4 GORDON-SCHAEFER AND GORDON-FOX MODELS IMPLEMENTATION AND MODELLING RESULTS[5]

4.1 BACKGROUND AND RATIONALE

After the introduction of commercial trawl fishing in Thailand, in the early sixties, demersal fisheries have become a major contributor to domestic fish supply, producing the bulk of the animal protein supply of the nation. In addition, demersal fisheries are a major source of foreign exchange earnings. Due to their great economic contribution and importance for food security the demersal fisheries require to be managed well.

4.2 TASK

The Working Group had the task to use the Gordon-Schaefer surplus production model:

1. To determine the optimum level of catch and effort;

2. To estimate net benefits (rent and consumer surplus if possible) from the fishery, and

3. To provide management advice at the aggregate and macro-level, while specific measures on vessel, gear and species can be based on other models such as BEAM 5.

4.3 MODEL LIMITATIONS

The original model was developed as a single stock model. It assumes stable environmental conditions. 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. Besides that, a fixed price model and a linear cost function were used.

4.4 MODEL DESCRIPTION

The Gordon-Schaefer model and the Fox model were applied to estimate MSY and MEY. For these models the basic formulas are as follows:

4.4.1 Gordon-Schaefer model

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

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

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

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

4.4.2 Fox model

$$\mathbf{Y = E^*e^{a+bE}} \qquad (3)$$

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

4.5 CATCH AND EFFORT DATA

Data on total catches and total effort were available for the period 1973-1997 for the following fleets:

Otterboard Trawlers (OBT), sizes <14m, 14-18 m and 18-25m;

Pair Trawlers (PT), sizes <14 m, 14-18 m and 18-25 m;

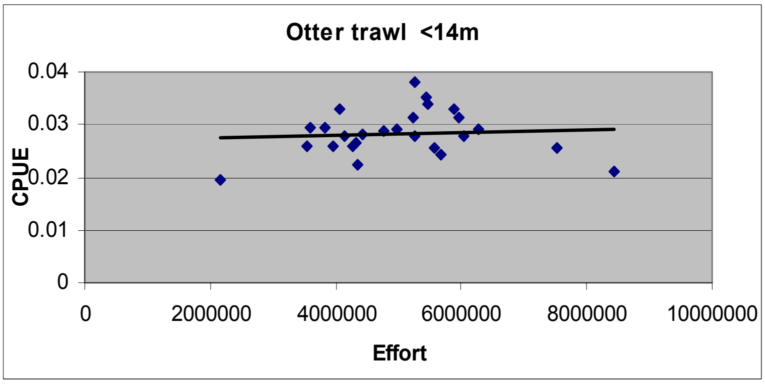
PushNetters (PN) (sometimes divided into small and medium/large);

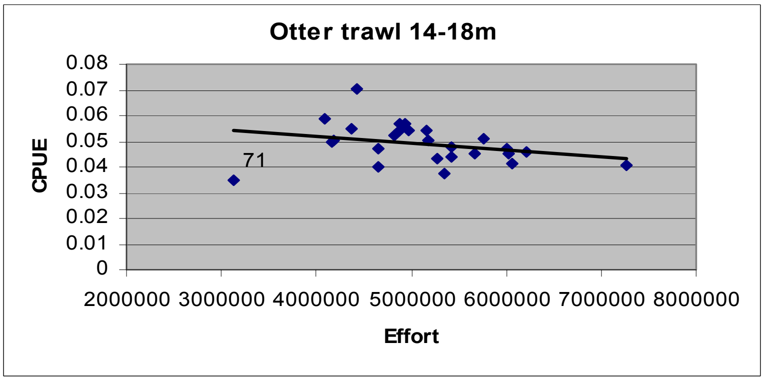
Beam Trawlers (BT)

As indicated in Figures 4.1a to c, a clear declining trend in CPUE with increasing effort can be observed only for medium and large otterboard trawlers (14-18 m and 18-25 m) and for large pair trawlers (18-25 m). Since experimental survey data from the same period indicate a decreasing trend in stock abundance, measured as a decrease in CPUE, which is not observed in many of the commercial fleets it may be assumed that there has been an increase in catchability of those fleets. As the catchability of the research vessel is assumed to have remained the same during the entire time period in question, it was decided to use the research vessel as the reference vessel and to standardise the total annual fishing effort of each fleet in research vessel units.

