0039	.0039
C.P.U.E Pomfret	.0087	.0087	.0210	.0210	.0074	.0074	.0150	.0150	.0015	.0015	.0001	.0001
C.P.U.E Other pelagics	.0157	.0157	.1667	.1667	.6924	.6924	.5651	.5651	.0011	.0011	.0064	.0064
C.P.U.E Shrimps	.0483	.0483	.6106	.6106	.0356	.0356	.0263	.0263	.0115	.0115	.0357	.0357
C.P.U.E Demersal	.0794	.0794	.3138	.3138	.0695	.0695	.0099	.0099	.0053	.0053	.0459	.0459
C.P.U.E Trash fish	.0423	.0423	.1040	.1040	.0557	.0557	.0254	.0254	.0008	.0008	.0067	.0067
Val.P.U.E Rastrelliger	0.0000739	0.0000739	0.0003821	0.0003821	0.0024016	0.0024016	0.0013634	0.0013634	0.0000809	0.0000809	0.0000097	0.0000097
Val.P.U.E Large pelagic	0.0000250	0.0000250	0.0001090	0.0001090	0.0013648	0.0013648	0.0003437	0.0003437	0.0000082	0.0000082	0.0000177	0.0000177
Val.P.U.E Pomfret	0.0000673	0.0000673	0.0001640	0.0001640	0.0000575	0.0000575	0.0001171	0.0001171	0.0000118	0.0000118	0.0000010	0.0000010
Val.P.U.E Other pelagics	0.0000289	0.0000289	0.0003477	0.0003477	0.0013899	0.0013899	0.0011787	0.0011787	0.0000022	0.0000022	0.0000126	0.0000126
Val.P.U.E Shrimps	0.0002473	0.0002473	0.0031680	0.0031680	0.0001843	0.0001843	0.0001367	0.0001367	0.0000593	0.0000593	0.0001844	0.0001844
Val.P.U.E Demersal	0.0002068	0.0002068	0.0008858	0.0008858	0.0001913	0.0001913	0.0000279	0.0000279	0.0000143	0.0000143	0.0001240	0.0001240
Val.P.U.E Trash fish	0.0000128	0.0000128	0.0000325	0.0000325	0.0000175	0.0000175	0.0000079	0.0000079	0.0000002	0.0000002	0.0000021	0.0000021

Table 16b: Simulation with low mortality and growth rates and double number of vessels and effort compared to the reference simulation.

Reference variable	Small Trawler 2001	Small Trawler 2015	Large Trawler 2001	Large Trawler 2015	Medium purse seiner 2001	Medium purse seiner 2015	Large purse seiner 2001	Large purse seiner 2015	Drift nets 2001	Drift nets 2015	Other gears 2001	Other gears 2015
Landings Rastrelliger	23878	16558	12799	8806	4784	3069	10149	6982	43898	27180	2032	1258
Landings Large pelagic	5655	2103	2607	1484	2020	884	1826	1040	3339	1234	2786	1030
Landings Pomfret	8481	2995	2542	2034	49	24	403	323	2637	893	87	29
Landings Other pelagics	17526	13341	20682	16428	5082	3683	15581	12376	2179	1483	4842	3296
Landings Shrimps	53738	45669	76141	67025	263	221	730	643	21628	17424	25966	20919
Landings Demersal	77833	41628	39491	38044	495	361	276	266	9210	4390	30754	14660
Landings Trash fish	44354	25241	12463	10979	378	221	676	596	1409	693	4790	2357
Total Landings	**231465**	**147535**	**166726**	**144801**	**13069**	**8462**	**29642**	**22225**	**84300**	**53298**	**71258**	**43549**
Value Rastrelliger	80.269	53.680	46.125	31.591	16.960	10.722	36.573	25.049	154.404	93.596	7.146	4.332
Value Large pelagic	25.519	7.992	13.301	7.379	9.542	3.833	9.318	5.169	15.120	4.726	12.617	3.943
Value Pomfret	64.923	19.273	19.880	15.775	.379	.170	3.155	2.503	20.512	5.942	.675	.195
Value Other pelagics	31.848	22.991	43.213	34.158	10.210	7.237	32.555	25.734	4.266	2.788	9.482	6.197
Value Shrimps	274.460	232.585	395.028	347.717	1.360	1.145	3.787	3.333	111.755	89.938	134.171	107.978
Value Demersal	200.254	94.710	111.614	107.398	1.367	.976	.781	.751	24.836	10.738	82.930	35.855
Value Trash fish	13.275	6.999	3.887	3.401	.119	.067	.211	.185	.443	.207	1.506	.705
Total Value	690.55	438.23	633.05	547.42	39.935	24.150	86.379	62.724	331.34	207.93	248.53	159.21
Mean Value/kg	.0029834	.0029704	.0037969	.0037805	.0030558	.0028538	.0029141	.0028222	.0039304	.0039014	.0034877	.0036558
Number of Crew	19080	19080	2160	2160	555	555	1800	1800	21450	21450	8280	8280
Number of boats	**6360**	**6360**	**540**	**540**	**37**	**37**	**120**	**120**	**10725**	**10725**	**4140**	**4140**
C.P.U.E Rastrelliger	.0168	.0117	.0988	.0679	.5387	.3456	.3524	.2424	.0171	.0106	.0020	.0013
C.P.U.E Large pelagic	.0040	.0015	.0201	.0115	.2275	.0996	.0634	.0361	.0013	.0005	.0028	.0010
C.P.U.E Pomfret	.0060	.0021	.0196	.0157	.0055	.0026	.0140	.0112	.0010	.0003	.0001	.0000
C.P.U.E Other pelagics	.0124	.0094	.1596	.1268	.5723	.4148	.5410	.4297	.0008	.0006	.0049	.0033
C.P.U.E Shrimps	.0379	.0322	.5875	.5172	.0296	.0249	.0253	.0223	.0084	.0068	.0261	.0211
C.P.U.E Demersal	.0549	.0293	.3047	.2936	.0557	.0406	.0096	.0092	.0036	.0017	.0310	.0148
C.P.U.E Trash fish	.0313	.0178	.0962	.0847	.0425	.0249	.0235	.0207	.0005	.0003	.0048	.0024
Val.P.U.E Rastrelliger	0.0000566	0.0000378	0.0003559	0.0002438	0.0019099	0.0012074	0.0012699	0.0008698	0.0000600	0.0000364	0.0000072	0.0000044
Val.P.U.E Large pelagic	0.0000180	0.0000056	0.0001026	0.0000569	0.0010746	0.0004317	0.0003236	0.0001795	0.0000059	0.0000018	0.0000127	0.0000040
Val.P.U.E Pomfret	0.0000458	0.0000136	0.0001534	0.0001217	0.0000427	0.0000191	0.0001095	0.0000869	0.0000080	0.0000023	0.0000007	0.0000002
Val.P.U.E Other pelagics	0.0000225	0.0000162	0.0003334	0.0002636	0.0011497	0.0008150	0.0011304	0.0008935	0.0000017	0.0000011	0.0000095	0.0000062
Val.P.U.E Shrimps	0.0001935	0.0001640	0.0030481	0.0026830	0.0001531	0.0001290	0.0001315	0.0001157	0.0000434	0.0000349	0.0001350	0.0001087
Val.P.U.E Demersal	0.0001412	0.0000668	0.0008612	0.0008287	0.0001539	0.0001099	0.0000271	0.0000261	0.0000096	0.0000042	0.0000835	0.0000361
Val.P.U.E Trash fish	0.0000094	0.0000049	0.0000300	0.0000262	0.0000133	0.0000075	0.0000073	0.0000064	0.0000002	0.0000001	0.0000015	0.0000007

4.3 DISCUSSION OF BIOLOGICAL PARAMETER VALUES

The results of the BEAM 5 simulations with small parameter values for growth and natural mortality is in accordance with the overall perception of fisheries resources (world-wide as well as for Malaysia). Most marine fishery resources are heavily exploited, and a reduction in fishing capacity and effort would lead to higher landings as well as a much improved financial and economic performance of the vessels remaining in the fishery.

