5 BEAM 5 IMPLEMENTATION AND MODELLING RESULTS[6]

5.1 OBJECTIVES

The overall objective of the BEAM 5 working group was to make predictions about the financial, economic and social implications of reducing fishing effort and fishing capacity in the Thai demersal fisheries in the Gulf of Thailand to a level that would restore and conserve fishery resources, improve the returns on investment of the remaining operators in the demersal fisheries and generate high resource rent for the national economy. The specific objectives have been stated in Section 1.2 and in Table 3.1.

5.2 METHODOLOGY

A summary of BEAM 5 was presented in Section 3.4. An abbreviated description of the BEAM 5 methodology is given in Appendix F.

5.3 TASKS

The tasks of the working group were as follows:

- Establish the model dimensions;
- Prepare the model input parameters;
- Make a set of simulations in accordance with the specific objectives listed above;
- Report and interpret the results of the model simulations.

5.3.1 Model dimensions and biological/technical input data

A number of scientific papers, working papers and reports provided the background information for the design of the modelling exercise and the input parameters. These included, Kongprom *et al.* (1999); Supongpan and Suwanrumpa (1997) and earlier Scientific and Advisory reports (FAO/DANIDA, 1996).

"Model dimensions" include:

(a) The number of stocks;

(b) The age groups of each stock;

(c) The number of fleets;

(d) Vessel age groups of each fleet and

(e) The number of areas accounted for in the model.

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The dimensions of the BEAM 5 simulation of the demersal fisheries of the Gulf of Thailand are shown in Table 5.1. The corresponding input parameters are contained in nine EXCEL worksheets as follows:

1. Stock-structured input (this sheet also defines and contains the model dimensions);
2. Fleet-structured gear input and fleet/stock-structured catchability parameters;
3. Effort (fleet-structured);
4. Number of vessels (fleet-structured);
5. Prices (fleet/stock-structured);
6. Economy input (fleet-structured);
7. Fleet behaviour parameters (fleet-structured);
8. Tuning input (estimated fishing mortalities, fleet/stock-structured);
9. Observed landings to be used for tuning (fleet/stock-structured).

Table 5.1. Dimensions of Gulf of Thailand simulation

BEAM 5 SYSTEM DIMENSIONS								
Time steps/year 12 (one time step = 0.0833 year) Number of stocks 9 Number of fleets 8 Number of areas 2								
Stock names (9)		Number of age groups	Fleet names (8)		Number of vessel ages	Area names (2)		
1	Threadfin bream	3	**1**	Small OBT	15	**1**	Inshore	
2	Bigeye	3	**2**	Medium OBT	15	**2**	Offshore	
3	Ponyfish	2	**3**	Large OBT	15			
4	Grouper	10	**4**	Small PT	15			
5	Shrimp, School prawn (*M. affinis*)	2	**5**	Large PT	15			
6	Shrimp, Banana prawn (*P. merguiensis*)	3	**6**	Small PN	15			
7	Crab	3	**7**	Large PN	15			
8	Squid	3	**8**	Other Gears (OG)	15			
9	Cuttlefish	3						

The choice of the model dimensions and their implications are discussed in the following.

5.3.2 Fleet structure used for BEAM 5 for the Gulf of Thailand

Four types of vessels were considered in the BEAM 5 simulation, namely otterboard trawl (OBT), pair trawl (PT), push net (PN) and other gears (OG).

The three first groups were further divided into vessel size groups, according to the length of the vessels. Thus, altogether, 8 fleets were considered in the simulation of the total demersal fisheries as indicated in Table 5.2 below.

Table 5.2 Fleets by vessel type and size categories

1	OBT Small	Less than 14 meter
2	OBT Medium	14-18 meter
3	OBT Large	More than 18 meter
4	PT Small	Less than 18 meter
5	PT Large	More than 18 meter
6	PN Small	Less than 14 meter
7	PN Large	More than 14 meter
8	OG (Other Gears)	

5.3.3 Selection of nine species to represent the demersal resources of the Gulf of Thailand

The number of commercially important species in the Gulf of Thailand is large and for practical reasons (primarily lack of detailed information on all species) it was necessary to select a (small) number of species to represent the entire demersal resources (Table 5.3).

Table 5.3 Nine species, selected to represent the nine species groups that represent the entire demersal fishery of the Gulf of Thailand

	Common name	**Scientific name**	**Species group represented**
Four species of demersal fish			
1.	**Threadfin bream**	***Nemipterus hexodon***	Small size fish, medium price
2.	**Bigeye (bull's eye)**	***Priacanthus tayenus***	Small size fish, low price
3.	**Grouper**	***Epinephalus sexfasciatus***	Large size fish, high price
4.	**Ponyfish**	***Leiognathus bindus***	Trash fish
Two species of shrimp			
5.	**School prawn**	***Metapenaeus affinis***	All small-sized shrimp
6.	**Banana prawn**	***Penaeus merguiensis***	All large-sized shrimp
One species of crab			
7.	**Swimming crab**	***Portunus pelagicus***	All crabs
Two species of Cephalopods			
8.	**Squid**	***Loligo duvauceli***	All squids
9.	**Cuttlefish**	***Sepia aculeata***	All cuttlefishes

Threadfin breams, bigeyes and groupers are the most important fish species, representing more than 60% of the total demersal fishes. Of the threadfin breams the genus *Nemipterus* comprises about 10 species, including *N. hexodon, N. mesoprion* and *N. japonicus*. The species *N. hexodon* was chosen because it accounts for 48% of the catch of Nemipteridae. Among the bigeyes *Priacanthus tayenus* accounts for about 95% of the catch. The grouper *Epinephalus sexfasciatus* and the ponyfish *Leiognathus bindus* were also selected.

Shrimps and cephalopods are the most valuable part of the catch of the demersal species. The representative species were also selected because of high landings and/or high market values.

Shrimp landings consist for 25% of school prawns of which *Metapenaeus affinis* is the dominant species (80%) and for 23% of the banana prawn, *Penaeus merguiensis*. Those two species were selected. Also the swimming crab *Portunus pelagicus* was selected.

Squids and cuttlefishes represent more than 83% of the cephalopods. *Loligo duvauceli* constitutes about 68% of landings of squid and *Sepia acculeata* accounts for 55% of the catch of cuttlefish. Those two species were selected.

Length frequency data applicable for analysis of growth parameters and mortality (such as K, L_∞ and fishing mortality) were available for the year 1997. Length frequency data from the Gulf of Thailand were available for three of the four species of demersal fish, the two shrimp species, the crab species and the two cephalopods. One of the selected species (ponyfish) was not represented in those data and therefore its biological parameters were extracted from the literature via FishBase (Froese and Pauly, 2000).

The total catch of the demersal fisheries in the Gulf of Thailand in 1997 was about 1.4 million tonnes, which was composed of 0.8 million tonnes of food fish (for human consumption) and 0.6 millions tonnes of trash fish (used for fish meal and oil).

The total landings of the nine selected species were 0.9 millions tonnes (64%), composed of about 0.3 millions tonnes of food fish (50% of all food fish) and 0.6 millions tonnes of trash fish.

The catch from the Gulf of Thailand, in year 1997, by species group and by fleet is shown in Table 5.4. The landings are assumed to be equal to the catch since no discarding takes place in the fisheries.

