NAT. HIST. BULL. SIAM SOC. 51(1): 109–126, 2003

OPTIMIZED FISHING GEAR OPERATIONS IN SIRINTHORN RESERVOIR, THAILAND

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ABSTRACT

Fishery regulations, based on the selectivities and impacts of gear on the targeted species are proposed for Sirinthorn Reservoir. Simulations are focused on the four main fishing gear used: gillnets, hooks and long lines, combined traps, and lift nets. Data were compiled from the hydro-biological and fisheries surveys by the Management of Reservoir Fisheries Project, Mekong River Commission, from November 1998 to August 2000. The recommended size of gillnets is 40 mm. Meanwhile, current hook sizes are appropriate but there should be more concerned about the increasing fishing intensity. Traps should be totally banned during the closed season but the operation of lift nets during the closed season can be compromised.

Key words: fishing gear, fisheries management, Sirinthorn Reservoir

INTRODUCTION

One of the important questions in open access fishery is how a properly managed fishery should be operated. Many fishery regulations (e.g. closed season, closed area, size limitation, effort limitation and catch quota) have been applied globally. In the inland fisheries in Thailand, the closed season enforced by the Department of Fisheries (DOF), is the major measure. Its duration is from 16 May to 15 September, coinciding with the rainy season. In some areas, however, the closed season is varied according to the reproductive behavior of the indigenous fish species in those areas (for example: 13 April to 12 August in Nakorn Nayok Province and 1 October to 31 January in Pattalung Province). In the closed season, nevertheless, some fishing gears are allowed to operate *viz.*, hook (but not long line), scoop net (size not more than 2 x 2 m^2) and traps. Effectively closed areas, even though not declared, exist in temples and sacred areas, where people are prohibited to fish. Other regulations have not yet been established in Thai inland fisheries gazette except the banning of destructive and harmful gears and methods.

Following the initiation of the Management of Reservoir Fisheries Project (MRFP), Mekong River Commission (MRC), fishery co-management was introduced in 1998 for the reservoir fisheries in the lower Mekong Basin, which Sirinthorn Reservoir (Thailand) and Nam Ngum Reservoir (Lao PDR) were selected as study sites (NILSSON *ET AL.*, 2001). This has been a significant development, which may lead to more sustainable resource utilization than any other regulations enforced by the governments alone. The fisheries related issues, which have been raised and discussed by various stakeholders, were illegal fishing, fish

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Received 7 January 2003; accepted 20 June 2003.

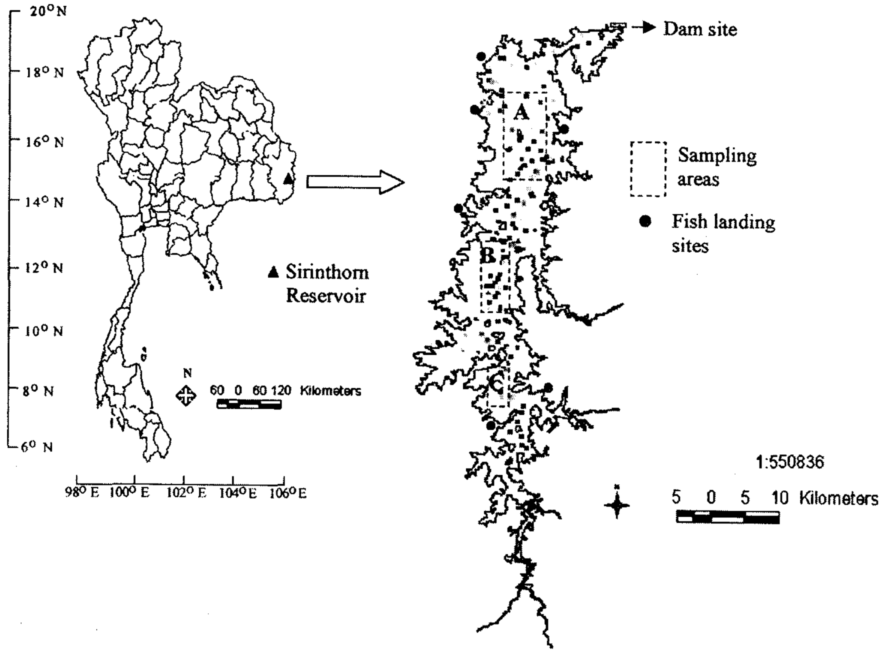

Figure 1. Location and map of Sirinthorn Reservoir

pricing, theft of fishing gears, and the intervention of fish conservation and patrol units (NILSSON *ET AL.*, 2001). In terms of fishery conservation, knowledge of the selectivity and impact of fishing gears on fishes is needed to implement an effective fishery regulation. This paper aims to present the efficiency and impacts of the main fishing gears used in Sirinthorn Reservoir, Thailand, and proposes an optimized fishing gear use in this lake.

STUDY AREA

Sirinthorn Reservoir (15°12'10"N and 105°25'56"E) is the fifth biggest reservoir in Thailand in terms of surface area (210 km^2) and was impounded in 1971 for hydroelectric purposes. Its storage area covers the districts of Phiboon Mungsaharn, Boontarik, and Sirinthorn of Ubon Ratchathani Province, Northeast Thailand. It was dammed across the Lam Dom Noi River, a tributary of the Mekong River (Fig. 1). A total of 49 fish species in 19 families have been recorded from this reservoir (BERNACSEK, 1997). A total number of 6,800 households are scattered around the lake, of which, over 700 families have fishing as their primary occupation, while some 3,700 have fishing as a part-time activity (MRFP, unpublished data). There are four main fishing gears in use, *viz.* gillnet, lift net, long line, and dtoom trap (Table 1). For gillnet and hook, there are many sizes of gear used (Tables 2 and 3). Other gears which are occasionally used include cast nets and spears.

