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Financial Implications of Fishery Management Strategies in a Newly Impounded Man-made Lake in Thailand, a Simulation

V. DULYAPRUK[1] , J. MOREAU[2*], S. JUMNONGSONG[1] , T. THAPANAND[1], S. JANEKITKARN [1] AND L. WONGRAT[1]

[1]Faculty of Fisheries, Kasetsart University

Chatuchak, Bangkok 10900 Thailand

[2] Department of Tropical Fisheries
Laboratoire d'Agronomie, Environnement et Ecotoxicologie

INP/ENSAT B.P. 32607 F, 31326

Castanet Tolosan, France

Abstract

The aim of this paper is to study the financial aspects of fisheries management strategies as if they can be approached by linking ecology, trophic relationships, aquatic resources evaluations and socio-economic aspects of fisheries in a newly impounded south East Asian reservoir (Pasak Jolasid near Bangkok, Thailand). This knowledge was used to identify possible risks of financial problems for artisanal fishermen. For that purpose, Ecopath was used to construct a mass-balanced model, which is considered to be a first step in summarizing ecological and biological information in a coherent framework through trophic networks in the reservoir. With Ecosim, two scenarios of increasing fishing effort were sketched: a fishing effort multiplied by two over ten years for all gears and for gill nets alone (other fishing effort assumed to remain constant). The outcomes are evaluated in terms of variations of biomass and catch of fish species and predictable impact on the financial situation of the fishermen. The results are discussed in comparison with the influence of the optimized fishing strategy which can be identified with the appropriate software associated with Ecopath for maximization of the economic or social value of the reservoir. The implications of the findings are discussed in terms of fisheries management of the ecosystem.

* Corresponding author. Tel.: +33 5621 93905, Fax: +33 5621 93901
E-mail address: jmoreau@ensat.fr

Introduction

In Thailand, reservoirs are very rarely, if ever, built mainly for fishery purposes even if reservoirs fisheries are quite active and diversified in that they exploit several fish stocks and native species of economic importance by using a high variety of fishing techniques. However, the total catch remains quite low, compared to other Asian reservoirs, particularly those of Sri Lanka, where fisheries are characterised by high levels of production (Moreau and De Silva 1990; Moreau et al. 2001). As a result, the socio-economic situation of the individual fishermen and of the fishery as a whole appears to be critical (Chantakanon et al. 1993). Various management schemes were implemented for improvement of the income of fishermen such as introductions or regular stocking of indigenous tolerant species (Baluyut 1984; Bhukaswan 1985).

The relevance of these stocking as well as the whole management strategy need to be approached from the ecological point of view e.g. the utilization of the food sources available in the water body and socio-economic surveys which will allow to characterize the socio-economic situation of the fishing communities.

Considering and quantifying in a standardized way the trophic network helps to assess the contribution of catch to the whole dynamics of the ecosystem fisheries. Quantitative trophic analyses at the ecosystem level were carried out in other south eastern Asian reservoirs: Parakrama Samudra, Sri Lanka (Moreau et al. 2001), Ubolratana (Chookajorn et al. 1994), Nam-Ngum and Sirinthorn reservoirs (Jutagate et al. 2002). It was made possible through Ecopath (Christensen and Pauly 1993; Christensen et al. 2005), a trophic model which has allowed to quantify spatial and temporal changes of biomass scales (Christensen et al. 2005**;** Walters et al. 1999; Christensen and Walters 2004).

Fisheries scientists become more and more aware of the necessity to combine usual aquatic resources assessment with inputs of socio economic data for a proper understanding and evaluation of the impact of fisheries on the general welfare of the fishermen and riparian human populations (Amarasinghe et al. 2001; Christensen et al. 2006). An interface between quantitative ecology and socio-economy has therefore been developed as part of the Ecopath software and is becoming progressively more and more important (Christensen et al. 2005).

The present study is an attempt to assess the possible evolution of the socio-economic situation of the riparian fishing community of the newly created Pasak Jolasid reservoir (Thailand) under possible management schemes with reference to the current situation as described in previous contributions (Thapanand et al. 2007; In press).