The species composition of landings by small pair trawlers is not known and therefore it was assumed to be the same as that of large pair trawlers. Total landings of small pair trawlers were estimated under the assumption that the CPUE of small pair trawlers is half of that of the large pair trawlers. This assumption is not crucial for the overall results as the small pair trawlers contribute only a small fraction of the total landings, but any conclusion derived for small pair trawlers should be taken with considerable reservation.

Table 5.4 Total landings (tonnes) of demersal resources by species groups and by fleet from the Gulf of Thailand in 1997

Species group Fleet	Thread fin breams	Big eyes	Pony fishes	Groupers	School prawns	Banana prawns	Crabs	Squids	Cuttle fishes	Total
Small OBT	1,643	1,496	4,663	34	2,288	625	2,100	2,015	2,229	**17,093**
Medium OBT	11,755	20,837	153,876	2,978	2,453	312	4,467	8,563	7,698	**212,939**
Large OBT	47,180	36,238	307,752	2,307	757	200	2,905	18,009	21,972	**437,320**
Small PT *)	8	21	854	1	1	1	7	32	24	**950**
Large PT	950	2,580	102,623	93	158	86	869	3,848	2888	**114,095**
Small PN	360	280	8,238	0	537	110	501	113	339	**10,478**
Large PN	32	24	915	0	47	10	44	10	29	**1,111**
Other Gear	503	2	14,173	134	2,018	7,169	23,604	20,363	1625	**69,591**
Total	**624,30**	**61,479**	**593,094**	**5,547**	**8,259**	**8,513**	**34,497**	**52,953**	**36,804**	**863,577**

*) Data for small PT are based on the composition of the large PT (rounded)

5.3.4 Fishing grounds in the Gulf of Thailand

The fishing grounds of the fleets were obtained from interviewing skippers. The small otterboard trawlers and pushnetters fish predominantly in the shallow waters (less than 20 m depth) and mostly in areas adjacent to river mouths. The medium and large otterboard trawlers operate in offshore areas. Pair trawlers also operate in the offshore area at depths of more than 20 m. As an approximation, it was decided to apply only two areas in the simulation of the Gulf of Thailand demersal fisheries, namely:

Inshore area	Depths of less than 20 m
Offshore area	Depths of more than 20 m

The difficulties encountered to split the catches by smaller geographical areas, with the data available to the working group, were another reason for the decision to use only two areas.

5.3.5 Growth, mortality and natural mortality of the Gulf of Thailand case study

Length frequency data collected from the "fish for human consumption" and the "trash fish" components of the landings were collected monthly in 1997at fishing piers. The term "trash fish" is used for "fish landed for fish meal or oil production". Trash fish may consist of species not suitable for human consumption and also small juvenile specimens of species suitable for human consumption.

The length measurements used were "total length" for demersal fish and shrimp, "mantle length" for cephalopods and "carapace width" for crabs.

The length frequency samples were stratified by gear and area. The first step in the data processing was to raise the samples to the total weight landed by the boat-trip represented by the sample. The next steps were to combine these data by gear and area and raise them to the statistical catch of the Gulf of Thailand. The data thus obtained were considered to be representative of the Gulf of Thailand.

The raised length frequency data were then used to estimate the von Bertalanffy growth parameters, L_∞ , K and t_o with the FISAT software package (Gayanilo *et al*., 1995).

The growth parameters of ponyfish were obtained from the literature, using "FishBase" of ICLARM (Froese and Pauly, 2000).

Parameters a and b in the length/weight relationship were estimated from

$$\text{Weight} = a^* \text{ Length}^{b} \text{ (weight in kg and length in cm)}$$

The maturity-at-age is in BEAM 5 modelled by the logistic curve. $L_{50\%}$ and $L_{75\%}$ of the maturity ogive were estimated from maturity data.

Natural mortality was estimated by Pauly's empirical formula (Pauly, 1980), using the von Bertalanffy growth parameters and a surface water temperature of 29°C.

The applied stock parameters are shown in Table 5.5.

Table 5.5 Growth parameters, maturity ogive and natural mortality of the nine selected species used as input for the BEAM 5 simulation

	Threadfin bream	**Big eye**	**Pony fish**	**Grouper**	**School prawn**	**Banana prawn**	**Crab**	**Squid**	**Cuttle fish**
GROWTH									
L_∞ (cm)	32.0	27.0	12.2	32.0	17.8	24.6	17.3	26.6	18.0
K / year	1.00	1.20	1.30	0.63	2.60	0.95	1.75	0.86	0.70
t_o year	0.0	0.0	0.0	0.0	-0.001	-0.002	0.0	0.0	0.0
WEIGHT-LENGTH RELATIONSHIP W = a*L^b									
a	0.000018	0.000018	0.000015	0.000016	0.000008	0.000010	0.000055	0.000374	0.001049
b	2.9000	2.9000	3.0000	2.9000	3.0143	2.6930	3.0590	2.0000	2.0000
MATURITY OGIVE									
$L_{50\%}$ (cm)	18.8	17.5	6.5	25.5	12.1	15.9	14.0	7.1	12.8
$L_{75\%}$ (cm)	23.8	21.7	7.5	28	15.8	22.3	16.6	9.3	15.2
NATURAL MORTALITY									
M/year	2.60	2.10	2.84	1.30	3.92	1.85	3.05	1.70	1.66

5.3.6 Catches of the Gulf of Thailand

The total landings were extracted from the fisheries statistics of 1997. They were subsequently split and allocated to the "Inshore" and "Offshore" area as explained above.

Table 5.6 Total landings (tonnes) of demersal resources by species and by fleet from the Gulf of Thailand in 1997 (see also Table 5.4)

	Threadfin breams	Big eyes	Pony fishes	Groupers	School prawns	Banana prawns	Crabs	Squids	Cuttle fishes	Total
INSHORE AREA										
Small OBT	1,643	1,496	4,663	34	2,288	625	2,100	2,015	2,229	**17,093**
Medium OBT	0	0	0	0	0	0	0	0	0	**0**
Large OBT	0	0	0	0	0	0	0	0	0	**0**
Small PT	0	0	0	0	0	0	0	0	0	**0**
Large PT	0	0	0	0	0	0	0	0	0	**0**
Small PN	360	280	8,238	0.1	537	110	501	113	339	**10,478**
Large PN	31.5	24.3	915	0.01	47	10	44	10	29	**1111**
Other Gear	503	2	12,756	116	2,018	7,169	17,229	3,864	387	**44,044**
Total	**2,538**	**1,802**	**26,572**	**150**	**4,890**	**7,914**	**19,874**	**6,002**	**2,984**	**72,726**
OFFSHORE AREA										
Small OBT	0	0	0	0	0	0	0	0	0	**0**
Medium OBT	11,755	20,837	153,876	2,978	2,453	312	4,467	8,563	7,698	**212,939**
Large OBT	47,180	36,238	307,752	2,307	757	200	2,905	18,009	21,972	**437,320**
Small PT*)	8	21	854	1	1	1	7	32	24	**950**
Large PT	950	2580	102,623	93	158	86	869	3,848	2,888	**114,095**
Small PN	0	0	0	0	0	0	0	0	0	**0**
Large PN	0	0	0	0	0	0	0	0	0	**0**
Other Gear	0	0	1,417	18	0	0	6,375	16,499	1238	**25,547**
Total	**59,893**	**59,676**	**566,522**	**5,397**	**3,369**	**599**	**14,623**	**46,951**	**33,820**	**790,851**
Grand total	**62,430**	**61,479**	**593,094**	**5,547**	**8,259**	**8,513**	**34,497**	**52,953**	**36,804**	**863,577**

*) Species composition and total landings of small pair trawlers are unknown. Species composition is assumed to be the same as that of large pair trawlers. Total landings are estimated under the assumption that CPUE is half of that for the large pair trawlers

5.3.7 Fishing mortality of the Gulf of Thailand case study

Length frequency data were used to estimate the total mortality rates of the eight representative species, except for the ponyfish that was assigned a plausible (but guessed) value, derived from the literature using "FishBase" of ICLARM.