The potential annual yield of Sirinthorn Reservoir is estimated to be about 1,277 tons per year (BERNACSEK, 1997). The dominant exploited fish species is the Thai river sprat *(Clupeichthys aesarnensis)*, which accounts for about 80% of total catch (CHOOKAJORN, 1992; BAMRUNGRAJHIRAN *ET AL.*, 1998). Other species include carps, barbs, gobies, mystus and tilapia (BERNACSEK, 1997).

METHODS

Selectivity data were obtained from the MRFP in the Mekong Basin's hydro-biological survey from November 1998 to October 1999. Data were collected by 12 fishers, selected from 8 out of 50 villages. A total of 5 gillnet fishers, 4 long line fishers and 3 dtoom trap fishers took part in the data collection by using logbooks. Species identification also formed part of the training. In addition, 15 lift net fishers around the lake were selected to collect lift net fishery data from September 1999 to August 2000. The fishers were free to decide when and where to use the gear, with the only obligation to record the length of each fish caught, by gear size, place and date (BAMRUNRAJHIRAN *ET AL.*, 1999). Once recorded the catch, sold or disposed of. The data were stored in PASGEAR, a customized DOS-based freeware database package for experimental and artisanal fishery data from mainly passive gear (KOLDING, 1997). The composition of the catches in each gear is presented in terms of an index of relative importance (IRI) (KOLDING, 1997):

$$IRI = [(W_i+N_i)\ F_i] / [\sum_{i=1}^{n} (W_j+N_j)F_j]*100 \qquad (1)$$

Table 1. General descriptions of the main fishing gears used in Sirinthorn Reservoir

Fishing gear	Description	Operation period
Gillnet	Mesh size range 20–140 mm; operated both night and day; during the daytime a beating technique is sometimes used.	September to May
Long line	Hooks range from No. 4–21 but most commonly used is No. 19. About 40 hooks per line; operated both day and night about 2–3 lines per fisher.	September to May (but single hook and pole can operate all year round)
Trap	Mostly made from bamboo; rice bran or steamed rice are used as bait; length from 30 cm to 7 m; operated in the early morning after leaving the trap in the fishing ground the over night.	All year round
Lift net	A net 5x5 m, 25-mesh 6.25 cm^2, is set beside the bamboo raft; luring light technique is used; operated during the new moon period.	September to May

Table 2. Dimension of the gillnets issued to fishers at Sirinthorn Reservoir

Mesh size (stretch; mm)	Mesh depth (meshes)	Net length (meshes)	Twine diameter (mm)
20	25	180	0.12
25	30	180	0.12
40	30	180	0.12
50	25	180	0.12
70	30	180	0.15
80	30	180	0.15
100	25	180	0.20
120	20	180	0.20
140	20	180	0.25

Table 3. Average hook width used in Sirinthorn Lake

Hook number	Average width (mm)
4	22.7
5	20.0
6	18.3
9	15.4
10	12.7
14	8.2
15	7.8
16	7.3
17	6.7
18	5.8
19	5.6
20	5.4
21	4.6
23	2.7

Table 4. The contribution to landings ($t{\cdot}km^{-2}{\cdot}yr^{-1}$) from each type of gear used

Group	Gillnets	Hooks	Long line	Traps	Lift net
Littoral predators	0.35	0.35			
Channa spp.		0.40		0.34	
Oxyeleotris spp.	0.50				
Mystus nemurus			1.00	0.40	
Notopterus notopterus	0.30			0.50	
Hampala spp.	1.48				
Morulius sp.	0.25			0.07	
Discherodontus sp.	1.00				
Barbodes gonionotus	4.20				
Pristolepis fasciatus	0.80			0.10	
Small cyprinids	1.40				
Oreochromis niloticus	1.40			1.30	
Clupeichthys aesarnensis					4.10
Total	11.68	0.75	1.00	2.17	4.10

where W_i and N_i are the percentage weight and number of each species i in the total catch, F_i is the percentage of occurrence of each species in the total number of settings (samples), and the sum in the denominator is the total number of species j.

Impacts of each gear on fish species were simulated by using the ECOSIM routine in the ECOPATH model (PAULY *ET AL.*, 1999). This routine allows simulation of the evolution of the ecosystem and expression of the biomass fluxes of fish-groups under various fishing management strategies (WALTER *ET AL.*, 1997), such as changes in fishing pressure of any gears used in this study.

The ECOPATH model is a software based on the fate of ecological production of the members at the ecosystem. The ecosystem is modeled using a set of simultaneous linear equations (one for each group i in the system), i.e.:

Production by (i) – all predation on (i) – non-predation loss of (i) – export of (i) = 0, for all (i) (2)

Equation (2) can be re-expressed as

$$B_i\,(P/B)_i\,EE_i - Y_i - \Sigma\,[B_j\,(Q/B)_j\,(DC)_{ji}] = 0 \qquad (3)$$

where B_i is the biomass of group i, $(P/B)_i$ is production per biomass ratio, EE_i is the ecotrophic efficiency, Y_i is the yield (equal to fisheries catch), B_j is the biomass of predator j, $(Q/B)_j$ is the food consumption per unit biomass of j and $(DC)_{ji}$ is the fraction of i in the diet of j.