Material and Methods

Study site

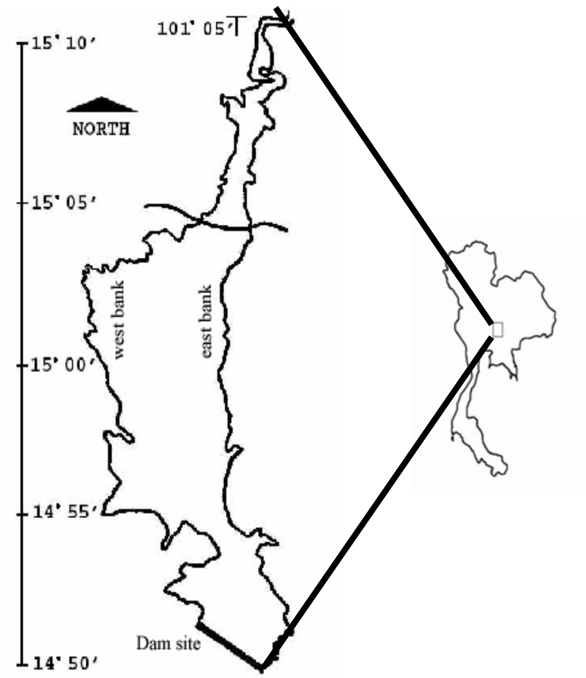

Fig. 1. Pasak Jolasid Reservoir

Pasak Jolasid Reservoir (Fig. 1) was created with the construction of the Pasak Jolasid Dam in 1999 which was built under His Majesty the King's Project across the Pasak River. On the average, the reservoir covers approximately 150 km^2, extending from the dam, located between Nong Bua Village, Nong Bua Sub-district, Pattana Nikom District, Lopburi Province and Kum Pran Village, Kum Pran Sub-district, Wang Moung District, Saraburi Province, to the upstream area around Tadindum Village, Chaibadan District, Lopburi Province. The reservoir is regularly replenished by the Pasak River which originates from Phetchaboon Mountain and is capable of storing up to 960 million m^3 of water at 45 m above sea level. The main functions of the reservoir are to support irrigation systems in adjacent farmlands and to protect the Lower Chao Praya River Basin, including Bangkok, from flooding. As with the other reservoirs in Thailand, fishery is not included as the priority role for the reservoir (Wongrat 2004).

The average water depth is about 10 m. It is a lake with a homogenous water column without permanent stratification and often mixing in case of strong winds. Annual precipitation in the region is about 985 mm and the lake experiences a strong seasonal climate which induces variations in water level of about 2 m (Royal Irrigation Department of Thailand 2003).

According to Chookajorn et al. (2002) and to Wongrat (2004), the fish diversity was quite high as more than 80 fishes from 24 families occupied the lake. A Tilapiine species, *Oreochromis niloticus* has been introduced and regularly stocked, along with several native species, by the Department of Fisheries, Ministry of Agriculture and Cooperatives (Chookajorn et al. 2002).

The fisheries are predominantly artisanal which is similar to other Thai reservoirs and covered 226 households who were interviewed (Wongrat 2004). The common fishing gears are gillnets, cast nets, long-lines and various kinds of traps. The most important catches were originally from riverine Cyprinids, *Channa striata* (Channidae), *Oxyeleotris marmorata* (Eleotridae) and *Notopterus notopterus* (Notopteridae) (Chookajorn et al. 2002). However, almost all species are effectively exploited. Fishing activities are not allowed from the 15th of May to the 15th of September as a management scheme to protect fish breeding activity.

The total catch per fishing gear, as documented by Wongrat (2004) is summarized in table 1. It appears that 80 % of the total catch originated from the gill net fisheries.

Theoretical approach

The first step was to construct the structure of trophic interactions occurring in the ecosystem, using the steady-state simulation program, Ecopath 5, as designed by Christensen and Pauly (1993), Walters et al. (1997) and Christensen et al. (2005). In structuring the model, the various organisms belonging to the ecosystem have to be grouped into “boxes” according to their common physical habitat, similar food preferences and life history characteristics. Then the model estimates, on an annual basis, parameters such as mean biomass, biomass production and biomass consumption or ecotrophic efficiency and flow to the detritus pool of every box were considered in the ecosystem. It was assumed for the period considered that input to each group is equal to the output from it in order to deal with equilibrium conditions. It was also required to standardize the data input by applying the same units in each parameter considered.

Table 1. Total catch by using several fishing gears in Pasak Jolasid reservoir (data from the SUMAFISH Project) and price per kg (Thai baht)