Using the FISAT program, the length-converted catch curve (see Sparre & Venema, 1998) was applied to estimate the total mortality rate with the linear equation:

$$\ln\left[\frac{C(L_1,L_2)}{\Delta t(L_1,L_2)}\right] = A - Z * t\left[\frac{L_1+L_2}{2}\right]$$

where $C(L_1,L_2)$ is the number of fish caught with body lengths between L_1 and L_2
$\Delta t(L_1,L_2)$ is the time it takes to grow from length L_1 to length L_2
t is the age of the fish

The slope of the linear regression is the total mortality rate, Z. Subsequently the total fishing mortality rate F is derived from the equation F = Z - M.

Table 5.7 shows the total mortality rates used as input to BEAM 5.

Table 5.7 Mortality rates of the nine species used as input to BEAM 5

Stock	Threadfin bream	Big eye	Pony fish	Grouper	School prawn	Banana prawn	Crab	Squid	Cuttle fish
Fishing mortality F / year	2.6	2.5	1.2	1.4	2.9	2.4	2.9	2.4	1.6
Natural mortality M /year	2.6	2.1	2.8	1.3	3.9	1.9	3.0	1.7	1.7
Total mortality Z / year	5.4	4.6	4.0	2.7	6.8	4.3	5.9	4.1	3.3

The total fishing mortalities (F for all fleets combined as in Table 5.7) were subsequently distributed over fleet components in the same proportions as the landings in tonnes, that is, by:

$$F(\textit{fleet } x,\ \textit{species } y) = F(\textit{All fleets},\ \textit{species } x)\frac{\textit{Landings of species x by fleet y}}{\textit{Total landings of species x}}$$

The catchability coefficient (Q) of each fleet catching each stock is derived from the equation:

Q(fleet x, species y) = F(fleet x, species y) / Effort(fleet x)

where fishing effort is measured in number of sea days (days away from port).

5.3.8 Cod end mesh size, and gear selection parameters

The cod end mesh size of otterboard trawls and pair trawls is 25 mm and for the pushnets it is about 15 mm. The gear selection parameters, $L_{50\%}$ and $L_{75\%}$ (in the logistic curve) were estimated from the length-converted catch curve as implemented in FISAT. Table 5.8 shows the results of the estimation of gear selection parameters. The values for ponyfish are assumed values.

Table 5.8 Gear selection parameters for the nine species used as input to BEAM 5

Species	**Threadfin bream**		**Bigeye**		**Ponyfish**		**Grouper**		**School prawn**		**Banana prawn**		**Crab**		**Squid**		**Cuttle 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}	L_{50}	L_{75}	L_{50}	L_{75}
Small OBT	10.6	11.7	15.5	17.1	4.0	5.0	14.6	15.6	9.0	9.6	12.1	12.6	9.7	10.5	7.8	8.8	8.2	8.9
Med. OBT	14.6	16.3	14.5	17.1	4.0	5.0	14.6	15.6	9.0	9.6	14.9	15.5	11.7	13	10.5	12.5	8.2	8.9
Large OBT	14.6	16.3	15.5	17.1	4.0	5.0	14.6	15.6	9.0	9.6	14.9	15.5	11.7	13	10.5	12.5	8.2	8.9
Small PT	13.4	14.4	15.1	16.3	4.0	5.0	14.6	15.6	10.0	11.0	14.9	15.5	11.7	13	10.5	12.5	9.4	10.0
Large PT	13.4	14.4	15.1	16.3	4.0	5.0	14.6	15.6	10.0	11.0	14.9	15.5	11.7	13	10.5	12.5	9.4	10.0
Small PN	5.0	6.0	7.0	8.0	4.0	5.0	5.0	6.0	8.0	8.6	8.6	9.2	8.9	9.6	5.0	6.0	3.5	4.0
Large PN	5.0	6.0	7.0	8.0	4.0	5.0	5.0	6.0	8.0	8.6	8.6	9.2	8.9	9.6	5.0	6.0	3.5	4.0
Other Gear	13.4	14.4	15	16	4.0	5.0	14.6	15.6	9.5	10.5	14	14.6	12	13	9.0	10.0	8.5	9.5
*Gear selection parameters $L_{50\%}$ and $L_{75\%}$																		

These parameters correspond to the selection factors and selection ranges shown in Table 5.9 and Table 5.10 respectively. The use of the selection factor as an input parameter facilitates the assessment of changes in mesh size, but $L_{50\%}$, $L_{75\%}$ might have been used as the only gear selection parameters.

Table 5.9 Mesh size and selection factors for the nine species corresponding to Table 5.8

FLEET	**Mesh size (cm)**	**SELECTION FACTOR**								
		Threadfin bream	**Bigeye**	**Pony fish**	**Grouper**	**School prawn**	**Banana prawn**	**Crab**	**Squid**	**Cuttle fish**
Small OBT	2.5	4.24	6.20	1.60	5.84	3.60	4.84	3.88	3.12	3.28
Med. OBT	2.5	5.84	5.80	1.60	5.84	3.60	5.96	4.68	4.20	3.28
Large OBT	2.5	5.84	6.20	1.60	5.84	3.60	5.96	4.68	4.20	3.28
Small PT	2.5	5.36	6.04	1.60	5.84	4.00	5.96	4.68	4.20	3.76
Large PT	2.5	5.36	6.04	1.60	5.84	4.00	5.96	4.68	4.20	3.76
Small PN	1.5	3.33	4.67	2.67	3.33	5.33	5.73	5.93	3.33	2.33
Large PN	1.5	3.33	4.67	2.67	3.33	5.33	5.73	5.93	3.33	2.33
Other Gear	2.5	5.36	6.00	1.60	5.84	3.80	5.60	4.80	3.60	3.40

Table 5.10 Selection ranges (=$L_{75\%}$ / $L_{50\%}$) for the nine species corresponding to Table 5.8

FLEET	Threadfin bream	Bigeye	Pony fish	Grouper	School prawn	Banana prawn	Crab	Squid	Cuttle fish
Small OBT	1.104	1.103	1.250	1.068	1.067	1.041	1.082	1.128	1.085
Med. OBT	1.116	1.179	1.250	1.068	1.067	1.040	1.111	1.190	1.085
Large OBT	1.116	1.103	1.250	1.068	1.067	1.040	1.111	1.190	1.085
Small PT	1.075	1.079	1.250	1.068	1.100	1.040	1.111	1.190	1.064
Large PT	1.075	1.079	1.250	1.068	1.100	1.040	1.111	1.190	1.064
Small PN	1.200	1.143	1.250	1.200	1.075	1.070	1.079	1.200	1.143
Large PN	1.200	1.143	1.250	1.200	1.075	1.070	1.079	1.200	1.143
Other Gear	1.075	1.067	1.250	1.068	1.105	1.043	1.083	1.111	1.118

As it is assumed that discarding does not to take place in the Thai fishery, the discard parameters ($L_{50\%}$ and $L_{75\%}$) all have the value zero.