For each fleet the standardised fishing effort by year was calculated by multiplying the total effort of the fleet in a given year with the ratio between the corresponding commercial CPUE and the CPUE of the survey vessel. However, experimental surveys were not carried out in 1990, 1992, 1994 and 1996 and for these years the mean CPUE of the research vessel in the preceding and the following years were used as an estimate of CPUE. Survey CPUE data were also not available for 1997 and in that particular case a preliminary estimate of 20 kg/hour was applied.

As indicated in Figure 4.2 the total (research vessel) standardised fishing effort increased from 10-15 million hours in the period 1973 to 1986 to 25-35 million hours in the period 1989 to 1997. This steep increase in fishing pressure may be the reason for the decline in total catches observed in the late 1980s.





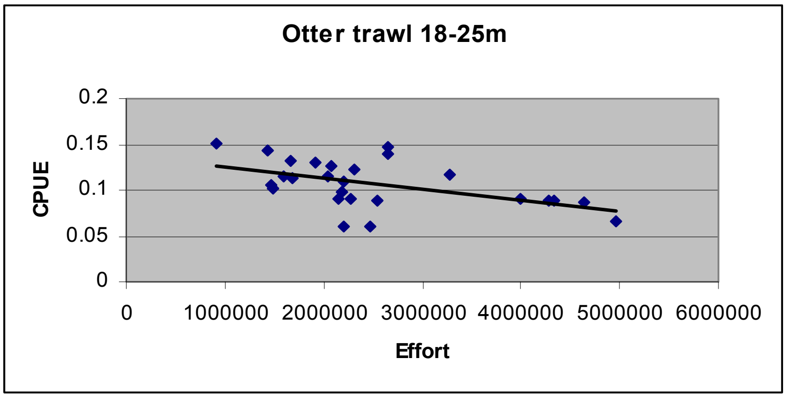
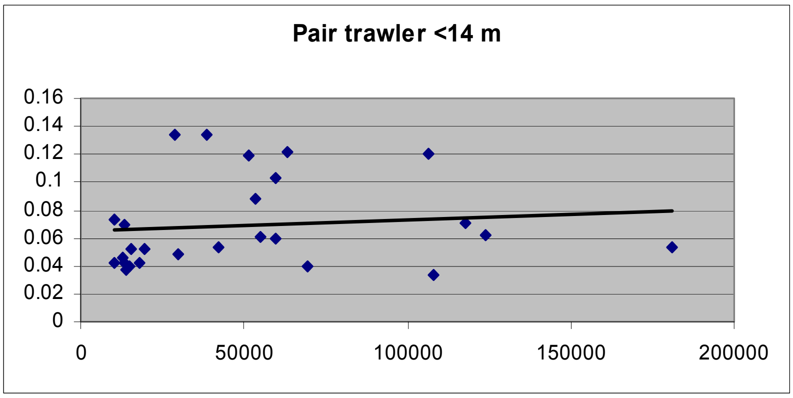
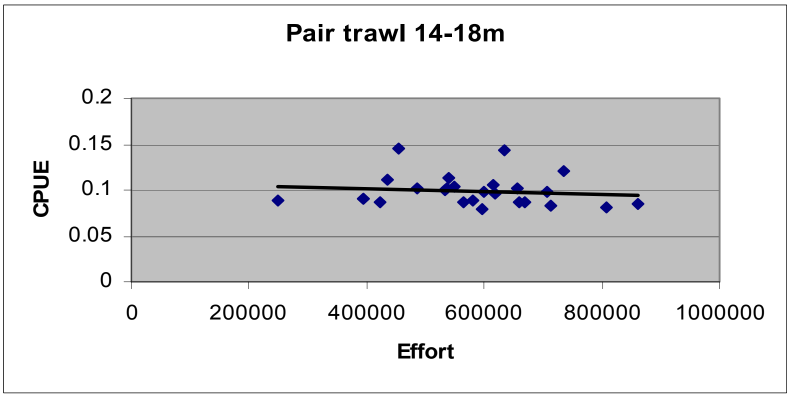


Figure 4.1a Plots of CPUE (tonnes/hour) versus effort (hours) for otterboardtrawlers