Group Name	TL	Gill nets	Cast nets	Lines	Fixed traps	Total	Price (/Kg)
Channa striata	3.2	8.25	3.45	14.40	7.05	33.15	40
H. macrolepidota	3.2	62.25	0.45	2.40	0.00	65.10	20
N. notopterus	2.9	8.55	0.30	1.50	0.75	11.10	25
O. marmorata	3.1	0.15	0.45	1.50	1.50	3.60	150
Hemibagrus & Mystus	3.2	12.90	0.45	2.25	0.15	15.75	50
Pangasius sp	3.1	0.15	0.00	0.15	0.00	0.30	20
L. hexanema	2.9	37.20	0.00	0.00	0.00	37.20	5
M. chrysophekadion	2.1	64.05	0.00	0.00	0.15	64.20	25
R. dusonensis	2.5	1.50	0.90	0.00	1.80	4.20	5
Dangila spp	2.1	33.60	3.15	0.00	6.30	43.05	5
Par. hardmandi	3.1	48.30	0.00	0.00	0.15	48.45	5
M. marginatus	2.2	5.55	0.15	0.00	0.15	5.85	5
H. siamensis	2.0	96.60	3.45	0.00	6.75	106.80	6
Osteochilus spp	2.1	12.90	5.40	0.00	10.80	29.10	5
B. gonionotus	2.0	171.60	24.00	0.00	48.00	243.60	15
Puntioplites sp	2.4	69.90	6.30	25.35	12.75	114.30	10
P. fasciatus	2.9	2.10	0.75	0.00	1.50	4.35	5
Mastacembidae	2.9	0.45	0.15	0.60	0.15	1.35	60
C. apogon	2.8	45.15	0.60	0.00	1.20	46.95	5
O. niloticus	2.1	87.90	0.75	3.30	1.65	93.60	20
C. aesarnensis	2.9	0.90	0.00	0.00	0.00	0.90	5
Ornamental fish	2.1	0.00	0.00	0.00	0.15	0.15	5
Trichogaster sp	2.9	0.15	0.15	0.00	0.00	0.30	5
Parambassis sp	2.5	45.00	0.15	0.00	0.15	45.30	5
Other benthic org.	2	0.00	0.00	0.00	3.00	3.00	5
Total (tons per year)		815.1	51	51.45	104.1	1021.65	

TL is the trophic level as computed with Ecopath (Thapanand et al. 2007; In press).

By establishing an equilibrium condition in the ecosystem, a system of biomass budget equation was determined for each considered group as:

Production – all predation on each grouped species – non-predatory mortality – all exports = 0 (1)

ECOPATH expresses each term in the budget equation as a linear function of the mean biomass. The resulting budget equations became a system of simultaneous equations following the formula:

$$B_i \frac{P}{B_i} = \sum_{j=1}^{n} B_j \frac{Q}{B_j} DC_{ji} + B_i \frac{P}{B_i} (1\text{-}EE_i) + EX_i \qquad (2)$$

where B_i is the biomass of group i (in t·km^{-2}); P/B_i is the annual production/biomass ratio of group i which is equal to the total mortality coefficient (Z) in steady-state conditions (Allen 1971); B_j is the biomass of the predator group j; Q/B_j is the annual food consumption per unit biomass of the predatory group j (Pauly 1986; Palomares and Pauly 1998); DC_{ji}, is the proportion of the group i in the diet of its predator group j (in percentage of weight or volume); EE_i is the ecotrophic efficiency representing the part of the total production transferred to a higher trophic level (TL) through predation or captured in the fishery (Ricker 1969); EX_i, is the export or catch in fishery of group *i*, that is assumed to be exploited in the fishery (Christensen et al. 2005).

In addition to balancing the model with Ecopath 5, we used the Ecosim routine (Walters et al. 1997; 1999) a simulation tool that provides descriptions of evolution occurring in the ecosystem considering various fishing management strategies. In order to use Ecosim, it is necessary to identify the various fishing gears in use as well as their contribution to the actual catch and the key targeted fish populations.

Model construction

For the present model, the groups to be considered have been identified according to their potential importance for fisheries and their contribution to the diet of the fish community or their ecological importance in the trophic relationships within the ecosystem (Thapanand et al. 2007; In press).

The trophic model was constructed using mostly data collected from field survey from March 2002 to February 2003 and complemented by literature. Fish species were categorised and grouped according to their similarities in habitat, maximum body size, feeding habits and physiological behaviour, and ecological distribution in order to keep homogeneous characteristics among the species within a group (Yodzis and Winemiller 1999).

Details of the implementation of the trophic model were provided in previous contribution (see Thapanand et al. 2007; In press). For fish groups, whenever it was possible, the *P/B* ratios were estimated from recently collected length frequency distributions collected within the project by using the FiSAT software (Gayanilo et al. 2002). Some *P/B* values were applied from Villanueva et al. (2007) for the same species in Ubolratana reservoir in which the maximum recorded size was more or less similar to those found in the Pasak Jolasid reservoir. The food consumption per unit of biomass (*Q/B*) has been estimated in a few cases using Maxims (Jarre et al. 1991). This software and model based on the method of Pauly (1986), allows the computation of *Q/B* from estimates of the daily food consumption of individual fish of particular sizes. Otherwise, *Q/B* was calculated using the multiple regression formula of Palomares and Pauly (1998).

For most fish groups local and recent information on diet composition were available and were used in the present study. Otherwise, diet compositions were adapted from Kakkaeo et al. (2004).

Biomass (*B*) of each fish group was evaluated during the surveys by using electric fishing sampling and gillnetting

Catch data and the proportion of each group in the total catch were obtained from surveys operated during the fieldwork of the SUMAFISH Project (Table 1).