But this conclusion does not come out of BEAM 5 (or any other model) if growth and natural mortality parameters are assumed to take high values.[2] There is thus a need to critically check all estimates of biological parameters. It is furthermore recommended to undertake comparative studies of Malaysian fisheries with other fisheries. It should be noted that the implication of high parameter values for growth and mortality is that the marine resources of West Peninsular Malaysia are not biologically overexploited. But if the same order of magnitude applies to the parameters here as to those of temperate waters, then the resources are overexploited. The outcome of the further simulation runs reviewed below refer only to the low parameter estimates. It has been impossible to obtain a satisfactory tuning of the simulation model with the high estimates of growth and mortality rates. At the time of reporting, there is no clarity about whether the inability of model tuning is specific to these parameter estimates or partly due to the specific characteristics of the BEAM 5 model.

4.4 BEAM 5 - ECONOMIC INPUT DATA

BEAM 5 requires estimates of a range of economic data including: a) average fish prices by species or species group; b) data on average variable and fixed harvesting costs of the different vessel categories; c) fisheries management costs; d) investment costs in fishing craft and gear; e) estimates of the adjustments needed to derive economic efficiency prices from observed input prices including data on taxes, license fees and other transfer payments; and f) the rates to discount costs and earnings that arise in future years from the point of view of vessel owners (financial discount rate) and the point of view of the economy at large (economic discount rate).

The sources for the estimates of economic data include cost and earnings surveys conducted in 1995 by the Malaysia Fisheries Development Board (LKIM) and a special costs and earnings sample survey conducted in December 2000 by DOF under the FAO/Norway FishCode project. The gear types covered included trawlers, purse-seiners, and drift gill nets.

The 1995 and 2000 surveys yielded data on:

- technical specifications of each fleet type (e.g. vessel length, horse power, life time of vessel, engine and gear);
- employment (i.e. number of crew and family members among crew);
- use of fuel, ice and oil per fishing month (quantity);

[2] Note, however, that the economic performance may nevertheless improve also under the assumption of high growth and natural mortality rates as a result of cost savings of a smaller fleet.

- initial investment into fishing vessel, engine and gear;

- operating cost per month, fishing day and/or fishing trip (i.e. fuel and oil, ice, repair and maintenance, crew remuneration and others);

- fixed cost per month (i.e. interest on debt, estimated depreciation from data on initial investment and lifetime of veseel, engine and gear); and

- type crew remuneration (i.e. sharing system and/or fixed monthly wage).

Certain data were compiled from the Annual Fisheries Statistics of DOF, as follows:

- number of fishing vessels by gear type and tonnage;

- intensity of fishing (i.e. number of fishing days per month and number of fishing months per year);

- total value of landings and average price per kg; and

- catch composition by main types of species groups/use (i.e. edible fish, trash fish, shrimp, cephalopods and others).

The numbers of fishing vessels and fishing days by fleet category indicated in Table 17 were used as input parameters. Trawlers and purse-seiners were grouped into two tonnage categories, namely below 40 GRT and above 40 GRT. These two categories correspond with the 1967 Maritime Fisheries Regulation provisions that prescribe fishing zones by vessel size and gear-type categories. Trawlers and purse-seiners above 40 GRT are required to stay outside the 5nm inshore zone .

Table 17: Vessel input parameters

Vessel type	No. boats	Av. No. crew	Tot. crew	Av. no. fish days	Tot. no. fish days
Trawlers <40 GRT	3180	3	9540	223	709212
Trawlers > 40 GRT	540	4	2160	240	129600
Purse-seiners <40 GRT	37	15	555	240	8880
Purse-seiners >40 GRT	120	15	1800	240	28800
Driftnets	10725	2	450	131	1411564
Other gear	4140	2	8280	142	590444

Data on current investment cost for a new vessel were obtained from the DOF Fishing Licensing Section. Price data were obtained from the 1997 Annual Fisheries Statistics.

Data on fuel market prices were obtained from the DOF and the countrywide subsidy rate was applied to calculate real fuel cost based on world market prices.

4.4.1 Prices

The following average prices (in Malaysian Ringgit per kg) were used in the BEAM 5 model:

Table 18: Average price model inputs

Species group	**Average price per kg (MR)**
Rastrelliger	3.64
Large pelagic	5.42
Pomfret	8.8
Other pelagics	2.13
Shrimps	5.19
Demersal	2.94
Trash Fish	0.33

Except for Rastrelliger (Indian Mackerel), the above prices refer to averages over assemblages of various species categories/groups.

4.4.2 Harvesting costs

Operating costs

Operating costs comprise expenditures for fuel, ice, repair, and maintenance, other materials, and food. The data in the surveys were reported on a per vessel and per trip basis which were converted into costs per fishing day by dividing the trip total by the average number of fishing days per trip. No specific data were available for the category of "other gear" which was included in the BEAM 5 simulation model to account for the catch that could not be attributed to any of the other gear types. As a rough approximation, it was assumed that all economic parameters that apply to driftnets apply equally to the category of "other gear" comprising a large variety of traditional inshore fishing methods including various types of gill nets, traps, hooks and lines and others.

Due to the high sample size, the data of the 1995 LKIM costs and earning survey were considered reliable and used for estimating the operating costs of the different vessel types by size category and gear. Weighted average operating costs were calculated for trawlers and purse-seiners below and above 40 GRT respectively from data given for four size class categories in the survey data (<10 GRT, >10 - 40 GRT, >40 -70 GRT and >70 GRT).

As fish price data referred to 1997, the 1995 cost estimates for ice and other operating costs were raised with the consumer price index increase of about 6 *percent* between 1995 and 1997. Fuel costs, however, have remained stable over this period.

The average operating costs per fishing day estimated for each type of fishing fleet and two operating zones (i.e. inshore comprising of zones A and B and offshore comprising zones C and C2) are shown in the following table.