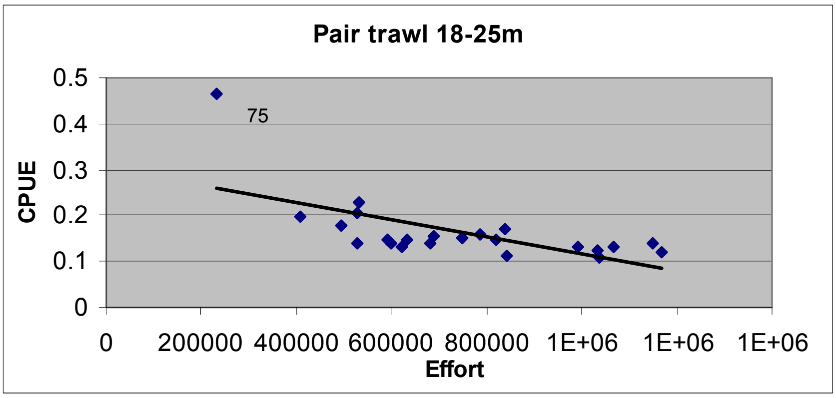
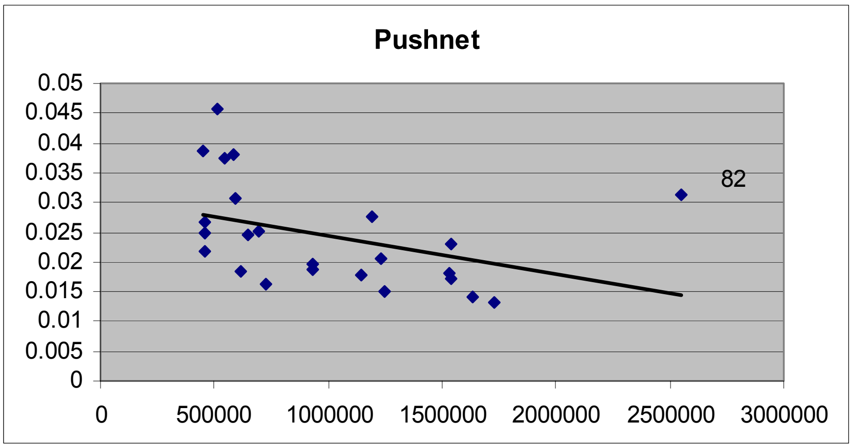


Figure 4.1b Plots of CPUE (tonnes/hour) versus effort (hours) for pair trawlers



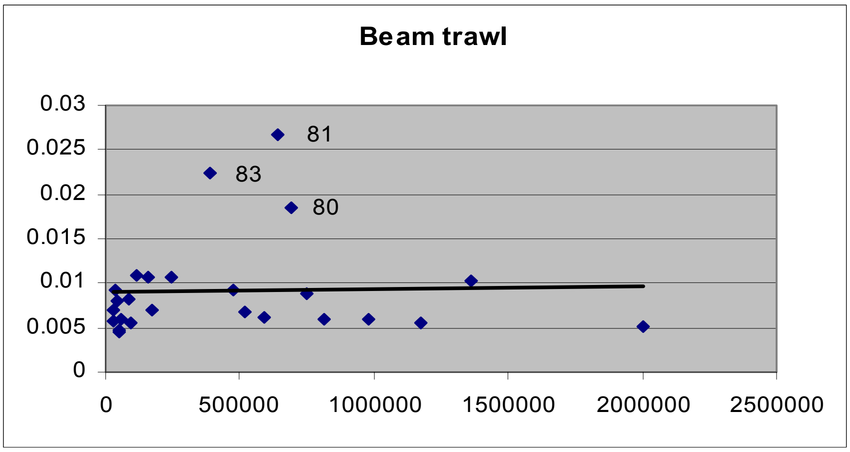


Figure 4.1c Plots of CPUE (tonnes/hour) versus effort (hours) for pushnetters and beam trawls