Entry data for the ECPATH program were obtained from the MRFP's survey from May 1999 to May 2000. In this survey, catches from many kind of traps are combined and used as entry data instead of dtoom traps alone. The survey obtained data on the species caught

Table 5. Proportions of various food groups in the diets of consumers

Food group	Predator or consumer type[2]																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Littoral predators	0.01	0.01															
2. *Channa* spp.	0.02	0.01															
3. *Oxyeleotris* spp.	0.01	0.01	0.02														
4. *M. nemurus*		0.01	0.01	0.02													
5. *N. notopters*	0.01	0.01	0.01		0.01												
6. *Hampala* spp.	0.05	0.05	0.03	0.01	0.01	0.02											
7. *Morulius* sp.	0.01	0.01	0.02	0.05	0.01	0.01											
8. *Discherodontus* sp.	0.05	0.05	0.05	0.20	0.05	0.05											
9. *Barbodes gonionotus*	0.35	0.35	0.30	0.05	0.10	0.05											
10. *P. fasciatus*	0.05	0.05	0.05	0.05	0.02	0.01											
11. Small cyprinids	0.10	0.10	0.10	0.05	0.05	0.05				0.05							
12. Tilapiine fish	0.10	0.10	0.05	0.05	0.05	0.05											
13. Clupeids	0.05	0.05	0.01			0.55							0.01				
14. Open water ZP[1]				0.05		0.01							0.45	0.02			
15. Littoral ZP	0.02	0.20	0.05	0.30	0.05	0.03	0.05	0.05	0.05	0.05	0.02	0.03	0.20		0.03	0.05	0.05
16. Aquatic insects	0.05	0.05	0.10	0.15	0.40	0.10		0.30	0.15	0.40	0.05	0.05	0.25			0.03	
17. Crustaceans	0.10	0.10	0.15		0.15	0.05		0.35	0.20	0.15	0.30						0.02
18. Open water PP[1]											0.05	0.50	0.04	0.90			
19. Littoral PP							0.05		0.15	0.05	0.30	0.20	0.03		0.90	0.02	0.03
20. Macrophytes							0.25		0.25	0.20	0.15	0.02					
21. Benthic algae			0.02		0.05	0.02	0.05	0.15	0.10	0.05	0.20	0.10				0.50	0.50
22. Detritus	0.02	0.02	0.03	0.02	0.05		0.60	0.15	0.10	0.05	0.20	0.10	0.01	0.08	0.07	0.40	0.40
23. Import													0.01				
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: 1. ZP and PP refer to zooplankton and phytoplankton, respectively.
2. 1–17 in the first row refers to littoral predators to crustaceans in the first column.

Table 6. Input data for the ECOSIM simulation in the ECOPATH model

Group name	Catch ($t \cdot km^{-2} \cdot yr^{-1}$)	Biomass ($t \cdot km^{-2} \cdot yr^{-1}$)	P/B (yr^{-1})	Q/B (yr^{-1})	EE
Littoral predators	0.70	0.617	1.5	7.5	0.95
Channa spp.	1.14	1.332	1.1	6.5	0.95
Oxyeleotris spp.	0.73	0.693	1.5	9.0	0.95
Mystus nemerus	1.40	1.102	1.7	10.5	0.95
N. notopterus	0.80	0.870	1.3	9.1	0.95
Hampala spp.	1.48	1.685	1.7	9.2	0.95
Morulius spp.	0.32	0.976	1.0	30.0	0.95
Discherodontus spp.	1.00	1.307	3.0	22.0	0.95
Barbodes gonionotus	4.20	9.043	1.7	37.0	0.95
P. fasciatus	0.90	1.943	1.5	43.0	0.95
Small cyprinids	1.40	3.256	3.0	50.0	0.95
O. niloticus	4.00	4.322	1.8	32.0	0.95
C. aesarnensis	4.10	2.875	5.5	38.0	0.95
Aquatic insects	-	2.013	7.0	50.0	0.95
Crustaceans	-	7.815	5.0	40.0	0.95
Open water ZP[1]	-	27.976	30.0	200.0	0.95
Littoral ZP	-	25.408	30.0	200.0	0.95
Open water PP[1]	-	1.280	365.0	-	0.95
Littoral PP	-	4.616	365.0	-	0.95
Macrophtytes	-	20.280	7.0	-	0.95
Benthic algae	-	91.101	15.0	-	0.95
Detritus	-	1.000	-	-	0.95

[1]ZP = zooplankton, PP = phytoplankton

in each gear type used in Sirinthorn Reservoir (Table 4) and representative samples of the gut contents of each species were analyzed for their food by means of percentage of occurrence (Table 5).

Other entry data are shown in Table 6, which are explained as follows:

1) EE-value is the fraction of the total production of a group *i* which is consumed by all the predators within the ecosystem or exported through fisheries or emigration, were set at 0.95 for all fish groups because of the heavy exploitation of all groups in the lake.

2) P/B for each fish group in this study was computed using the ELEFAN/F_iSAT software program (GAYANILO *ET AL.*, 1994) from length-frequency data provided by MRF (MRF, unpublished data); additional values were obtained from CHOOKAJORN *ET AL.* (1994) and MOREAU & SRICHAROENDHAM (1999).

3) Q/B was computed following the PALOMARES & PAULY (1998) procedure using the formula:

$$\log Q/B = 5.847 - 0.52 \log (W_\infty) + 0.28 \log (P/B) - 1.36\ T\ ^\circ C + 0.062A + 0.51H + 0.39D \quad (4)$$

where W_∞ is the asymptotic weight of fish (wet weight in grams), T °C is the mean habitat temperature (28.5 °C), and A is an index of activity of the fish, the aspect ratio of the caudal fin, expressed as:

$$A = h^2/S \quad (5)$$

where h and S are height and surface area of the caudal fin. The parameters H and D (not their log) expressed the diet: H = 1 for a phytophagous species (D = 0) and D =1 for a detritivorous species (H = 0).