5.3.9 Effort, number of vessels and CPUE

Table 5.11 shows the effort by area in units of 1000 sea days and the number of vessels in each fleet in the Gulf of Thailand in 1997.

Table 5.11 Effort by area and fleet and number of vessels by fleet in 1997

FLEET	Small OBT	Medium OBT	Large OBT	Small PT	Large PT	Small PN	Large PN	Other Gear	Total
Inshore effort (1000 sea days)	321.9	0.0	0.0	0.0	0.0	357.4	72.5	4153.7	**4,905**
Offshore effort (1000 sea days)	0.0	492.5	526.6	3.5	209.3	0.0	0.0	461.5	**1,693**
Total effort (1000 sea days)	**321.9**	**492.5**	**526.6**	**3.5**	**209.3**	**357.4**	**72.5**	**4,615.2**	**6,599**
Number of vessels	2,012	2,052	1,773	16	747	2351	331	18,710	**27,992**
Number of days/year/boat	160.0	240.0	297.0	216.0	280.2	152.0	219.0	246.7	

Table 5.12 shows the CPUE in kg per day per boat in 1997. The figures in Table 5.12 are calculated from Table 5.6 and Table 5.11 by CPUE = Landings/Effort (kg/day).

Table 5.12 CPUE in 1997 by fishing area, fleet and species group as catch per day per boat in kg

INSHORE AREA	Small OBT	Medium OBT	Large OBT	Small PT	Large PT	Small PN	Large PN	Other Gear
Threadfin breams	5.10					1.01	0.43	0.12
Bigeyes	4.65					0.78	0.34	0.00
Ponyfishes	14.48					23.05	12.62	3.07
Groupers	0.11					0.00	0.00	0.03
***Metapenaeus* spp**	7.11					1.50	0.65	0.49
***Penaeus* spp**	1.94					0.31	0.14	1.73
Crabs	6.52					1.40	0.61	4.15
Squids	6.26					0.32	0.14	0.93
Cuttlefishes	6.92					0.95	0.40	0.09
Total	**53.10**					**29.32**	**15.32**	**10.60**
OFFSHORE AREA	**Small OBT**	**Medium OBT**	**Large OBT**	**Small PT**	**Large PT**	**Small PN**	**Large PN**	**Other Gear**
Threadfin breams		23.87	89.60	2.29	4.54			0.00
Bigeyes		42.31	68.82	6.22	12.32			0.00
Ponyfishes		312.45	584.43	247.25	490.21			3.07
Groupers		6.05	4.38	0.22	0.44			0.04
***Metapenaeus* spp**		4.98	1.44	0.38	0.75			0.00
***Penaeus* spp**		0.63	0.38	0.21	0.41			0.00
Crabs		9.07	5.52	2.09	4.15			13.81
Squids		17.39	34.20	9.27	18.38			35.75
Cuttlefishes		15.63	41.73	6.96	13.80			2.68
Total		**432.38**	**830.49**	**274.88**	**545.01**			**55.35**

5.4 TUNING OF BEAM 5

The purpose of models like BEAM 5 is to predict (or simulate) the future bio-economic features of alternative management strategies (for further details, see Appendix F and the BEAM 5 manual).

In this section, the procedure of "tuning BEAM 5" to produce the reference simulation, which forms the basis for all other simulations, is explained below. The reference simulation aims at recreating the observed situation in the most recent data year.

The most recent year for which data were available for the Gulf of Thailand was 1997. The stock numbers in the sea were back-calculated to produce the observed landings by species group and by fleet in year 1997. This value of year 1997 was then used to represent the year 2000, the first year in the suite of prediction years of BEAM 5 (the fifteen years period 2000-2014). The parameters were selected so that the system was in equilibrium when BEAM 5

Table 5.13 Relative landings by area (relative distribution by species group by fleet)*)

RELATIVE LANDINGS									
	Threadfin breams	**Big eyes**	**Pony fishes**	**Groupers**	**School prawns**	**Banana prawns**	**Crabs**	**Squids**	**Cuttle fishes**
INSHORE AREA									
Small OBT	0.6475	0.8301	0.1755	0.2265	0.4679	0.0790	0.1057	0.3357	0.7470
Med. OBT									
Large OBT									
Small PT									
Large PT									
Small PN	0.1419	0.1554	0.3100	0.0007	0.1098	0.0139	0.0252	0.0188	0.1136
Large PN	0.0124	0.0135	0.0344	0.0001	0.0096	0.0013	0.0022	0.0017	0.0097
Other Gear	0.1982	0.0011	0.4801	0.7728	0.4127	0.9059	0.8669	0.6438	0.1297
Total	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**
OFFSHORE AREA									
Small OBT									
Med. OBT	0.1963	0.3492	0.2716	0.5518	0.7280	0.5211	0.3055	0.1824	0.2276
Large OBT	0.7877	0.6072	0.5432	0.4275	0.2247	0.3340	0.1987	0.3836	0.6497
Small PT	0.0001	0.0004	0.0015	0.0001	0.0004	0.0012	0.0005	0.0007	0.0007
Large PT	0.0159	0.0432	0.1811	0.0172	0.0469	0.1436	0.0594	0.0820	0.0854
Small PN									
Large PN									
Other Gear			0.0025	0.0033			0.4360	0.3514	0.0366
Total	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**

*) Empty boxes signify zero or negligible landings

was executed in the deterministic mode, that is, without stochastic variation of input parameters.

In the Workshop it was assumed (as an approximation to reality), that only Thai vessels exploit the stocks in the Gulf of Thailand and that no migration of fish takes place out of and into the area where these vessels are operating[7]. It was furthermore assumed (as an approximation to reality) that no migration takes place between the two areas used for the BEAM 5 simulation ("inshore" and "offshore").

BEAM 5 does not contain a parameter estimation module, since most parameters are assumed to be available before BEAM 5 is applied. However, there are a few vital parameters, which are estimated while "tuning" BEAM 5 to the case study. In the tuning process, these

[7] It also has been assumed that all the fish landed in Thailand was caught in Thai waters. This assumption may be wrong, since it is known that the Thai fleet also operates in the waters of Indonesia and Cambodia. It is likely that a considerable part of the Nemipterids was caught in Indonesia.

parameter values are modified until BEAM 5 produces the desired results. In this case these values were the estimated fishing mortality rates and the observed landings of year 1997.

Table 5.6 shows the total landings by area, fleet and species group. The landings of the nine "species" listed in the table are the total landings of the species groups represented by the species in the list. Thus, for example, "Threadfin breams" represents the landings of all threadfin breams and similar species. Similar species are species of approximately the same size and value (price/kg) and biological parameters (e.g. growth).