Table 19: Vessel average operating cost model inputs

Vessel type	Operating cost/day (MR)
Trawlers <40grt	411.67
Trawlers >40grt	921.97
Purse seine<40grt	822.02
Purse seine>40grt	1288.09
Driftnet	43.05
Other gear	43.05

Crew share

Two types of crew remuneration can be applied in BEAM 5, namely a sharing system and a fixed monthly (but effort-related) wage. Data were only available on the average crew share (percentage) by vessel category from the December 2000 costs and earning survey by DOF. In a typical sharing system, the crew share remuneration is calculated as gross revenue per fishing day minus operating costs per fishing day multiplied by the share accruing to the crew. Based on the 2000 costs and earnings survey, the following share ratios were applied for the different categories of vessels in the BEAM 5 simulation:

Table 20: Share ratiomodel inputs

Vessel type	Share ratio
Trawlers <40grt	0.40
Trawlers >40grt	0.50
Purse seine<40grt	0.53
Purse seine>40grt	0.50
Driftnet	0.40
Other gear	0.40

Fixed costs

The only fixed cost considered were depreciation costs. These were estimated from approximate current investment costs and a straight line depreciation over an estimated average economic lifetime of 15 years. The following values were used in the BEAM 5 simulation model:

Table 21: Fixed cost value model inputs

Vessel type	Cost (MR)
Trawlers <40 GRT	16667
Trawlers >40 GRT	41667
Purse seine<40 GRT	23333
Purse seine>40 GRT	61126
Driftnet	2667
Other gear	2667

License fees

License fees are paid by some categories of vessels. The data were obtained from figures reported in the 1967 Fisheries Maritime Regulations and later amendments. They were weighted to correspond with the two categories of trawlers and purse-seiners above and below 40 GRT:

Table 22: License fee value model inputs

Vessel type	Fee (MR)
Trawlers <40 GRT	53
Trawlers >40 GRT	2073
Purse seine<40 GRT	40
Purse seine>40 GRT	1723
Driftnet	2
Other gear	2

4.4.3 Investment costs of new vessel

The investment cost of a new vessel is needed in BEAM 5 to simulate replacements of boats that are retired from the fleet because they have reached the end of their technical lifespan. Investments into new vessels may also take place because of new entries into the fishery in expectation of good returns. The following figures are based on current estimates of investment and weighted in the case of trawlers and purse-seiners in accordance with the two categories considered in the BEAM 5 simulation model, i.e. below and above 40 GRT:

Table 23: Investment cost value model inputs

Vessel type	Cost (MR)
Trawlers <40 GRT	250005
Trawlers >40 GRT	625005
Purse seine<40 GRT	350010
Purse seine>40 GRT	916935
Driftnet	40005
Other gear	40005

4.4.4 Fisheries management costs

These costs are incurred by government and include expenditures for fisheries research, administration and, surveillance and enforcement. They were estimated from the average annual budgetary allocations made during the last 3 years and encompass half of the operating costs of the Penang Fisheries Research Institute. The other half is assumed to be attributable to aquaculture. The cost figure also includes rough estimates of the fixed costs (depreciation) of the fleet of patrol vessels and specific buildings used by enforcement staff.

The estimated total annual fisheries management costs of MR 11.9 million were approportioned among the fleets in five equal shares (ignoring the category of "other gear").

4.4.5 Adjustments to arrive at economic costs

Whereas the financial performance is undertaken from the point of view of the fishing firms or boat owners, the economic performance is assessed from the standpoint of society as a whole. Certain adjustments have to be made to arrive at the economic costs. In the current analysis, the most important adjustments relate to transfer payments such as subsidies and license fees and to opportunity costs of labour.

Subsidy

In the case of Malaysian fisheries, a significant adjustment arises from the implicit subsidy that applies to all fuel used in the country for both private and commercial purposes including diesel fuel in fisheries. As fuel makes up between 45 *percent* (purse-seiners) to about 70 *percent* (trawlers) of operating costs, the implicit fuel subsidy strongly influences the financial performance of all Malaysian fisheries. The actual subsidy element in the fuel price compared to the world market price is, however, affected by the exchange rate between the Malaysian Ringgit and the US $. To the extent that this exchange rate is controlled through the Central Bank of Malaysia, the subsidy element could be higher or lower than is reflected by the currently applicable exchange rate.

For the BEAM 5 simulation model, the following adjustment factor was used to calculate the economic operating costs (as against the financial operating costs paid by the fishermen):

Table 23: Adjustment factors for calculating economic operating costs

Vessel type	Adjustment factor
Trawlers <40 GRT	1.30
Trawlers >40 GRT	1.30
Purse seine<40 GRT	1.20
Purse seine>40 GRT	1.20
Driftnet	1.25
Other gear	1.25

Opportunity cost of labour

The Malaysian economy does not face high levels of unemployment that are typical for several of the neighbouring countries in Southeast Asia. In fact, until at least the onset of the recent economic crisis, a declining trend was noticeable of the number of fishers – a feature typical for industrialized countries. This trend, however, reversed itself in recent years when the downturn in the economy led to the retrenchment of significant numbers of workers in the modern sector. As a consequence of the still not entirely water-tight limit access regime, labourers displaced in other economic sectors entered fisheries, sometimes illegally. As this might be a rather temporary feature, the assumption was made for the BEAM 5 simulation model that labour opportunity costs are significant and amount to the average annual wage of a factory worker. Another consideration in the use of this amount was that the base case of the simulation model applied to 1997 data.

The 1997 Yearbook of Statistics reported an average monthly wage of a factory worker of MR 392; this value was multiplied by 12 to arrive at the annual amount of MR 4704 p.a. and per person.

Adjustment to fisheries management costs

No adjustments were made to fisheries management costs as no detailed breakdown of these cost items was available at the time of the workshop. To the extent that the fisheries administration, surveillance and enforcement and research incur fuel expenditures, an adjustment would be appropriate for the implicit fuel subsidy prevailing in the country (within the proviso mentioned above concerning the impact of the exchange rate).

4.4.6 Discount rates

Different discount rates were applied for the calculation of the financial and economic net present value. The base lending rate in 1997 of 10 *percent* was used as financial discount rate. A lower rate of 7 *percent* was used for as economic discount rate.

4.5 RESULTS OF THE BEAM 5 MODEL SIMULATIONS

Difficulties were encountered in tuning the model with the original set of estimated high growth and mortality parameters. While the reasons for these difficulties are believed to relate to these specific parameter values, it cannot entirely be ruled out certain characteristics of the BEAM 5 model have contributed. The results presented below, therefore, are based on the lower parameter values of growth and mortality. As these parameters have not been derived from biological assessment studies of West Peniinsular Malaysia fisheries, the findings of the simulation runs are very tentative and should be interpreted only as providing orders of magnitude. A future improved data set would allow for more detailed analysis of the various possible management options -- including, for example, an extension of the inshore no-trawl zone or variations in the timing of closed seasons. It should be noted, however, that the base year simulation results shown in Table 24 are not influenced by whether the high or low parameter set applies.

4.5.1 Base year simulation

The total catch in the base year amounts to just above one half million tonnes with an estimated ex-vessel value of MR 1727.5 million. This constitutes about 60 *percent* of the entire landings of Peninsular Malaysia and over half of the entire value of Malaysia's marine fish production in 1997 (FAO Fishery Country Profile April 2001). Two-thirds of the catch is taken primarily by bottom trawlers while the shares of purse-seiners, drift netters and other gear are 9.4, 12.5, and 12 *percent* respectively. Only about one fifth of the total landings comprise small-pelagics with the bulk of the catch comprising demersal species. Small pelagics are the main catch of purse-seiners and driftnetters but form only a small part of the total catch of trawlers and other gear types (see Table 16a for details).

All types of fishing gear show a positive financial and economic return in the base year. Indeed, the base year simulation would suggest that in aggregate the fishery produces a significant net economic cash flow (i.e. resource rent) on the order of MR 0.5 billion. The fact that sizeable resource rents are produced in these fisheries can likely be attributed to the positive impact of the comprehensive limited licensing policy adopted by the country as far back as in the early 1980s. The rent could be somewhat over-estimated if crew opportunity costs were underestimated. As can be seen in Table 24 the difference between crew remuneration and crew opportunity costs is on the order of MR 0.35 billion, thus contributing more than two-thirds to the total estimated resource rent.