RESULTS

Catch Composition

The total species caught in gillnets, long lines, dtoom traps and lift nets were 24, 8, 3 and 17, respectively; the dominant species caught by each gear are presented in Figure 2A–2D. The contribution in major landings (by weight) varied according to gear (Table 4) and depended on the main target species caught. Gill nets are a versatile type of gear, which can exploit large numbers of species of various sizes. Although 17 species were caught, the lift net is a specific gear for exploiting Thai river sprat, which accounted for more than 90% of the lift net catch with the other lift net catches being minimal in both numbers and weight. The main species caught using long lines and combined traps were *Mystus nemurus* and *Oreochromis niloticus*, respectively.

Gear Selectivity

The selectivity of species caught using gillnets and lift nets has been studied by JUTAGETE *ET AL.* (2001b) and JUTAGATE (2002), respectively. The selectivity of gill nets conforms to a bell shape (HAMLEY, 1975), in which the size of caught fishes corresponds to the mesh size used (Fig. 3). For the lift net, the gear efficiency depended on the weather, since strong winds and turbulent water surfaces during the northeast monsoon season can obstruct lift net operation. The range *C. aesarnensis* biomass around a lift net was 4.5 to 9.5 kg (Fig. 4) and the average size of *C. aesarnensis* caught varied from 2 to 7 cm, and other fish caught were minimal. No fish larvae were caught during the study period.

In this study, there was no attempt to standardize the size of the fishes caught by hook size and traps, since there are no simple models to describe well the selectivity of these gears (RALSTON, 1990; MILLAR & FRYER, 1999). Therefore, the sizes of fishes presented are in the average size range with their standard deviation. The average catch size at each hook size was found to fluctuate (Fig. 5). However, the average size (±sd) of *M. nemurus* and *Oxyeleotris marmorata* caught in dtoom traps were 22.10 ± 5.45 and 24.8 ± 2.56 cm, receptively. The range of catches was 10 to 46 cm for *M. nemurus* (N = 7,521) and 21 to 28 cm for *O. marmorata* (N = 6). Only one individual *Morulius chrysophekadion* (38.2 cm) was caught by dtoom trap during the sampling period.

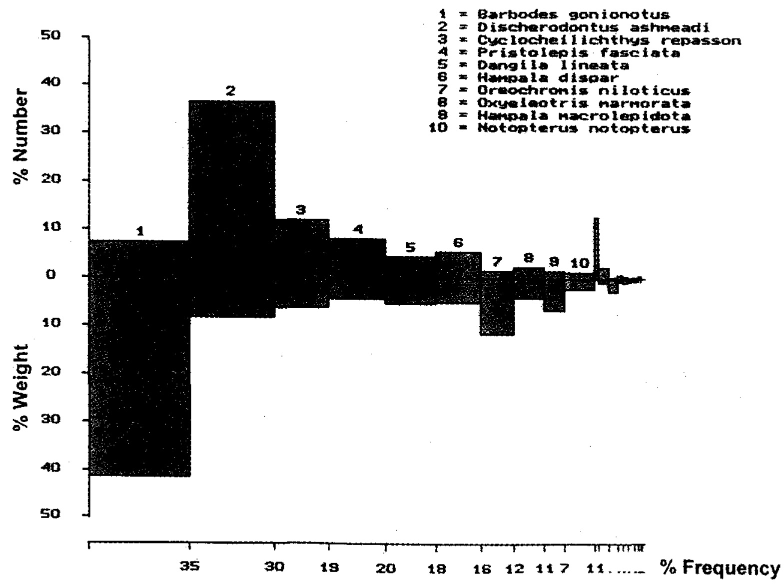

Figure 2A. IRI of gill net fishery, showing the % Weight, % Number and % Frequency of the ten main catches.

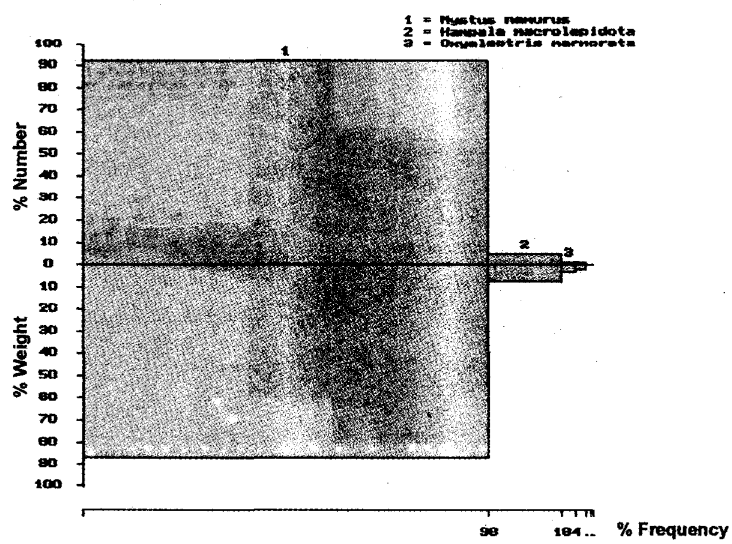

Figure 2B. IRI of long line fishery, showing the % Weight, % Number and % Frequency of the three main catches.

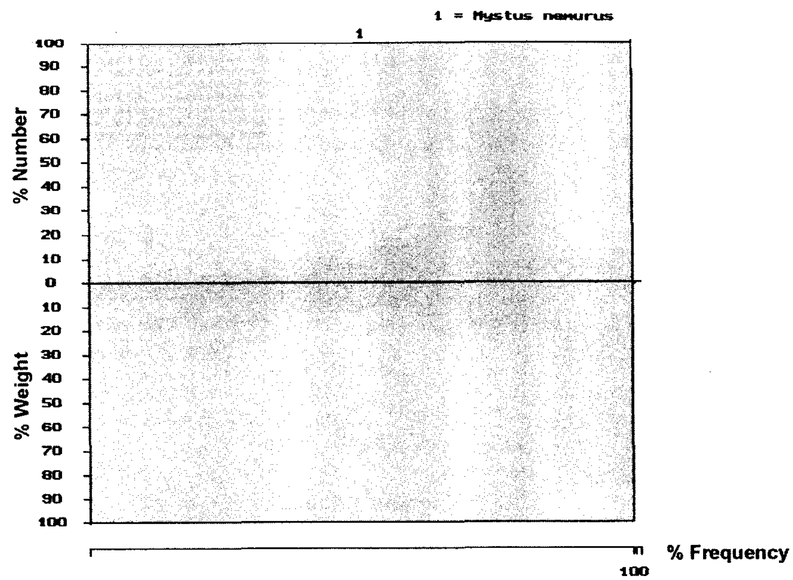

Figure 2C. IRI of dtoom trap fishery, showing the % Weight, % Number and % Frequency of the main catch.