The socio economic survey by Dulyapruk and Jumnongsong (2004) allowed obtaining estimates of the financial accounting for fishermen using the different fishing gears. Fish price per kilogram and economic studies of the income and costs of fishing operations were made available. Fixed costs are essentially depreciation costs; effort related costs are mostly implicit labor costs and sailing costs associated with trips on the lake as computed by Dulyapruk and Jumnongsong (2004). The data were standardized to the appropriate format of ecopath as shown in table 2.

Table 2: Relative fishing costs, profit (in percentages of the total value) for the fishermen operating with each fishing gear in Pasak Jolasid reservoir as used for the present contribution (from original data by Dulyapruk and Jumnongsong 2004)

Fishing gear	Fixed cost (%)	Effort related costs (%)	Sailing related costs (%)	Profit (%)	Total value (%)
Gill nets	3	60	3	34	100
Cast nets	2	30	2	66	100
Hooks and long lines	1	48	1	50	100
Various traps	1	65	3	31	100

Ecosim was used in order to sketch an increase of the fishing effort which would be multiplied by two over ten years. This was considered to be reasonable to meet the increasing demand of jobs and fish supply in rural environment. Two scenarios were investigated:

1. The increase concerning all the fishing gears together (option “combined gears" of the Ecosim routine)
2. The increase concerning only the gill net fishery, the fishing effort with other gears would remain constant and their catch would be regarded as low compared to that of the gill net fisheries.

It should be noted that a proper use of Ecosim for that purpose requires a preliminary calibration of Ecosim by fitting the results to time series data on catch/effort of the key species, which were not available here. Therefore, in order to minimize the risks of misleading results we adopted the default values of the various parameters which need to be settled before running Ecosim, particularly the “group info” (see Christensen et al. 2005 for these concepts) and the vulnerability, a parameter which expresses the relative impact on the whole foodweb of the bottom-up and top-down control. A default value of 2, as suggested by Christensen et al. (2005) has been selected for all groups during the present exercise.

It was assumed that cost of the fishing operations was proportional to the fishing effort.

Results

The results obtained with the mass-balanced model are those of Thanapand et al. (In press).

Running ecosim, influence on biomass and catch of each group

From the two scenarios sketched with Ecosim (see above) the results are the following:

The possible trends of variations of total catch and total value for both scenarios for a 10-year period are summarized in figure 2. Detailed results in terms of evolution of biomass, catch, value and cost, at the species level and at the gear level for both scenarios are given in tables 3 to 6 whereas a comparative profit analysis is presented in table 7. The total value of the ecosystem would increase for each fishing technique except for the hooks and long lines in the first scenario and for every fishing gear except gill nets in the second scenario. Nevertheless, the decrease in the total value is maximized for hooks and long lines.

It can be seen from figure 2 that the increase in total value is lower than the increase in catch. However, more importantly, the profit, which might be quite substantial in the current situation, would be drastically reduced if the gillnet fisheries would be the only one to develop. Increasing the fishing effort would lead even to negative values of the benefit and to the financial collapse of the fishery. The best profit would be obtained from the cast net fisheries in both scenarios as it appears on table 7.

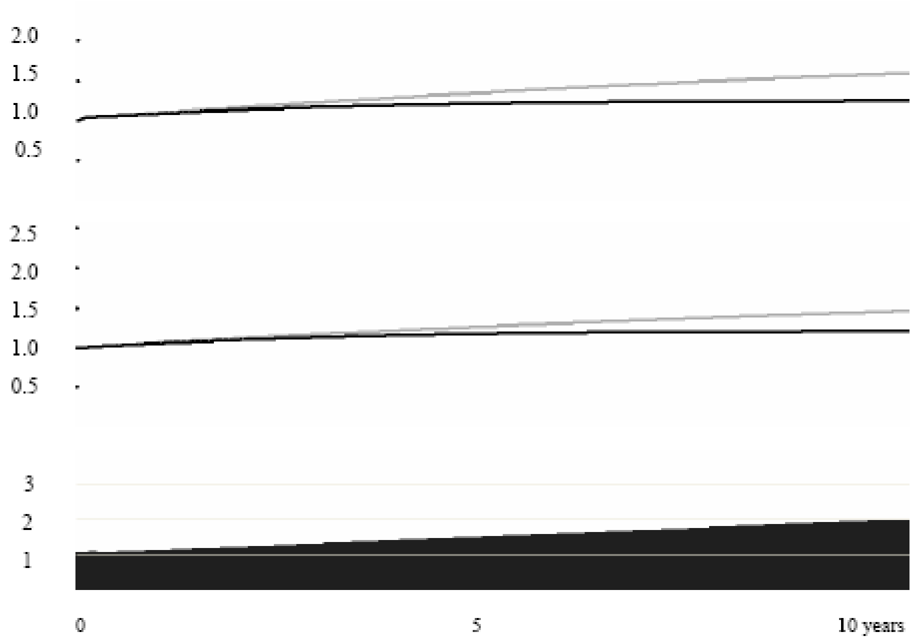

Fig. 2. The trend of increase of the total catch (grey line) and total value (black line) under scenarios 1 (top) and 2 (bottom). Fishing effort to be multiplied by 2 within 10 years in both scenarios. Ordinates: coefficient of variations of the catch and total value, 1 is the original situation