The contribution of trawlers, purse-seiners, driftnetters and other gear to total resource rent is 51, 10, 12.5, and and 26.7 *percent*, respectively. This compares with the following percentage shares on aggregate investment into the fishing fleet estimated at MR 1850 million at current replacement values: trawlers = 61 *percent*; purse-seiners = 6.7 *percent*; driftnetters = 23 *percent*; and other gear = 9 *percent*. These figures indicate that purse-seiners and other gear make contributions to resource rent in excess of their respective investment shares while the contrary applies to trawlers and driftnetters.

It is interesting to note that this high resource rent is captured in spite of the substantial subsidy on fuel cost (as the average domestic fuel price is below the world market price). Trawlers are the main beneficiaries of this subsidy and, in fact, would produce only a marginal financial return in its absence. The subsidy is the main factor why the government budget depicts a negative cash flow. In comparison, fisheries management costs are low with MR 11.9 million amounting to less than one *percent* of the catch value (0.7 %). Current licensing fees are so low that they hardly make any contribution to the extraction of resource rent from the fisheries for the government treasury.

Table 24: Base Year (1997) simulation*

	Trawlers	**Purse-seiners**	**Drift nets**	**Other gear**	**Total**
Total catch (tonnes)	331310	47538	63245	59839	501932
Vessels (number)	3720	157	10725	4140	18742
Crew (number)	11700	2355	21450	8280	43785
FINANCIAL ANALYSIS					
Catch value	1129.07	141.238	249.65	207.54	1727.498
Operating cost (excluding crew cost)	660.38	35.52	60.77	25.42	782.08
Effort subsidy	89.14	5.33	11.55	4.83	110.84
Crew remuneration	353.00	54.18	75.55	72.85	555.58
Fixed costs	75.50	8.20	28.60	11.04	123.34
Licence fees	1.29	0.21	0.02	0.01	1.53
Net Cash Flow	128.03	48.46	96.25	103.05	264.97
GOVERNMENT BUDGET					
Management cost	4.75	4.75	2.38	0	11.88
Effort subsidy	89.14	5.33	11.55	4.83	110.84
Licence fees	1.29	0.21	0.02	0.01	1.53
Net Cash Flow	-92.60	-9.87	-13.90	-4.82	-121.20
ECONOMIC ANALYSIS					
Gross revenue	1129.07	141.238	249.65	207.54	1727.498
Operating cost (excluding crew cost)	758.03	69.38	62.11	25.98	915.50
Replacement invest.	56.63	5.50	21.45	8.28	91.86
Crew opportunity cost	55.04	11.08	100.90	38.95	205.96
Management cost	4.75	4.75	2.38	0	11.88
Net Cash Flow	254.62	50.53	62.82	134.33	502.29

* Values in million Malaysia Ringgit, unless otherwise indicated. In 1997, the average exchange rate to the US Dollar was MR 2.80.

The total number of crew employed in these fisheries is about 43800. About one half of them are employed on driftnetters, one quarter on trawlers, one fifth use other gear and five *percent* are engaged on purse-seiners.

4.5.2 Reduced effort and capacity simulations

Table 25 shows a summary of the results of three simulation runs over a time horizon of 15 years. In the first two runs (B and C of Table 25) fishing effort and capacity of all fleets were reduced by 25 *percent* and 50 *percent* respectively. In the third run (D), the fishery by small trawlers in inshore areas was put to zero. The reason for undertaking the third run is that the small trawlers are in most direct competition with other inshore gear and capture a significant amount of juveniles of commercially important demersal resources. There is a perception, even shared by the association of trawl fishers, that trawling is not a preferred fishing method in inshore areas. According to current regulation, there should be no trawling in the area up to 5nm from the shore but this is not always possible to enforce. The Department of Fisheries, moreover, would like to move trawling further away from inshore waters into Zone C and beyond.

As has already been pointed out, the simulation results are very tentative because of the use of lower growth and natural mortality estimates than are suggested by assessment studies applying the length-based catch analysis method and using the FISAT software. The consequence of these lower parameter values is that there is a distinct increase in the biomass and thus catch rates by reducing fishing effort (i.e. fishing mortality) from the assumed level of about 1 on an average.

As can be seen in Table 25, while the initial impact of a reduction of fishing effort by 25 *percent* and 50 *percent* respectively in Year 1 is a drop in aggregate catch, the long-term impact in Year 15 is to increase it by 10 *percent* in the case of the lower effort reduction and by more than 20 *percent* if effort were to be cut by half. As the higher catch and gross revenues are obtained at lower harvesting costs, there would be a dramatic improvement in the Net Cash Flow (NCF) and Net Present Value (NPV) of the fisheries. The economic NPV would about double in the case of a 25 *percent* cut in fishing effort and nearly triple to MR 12900 million if fishing effort and capacity would be halved. This gain would come at the cost of needing to find alternative employment opportunities for some 20,000 fishers.

Nearly the same extent of improvement in economic and financial performance could be realized by ceasing entirely the operation of small trawlers in the inshore zone (see D in Table 25). This would have two additional advantages. First, the total catch would even be higher than in the case of a global 50 *percent* cut in fishing effort and it would have a higher average ex-vessel price. Second, the number of fishers displaced would be 10,000 rather than the 20,000 in the case of a halving of global fishing effort and capacity. While this is still a sizeable figure it should be seen in the context of the long-term trend of a shrinking number of fishers in Malaysia during the last 2 decades (this has only recently slightly reversed because of the Asian economic crisis and a return of some workers into the fisheries sector). It should also be noted that significant additional employment opportunities would arise in fish processing, distribution and marketing to handle the about 130,000 tonnes of additional catch that the increased abundance of fish stocks would produce in the medium and long term.

Table 25: Reduced effort and capacity simulations

Option	Financial analysis (million MR)	Economic analysis (million MR)	Government finance (million MR)	Total catch (tonnes)	Total value or gross revenue (million MR)	Average price (MR/kg)
		A	**BASE CASE**			
Net Cash Flow	264.97	502.29	-121.20	501933	1727.50	3.44
Fin. NPV 10%	2,015.38		921.86	**No. of vessels**: 18742		
Eco. NPV 7%		4,574.81		**No. of crew**: 43785		
		B	**REDUCTION OF EFFORT BY 25%**			
Year 1: Net Cash Flow	556.34	496.65	-93.73	412673	1417.12	3.43
Year 15 Net Cash Flow	818.12	971.55	-93.73	553309	1892.03	3.42
Fin.NPV 10%	6860.17		-712.92	**No. of vessels**: 14047		
Eco.NPV 7%		9048.83		**No. of crew**: 32745		
		C	**REDUCTION OF EFFORT BY 50 %**			
Year 1: Net Cash Flow	426.65	425.62	-66.46	304556	1043.26	3.43
Year 15 Net Cash Flow	1009.88	1481.59	-66.46	616282	2099.23	3.41
Fin.NPV 10%	7911.36		-505.49	**No. of vessels**: 9360		
Eco.NPV 7%		12890.93		**No. of crew**: 21825		
		D	**BAN OF SMALL TRAWLERS**			
Year 1: Net Cash Flow	605.21	586.60	-54.22	384441	1392.04	3.62
Year 15 Net Cash Flow	1066.65	1398.38	-54.22	630187	2203.82	3.50
Fin.NPV 10%	8611.69		-412.37	**No. of vessels**: 15562		
Eco.NPV 7%		12524.49		**No. of crew**: 34245		

4.5.3 Conclusion

In conclusion, there could be significant scope to increase the economic benefits from West Peninsular Malaysia marine fisheries through a reduction of fishing effort, especially of trawling in the inshore zones A and B. These findings though are very tentative and should be validated, or refuted, through increased research efforts in the estimation of critical and sensitive growth and mortality estimates for a range of commercially important species. Current fisheries management expenditures including research costs are very low and amount to less than one *percent* of the value of the catch. Increased research efforts that result in greater precision of fisheries management advice are likely to yield high or even very high returns. Malaysian fisheries are in the exceptional position of having been subjected to a limited licensing scheme for nearly two decades. The current analysis suggests that this scheme was able to contain the expansion of fishing effort and capacity to an extent where sizeable resource rents accrue. Much of the rent is to the benefit of fishing crew.