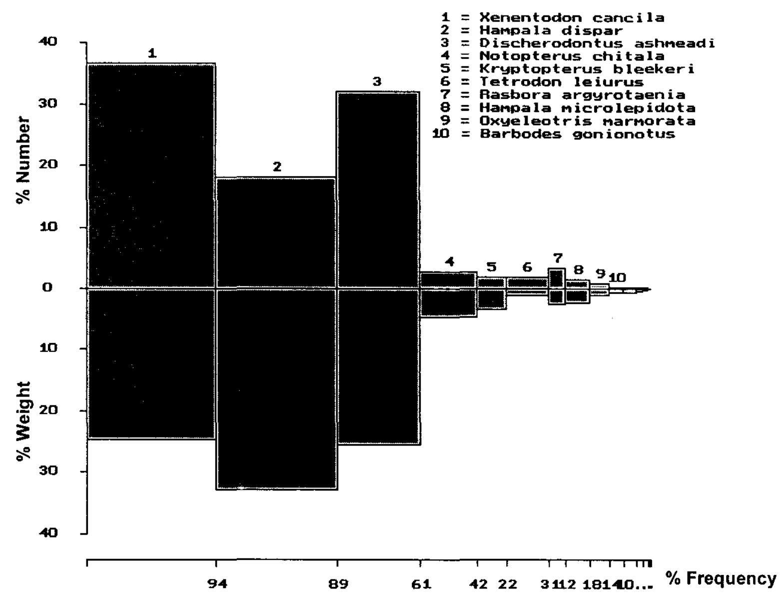

Figure 2D. IRI of lift net fishery, showing the % Weight, % Number and % Frequency of the ten main by-catches but *Pseudambassis notatus* are excluded.

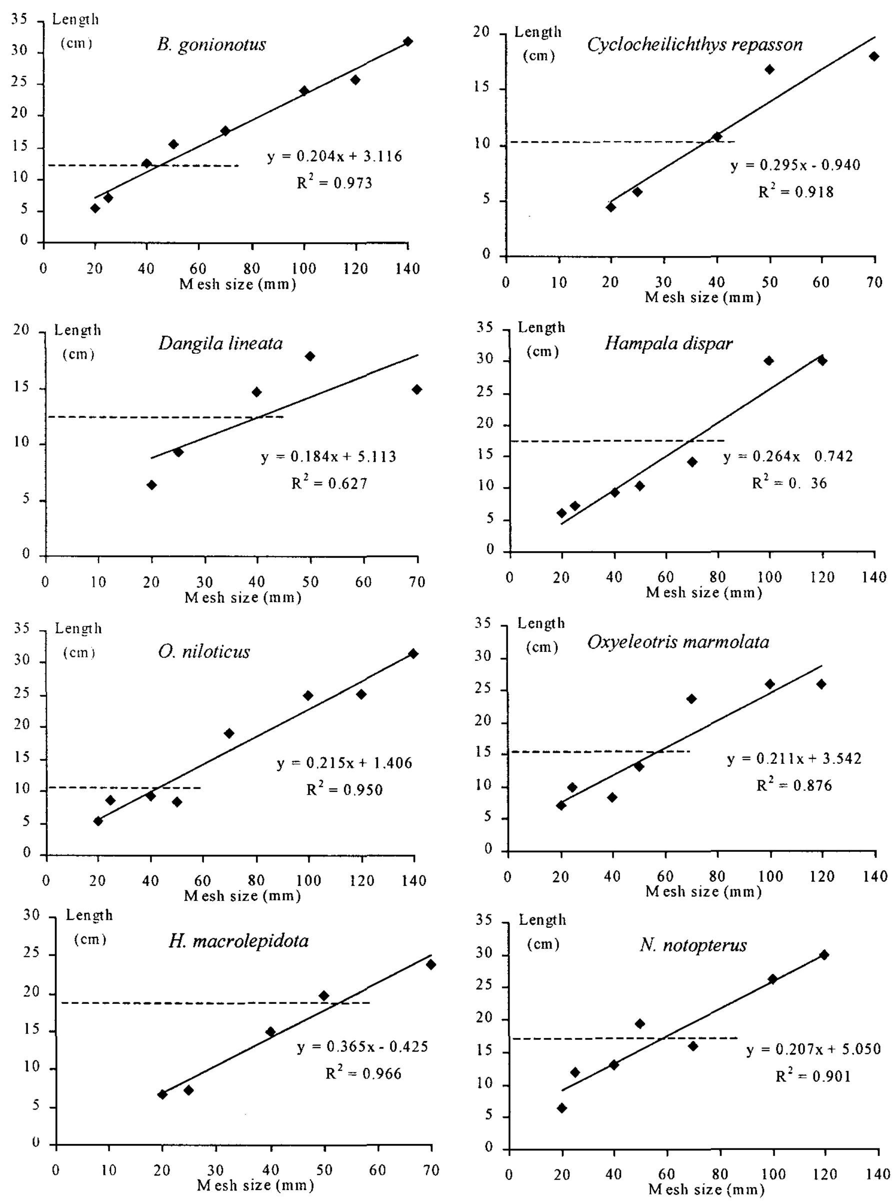

Figure 3. Gillnet selectivity on each main species in Sirinthorn Reservoir.
Dot (♦) shows the mean length of fish for each mesh size. Dashed line indicates the length at first maturity (L_m)