A detailed examination of tables 3 and 5, when associated to table 1, facilitates a possible explanation for the above comments. It can be noticed that some species of high commercial values experience a clear decrease in their catch. They mostly belong to the higher trophic levels. On the opposite, species of low commercial value, also belonging to the lower trophic levels, would provide higher catches. The original trophic level of the catch, as computed by Thapanand et al. (In press) was 2.37. It would decrease to 2.31 in the first scenario and to 2.34 in the second one.

When computed for each fishing gear separately, the original trophic levels of their catch were 2.38 with gillnets, 2.22 with cast nets, 2.72 with hooks and lines and 2.20 with traps. At the end of the first scenario, these trophic levels associated to each fishing technique would be: 2.34, 2.08, 2.48 and 2.13, respectively. The maximum decrease would be a result from the hooks and lines. At the end of the second scenario, the trophic levels of the catch of each fishing gear would be 2.36, 2.16, 2.60, and 2.17, respectively. Therefore, the decrease in trophic level would be reduced when only the gillnet fisheries is developed (Figure 3).

Table 3. Summary of the variations of biomass and catch in a scenario when the fishing effort is increased with any fishing gear

Groups	O B	FB	FB/ OB	OC	FC	FC/ OC	OV	FV	FV/ OV
Channa striata	0.20	0.01	0.02	0.23	0.01	0.05	9.09	0.43	0.05
H. macrolepidota	0.66	0.29	0.45	0.45	0.41	0.91	8.95	8.11	0.91
N. notopterus	0.10	0.02	0.23	0.08	0.04	0.46	0.44	0.20	0.46
O. marmorata	0.02	0.00	0.01	0.03	0.00	0.02	3.70	0.09	0.02
Hemibagrus Mystus	0.14	0.04	0.27	0.11	0.06	0.55	5.41	2.96	0.55
Pangasius sp	0.13	0.22	1.67	0.00	0.01	3.38	0.04	0.14	3.38
L. hexanema	0.38	0.37	0.97	0.26	0.50	1.96	1.28	2.51	1.96
M. chrysophekadion	0.66	0.22	0.33	0.44	0.30	0.67	11.04	7.45	0.67
R. dusonensis	0.04	0.06	1.40	0.03	0.08	2.84	0.15	0.41	2.84
Dangila spp	0.45	0.37	0.82	0.30	0.50	1.67	1.48	2.48	1.67
Par. hardmandi	0.50	0.40	0.79	0.33	0.54	1.61	1.67	2.69	1.61
Mystocoleucus marginatus	0.06	0.06	1.05	0.04	0.09	2.14	0.20	0.43	2.14
H. siamensis	1.11	1.22	1.10	0.74	1.65	2.24	4.41	9.88	2.24
Osteochilus spp	0.31	0.16	0.53	0.20	0.22	1.08	1.00	1.08	1.08
B. gonionotus	2.55	2.59	1.02	1.68	3.46	2.06	25.17	51.88	2.06
Puntioplites sp	0.93	0.80	0.87	0.79	1.38	1.76	7.86	13.83	1.76
P. fasciatus	0.05	0.06	1.30	0.03	0.08	2.64	0.15	0.40	2.64
Mastacembalidae	0.01	0.02	1.66	0.01	0.03	3.36	0.56	1.87	3.36
C. apogon	0.48	0.59	1.22	0.32	0.80	2.47	1.62	4.00	2.47
O. niloticus	0.93	0.24	0.25	0.64	0.33	0.51	12.88	6.56	0.51
C. aesarnensis	0.01	0.01	1.22	0.01	0.02	2.47	0.03	0.08	2.47
Ornamental fish	0.00	0.01	2.30	0.00	0.01	4.67	0.01	0.02	4.67
Trichogaster sp	0.11	0.19	1.80	0.00	0.01	3.66	0.01	0.04	3.66
Parambassis sp	0.47	0.41	0.88	0.31	0.56	1.79	1.56	2.79	1.79
Other benthic org.	103.3	104.1	1.01	0.02	0.04	2.04	0.10	0.21	2.04
Total	217.2	217.3	1.00	7.03	11.1	1.58	98.79	120.5	1.22