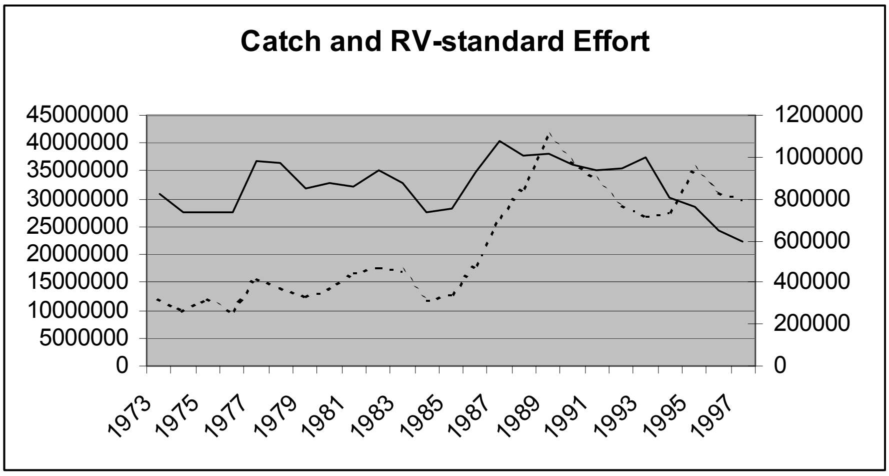


Figure 4.2 Time series of standardised effort (broken line - left y-axis) and catch (solid line - right y-axis)

4.6 ECONOMIC DATA

A fixed price was used for the fish, calculated as the average weighted price for 1998. The cost data for 1998 were determined from fixed costs and variable costs calculated as an average cost per unit of standardized effort.

A variable price model to estimate consumer surplus was not available during the workshop. Such model would require data on prices of fish, substitute prices and disposable income to estimate a demand function.

4.7 BIOLOGICAL ANALYSIS

Catch and effort data over the period 1973 to 1997 from OBT <14 m, 14-18 m, 18-25 m; PT <14 m, 14-18 m, 18-25 m; PN and BT were applied to the Gordon-Schaefer model (Figure 4.3) and Fox model (Figure 4.4).

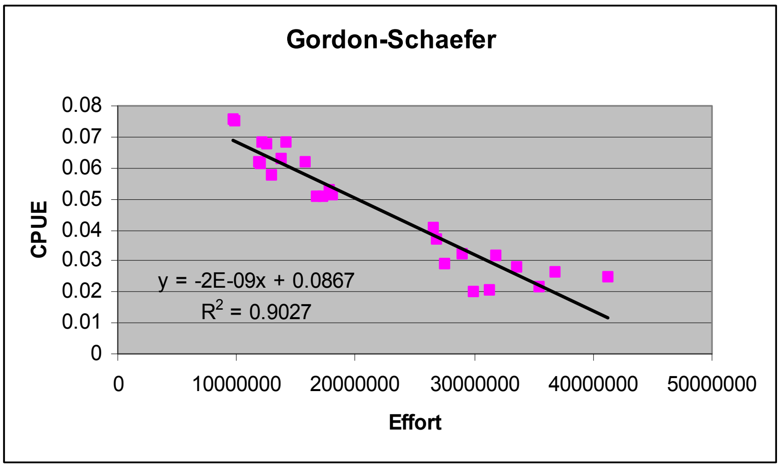


Figure 4.3 Total CPUE versus total standardised effort

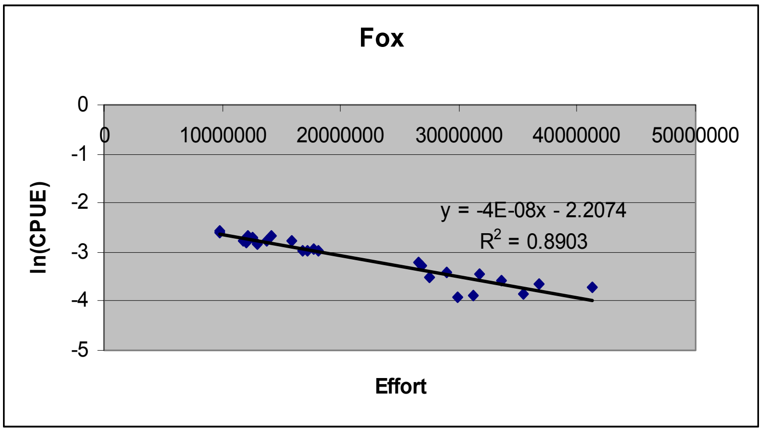


Figure 4.4 Log-transformed total CPUE versus total standardised effort

The constants (a and b) of the Fox model (Yield = Effort*$e^{a+b*Effort}$) were estimated by a linear regression with logarithmically transformed CPUE as the dependent variable (y) and total standardised effort as the independent variable (x). The result of the regression is indicated in Figure 4.4. Fishing effort at maximum sustainable yield (MSY) is estimated as –1/b.