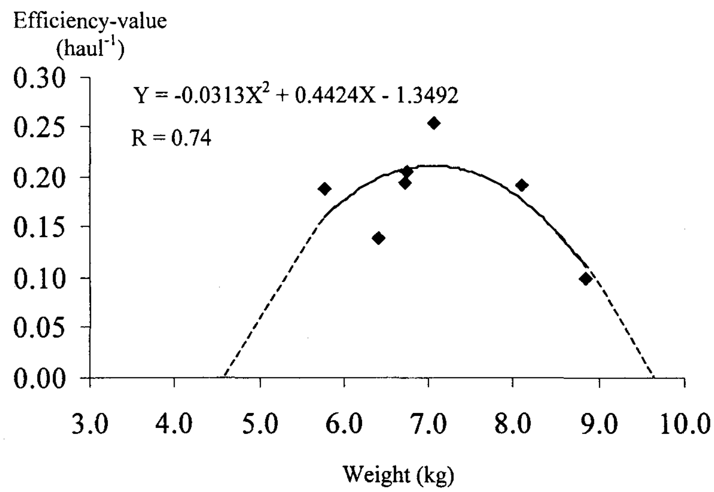

Figure 4. Plot of lift net efficiency against the biomass of *C. aesarnensis* aggregates around a lift net in Sirinthorn Reservoir

Impact of Fishing Gears on Fish Species

From the ECOSIM routine in the ECOPATH program, trends of changes in the biomass of aquatic species or groups in the Sirinthorn Lake and the catch of specific target species from each gear, were simulated. ECOSIM was run on the main catches, which were *Barbodes gonionotus, M. nemurus, O. niloticus* and *C. aesarnensis* for gillnets, long lines, combined traps, and lift nets, respectively. For each gear, the catch (the red line) increased as the fishing effort increased until it reached a peak and then the catch gradually decreased. In the current fishing situation (fishing effort = 1), catches of *M. nemurus* using long lines (Fig. 6B) were beyond the optimum level since the peak of the curve is reached before 1. Meanwhile, the other three gears still can be used to increase fishing effort.

The impacts of increasing fishing effort toward caught fish species in each fishing gear, in terms of biomass/original biomass, are also presented (Fig. 6A–6D). A pattern of decline in the biomass of main catches in each gear is seen. Meanwhile, the other fish species, which are only caught in small numbers but compete for the same food resources as the catches in that gear, seemed to increase and not make any harm to other organisms which occupy other niches.

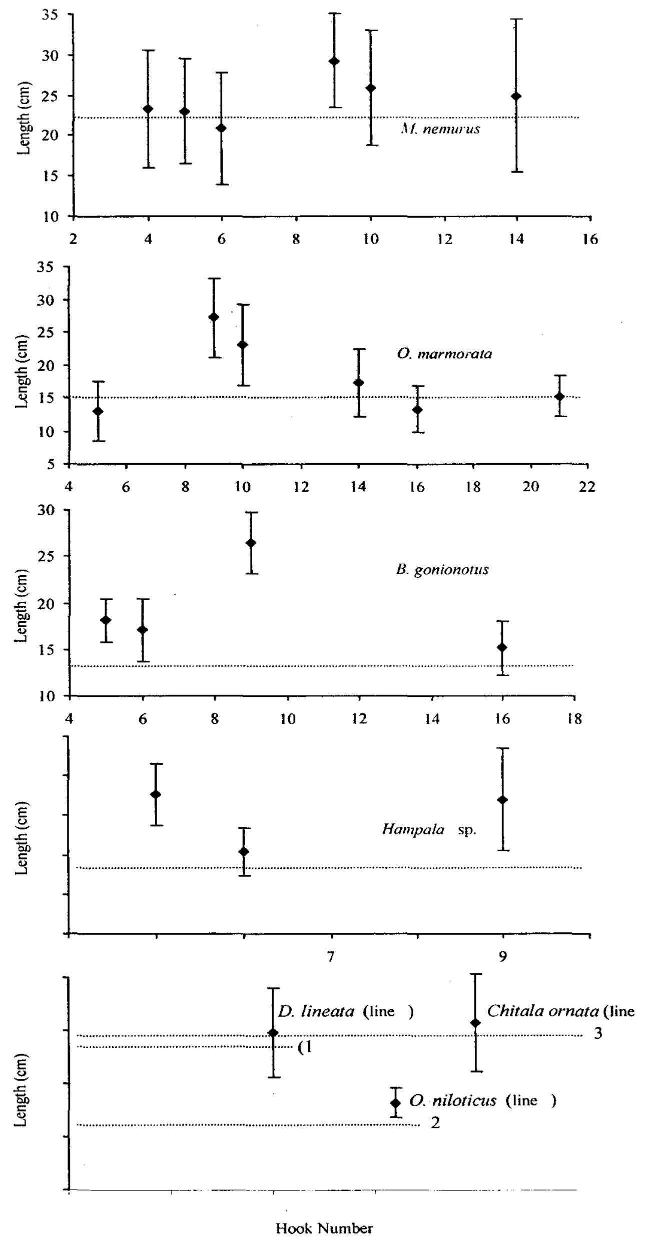

Figure 5. Hook selectivity on each main species in Sirinthorn Reservoir.
Dot (♦) shows the mean length of fish for each hook number. Dashed line indicates the length at first maturity (L_m)

