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Broodstock Assessment and the Analysis of the Relationship between Length and Fishing Mortality Coefficient of Giant Tiger Prawn (*Penaeus monodon* Fabricius) in Trang Province, Thailand by Sommani's Method

Thanitha Thapanand

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Ecosystems in Sirinthorn and Nam Ngum Reservoirs; A comparison

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ABSTRACT

Trophic models were constructed for Sirinthorn Reservoir (Thailand) and Nam Ngum Reservoir (Lao PDR), using ECOPATH software to understand their ecosystems. The models reveal that the trophic structure of the reservoirs is similar. Results show that the ecosystems in both lakes are sustained and considered as productive reservoirs. The transfer efficiency is between 10 and 15 % at all levels, indicating an intact food web. In both reservoirs, total fish productions can support fishing activities. There are also presented the (1) energy flow in each trophic level, (2) mixed trophic impact, in term of predator-prey relationship and fishery and (3) calculate the net biomass and production of the groups of organisms. The fishery operates at a trophic level around three, meaning that mainly zoophagous fishes are targeted.

Key words: Sirinthorn Reservoir, Nam Ngum Reservoir, ecosystem, ECOPATH software

INTRODUCTION

Reservoirs in Asia are very rarely, if ever, built for fishery purposes. However, the utilization of impounded waters for fisheries development has assumed urgency in the light of the need to meet the increasing demand for fish (De Silva, 2000). Despite the huge benefit in fisheries from reservoir damming, there is little knowledge on the trophic structure and their capacity, which is crucial, to sustain both fisheries and aquaculture in the reservoir (Moreau, 2000). The ECOPATH model (Christensen and Pauly, 1992a; Christensen, 1998; Pauly et al., 1999) was used to achieve understanding on the above need. It is the programme developed for understanding functions and interrelationships of various components in aquatic ecosystem and the possible impacts of different ecological changes on the system as a whole (Chookajorn et al., 1994). ECOPATH partitions the ecosystem into boxes comprising species having a common physical habitat, similar diet and life history characteristics (Polovina 1984; Christensen and Pauly, 1992b). It assumes that the ecosystem is at equilibrium, which means that input to a group equals output from it for the period considered (Chookajorn et al., 1994). The aim of this study is to come up with a model, which explain the relationships in the ecosystem and impact of fisheries to the fish resources in both man-made lakes.

MATERIALS AND METHODS

The Sirinthorn (Thailand) and Nam Ngum (Lao PDR) Reservoirs were the selected studied sites by Mekong River Commission (MRC) Fisheries Component: Management of Reservoir Fisheries (MRF) in the Mekong Basin. The location of both lakes are at 15° 12' 10'' N; 105° 25' 56'' E for Sirinthorn and 18° 32' N; 102° 33' E for Nam Ngum. The surface area and average depth are 288 km^2 and 5 m in Sirinthorn and 475 km^2 and 20 m in Nam Ngum, respectively (Bernacsek, 1997). The first three major catches are *Barbodes gonoinotus*, *Clupeichthys aesarnensis*, and *Oreochromis niloticus* in Sinthorn and *Clupeichthys aesarnensis*, *Hampala* spp. and *Puntioplites* spp. in Nam Ngum. Major fishing gears used in both areas are gill net, longline, trap, clupeid lift net and cast net.

Fisheries and related data on Sirinthorn and Nam Ngum Reservoirs were collected and trophic models were studied using the ECOPATH III program (Pauly et al., 1999). Catches from the main fishing gears (Table 1) were carried out under the MRF project in associated with the hydrobiological surveys throughout 1999 and was used as input data for ECOPATH. Some fishes were grouped according to their feeding habits for the proper explains in the mixed trophic impact *viz*

(A) For Sirinthorn Lake: (a) littoral predators include *Anabas testudineus*, *Clarias bratachus* and *Ompok* spp., (b) small zoophagus include *Discherodontus* spp. and *Macrognathus* spp. and (c) small cyprinids include *Dangila lineata*, *Cyclocheilichthys repasson*, *Probarbus julieni* and *Rasbora* spp.

(B) For Nam Ngum Lake: (a) large predators are mostly *Channa* spp. and other littoral predators of marginal importance and (b) small cyprinids are *C. repasson*, *D. lineata* and *Barbodes* spp.

The average surface of the lake for the considered period is 210 km^2 in Sirinthorn and 450 km^2 in Nam Ngum.The entered data, except catches, were derived from:

Table 1 Catches (t km^{-2} yr^{-1}) from various fishing gears as inputs in ECOPATH

(A) Sirinthorn

Group	Gillnet	Hooks	Spear	Traps	Long line	Lift net	Total catch
Littoral predator	0.35	0.35					0.70
Channa spp.	0.40	0.40	0.34			1.14	
Oxyeleotris sp.	0.50		0.23				0.73
Mystus nemerus				0.40	1.00		1.40
Notopterus notopterus	0.30			0.50			0.80
Hampala spp.	1.48						1.48
Morulius sp.0.25			0.07			0.32	
Small zoophagus	1.00						1.00
Barbodes gonionotus	4.20						4.20
Pristolepis fasciatus	0.80			0.10			0.90
Small Cyprinids	1.40						1.40
Tilapiine fish	1.40		1.30	1.30			4.00
Clupeids					4.10	4.10	
Total catch11.68	**0.75**	**1.93**	**2.71**	**1.00**	**4.10**	**22.17**	