Table 5.14 Fishing mortality distributed by fleet in the same proportions as the relative landings (see Table 5.13)

	FISHING MORTALITY BY FLEET AND STOCK									EFFORT[8]
INSHORE AREA	**Threadfin bream**	**Big eye**	**Pony fish**	**Grouper**	**School prawn**	**Banana prawn**	**Crab**	**Squid**	**Cuttle fish**	
Small OBT	1.6835	2.0751	0.2106	0.3171	1.3569	0.1895	0.3064	0.8057	1.1952	321.9
Med. OBT										0.0
Large OBT										0.0
Small PT										0.0
Large PT										0.0
Small PN	0.3689	0.3884	0.3720	0.0009	0.3185	0.0334	0.0731	0.0452	0.1818	357.4
Large PN	0.0323	0.0337	0.0413	0.0001	0.0279	0.0030	0.0064	0.0040	0.0155	72.5
Other Gear	0.5154	0.0028	0.5761	1.0819	1.1968	2.1741	2.5140	1.5451	0.2075	4153.7
TOTAL	**2.6000**	**2.5000**	**1.2000**	**1.4000**	**2.9000**	**2.4000**	**2.9000**	**2.4000**	**1.6000**	
OFFSHORE AREA	**FISHING MORTALITY BY FLEET AND STOCK**									**EFFORT**
Small OBT										
Med. OBT	0.5103	0.8729	0.3259	0.7725	2.1113	1.2507	0.8859	0.4377	0.3642	492.5
Large OBT	2.0481	1.5181	0.6519	0.5985	0.6516	0.8017	0.5761	0.9206	1.0395	526.6
Small PT	0.0003	0.0009	0.0018	0.0002	0.0011	0.0029	0.0014	0.0016	0.0011	3.5
Large PT	0.0412	0.1081	0.2174	0.0241	0.1360	0.3447	0.1723	0.1967	0.1366	209.3
Small PN										0.0
Large PN										0.0
Other Gear			0.0030	0.0047			1.2643	0.8434	0.0586	461.5
TOTAL	**2.6000**	**2.5000**	**1.2000**	**1.4000**	**2.9000**	**2.4000**	**2.9000**	**2.4000**	**1.6000**	

[8] Effort measured in 1000 sea days (days away from port)

In simulations it was assumed that all catches are landed, thus that no discarding takes place in the Thai fishery.

The parameters estimated during the tuning process were:

1. The catchability coefficients (the relationship between effort and fishing mortality).

2. The number of recruits (0-group fish) entering the stock each year.

3. The relative catch by each fleet derived from Table 5.6 as shown in Table 5.13.

For each species the total fishing mortality (F = fishing mortality of all fleets combined) was derived from the length-converted catch curve or from length-based cohort analysis, using the FISAT software (Gayanilo, *et al.,* 1995), as discussed in Section 5.3.5. These stock assessment analyses were made before the start of the workshop. Natural mortalities (M) were estimated by Pauly's formula (Pauly, 1980). The results were presented above in Table 5.7. Some fish stock assessment results, however, gave unrealistically high total mortality rates (Z), ranging from 2.7 for groupers to 5.4 for threadfin breams. With such high total mortality rates fish (and other animals) would die at a very fast rate and rarely get more than half a year old. With a total mortality of Z = 5 per year, only 8 % of the recruits would survive for six months and only 0.5% would survive the first year. (Such high values may be realistic for small shrimps, which have a short life span of less than one year.)

In the simulations high values for total mortality (Z) will reduce the effect of reducing fishing mortality (F), as most young fish that are not caught, would die anyway from natural causes (M) before they could reach a bigger and more valuable size.

The values of the mortality rates were also discussed in the working group and were found to be on the high side, compared to values observed in other areas by some members of the working group and therefore the values were reduced to levels believed to be more realistic.

The values of fishing mortalities (F) used for the BEAM 5 simulations are shown in Table 5.14.

Taking the average values of natural and fishing mortalities as derived from the assessments and subsequently somewhat adjusted by the BEAM 5 working group and comparing them with the values used by the ECOPATH working group (see Section 6 and Table 5.15), indicates that mortalities used in BEAM 5 were indeed on the high side.

Table 5.15 Comparison of average mortality rates in BEAM 5 and ECOPATH for Gulf of Thailand

Mean mortality over species groups	F	M	Z
ECOPATH	0.4	1.5	1.9
BEAM 5	2.2	2.3	4.5

The total fishing mortalities were distributed over the fleets in the same proportions as the landings, as shown in Table 5.14. It was assumed that fishing mortalities were the same in the two areas. This assumption was made because separate estimates for the two areas were not available. Table 5.14 also contains the effort of each fleet in each area in the right most column, in units of 1000 sea days (days away from port).

A zero value in the last column of Table 5.14 indicates that the fleet in question is assumed not to operate in that particular area. The assumption that the two areas are fished by different fleets further leads to suggest that the exploitation patterns and fishing mortalities are also different for the two areas. However, no data were available to throw light on this question.

The catchability coefficient, Q, was then derived from Q = F/Effort, where F is the fishing mortality (see Table 5.14). (Table 5.16).

Table 5.16 Catchability coefficients (Q = Fishing mortality/Effort)

CATCHABILITY COEFFICIENTS									
INSHORE AREA	**Threadfin bream**	**Bigeye**	**Ponyfish**	**Grouper**	**School prawn**	**Banana prawn**	**Crab**	**Squid**	**Cuttle fish**
Small OBT	0.05229	0.06446	0.00654	0.00985	0.04215	0.00589	0.00952	0.02503	0.03713
Med. OBT									
Large OBT									
Small PT									
Large PT									
Small PN	0.01032	0.01087	0.01041	0.00003	0.00891	0.00093	0.00205	0.00126	0.00509
Large PN	0.00445	0.00465	0.00570	0.00001	0.00385	0.00042	0.00089	0.00055	0.00215
Other Gear	0.00124	0.00001	0.00139	0.00260	0.00288	0.00523	0.00605	0.00372	0.00050
OFFSHORE AREA									
Small OBT									
Med. OBT	0.01036	0.01772	0.00662	0.01569	0.04287	0.02540	0.01799	0.00889	0.00739
Large OBT	0.03889	0.02883	0.01238	0.01137	0.01237	0.01522	0.01094	0.01748	0.01974
Small PT	0.00099	0.00260	0.00524	0.00058	0.00328	0.00831	0.00415	0.00474	0.00329
Large PT	0.00197	0.00516	0.01038	0.00115	0.00650	0.01647	0.00823	0.00940	0.00653
Small PN									
Large PN									
Other Gear			0.00007	0.00010			0.02739	0.01827	0.00127

The stock numbers in the sea were back-calculated to produce the observed catches together with the observed fishing mortalities. The stock numbers in BEAM 5 can be manipulated by the following input parameters:

1. The initial stock numbers

2. The parameters in the Beverton and Holt stock recruitment model:

$$\mathrm{Re}cruitment = B_1 \frac{SSB}{1 + B_2 * SSB}$$

where recruitment is the number of 0-group fish on the 1st of January and SSB is the spawning stock biomass, that is the biomass of mature fish. B_1 and B_2 are the parameters of the model.

Although BEAM 5 allows for continuous recruitment during the year, it was assumed as a simplifying approximation that all fish recruit on the 1st of January. The parameter B_2 was given the value 0.01 for all stocks. This relatively large value only produces a stock and recruitment relationship for small values of SSB. For larger values of SSB the model does not generate a relationship between recruitment and SSB, because the factor $\frac{SSB}{1+B_2 * SSB}$ approaches $1/B_2$ when SSB is large. This means that recruitment is (almost) constant if BEAM 5 is run in the deterministic mode.

The parameter B_1, then becomes proportional to the recruitment, which in turn is proportional to the catches and thus to the weight of the landings. Thus by manipulating the value of B_1 one can create any desired amount of landings. The B_1's of the various species were given a value to recreate the observed landings in 1997. The values of B_1 (based on numbers in units of 1000 fish and biomass in tonnes) are shown in the bottom row of Table 5.17.