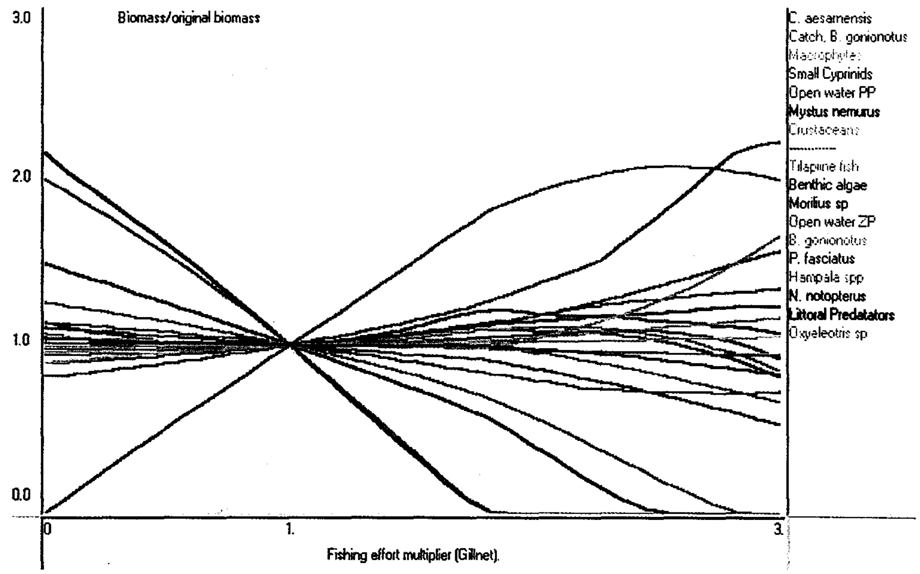

Figure 6A. Relationship between biomass/origin biomass of impacted groups and fishing effort (gill net)

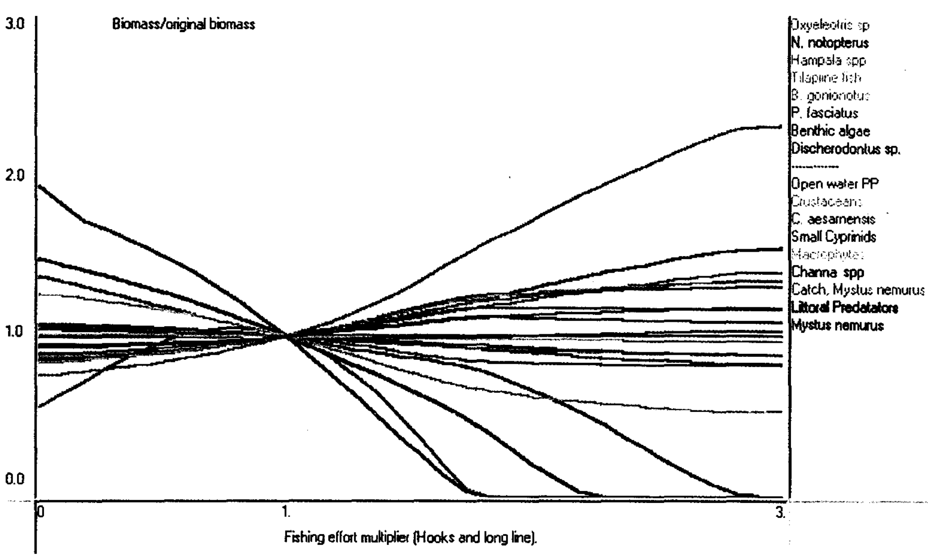

Figure 6B. Relationship between biomass/origin biomass of impacted groups and fishing effort (long line)

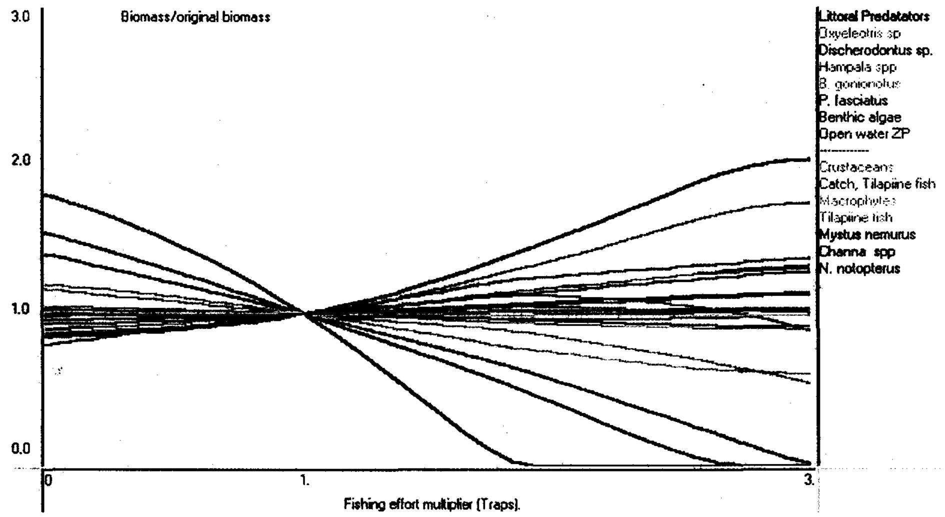

Figure 6C. Relationship between biomass/origin biomass of impacted groups and fishing effort (traps)