The analysis also suggests that the license limit scheme could produce much higher net benefits by reducing significantly the fishing effort, especially trawling effort in inshore waters. It is to be expected that without a periodic reduction in fishing capacity, the so-called seepage effect would cause an increase in effective fishing effort over time even where a limited licensing scheme is effective in keeping the number of vessels at a constant level. This occurs because of two factors. First, there is technological progress through the adoption, for example, of improved fish finding and navigational equipment or better rigging of fishing gear. Secondly, fishers are known to be highly adept at finding ways to expand fishing effort along uncontrolled or uncontrollable dimensions of fishing capacity (e.g. effective engine horse-power).

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APPENDIX A

LIST OF PARTICIPANTS

FAO/FISHCODE/DOF Workshop On Bio-economic Modelling, Penang, 12-16 February 2001

No.	Name	Profession	Address	E-mail address
1.	Abd. Haris Hilmi Ahmad Arshad	Fisheries Research Officer	Fisheries Research Institute, 11960 Penang	haris_arshad@yahoo.com
2.	Abdullah bin Md. Dan	Fisheries Officer	State Fisheries Department, 5th Floor, Wisma	suriani_abd@hotmail.com
			Persekutuan, Jalan Kg. Baru, Alor Star, Kedah	
3.	Abu Talib Ahmad	Fisheries Research Officer	Fisheries Research Institute, 11960 Penang	abuahm01@dof.moa.my
				abutalib01@yahoo.com
4.	Alias Man	Fisheries Research Officer	Fisheries Research Institute, 11960 Penang	aliman01@yahoo.com
5.	Azwa Abd. Hamid	Fisheries Officer	Fisheries Headquarters, WISMA TANI	Hazwa51@hotmail.com
			Jalan Sultan Salahuddin, 50628 Kuala Lumpur	
6.	Chee Phaik Ean	Fisheries Research Officer	Fisheries Research Institute, 11960 Penang	chepha01@dof.moa.my
				phaikean@hotmal.com
7.	Huang Min Tuoo @ Thoo	Asst. Fisheries Officer	Fisheries Headquarters, WISMA TANI	
			Jalan Sultan Salahuddin, 50628 Kuala Lumpur	
8.	Lim Chai Fong	Fisheries Officer	Fisheries Headquarters, WISMA TANI	limcf@tm.net.my
			Jalan Sultan Salahuddin, 50628 Kuala Lumpur	
9.	Mahyam Mohd Isa	Fisheries Research Officer	Fisheries Research Institute, 11960 Penang	mahyam@rocketmail.com
10.	Mohd. Ghazali Abd Manap	Fisheries Officer	Fisheries Headquarters, WISMA TANI	mohman01@dof.moa.my
			Jalan Sultan Salahuddin, 50628 Kuala Lumpur	ghazalimanap@hotmail.com
11.	Mohd Norddin Yakob	Fisheries Officer	State Fisheries Department, Jalan Akuarium	
			11700 Gelugor, Penang	
12.	Norhanida Daud	Fisheries Research Officer	Fisheries Research Institute, 11960 Penang	norhanida@hotmail.com
13.	Per Sparre	Scientist	Danish Fisheries Research Institute	
			2920 Charlottenlund Slot, Denmark	PJS@DFU.MIN.DK
14.	Purwito Martosubroto	Fishery Resources Officer	Via delle Terme di Caracalla, 00100 Rome, Italy	Purwito.Martosubroto@fao.org
15.	Rolf Willmann	Senior Fishery Planning Officer	Via delle Terme di Caracalla, 00100 Rome, Italy	ROLF.WILLMANN@fao.org
16.	Shamila Zainol	Fisheries Officer	Fisheries Headquarters, WISMA TANI	shamilazainol@hotmail.com
			Jalan Sultan Salahuddin, 50628 Kuala Lumpur	
17.	Sharum Yusof	Fisheries Research Officer	Fisheries Research Institute, 11960 Penang	shayus_95@hotmail.com
18.	Tai Shzee Yew	Associate Professor	Universiti Pertanian Malaysia	sytai@econ.upm.edu.my
19.	Tan Geik Hong	Fisheries Officer	Fisheries Headquarters, WISMA TANI	geikhong@hotmail.com
			Jalan Sultan Salahuddin, 50628 Kuala Lumpur	
20.	Thalathiah bt Hj. Saidin	Fisheries Officer	Fisheries Headquarters, WISMA TANI	thalathiah@hotmail.com
			Jalan Sultan Salahuddin, 50628 Kuala Lumpur	
21.	Zainudin Abd. Wahab	Fisheries Officer	Fisheries Headquarters, WISMA TANI	zainudin@hotmail.com
			Jalan Sultan Salahuddin, 50628 Kuala Lumpur	

APPENDIX B

AGENDUM

Bioeconomics Modelling Workshop On The Small Pelagic Fisheries on the West Coast of Peninsular Malaysia
Vistana Hotel, Pulau Pinang, 12-16 February 2001

11.2.2001 (Sunday)

1700	Registration

12.2.2001 (Monday)

0830	Registration
900	Workshop Opening : Ms. Choo, Acting Director Research, FRI Introduction to FISHCODE and workshop objectives by Dr. Purwito Martosubroto
0930	Introduction to Fisheries Bioeconomics by Mr. Rolf Willmann
0945	The Gordon Schaefer Model by Dr. Purwito Martosubroto and Mr. Rolf Willmann
1030	Coffee break
1100	BEAM 5 Model by Mr. Rolf Willmann and Mr. Per Sparre
1200	Basic Concepts of Bioeconomic Modelling by Dr. Tai Shzee Yew
1245	Lunch
1400	Bioeconomic Model for Small Pelagic Fisheries on the Northwest Coast of Peninsular Malaysia by Dr. Tai Shzee Yew
1500	An overview of the available data on the small pelagic fisheries on the west coast of Peninsular Malaysia. Biological and ecological data (e.g. Time series of catches, catch composition, CPUE, estimates of stock sizes and of F & M, changes of fish habitats, data gaps by Mr. Abu Talib Ahmad Economic data related to cost and earning (e.g. Fixed and variable harvested costs, crew income, return on investment of different types of vessels and vessel sizes), Institutional data (eg enforcement cost and fisheries management costs) by Ms. Tan Geik Hong
1530	Coffee break
1600	Break-up into 2 Working Groups – Biology and Economics Groups for data preparation. Data preparation by Working Groups.
1700	Close for Day 1.