The distributions by area of the biomass as well as the total number of recruits were also estimated using the proportions of the landings from each area as given in Table 5.6. The results are shown in Table 5.17.

Table 5.17 Distribution of relative landings by area by species (used to estimate recruitment and biomass distribution on areas) and Parameter, B_1, in the Beverton and Holt stock/recruitment model by species

Landings by area as % of total and B_1	Threadfin bream	Bigeye	Pony fish	Grouper	School prawn	Banana prawn	Crab	Squid	Cuttle fish
Inshore (%)	5	3	4	3	58	93	64	11	11
Offshore (%)	95	97	96	97	42	7	36	89	89
***B_1* (recruitment parameter)**	105000	83000	17000000	7050	66000	57000	63000	47000	38000

The stock numbers in the first month of the first year (the initial stock numbers), have to be given as input and these numbers have an influence on the catches, biomass etc. in the first year. The initial stock numbers were selected to produce the equilibrium situation at the beginning of the simulation period.

Mesh selection parameters ($L_{50\%}$ and $L_{75\%}$) used for the reference simulation, are those estimated for the present fishery (see Table 5.8).

BEAM 5 allows for change from year to year of most parameters and inputs, but in the reference simulation all parameters and inputs were kept constant from year to year.

The simulation of BEAM 5, which recreated the observed landings in 1997, was used as the reference for the various predictions made to analyse alternative management regimes.

BEAM 5 allows for stochastic simulation of (for example) recruitment (see BEAM 5 manual for further explanation), but due to time constraints this option was not used.

5.5 ECONOMIC 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;

f) Estimates of decommissioning costs to compensate owners of vessels that are withdrawn from the fisheries and costs of compensating displaced crew;

g) The financial and economic discount 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).

Further details can be found in Appendix F.

The data sources for the estimates of economic data included cost and earnings surveys conducted in 1995 & 1998 by the Department of Fisheries and a special survey in 1998, also by DOF, on small-scale fisheries. The latter covered the following gear types:

- Small Otterboard trawlers
- Medium Otterboard trawlers
- Large Otterboard trawlers
- Small pair trawlers
- Large/medium pair trawlers
- Small pushnetters
- Large/medium pushnetters
- Small-scale fishing gears:
  - whiting gill net
  - crab gill net
  - shrimp gill net
  - cuttlefish trammel net
  - fish, squid, shrimp, crab traps
  - squid falling net

The three surveys inquired about the following data:

- Technical specifications of each fleet type (e.g. vessel length, age of vessel, engine type, horse power and gear);
- Intensity of fishing (i.e. number of fishing days per month and number of fishing months per year);

- Employment (i.e. number of crew and family members among crew);
- Use of fuel, ice and oil per fishing month (quantity);
- Total value of landings and average price per kg;
- Catch composition by main types of species groups and their use (i.e. edible fish, trash fish, shrimp, cephalopods and others);
- Initial investment into fishing vessel, engine and gear;
- Operating cost per month, fishing day and/or fishing trip (i.e. fuel & 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 vessel, engine and gear);
- Type of crew remuneration (i.e. sharing system and/or fixed monthly wage).

The number of fishing vessels by category was derived from the following two sources:

- Fishing Vessel Register;
- 1995 Marine Fisheries Census.

The numbers of fishing vessels and fishing days by fleet category given in Table 5.18 were used as input parameters.

Table 5.18 Input parameters for fleet and fishing effort for the BEAM 5 model

Fleet	Vessels (number of units)	Crew (average number)	Crew (total number)	Fishing days (average number)	Fishing days (total number)
Small OBT	2,012	4	8,048	160	321,920
Med. OBT	2,052	8	16,416	240	492,480
Large OBT	1,773	16	28,368	297	526,581
Small PT	16	10	160	216	3,456
Large PT	745	19	14,155	281	209,345
Small PN	2,351	2	4,702	152	357,352
Large/medium PN	331	4	1,324	219	72,489
Other Gear	18,170	1.7	30,889	254	4,615,180

Data on current investment cost for a new vessel were obtained from the DOF Fishing Vessel Development Section, while price data were obtained from a recent survey by the DOF Marine Fishery Division.

For estimating adjusted costs for the economic analysis in BEAM 5, the data applied in the "Study on Fishery Complex of the Andaman Sea Coast, 1997" were used. These refer to 1997 estimates of the Standard Conversion Factor (SCF = 0.956) and the opportunity cost of unskilled labour.

Data on fuel market prices and fuel tax structure were obtained from the Office of National Energy Policy. These were used to estimate the tax revenue part in the market price per litre of High Speed Diesel Fuel that is commonly used by fishing vessels. The estimate of total tax revenue income by the government from the fishing fleet may be an overestimate because some larger-sized vessels are reportedly purchasing fuel at sea outside Thai territorial waters.

5.5.1 Prices

The average prices given in Table 5.19 (in Baht/kg) were used in the BEAM 5 model.

Medium and small sized pony fish were used to model a combination of fast growing small-sized species that are currently reported in catch statistics in the category of "trash fish".

Table 5.19 Average prices in Baht/kg for the nine species groups by size category

Species group	Size category		
	Large	Medium	Small
Threadfin bream	25	15	10
Big eye	10.7	7	5
Pony fish	10	5	5
Grouper	60	15	10
School Prawn	120	110	80
Banana Prawn	430	300	200
Crab	80	70	40
Squid	62.8	42	28
Cuttle fish	70	57	22

Table 5.20 Percentage of harvesting costs applied

Fleet	%
Small otterboard trawlers	59
Medium otterboard trawlers	78
Large otterboard trawlers	69
Small pair trawlers	75
Large/medium pair trawlers	47
Small pushnetters	47
Other gear	100

5.6 HARVESTING COSTS

The cost data presented below represent the full annual harvesting costs of an average boat in each fleet category. Except for the cost of fish handling calculated on a per unit weight basis, all other cost categories have been adjusted by a reduction factor to account for the fact that the base year simulation did not incorporate the total catch. The percentage of the actual cost used in calculating the financial and economic performance of the fleets is shown in Table 5.20

5.6.1 Cost of handling

Based on the costs and earnings survey data of monthly operating costs, the cost of handling per kg were derived as the sum of landing charges and transportation cost from the point of landing to the point of first sale. The average costs for each fleet type are given in Table 5.21.

Table 5.21 Cost of handling per kg, in Baht

Fleet	Baht
Small otterboard trawlers	0.44
Medium otterboard trawlers	0.6
Large otterboard trawlers	0.57
Small pair trawlers	0
Large/medium pair trawlers	0.46
Small pushnetters	0
Other gear	0.18

5.6.2 Operating costs

Operating costs comprise of expenditures for fuel, ice, repair and maintenance, other materials and food. The data in the survey were reported on a monthly basis, which were converted in costs per fishing day by dividing the monthly total by the number of fishing days per month.

Table 5.22 Operating cost per fishing day by fleet and area (Baht)

Fleet	<20 m depth	>20 m depth
Small otterboard trawlers	2,948	
Medium otterboard trawlers		5,791
Large otterboard trawlers		6,827
Small pair trawlers		5,775
Large/medium pair trawlers		10,696
Small pushnetters	1,864	
Large/medium pushnetters	4,795	
Other gear	115	

The average operating costs per fishing day for each type of fishing fleet and two fishing areas defined as fishing grounds with a depth of less and more than 20 m are shown in Table 5.22.