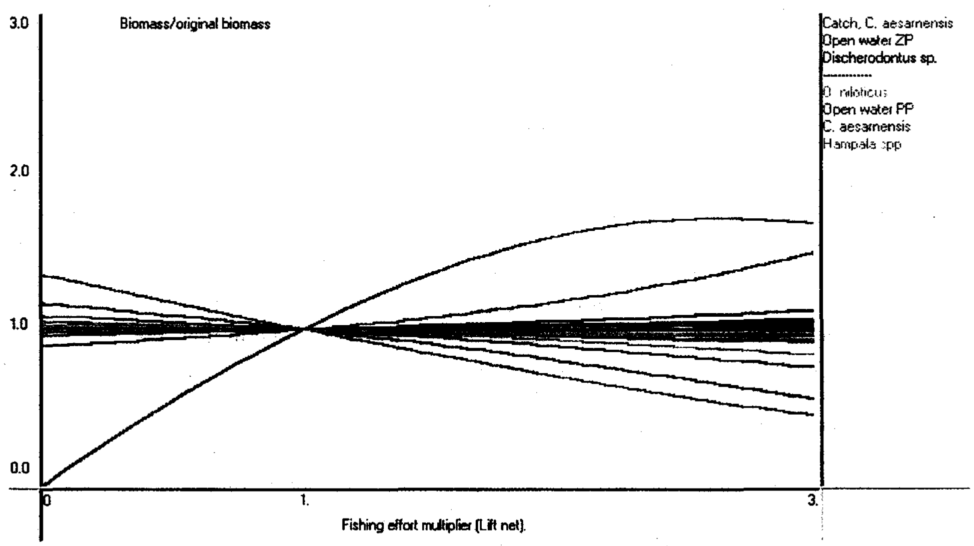

Figure 6D. Relationship between biomass/origin biomass of impacted groups and fishing effort (lift net)

DISCUSSION

Fishing Intensity

In the current fisheries situation, only the use of long line fishery shows that the target fish stock is at risk. The bell shape (Fig. 6B) in the catch of the main target fish, *M. nemurus*, indicates a strong sensitivity to fishing effort, in particular to the predator species (MOREAU, 1995; MOREAU *ET AL.*, 2001). A wide range of fishing mortality produces the flat-topped curve of *C. aesarnensis* catch in the lift net fishery (Fig. 6D), a pattern always seen in short-lived species (MOREAU *ET AL.*, 2001). This result elucidates the rapid replacement rate and is independent of fishing effort, which are characteristic of the small-sized clupeid stocks (MURPHY, 1977; COULTER, 1988).

In terms of the predator-prey changes, interestingly, instead of the expectation of increasing *C. aesarnensis* biomass in the long line fisheries (since it is the main prey of *M. nemurus* in this lake system) a reduction in *C. aesarnensis* was observed (Fig. 6B). This situation can be explained by the increases in other fishes predatory on *C. aesarnensis* such as *Oxyeleotris* spp. and *Hampala* spp., which are not target catches of the long line fishery. On the other hand, the biomass of *C. aesarnensis* increased when gillnet effort increased (Fig. 6A), because of the depletion of the most predatory species which feed on *C. aesarnensis*.

JUTAGATE *ET AL.* (2002) mentioned that the impact of the fisheries in Sirinthorn Lake consists mainly of harvesting the zoophagous species. This finding is obviously seen in the gillnet fishery simulation (Fig. 6A). Therefore, the increase in fishing intensity using gillnets is of concern. In the combined-trap fisheries, decline in the biomass of *Notopterus notopterus*, *Channa* spp. and *M. nemurus* were greater than that of the main catch, *O. niloticus*, when the fishing effort increased (Fig. 6C). This may have been due to the annual stocking program of tilapia (Head of Sirinthorn conservation unit, pers. comm.) and its high reproductive potential (FERNANDO, 1980).

Management Strategies

Before being exploited, fish should be allowed to reach at least the length at first maturity (L_m). A mesh or hook should be used that is large enough to allow species to approach this optimum size. However, fish size limitation works fairly well in trawl and gillnet fisheries. In hook and long line fisheries, however, the size of fish caught can be influenced by the size of the hook, but the relationship is poor (ANDERSON, 1997). From this point of view, the minimum mesh and hook size to operate in this lake should be 40 mm and number 6, respectively. The advantage of the size-selectivity is that the juveniles and pre-recruits are protected from harvest (GULLAND, 1983; WILEMAN *ET AL.*, 1996), and unaccounted fishing mortality is avoided (CHOPIN & ARIMOTO, 1995).

ANDERSON (1997) suggested that when a beach and/or purse seine is used, it is almost impossible to regulate the fish size at capture. This condition is similar to the trap, which is designed to prohibit (as much as possible) the escape of fish of all sizes (MILLAR & FRYER, 1999). The appropriate way to regulate exploitation by traps is to totally ban this gear during the closed season, particularly in the upstream area where most fishes in this lake have to migrate to spawn (DUMRONGTRIPOB *ET AL.*, 1997). So far, the Thai fisheries gazette compromisingly permits fishers to operate any kind of traps during the closed season but not more than three per fisher.

The need for management proposal on the lift-net fishery in this lake is well documented (JUTAGATE *ET AL.*, 2001a; JUTAGATE, 2002). The number of nets should be limited to 6 per fisher (based on the year 2000 data, in which there were 122 lift-net fishers in Sirinthorn Lake) and set at least 5 m from the shore. The closed season for this fishery can be ignored because of the year-round recruitment of the main target, *C. aesarnensis*, and the by-catches are minimal. The alternative closed season for lift net fishery is during the northeast monsoon season (November to January) because of the low catches in this period.

ACKNOWLEDGMENTS

This research was conducted under the Project for Management of Reservoir Fisheries in the lower Mekong Basin, Mekong River Commission, in cooperation with the National Inland Fisheries Institute, Royal Thai Department of Fisheries. For the lift net fishery study, a grant was provided by Deakin University, Australia. We thank Prof. Jacques Moreau, INP, Toulouse, France, for the ECOPATH knowledge. We are grateful to the anonymous referees and the editor for their useful criticisms and comments.

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