13.2.2001 (Tuesday)

0830	Review of data prepared. Working Groups
10.30	Coffee break
1100	Working Groups (Continue)
13.00	Lunch
14.00	Working Groups (Continue)
15.30	Coffee break
16.00	Working Groups (Continue)
17.30	Close for Day 2.

14.2.2001 (Wednesday)

830	Preliminary run of Biological sub-model. Discussion. Review of data prepared. Working Groups (Continue).
1030	Coffee break
1100	Working Groups (Continue)
13.00	Lunch
1400	Working Groups (Continue)
1530	Coffee break
16.00	Working Groups (Continue)
1730	Close for Day 3.

15.2.2001 (Thursday)

830	Re-run of Biological sub-model. Discussion. Review of data prepared. Biology Working Group (Continue). Data preparation by Economics Working Group for Gordon-Schaefer Model
1030	Coffee break
1100	Working Groups (Continue)
1300	Lunch
1400	Working Groups (Continue)
1530	Coffee break
1600	Working Groups (Continue)
1730	Close for Day 4.

16.2.2001 (Friday)

0830	Plenary presentation of results from BEAM5 model. Discussion. Re-run of BEAM5.
1030	Coffee break
1100	Plenary presentation of results from Gordon-Schaefer model. Discussion.
1200	Lunch
1445	Preparation of draft report of modelling results
1530	Coffee break
1600	Preparation of draft report of modelling results
1700	Plenary discussion of results
1800	Close of Workshop

APPENDIX C

ABBREVIATED DESCRIPTION OF BEAM 5

by
Per Sparre
and
Rolf Willmann

INTRODUCTION

BEAM 5 stands for "Bio-Economic Analytical Model No. 5. It is a multi-species, multi-fleet dynamic software implementation of a bio-economic stochastic simulation model, 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 (Cochet & Gilly, 1990; Coppola, Garcia & Willmann, 1992; Sparre & Willmann, 1993).

Apart from being implemented in Visual Basic with an EXCEL user interface, the key new features of BEAM 5 as compared to BEAM 4 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. Such transition costs would often have to be financed by government whether or not they are subsequently recovered from the fishery participants through taxes, fishing licensing fees or other levies.[3] Investments may also be needed to upgrade the fisheries management capacity at various levels: for improved research; monitoring, control and surveillance; and educational and organisational 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 calculus. These include fisheries management costs such as research, administration and surveillance and enforcement.[4] 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. Furthermore, pure transfer payments from one ‘pocket’, i.e. the fishing industry, into another ‘pocket’, i.e. the government treasury, such as taxes and subsidies, are excluded from the economic analysis.

BEAM 5 also allows analysing the impact of the adjustment or transition process on the government 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, 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.

BEAM assumes a one-to-one functional relationship between Effort and fishing mortality, which in its simplest form reads: “Fishing Mortality = Q * Effort”, where Q is the catchability coefficient. This is one of the essential links between the biological production function (based on the traditional Thompson and Bell prediction model) and the economic model. In the latter, changes in effort result in changes in operating costs. Where changes in fishing effort cannot be accommodated within a certain fishing capacity limit (expressed as the product of the maximum number of effort units per vessel multiplied by the number of vessels), the number of fishing vessels will change and with it fixed harvesting cost. Two other links between the biological and economic model are also indirectly related to effort. Firstly, fish handling costs increase or decrease with the amount of fish landings. Secondly,

[3] There is a strong argument in favour of recuperating from fishery participants transition costs such as vessel decommissioning payments in order to avoid the principal threat of such buy-back programmes, namely that the compensatory funds received by vessel owners are used to re-invest into new and more powerful vessels or to modernize existing vessels (Holland, D., E. Gudmundsson and J. Gates. 1999)

[4] It can be argued that where industry benefits from fisheries management, management costs should be recovered from fishery participants (Arnason, R., R. Hannesson and W.E. Schrank. 2000).

where prices are responsive to supply, these will increase or decrease with the amount of landings.

THE BIOLOGICAL FRAME OF BEAM 5

The biological model behind BEAM 5 is the traditional model by Thompson and Bell (1934), which has been discussed in many textbooks on dynamics of fish stocks (e.g. Ricker, 1975, Beverton & Holt, 1957 and with emphasis on tropical fisheries Sparre & Venema, 1998). The major part of the biological model behind BEAM 5 is the traditional model, or generalizations of the traditional model. BEAM 5 extends the traditional models with a spatial model, among opthers accounting for migration, using the approach of Quinn *et al.* (1990). All these models originally were thought of as "fish stock assessment models", where parameters were estimated by methods like Virtual Population Analysis (VPA) or Cohort Analysis (Derzhavin, 1922; Fry, 1949). Lassen and Medley (2001) give a summary of contemporary practical applications of VPA.

In its present form BEAM 5 focuses on the fisheries component of the exploited marine ecosystem. It is, however, imagined that BEAM 5 will be added to some general ecosystem model, such as the ECOPATH suite of models (Christensen *et al.*, 2000; Pauly *et al.*, 2000) and multi-species VPA (Sparre, 1991). BEAM 5, has certain areas which overlap with that type of ecosystem models and therefore merging should be possible. Application of fish stock assessment in tropical waters, however, is problematic (Mahon, 1997). The so-called "tuning of model" in BEAM 5 can replace the traditional fish stock assessment to some extent.

The concept of "stock" is rather complicated and there is no consensus among scientists on how to define it. A full discussion of the stock concept in the context of fisheries management is given in Begg *et al*. (1999). The separation of species into stocks is often very problematic. Even for stocks in non-tropical waters with relatively few species, stock separation is often difficult. Tropical stocks may in theory be separated by the same methods as used in cold waters, such as comparison of meristic characters (for example, size and position of fins and other body parts), number of vertebrae, blood type, parasites, etc. However, these kinds of data collection may well exceed the capacity of the resources of a developing tropical country. The collection of data on maturity, spawning grounds and migration routes often may be within reach of a modest research budget, but usually not for all species of commercial interest.

In a tropical country, more than 500 species of fish, cephalopods and shrimps may be included in the list of species of commercial interest that ought to be sampled, in addition each of the species could consist of a number of "stocks". Thus in practice, a sampling programme is often not able to apply the stock concept rigorously. Therefore, a more operational concept is required. For management of fisheries the concept of "management unit" is more useful. A management unit is a fisheries resource for which it is possible to make predictions, or, in other words, something for which we can give answers to "What-if questions".

Due to limited personnel and funds, it is usually not possible to collect data for fish stock assessment from all species (stocks) of commercial interest in the waters of a tropical country, therefore a limited number of species has to be selected as "representatives" for the entire living resources. The selection of representative species must account for both their ecological and economic importance, that is, large stock size (potential yield) and high price per kg should be the main criteria to implement biological sampling.

According to the agreed international standards (FAO, 1995,1996,1997,1999, ICES, 1998, UN 1995), "reference points" are an important concept in implementing a precautionary approach to fishing. Reference points are closely related to the stock concept (Caddy & Mahon, 1995, Gislason, 1999). Therefore, fishing mortality rates, biomass, or other measures should be regarded as indicators of the status of the stock in relation to predefined reference limits, that should be avoided, or targets, that should be aimed at, in order to achieve the management objective.