5.6.3 Crew share

Two types of crew remuneration were applied, namely a sharing system and a fixed monthly wage. In BEAM 5, the crew share is expressed as gross revenue per fishing day minus operating costs per fishing day multiplied by the share accruing to the crew. In the costs and earnings survey, the share income of the crew was expressed in Baht per month. This amount formed the basis to estimate the average share (in %) that serves as the input data for the BEAM 5 model. The average fixed monthly crew income by fleet type was derived directly from the costs and earnings surveys. The data on crew remuneration used as input into BEAM 5 are summarized in Table 5.23.

Table 5.23 Crew remuneration as shares of the catch (see text)

Fleet	Crew share in %	Fixed crew income per month (Baht)
Small otterboard trawlers	34.8	301
Medium otterboard trawlers	23.0	916
Large otterboard trawlers	35.7	669
Small pair trawlers	0	1,889
Large/medium pair trawlers	8.7	3,649
Small pushnetters	36.0	294
Large/medium pushnetters	62.0	0
Other gear	0	330

5.6.4 Fixed costs

Fixed costs were estimated from the costs and earnings surveys that included the following categories: a) interest on debt, b) depreciation and c) opportunity cost of own capital. The fact that a large number of vessels are older than 15 to 20 years is reflected in low depreciation costs. For the financial analysis, depreciation costs were excluded from the fixed costs for the reason that in BEAM 5 fleet performance is assessed over a period of 15 (or more) years. During this period, the simulation model allows for investments in new vessels whereby the invested amount is shown as a cash outflow at the time of investment thereby reducing the net present value over the whole simulation period. The inclusion of depreciation in this type of analysis would result in double counting of capital expenditures.

Fixed costs (in Baht) used as input parameters into BEAM 5 are shown in Table 5.24.

Table 5.24 Fixed cost per vessel per year by fleet type

Fleet	Baht
Small otterboard trawlers	51,300
Medium otterboard trawlers	147,780
Large otterboard trawlers	225,612
Small pair trawlers	281,496
Large/medium pair trawlers	281,299
Small pushnetters	36,780
Large/medium pushnetters	156,351
Other gear	28,849

5.6.5 Licence fee

Licence fees are paid by some categories of vessels. The data were obtained from figures reported in the costs and earnings surveys (Table 5.25).

Table 5.25 Annual licence fee per vessel type, in Baht

Fleet	Baht
Small otterboard trawlers	2,220
Medium otterboard trawlers	6,168
Large otterboard trawlers	13,668
Small pair trawlers	0
Large/medium pair trawlers	4,800
Small pushnetters	2,232
Large/medium pushnetters	15,468
Other gears	0

5.6.6 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 figures in Table 5.26 are based on current estimates of investment costs that largely vary with the size of the vessels and their horsepower rather than with the type of fishing method:

Table 5.26 Investment cost per vessel (1000 Baht)

Fleet	Cost
Small otterboard trawlers	2,250
Medium otterboard trawlers	4,250
Large otterboard trawlers	6,250
Small pair trawlers	2,250
Large/medium pair trawlers	5,250
Small pushnetters	800
Large/medium pushnetters	4,250
Other gears	300

5.6.7 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 five years. Fisheries management costs were apportioned among the fleets in ratio to their respective contribution to the total value of landings in 1998 (Table 5.27).

Table 5.27 Fisheries management costs per fleet, in thousand Baht

Fleet	Costs
Small otterboard trawlers	32,844
Medium otterboard trawlers	47,744
Large otterboard trawlers	81,744
Small pair trawlers	100
Large/medium pair trawlers	25,944
Small pushnetters	14,244
Large/medium pushnetters	6,930
Other gears	30,644
Total	**240,194**

5.7 INPUT PARAMETERS FOR THE ECONOMIC ANALYSIS

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. Transfer payments between different economic agents (including the government treasury) such as interest payments, re-payment of principal, taxes, import duties, license fees etc. are not considered as costs and therefore excluded from the calculation of the net return to society as a whole (i.e. economic rent) in the economic analysis. Internationally traded inputs such as fuel are valued at their border prices net of duties and taxes. Prices of domestically produced goods were adjusted by a Standard Conversion Factor (SCF). An SCF of 0.956 was reported in the above referenced fisheries project analysis report of 1997[9].

The current fuel tax per litre is Baht 2.753 equal to 26.5 % of the retail price of H. Diesel of Baht 10.39.

Opportunity cost of labour was estimated as a weighted average of skilled and unskilled crew remuneration as follows:

- Skilled crew usually comprise the skipper and on larger vessels also an engineer. Opportunity cost of skilled labour is estimated from reported earnings in the cost and earnings surveys multiplied by the SCF;
- Opportunity cost of unskilled labour was estimated at B 3800 per month as reported in 1997 project analysis report. The monthly figure was multiplied by the number of reported fishing months per year.

Fisheries management costs (in Baht) were adjusted by the SCF. All other costs items remained unchanged.

Table 5.28 Parameters of the Economic Analysis

	Cost of handling per kg (Baht)	Operating cost per fishing day (Baht)	Fuel tax per fishing day (Baht)	Opportunity cost of labour (per person per year) (Baht)
Small otterboard trawlers	0.42064	2,433	462	38,670
Medium otterboard trawlers	0.5736	4,713	987	49,383
Large otterboard trawlers	0.54492	5,498	1,234	58,523
Small pair trawlers	0	4,769	902	37,016
Large/medium pair trawlers	0.43976	9,006	1,463	60,280
Small pushnetters	0	1,533	299	37,432
Large/medium pushnetters	0.17208	3,829	906	87,988
Other gears	0	96	17	38,000

[9] "Study on Fishery Complex of the Andaman Sea Coast, 1997"

5.8 SIMULATION RESULTS

A word of caution should precede the presentation of the simulation results. In the preparation of the input parameters a series of difficulties were encountered including inconsistencies between data obtained from different sources, incomplete vessel registries, the need to aggregate or segregate data across different types of gear and others. While great efforts and reasoned estimates and judgements have been made in addressing these difficulties, they are unlikely to have removed all errors. Therefore, the outcomes of the simulations 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.

As can be seen in Table 5.29, nearly three quarters of the total simulated demersal catch of 892 thousand tons were taken by otterboard trawl. Pair trawl and other types of fishing gear (i.e. mostly various types of small-scale gear) made up 14% and 10% respectively, while pushnets contributed just about 1% of total demersal landings. However, more than one third of the total catch value of Baht 16.4 billion (US $ 449 million) is produced by coastal small-scale fishermen because of the higher share of high priced species in the catch including shrimp, squids and crabs. Conversely, the predominant catch by trawlers is made up of so-called trashfish comprising low value small species as well as juveniles of commercial species.

The demersal fisheries as a whole continue to show, perhaps surprisingly, positive financial and economic returns. In aggregation, the industrial fleets, however, indicate losses while small-scale fisheries (i.e. OG, other gear types) appear to be highly profitable, both from the point of view of the individual operator as well as from society's point of view. This would suggest that wherever possible, preference should be given to operations by small-scale fishing gear. This could be achieved by, for example, extending the exclusive inshore zone for small-scale operations further out into the sea.