Figure 4.5 shows the Gordon-Schaefer and Fox equilibrium yield curves and the observed total yield and total standardised effort during the time period. The fishing efforts at maximum sustainable yield are very similar for both models. However, the Gordon-Schaefer model indicates a higher level of MSY than the Fox model.

Table 4.1 Results of the application of Gordon-Schaefer and Fox models

	Effort at MSY (million hours)	MSY (tonnes)
Gordon-Schaefer	23.9	1,036,428
Fox	23.3	944,632

It may be noted that all actual effort observations from the 1990s, represented by the dots on the right side of the curve, are well beyond the effort at MSY (23.9 or 23.3 million hours).

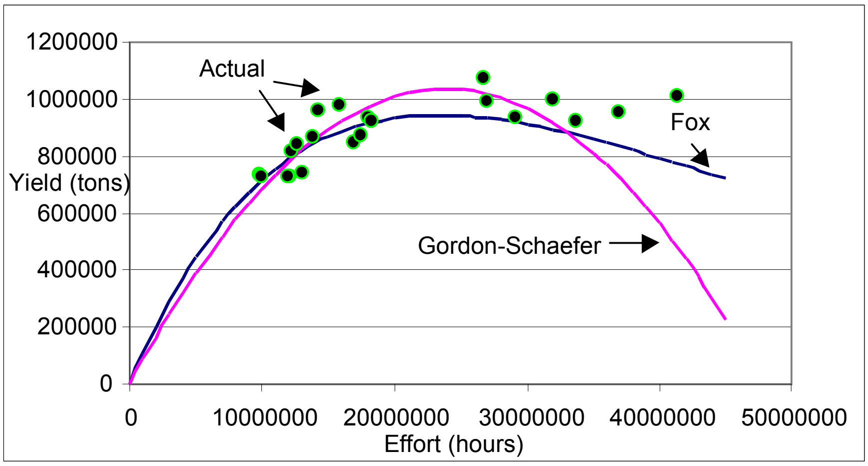


Figure 4.5 Gordon-Schaefer and Fox equilibrium yield curves

4.8 ECONOMIC ANALYSIS

On the economics side, total fishery cost and total revenue are relevant. The economic objective is to maximize resource rent from the fishery. In open access fisheries, fishermen will increase their fishing effort as long as that is profitable. The open access equilibrium (i.e. no further entries in the fishery) occurs where total revenue (TR) equals total cost (TC) and hence resource rent becomes zero. In mathematical terms:

At open access equilibrium: Total Revenue = Total Cost

or $TR = TC$

$PY(E) = CE$

where P is fixed price

E = Effort; Y = Yield

C = average cost per one unit of fishing effort.

At maximum economic yield:

Marginal Revenue = Marginal Cost

$dTR/dE = dTC/dE$

In order to reach the economic objective the fishing effort must be cut down to the point where marginal cost is equal to marginal revenue. The society will gain and be better off in the sense that there is at that point an efficient use of both the fish resources and all factors of production (i.e. input use labour, capital asset etc.).

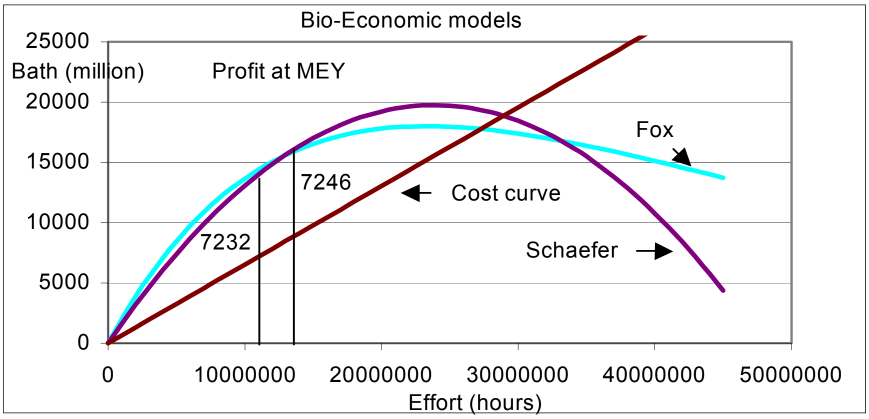


Figure 4.6 Gordon-Schaefer and Fox curves for revenue over standardized effort derived from 1973 - 1997 demersal fisheries data and the resulting maxima for profits at MEY for given constant costs for standard effort

At maximum economic yield the distance between the yield or revenue curve (Schaefer or Fox) and the cost curve is at its maximum, as indicated in Figure 4.6 by one vertical line for each model. From the results shown in Figure 4.6 and in Table 4.1 the optimum levels of effort and catch derived from the Gordon-Schaefer and Fox models are not significantly different.