Legend: OB: original biomass of the group (biomass in the balanced ecopath model t•km-^{2}); FB: final biomass of the group at the end of the scenario (t•km^{-2}); OC: original catch on this group (an input in the balanced ecopath model (t•km^{-2}•yr^{-1}); FC: final catch of the group at the end of the scenario (t•km^{-2}•yr^{-1}); OV: original value of the catch on this group (an input in the balanced ecopath model (1000 Thb•km^{-2}•yr^{-1}); FV: final value of the catch of the group at the end of the scenario (1000 THb•km^{-2}•yr^{-1})

Table 4. Summary of the variations of catch total value and costs in a scenario per fishing gear when the fishing effort is increased with any fishing gear

Gear	OC	FC	FC/OC	OV	FV	FV/OV	OCs	FCs	FCs/OCs	FFE/OFF
Gill nets	5.61	8.87	1.58	73.25	93.58	1.28	48.48	96.19	1.98	2.03
Cast nets	0.35	0.61	1.73	5.28	7.30	1.38	1.80	3.55	1.97	2.03
hooks and lines	0.35	0.37	1.04	9.31	5.26	0.57	4.69	9.42	2.01	2.03
Various traps	0.72	1.24	1.74	10.95	14.39	1.31	7.59	15.30	2.01	2.03
Total	7.03	11.09	1.58	98.79	120.53	1.22	62.56	124.45	1.99	

Legend: OC: original catch with this fishing gear (an input in the balanced ecopath model in t•km^{-2}•yr^{-1}); FC: final catch with this fishing gear at the end of the scenario (t•km^{-2}•yr^{-1}); OV: original value of the catch (an input in the balanced ecopath model (1000 Thb•km^{-2}•yr^{-1}); FV: final value of the catch at the end of the scenario (1000 Thb•km^{-2}•yr^{-1}); OCs: original cost of the fishing operations (an input in the balanced ecopath model (1000 Thb•km^{-2}•yr^{-1}); FCs: final cost of the fishing operations gear at the end of the scenario (1000 Thb•km^{-2}•yr^{-1})

Table 5. Summary of the variations of biomass and catch in a scenario when only the fishing effort with gill net fisheries is increased

Group	O B	FB	FB/OB	OC	FC	FC/OC	OV	FV	FV/OV
Channa striata	0.20	0.11	0.53	0.22	0.15	0.66	8.92	5.88	0.66
H. macrolepidota	0.65	0.33	0.50	0.45	0.43	0.95	9.03	8.61	0.95
N. notopterus	0.10	0.04	0.42	0.08	0.06	0.72	0.42	0.18	0.42
O. marmorata	0.02	0.02	0.87	0.02	0.02	0.91	3.60	3.26	0.91
Hemibagrus Mystus	0.14	0.04	0.28	0.11	0.05	0.49	5.43	2.68	0.49
Pangasius sp	0.13	0.22	1.64	0.00	0.01	2.43	0.04	0.10	2.43
L. hexanema	0.38	0.35	0.92	0.26	0.46	1.78	1.29	2.31	1.78
M. chrysophekadion	0.66	0.20	0.31	0.45	0.27	0.60	11.16	6.66	0.60
R. dusonensis	0.04	0.07	1.54	0.03	0.06	2.08	0.14	0.30	2.08
Dangila spp	0.45	0.41	0.90	0.30	0.47	1.58	1.48	2.34	1.58
Par. hardmandi	0.50	0.38	0.76	0.34	0.50	1.47	1.68	2.48	1.47
Mystocoleucus marginatus	0.06	0.05	0.80	0.04	0.06	1.52	0.20	0.31	1.52
H. siamensis	1.10	1.13	1.02	0.74	1.40	1.89	4.44	8.41	1.89
Osteochilus spp	0.31	0.33	1.06	0.20	0.30	1.51	0.99	1.49	1.51
B. gonionotus	2.55	2.61	1.02	1.68	2.86	1.71	25.12	42.90	1.71
Puntioplites sp	0.93	1.02	1.10	0.78	1.37	1.75	7.82	13.67	1.75
P. fasciatus	0.05	0.06	1.27	0.03	0.06	1.87	0.15	0.28	1.87
Mastacembalidae	0.01	0.01	1.36	0.01	0.02	1.80	0.55	0.98	1.80
C. apogon	0.48	0.49	1.01	0.33	0.63	1.92	1.63	3.13	1.92
O. niloticus	0.93	0.24	0.25	0.65	0.31	0.48	12.98	6.24	0.48
C. aesarnensis	0.01	0.01	1.15	0.01	0.01	2.24	0.03	0.07	2.24
Ornamental fish	0.00	0.00	1.66	0.00	0.00	1.66	0.01	0.01	1.66
Trichogaster sp	0.11	0.18	1.73	0.00	0.01	2.57	0.01	0.03	2.57
Parambassis sp	0.47	0.42	0.89	0.32	0.55	1.73	1.58	2.73	1.73
Other benthic organisms	103.31	104.05	1.01	0.02	0.02	1.01	0.10	0.10	1.01
Total	279.94	279.92	1.00	7.05	10.05	1.43	98.78	115.13	1.17