The identification of reference points requires a time series of scientific data, often over many years. A key concept in some reference points is the Spawning Stock Biomass (SSB), which is defined as the number of individuals multiplied by the fraction of mature individuals for each age group, summed over all age groups. Another important concept is the "recruit", which is a juvenile fish entering the exploited part of the stock.

With a few rare examples, the identification of the relationship between parent stock (SSB, spawning stock biomass) and subsequent recruitment (R) has remained elusive for marine fishes (Gilbert, 1977, Hilborn, 1997, Myers, 1997). The precautionary approach dictates that unless it is scientifically demonstrated that there is no relationship between the parent stock and subsequent recruitment, such a relationship should be assumed to exist, even if the data are ambiguous. Observations of stock and recruitment show large variation around any SSB/R curve, so scientists are not in a position to predict future recruitment with any accuracy. They are only able to tell the probability distribution of the future recruitment and only in cases where a long time series of SSB/R observations is available.

For the tropical fish stocks it is often not possible to apply the methodology of reference points, for the simple reason that information on stock and recruitment, as well as fishing mortalities and other population parameters are not available. The typical information needed for the calculation of reference points is a long time series of recruitment estimates. This type of data is usually only available for stocks in temperate waters.

If a data collection programme is to implement international standards for responsible fishing, it has to choose reference points that can be calculated by means of the data currently available. The basic data collected is first of all catch rates or CPUE (Catch Per Unit of Effort), usually expressed in kg per day by fleet, season, fishing grounds and species group. Thus, possible candidates for reference points could be derived from catch rates. BEAM 5 is designed as a tool to be used in cases where long time series of data are not available and where the definition of stocks is problematic or even impossible.

THE TECHNICAL FRAME OF BEAM 5

The technical units of BEAM 5 are the "fleets". The definition of fleet is also problematic (Sparre, 2000). A formal definition is: A "fleet" is a group of uniform vessels, which have approximately the same size and the same construction. The vessels should use the same type of gear and fishing techniques and most often, they share fishing grounds.

The definition is problematic, because, the operations of a vessel may change during the year. A vessel may, for example, do pair trawling for fish during one season and do single trawling for shrimp during another season. Some vessels use a combination of gears during a fishing trip, which may complicate the allocation of vessel to fleets.
Fleets may be defined by a combination of gear, engine horsepower (size of vessel), type of construction and fishing grounds. Horsepower, tonnage and length of vessel are usually correlated within a group of vessels of the same basic construction type. One practical problem is that BEAM 5 must adequately cover every major fleet. An example of pragmatic fleet definitions is given in Holland & Sutinen, 1999.

When the fleets have been defined, we assume (as an approximation to reality) that all vessels in a fleet are exactly equal and behave in exactly the same way. All members of a fleet are assumed to have the same "fishing power". Two fishing vessels are said to have the same "fishing power" if they can catch the same amounts and types of fish under similar conditions. One may simplify the concepts of fishing power by making it species-specific. In practice, this ideal definition can rarely be shown to hold. Instead, if two trawlers catch the same amount of "demersal fish" during a fishing operation on average, they have the same fishing power, and if one vessel catches X *percent* more on average than the other vessel it has X *percent* more fishing power.

A concept closely linked to fishing power is that of a "standard vessel". It is often desirable to express the fishing power relative to some selected vessel type. Usually the most common vessel type is selected as "standard vessel" (e.g. bottom trawlers of 15 m length with an engine of 60 HP and perhaps some other more specific characteristics). Other types of vessels are then expressed in units of standard vessels. If a vessel has 80 *percent* of the fishing power of a standard vessel, it counts as a "0.8" standard vessel.

THE SPATIAL FRAME OF BEAM 5

BEAM 5 offers the opportunity to account for spatial aspects, in the sense that fish and fleets can be allocated to a number of areas in a given time period. BEAM 5 uses a simple "box-model" to handle spatial aspects. However, the inclusion of spatial aspects is optional and the user may choose to consider the sea one homogenous area. If several areas are considered, this will require a number of additional input parameter, for example, "migration coefficients", the concept of which will be explained below.

The selection of areas or "fishing grounds" is most often constrained by the data. If logbooks are not maintained, precise information on where catches were taken is often absent. Often the practical circumstances dictates that only few areas are considered, sometimes all fishing areas have to be merged into one single area. A first natural division of the fishing area would be to use depths for the definition of areas. That may lead to areas like "in-shore", (say from 0-20 m depth) and "off-shore" (say, >20 m depth). Such a division will match both the distributions of vessels (mainly small vessels in the in-shore area, and large vessels in the off-shore area) as well as the distribution of stocks and size groups within a stock. Some areas may also be defined as "nursery areas", that is, areas where juvenile fish are known to be abundant. Such areas may be closed for fishing to protect the juvenile fish and to avoid discarding (see example in Pastoors *et al.*, 2000). Other criteria may be used, which depends on the size and nature of the marine area under study. For example, it will be natural to separate coral reefs from other areas. Bottom type (sandy, muddy, rocky) combined with depth may also

form the basis for area definition. In large areas, currents and temperature gradients may give natural definitions of areas. Examples of pragmatic fleet and area definitions are given by Holland & Sutinen (1999).
BEAM 5 however, is not suited for the handling of a large number of areas. It is not anticipated that BEAM 5 applications will use more than, say, 20 divisions of the total area. BEAM 5 also is not constructed to deal with a division of the areas into small squares (say, 30 by 30 nm, or smaller).

For a theoretical discussion of migration in connection with age-based fish stock assessment the reader is referred to Quinn II *et al*. (1990). These authors also discuss the estimation of migration parameters. In principle their model is the approach planned for BEAM 5. Chapter 11 in Sparre & Venema, 1998 discusses the assessment of migratory stocks at a somewhat lower mathematical level, and it does not deal with the estimation of migration parameters.

THE ECONOMIC FRAME OF BEAM 5

The economic part of BEAM 5 uses the concepts developed for project analysis to evaluate the financial and economic performance of the fishery during the project horizon (i.e. simulation life span) given different fisheries management measures, government financial transfers and assumptions about the investment and operational behaviour of fishing firms. The financial performance is assessed from the point of view of both the fishing firms and the government treasury[1].

The project horizon is defined as the time span from the initial base year, until the ‘end’ of the project. The user of BEAM 5 determines the number of project years. In the choice of project years, the user would be guided by various factors and assumptions including the time when management measures are taken and the number of years they take to produce the expected biological and economic results, the chosen value of the discount rate, the lifetime of fishing vessels and other factors as appropriate. A short project horizon of say 5 years may fail to reveal the full benefits of taking management measures such as a reduction of fishing capacity and effort because the population dynamics of the fish stocks have not yet yielded their full recovery to the desirable level. A long project horizon of say 20 years would show very little discernible difference in results to a project horizon of 15 years whenever the discount rate is 15 *percent* or higher.

The evaluation of the financial performance is undertaken from the point of view of both the fishing firms and the government, while the economic performance is assessed from the standpoint of the economy as a whole. The principal differences between the two financial analyses and the economic analysis are as follows:

1) The economic analysis 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 surveillance and enforcement. These costs lead to a cash outflow from the government budget or treasury. This cash

[1] The user of BEAM 5 is directed to the specialised literature for detailed explanations of the terms and concepts applied in project analysis. A well-written and quite accessible text, even for non-economists is provided by Gittinger (1984). Other standard literature includes Little & Mirrlees (1974), Squire & Tak (1975) and Dasgupta *et al.* (1972).

outflow, however, might not be equal to their true costs to society to be accounted for in the economic analysis as is further explained below.