The Gordon-Schaefer model indicates a maximum resource rent of 7,246 million Baht at an optimum effort level of 14.48 million hours and a related catch of 875 thousand tonnes. The

Table 4.2 Gordon-Schaefer and Fox model results for the MSY, MEY and open access situation in 1998

	MSY		MEY		Open access		Actual
	Schaefer	Fox	Schaefer	Fox	Schaefer	Fox	(1997)
Effort (million hours)	23.89	23.35	14.48	11.48	28.95	27.27	29.92
Catch (thousand tonnes)	1,036.43	944.63	875.37	772.14	990.00	932.69	776.14
Resource rent (million Baht)	4,178	2,787	7,245.92	7,231.88	0	0	-809.15
Note: average price/kg = 19.05 Baht; cost/unit of effort = 651.44 Baht							

Fox model indicates a maximum resource rent of 7,232 million Baht at an optimum effort level of 11.48 million hours and a related catch of 772 thousand tonnes.

The open access equilibrium is reached when the resource rent is 0, which is the point where the cost curve intersects the revenue curve. The related effort and catch are given in the third column (open access) of Table 4.2. The actual situation (column four) lies beyond the open access equilibrium, resulting in a negative resource rent of 809 million Baht.

4.9 IMPLICATIONS

Table 4.3 shows the number of vessels by gear type that need to be phased out, based on the proportional reduction of standardized fishing effort to reach optimum fishing effort. The impact on unemployment of crew (if they are not immediately reemployed elsewhere) is 44,972 people according to the Gordon-Schaefer model and 53,447 people in the Fox model.

Table 4.3 Reduction of fishing fleet and crew based on Gordon-Schaefer and Fox models

Vessel type	Boat length (m)	Number of crew per boat	Present number of boats	Optimum number of boats at MEY		Number of boats to be removed from the fisheries		Number of crew having to leave fisheries	
				Schaefer	Fox	Schaefer	Fox	Schaefer	Fox
OBT	<14	4	**1,970**	922	724	1,048	1,246	4,193	4,983
	14-18	8	**2,165**	1,013	796	1,152	1,369	9,216	10,952
	18-25	16	**1,761**	824	647	937	1,114	14,992	17,817
PT	<14	10	**29**	14	11	15	18	154	183
	14-18	19	**466**	218	171	248	295	4,711	5,599
	18-25	19	**1,051**	492	386	559	665	10,625	12,627
PN		2.3	**771**	361	283	410	488	944	1,121
BT		1.7	**152**	71	56	81	96	137	163
Total			**8,365**	**3,915**	**3,074**	**4,450**	**5,291**	**44,972**	**53,447**

Table 4.4 shows the optimum number of vessels and the number that would need to be removed by gear type, given that pushnetting is banned and the remaining standardized fishing effort is allocated proportionally to the existing number of vessels. The impact on employment would be grave: a reduction of 42,931 crew in the Gordon-Schaefer model and 51,542 crew in the Fox model, about 2,000 less than without the ban on pushnets.

Table 4.4 Reduction of fishing fleet and crew based on Gordon-Schaefer and Fox models in case of a ban on pushnet fisheries

Vessel type	Boat length (m)	Number of crew per boat	Present number of boats	Optimum number of boats at MEY		Number of boats to be removed from the fisheries		Number of crew having to leave fisheries	
				Schaefer	Fox	Schaefer	Fox	Schaefer	Fox
OBT	<14	4	**1,970**	990	785	980	1,185	3,919	4,739
	14-18	8	**2,165**	1,088	863	1,077	1,302	8,615	10,417
	18-25	16	**1,761**	885	702	876	1,059	14,014	16,947
PT	<14	10	**29**	15	12	14	17	144	174
	14-18	19	**466**	234	186	232	280	4,404	5,325
	18-25	19	**1,051**	528	419	523	632	9,932	12,011
PN		2.3	**771**	0	0	771	771	1,773	1,773
BT		1.7	**152**	76	61	76	91	129	155
Total			**8,365**	**3,816**	**3,028**	**4,549**	**5,337**	**42,931**	**51,542**