Legend: OB: original biomass of the group (Biomass in the balanced ecopath model $t\bullet km^{-2}$); FB: final biomass of the group at the end of the scenario ($t\bullet km^{-2}$); OC: original catch on this group (an input in the balanced ecopath model in $t\bullet km^{-2}\bullet yr^{-1}$); FC: final catch of the group at the end of the scenario ($t\bullet km^{-2}\bullet yr^{-1}$); OV: original value of the catch on this group (an input in the balanced ecopath model, 1000 $Thb\bullet km^{-2}\bullet yr^{-1}$); FV: final value of the catch of the group at the end of the scenario (1000 $Thb\bullet km^{-2}\bullet yr^{-1}$)

Table 6. Summary of the variations of catch, total value and costs in a scenario per fishing gear when only the fishing effort with gill net fisheries is increased

Gear	OC	FC	FC/ OC	OV	FV	FV/ OV	OCs	FCs	OCs/ FCs	FFE/ OFE
Gill nets	5.67	8.76	1.54	74.08	95.01	1.28	49.07	93.30	1.90	1.94
Cast nets	0.34	0.33	0.98	5.10	4.52	0.88	1.74	1.74	1.00	1.00
Hooks and long lines	0.34	0.27	0.80	9.01	6.12	0.68	4.53	4.53	1.00	1.00
Various traps	0.69	0.68	0.99	10.58	9.48	0.90	7.33	7.33	1.00	1.00
Total	7.05	10.05	1.43	98.78	115.1	1.17	62.66	106.9	1.71	

Legend: OC: original catch with this fishing gear (an input in the balanced ecopath model ($t \cdot km^{-2} \cdot yr^{-1}$); FC: final catch with this fishing gear at the end of the scenario ($t \cdot km^{-2} \cdot yr^{-1}$); OV: original value of the catch with this fishing gear (an input in the balanced ecopath model (1000 $Thb \cdot km^{-2} \cdot yr^{-1}$); FV: final value of the catch with this fishing gear at the end of the scenario (1000 $Thb \cdot km^{-2} \cdot yr^{-1}$); OCs: original cost of the fishing operations with this fishing gear (an input in the balanced ecopath model (1000 $Thb \cdot km^{-2} \cdot yr^{-1}$); FCs: final cost of the fishing operations with this fishing gear at the end of the scenario (1000 $Thb \cdot km^{-2} \cdot yr^{-1}$)

Table 7. Economical pattern of the fishery at the beginning and at the end of the scenarios

A: all gears concerned

Gears	OC	FC	OV	FV	OC	FC	FC/OC	OP	FP
Gill nets	5.61	8.87	73.25	93.58	48.48	96.19	1.98	24.77	-2.61
Cast nets	0.35	0.61	5.28	7.30	1.80	3.55	1.97	3.48	3.75
hooks and long lines	0.35	0.37	9.31	5.26	4.69	9.42	2.01	4.62	-4.16
Various traps	0.72	1.24	10.95	14.39	7.59	15.30	2.01	3.36	-0.91
Total	7.03	11.09	98.79	120.53	62.56	124.45	1.99	36.23	-3.92

B: Increase of gill net activity only.

Gears	OC	FC	OV	FV	OC	FC	OC/FC	OP	FP
Gill nets	5.61	8.76	73.25	95.01	48.48	93.30	1.92	24.77	1.71
Cast nets	0.35	0.33	5.28	4.52	1.80	1.80	1.00	3.48	2.72
hooks and long lines	0.35	0.27	9.31	6.12	4.69	4.69	1.00	4.62	1.43
Various traps	0.72	0.68	10.95	9.48	7.59	7.59	1.00	3.36	1.89
Total	7.03	10.05	98.79	115.13	62.56	1.72	1.07	36.23	7.75

Legend: OP: original profit (1000 $Thb \cdot km^{-2} \cdot yr^{-1}$); FP: final profit (1000 $Thb \cdot km^{-2} \cdot yr^{-1}$); other abbreviations are as given in Table 6.