2) The economic analysis uses shadow prices as 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. For example, where fuel prices are subsidised, thus lowering fuel expenditures incurred by fishing firms, the economic analysis will be based on fuel prices net of such subsidies.

3) The financial performance of fishing firms will be affected by the way investments into fishing craft and gear were financed (i.e. own savings or loans) and by the capital servicing terms of any loans taken in the past or in future years.

4) The financial performance of the government treasury depends on the cash inflows from the fishery through taxes, licensing fees, fines etc. and cash outflows for fisheries management expenditures, subsidies, etc. during the project horizon.

5) The economic analysis applies opportunity costs of capital to reflect the real social cost of using capital in fisheries rather than elsewhere in the economy. The opportunity cost concept is only applied to new investments. Past investments are sunk costs to the extent that they have no alternative economic use outside of fisheries.

6) In the financial analyses, labour costs are based on observed payments made to the fishing crew or government employees.

7) In the economic analysis, opportunity cost of labour is applied to reflect the real social cost of employing people in fishing or government rather than elsewhere in the economy.

8) In the financial analysis, payments made to fishing firms to decommission excess fishing capacity increase their net cash flows. Some firms may exit the fishery altogether and may invest decommissioning payments into other economic activities. If so, these firms would not be further considered in the simulation model of the fishery.

9) Decommissioning payments (i.e. compensations to fishing firms and to displaced fishing crews) are considered as transfer payments, i.e. a cash outflow from the government treasury. These payments are not considered a cost in the economic analysis.

No adjustments are made to fish prices observed in the market which are assumed to accurately reflect social values. However, a simple function has been included to model changes in fish prices as a result of changes in fish landings.

The rules (or algorithms) that attempt to model the behaviour of the skippers or owners of the fishing vessels are a crucial component of BEAM 5. As all vessels in a fleet are assumed to be the same (i.e. the fleet is perfectly represented by the average vessel), these rules are fleet and not vessel specific. There is one exception, however, to the extent that the fleet is structured according to the age of the vessels. The age takes importance for some of the rules that deal with vessel decommissioning (buy-back) and with vessel attrition (retirement due to old age, i.e. wear and tear and technological obsolescence).

The rules have been introduced into BEAM 5 for several reasons. First, being a dynamic model, there is a need to allow additions and reductions in the number of vessels over the simulation period arising from investments into new vessels, attrition of old vessels, bankruptcy and vessel decommissioning. Second, to achieve certain realism, there is a need to model the response of skippers and vessel owners to changes in profitability. This is especially important for simulating a vessel buy-back scheme for the following reason: the higher returns that the decommissioning payments, a smaller fleet and a restored stock produce create a powerful incentive for re-investments when no measures are taken to extract the resource rent and/or have in place effectively enforced exclusive use or property rights.

THE APPLICATION OF BEAM 5

In a typical BEAM 5 simulation of a fishery, the team of biologists and economists would first decide jointly on the system dimensions, i.e. the number of fleets, species and areas to model and the simulation horizon. As a general rule one could say that the model dimensions should be kept as simple as possible for generating relevant answers to relevant ‘what-if-questions’.

The team would then create the ‘base year’ that is the set of biological, technical and economic parameters that best represent the current bio-economic condition of the fishery (say some average over recent years). The base year parameters can be assumed to either remain stable over the simulation horizon or change in accordance with reasoned predictions about future developments (e.g. in respect of fish prices, operating and fixed costs, catchability, etc.).

BEAM 5 has been designed in a manner to allow for maximum flexibility as decided by the users and to take advantage of the opportunities offered by the program EXCEL. For most part, BEAM 5 only specifies broad cost categories and leaves it up to the user to decide which specific kinds of costs are subsumed under each of these categories. For this reason, ample space is provided next to the columns of input parameters where the specific cost items can be listed, mathematically manipulated and the result directed into the appropriate input cells.

Once all the parameters have been entered, the team can start to perform some simple deterministic simulations without enabling the behavioural rules. This will allow checking whether the model can re-produce the current fishery situation in the base-year. It can also produce an estimate of the Net Present Value for each fleet and all fleets combined under the assumption that the fishery remains stable over the simulation horizon.

More complex simulations can then be performed (e.g. stochastic simulations; changes in price and cost parameters during the simulation horizon, enabling of the behavioural rules; etc.) and assumptions made about the use of various governmental management measures (e.g. buy-back programme; changes in taxes and licensing fees; closed seasons and areas; fishing capacity and effort limits).[5]

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[5] For introduction to fisheries bio-economics the reader is referred to, for example, Anderson, 1977, Clark, 1985, Cunningham, *et al.*, 1985, Gilbert, 1988, Gordon, 1954 and Hanneson, 1988, 1993.

APPENDIX D

STANDARDIZATION OF FISHING EFFORT

1. Effort and CPUE data set, 1978 to 1997

Year	Effort	CPUE
1978	407752.8	0.176063
1979	488786.4	0.162685
1980	504699.8	0.204559
1981	520813.4	0.174425
1982	533910.7	0.196306
1983	525202.6	0.230886
1984	542188.8	0.222808
1985	540216	0.178836
1986	450809.8	0.161818
1987	409315	0.287795
1988	497527.7	0.186665
1989	489496.4	0.182727
1990	445015.4	0.238861
1991	441666.9	0.177124
1992	411434.9	0.226925
1993	381200.9	0.219669
1994	376400.1	0.311071
1995	382135.2	0.417248
1996	369917.4	0.348537
1997	380816.8	0.315425

2. Standardization of fishing effort

A vital variable in the estimation of surplus production model is the fishing effort. However, in a multi-gear fisheries there exists heterogeneity in the gear, vessel size, tonnage class, engine power and ancillary equipment. These heterogeneous inputs will exert different effects on the fish stocks. Thus, Standardization of fishing efforts of various gear types is required in order to reflect appropriately their effects on fish stocks. This involves estimating the relative fishing power of the vessel and gears as follows (Robson, 1966; Gulland, 1983):

$$P_{cj} = \overline{U}_{cj} / \overline{U}_s$$

Where Pcj is the estimated fishing power of vessels using gear type j in tonnage class c, Ucj is the average catch per vessel of gear j in tonnage class c and Us is the average catch per vessel of a particular gear in a particular tonnage class and this is used as the standard against which all other gears are compared.

The fishing power for vessels in various tonnage classes of a particular gear type (Pj) can be estimated by weighted-averaging the Pcj, with the ratio of the number of vessels in a particular tonnage class (Vcj) to the total number of vessels for gear j (Vj) is used as weight.

$$P_j = \sum_c P_{cj} \, (V_{cj}/V_j)$$

Following (Tai (2001), the index of fishing power with drift net as the standard gear for trawl, purse seine and drift net is respectively 12.66, 35.87 and 1. Since purse seines are the main gear used in catching the small pelagics, it is felt more appropriate to be the standard gear. The fishing power index (with purse seine as the standard) can be calculated by dividing by 35.87 the respective index of various gears based on drift net as the standard. The resulting index is 0.35, 1 and 0.028 respectively for trawl, purse seine and drift net.