These results are averages thus hiding perhaps large variations between individual vessels in each gear category. Moreover, an overestimate of the number of fishing vessels would lead to an underestimate of the average catch and catch value per vessel and thus of profitability

The large difference in profitability between otterboard trawling and pair trawling could be related to the shifting of vessels within the season between these methods rather than to a genuine difference in performance. Such shifts could pose difficulties in attributing correctly the catch to either one or the other category. In aggregation, these two fleets would just break-even in financial terms. This result is corroborated by a high percentage of old vessels above 20 years of age (Somying Piumsomboon, 1999). A high average age of the fleet is a typical feature of a mature open access fishery because low or negative average returns make it hard for the owners to re-invest.

Table 5.29 Base Year 1997[10]

	Otterboard trawl	Pair trawl	Pushnet	Other gear	Total
Total catch (tonnes)	655,075	132,154	12,596	91,822	891,648
Vessels (number)	5,837	761	2,682	18,170	27,450
Crew (number)	52,832	14,315	6,026	30,889	104,062
FINANCIAL ANALYSIS					
Catch value	8,737	1,370	282	5,998	16,387
Costs of effort	4,350	1,578	395	407	6,730
Effort tax	915	250	81	78	1,325
Cost of landing	377	52	0	0	430
Crew remuneration	1,282	624	83	1,523	3,512
Fixed costs	573	174	65	524	1,336
Licence fees	29	3	5	0	37
Net Cash Flow	1,211	-1,311	-348	3,465	3,016
GOVERNMENT BUDGET					
Management cost	162	26	21	31	240
Effort tax	915	250	81	78	1,325
Licence fees	29	3	5	0	37
Net Cash Flow	782	227	65	48	1,122
ECONOMIC ANALYSIS					
Gross revenue	8,737	1,370	282	5,998	16,387
Cost of effort	4,287	1,540	388	399	6,597
Cost of landings	361	50	0	0	411
Crew opportunity cost	1,961	697	137	1,174	3,970
Management cost	155	25	14	29	224
Net Cash Flow	1,990	-942	-258	4,396	5,185

[10] Values in million Baht, unless otherwise indicated

Table 5.30 Summary of results

Option	Financial analysis (million Baht)	Economic analysis (million Baht)	Government finance (million Baht)	Total catch (tonnes)	Total value or gross revenue (million Baht)	Average price (Baht/kg)
A BASE CASE						
Net Cash Flow	3,016	**5,185**	1,122	891,648	16,387	18
NPV-12%	25,136	43,209	9,350			
NPV-7%	43,090	**74,073**	16,029			
B NO PUSHNET						
Net Cash Flow	3,501	**5,596**	1,036	883,481	16,260	18
NPV-12%	29,178	46,633	8,634			
NPV-7%	50,020	79,942	14,801			
C NO PUSHNET AND TRAWL AT 50%						
Net Cash Flow	5,239	**6,989**	437	592,981	13,265	22
NPV-12%	43,659	58,244	3,643			
NPV-7%	74,843	**99,846**	6,245			
D PUSHNET FISHING AND TRAWL AT 50%						
Net Cash Flow	4,813	6,624	523	602,253	13,424	22
NPV-12%	40,107	55,196	4,359			
NPV-7%	68,755	**94,622**	7,472			
E NO PUSHNET AND TRAWL AT 25%						
Net Cash Flow	5,506	6,878	138	385,874	10,933	28
NPV-12%	45,887	57,320	1,148			
NPV-7%	78,663	98,263	1,968			

An interesting finding is that the economic performance of the demersal fisheries is apparently considerably better than their financial performance. This is the result of two factors.

One reason is the sales tax on fuel, which is an income to government but a cost to the fishing firms. The simulation results may, however, overestimate the fuel purchased domestically by Thai fishing vessels and thus the amount of fuel tax collected by the government. There is evidence that larger Thai fishing vessels often purchase fuel at sea outside Thai territorial waters at close to world market prices. There are also reports indicating that fuel is bought by Thai fishing vessels at Malaysian fishing ports or at sea from Malaysian vessels. Fuel is sold in Malaysia for either commercial or private use at below world market prices.

The other reason is that non-traded domestic inputs were adjusted by the standard conversion factor of 0.956 leading to slightly lower economic costs of such inputs.

In aggregation, the simulation results indicate slightly lower opportunity costs of labour than observed labour remuneration as derived from cost and earnings sample surveys. The expectation would have been that opportunity costs of labour are below actual labour remuneration. The reason might be the widespread employment of Burmese fishermen on the medium and large trawlers who are not always paid the legal minimum wage. The latter was used to estimate the opportunity cost of unskilled labour.

Apart from the base case simulation (i.e. data of the base year of 1997, see Base Case, A in Table 5.30), a series of simulations were run to assess the impact on financial and economic performance of

- The complete cessation of the pushnet fishery (see B in Table 5.30)
- The reduction of all types of fishing effort by 50% as well as the cessation of pushnet fishing (see C in Table 5.30)
- The reduction of all types of fishing effort by 75% as well as the cessation of pushnet fishing (see E in Table 5.30)
- A reduction of fishing effort of all gear-types by 50% and maintaining pushnet fishing (see D in Table 5.30).

The salient results of these simulations are shown in Table 5.30 and are further discussed below. At the outset, it should be kept in mind that the costs of bringing about the reduction of fishing capacity and effort through, for example, a vessel buy-back scheme and the re-training of displaced labour force, have not been considered in these simulations.

The complete cessation of pushnet fishing would increase annual net economic benefit from 5,185 (see A) to 5,596 million (see B), thus by Baht 411 million (about US $ 11 million). The largest gain, however, would occur from an additional reduction of excessive and wasteful trawling effort to as low as one half of the current level. The simulation results indicate that this would increase the annual net economic benefit by an additional Baht 1.8 billion (US $ 48 million). This gain is the result of both, cost savings of a smaller fleet and higher average fish prices because more of the commercial species are given time before capture to grow to larger specimens that fetch higher prices.

If the annual gain in financial and economic net cash flows is translated into permanent future income streams and discounted at a discount rate of 7 percent (or 12 percent respectively), the Net Present Values (NPV) are obtained. As can be seen in Table 5.30C, the banning of pushnet fishing and the halving of fishing effort would increase the NPV (7% discount rate) from 74.1 to about 99.8 billion Baht (about US $ 2 billion to about US $ 2.7 billion). If pushnet fishing were to be maintained at the current level and the other gear reduced by 50% (see Table 5.30D), the NPV would increase only to Baht 94.6 billion (US $ 2.6 billion).

The estimates of the potential financial and economic benefits from improved fisheries management derived from the BEAM 5 simulations appear to be relatively small even when considering that they are, on an average, somewhat underestimated because of the fact that only about 70 percent of the catch was included into the modelling exercise. There are two principal reasons for this outcome. First, the BEAM 5 analysis does not incorporate potential eco-system and bio-diversity benefits from improved fisheries management. Higher overall abundance of fish stocks could make the eco-system more resilient and more stable over time. It would also avoid the potential threat of species extinction that would have to be reckoned with were the current high level of fishing effort to continue into the future.

An even more fundamental reason could be that the current high estimates of natural and fishing mortalities are erroneous. The high estimates of natural mortality values (M) ranging between 1.7 and 3.9 imply that the gains are small from leaving the fish longer in the sea to grow to a larger size as many specimens would die in the process due to natural causes. There are some valid reasons to doubt the accuracy of the typical estimates of both high fishing mortality and natural mortality in tropical fisheries.

Lower mortality estimates were applied in the ECOPATH model, discussed below in Section 6. To corroborate model consistency the same rates should be applied in both models.