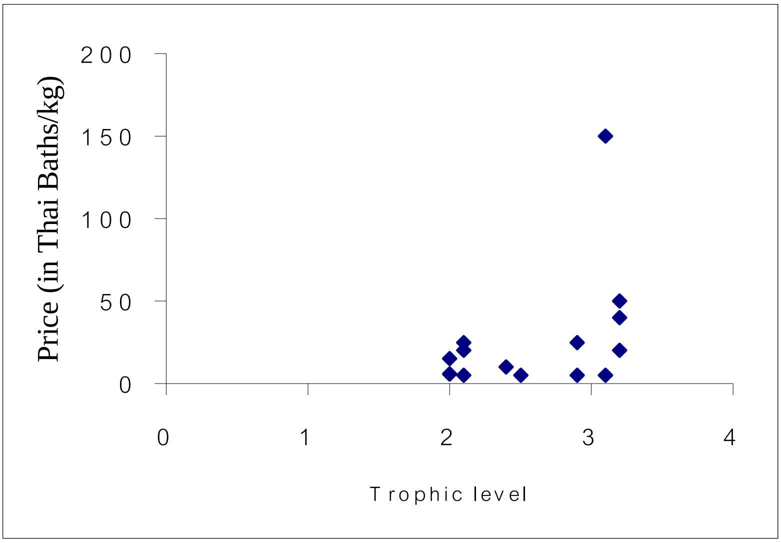

Fig 3. Relationship between the selling price and the trophic level of the fish groups

Discussion

In the present analysis Ecosim was used to investigate the trends in fishery due to variations in the fishing effort. However preliminary calibration of the various Ecosim parameters through time series data analyses was not possible in the present situation. It would have allowed the indirect evaluation of the relative importance of the bottom-up and top-down effects, a crucial point in the trophic networks analysis (Herendeen 2004).

The market prices of each species were assumed to be constant, or at least, not decreasing. Even with an increase in the catch of some economically important species, we did not expect prices to decrease due to the steadily increasing demand.

The costs of the fishing operations were admitted to be directly proportional to the fishing effort. This implies that there might be no mechanism to reduce these costs. In the case of fishing techniques, which permanently involved the fishermen (cast net), this would be appropriate; otherwise, this point would need a detailed examination. For instance, increasing fishing effort with gillnets, lines and traps is due to the fact that more fishermen are adopting these techniques and the implicit labor cost would grow accordingly.

The reduction in the total value of the fishery appears to be, at least partly, associated to the decrease of the trophic of the fishery as a whole and for each particular fishing technique.

The decrease in the trophic level of the total catch associated with apparent over fishing was documented in Ubolratana reservoir by Chookajorn et al. (1994). It is also a general concern of the world fisheries as demonstrated by Pauly et al. (1998).

Thapanand et al. (2007) investigated the optimization of fishing policy in order to elaborate a management strategy, which would contribute to an increase in the total value of the fishery and simultaneously preserve the social value in terms of employment opportunities, the ecological structure and the biodiversity of the ecosystem. It took into account the likely distribution of each particular fish groups and other organisms and assumed the fishing effort to be distributed accordingly in relation to the distribution of the key target species. This spatial approach indicated that the development of cast net fisheries would be compatible with the different values of the reservoir. Our results here confirm indirectly these observations as they show that this fishery would still have some benefits within the two scenarios considered here

In this contribution, we did not account for the transitional ecological phase during the early stages of post-impoundment when the fish communities were expected to exhibit adaptative mechanisms to changes from a riverine to a lacustrine environment. This was documented in several reservoirs, including the Ubolratana reservoir in Thailand (Pawapootanon 1986; Pholprasith and Sirimongkonthaworn 1999). The crucial role of this transitional ecological phase in the future evolution of the fish community of the reservoir might contribute to uncertainties when using Ecosim for long term predictive purposes. Therefore we limited our exercise to the next ten years.

The possible overfishing towards top predators of high trophic levels might reduce their inter and intra specific competition and could reduce their direct effects on their preys and alleviate their indirect effects on ecosystem processes (Lawton and Brown 1993; Loreau et al. 2001; Raffaelli et al. 2002; Stachowicz et al. 2002). It can also act as compensatory mechanisms in the face of an increasing fishing effort which is taken into consideration for Ecosim computations (Walters et al. 1997). From the financial point of view, the decreasing catch of top predators leads to an increase in the fishing pressure towards lower trophic levels which have initially a lower commercial value. However, in such circumstances, it happens that the price of these low trophic levels slightly increases, thus minimizing the financial loss usually noticed with the decrease in the trophic level of the whole catch

Conclusion

For this study, the Ecopath software was used mostly through its interface with social sciences and economy. From the ecological trophic model already existing, the authors could consider the possible financial implications of a fisheries management, which might occur in the near future. The ecological approach shows the possible reduction of the trophic level of the catch as documented in several other circumstances. The evolution of the fish populations and catch would contribute to a slight increase in the economic value of the ecosystem. However, without any mechanism for reducing the fishing operational costs, the financial situation of the fishermen would become, at least theoretically, critical. The present exercise has to be regarded as a possible simulation as it incorporates some of the possible limits of the use of Ecosim.

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