(B) Nam Ngum

Group	Gillnets	Clupeid	Traps	Long	Spear	Cast net	Total catch
		fishery		Line	guns		catch
Large predators	0.02			0.08			0.10
Notopterus notopterus	0.42			0.20			0.62
Mystus nemerus	0.12		0.86	0.40			1.38
Hampala spp.	1.58			1.80			3.38
Morulius sp.0.24						0.24	
Osteocheilus spp.	0.21						0.21
Puntioplites sp.	2.56						2.56
Pristolepis sp.	0.14						0.14
Amblyrhynchichthys	0.43						0.43
truncatus							
Cirrhinus molitorella	0.40				0.11		0.51
Small Cyprinids	0.60					0.26	0.86
Oreochromis niloticus	0.10				0.11		0.21
Clupeids	4.30					4.30	
Total catch6.82	**4.30**	**0.86**	**2.48**	**0.22**	**0.26**	**14.94**	

(a) The production/biomass ratio, P/B;

P/Bs for fish groups in this study were computed using the ELEFAN/FISAT software (Gayanilo et al., 1995) on the length-frequency distributions available from the Mekong Secretariat (1984) and from the 1999 survey by the

MRF for Sirinthorn and Nam Ngum, respectively (MRF, unpublished data). Additional values are from Chookajorn et al. (1994) and Moreau and Sricharoendham (1999).

(b) The relative food consumption, Q/B;

Q/Bs were computed according to Palomares and Pauly (1998) using the formula:

$$\log Q/B = 5.847 - 0.52 \log W_{\infty} + 0.28 \log(P/B) - 1.36\,T + 0.062A + 0.51H + 0.39D \quad ....(1)$$

where

Q/B is the annual food consumption/biomass ratio

W_{∞} is the asymptotic weight of fish (wet weight in gram)

T is the mean habitat temperature (°C) for the same fish

A is an index of activity of the fish; the aspect ratio of the caudal fin, which express as:

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

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

(c) The ecotrophic efficiency, EE;

EE is the fraction of total production of a group *i* which is consumed by all the predators within the system or exported, through fisheries or emigrations (Moreau, 1997). It usually ranges beteen 0.6 (low value for apex predators) and 0.95 (Ricker, 1969). In this study, the two reservoirs appear to be heavily exploited and EE values have been set to 0.95 for all groups.

(c) The diet composition

In Sirinthorn Reservoir, diet composition data were made available through the hydrobiological survey carried out with the MRF project (MRF, unpublished data). For the Nam Ngum Reservoir, the diet composition of most the main groups (*Channa* spp., *Hampala* spp., *Mystus nemerus*, *Notopterus notopterus*, *Pristolepis fasciatus*, *Puntioplites* spp. and *Osteochilus* spp.) were from the Mekong Secretariat (1984) whereas other groups were documented in Uboratana Reservoir, Thailand (Wongtirawatana, 1981), which is also the reservoir in the Lower Mekong Basin (Table 2)

Table 2 Diet composition of various groups

(A) Sirinthorn

Prey/Predator	**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. Small zoophagus	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				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											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. Detritus0.02	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: ZP and PP refer to zooplankton and phytoplankton, respectively

(B) Nam Ngum

Prey/Predator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1. Large predators	0.01															
2. *Notopters* spp.	0.05															
3. *M. nemurus*	0.01	0.01	0.01													
4. *Hampala* spp.	0.10	0.01	0.03	0.02												
5. *Morulius* sp.	0.02	0.02	0.02	0.02												
6. *Osteocheilus* spp.	0.02	0.02	0.05	0.02												
7. *Puntioplites* sp.	0.25	0.05	0.15	0.05												
8. *Pristolepis* sp.	0.02	0.02	0.02													
9. *A. truncatus*	0.05	0.03	0.05													
10. *C. molitorella*	0.05	0.05	0.05													
11. Small cyprinids	0.10	0.05	0.10	0.05				0.05								
12. *O. niloticus*	0.01															
13. Clupeids	0.08		0.05	0.60					0.01							
14. Zooplankton	0.02		0.05	0.02	0.05	0.05	0.05	0.05	0.05	0.02	0.03	0.02	0.65	0.03	0.05	0.05
15. Aquatic insects	0.05	0.50	0.25	0.10			0.35	0.40	0.05	0.03	0.05	0.05	0.30		0.03	
16. Crustaceans	0.15	0.15	0.15	0.05		0.05	0.25	0.20			0.02					0.20
17. Phytoplankton				0.05	0.25	0.10		0.50	0.05	0.35	0.65	0.03	0.92		0.03	
18. Benthic algae				0.05	0.20	0.10	0.05	0.10	0.10	0.20	0.20			0.40	0.40	
19. Aquatic weeds	0.05		0.05	0.25	0.20	0.10	0.20	0.20	0.25	0.15				0.02		
20. Detritus 0.01	0.04	0.02	0.02	0.60	0.25	0.05	0.05	0.10	0.55	0.20	0.08	0.01	0.05	0.50	0.50	
21. Import																
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

RESULT AND DISCUSSION

As shown in Table 3, Sirinthorn generated annual average finfish catch of 22.17 t km^{-2} yr^{-1} meanwhile about 14.94 t km^{-2} yr^{-1} were obtained from Nam Ngum from the fish biomass of 28.5 and 20.8 t km^{-2} yr^{-1}, respectively. The mean trophic level from fisheries operation in both lakes is about three (2.73 at Sirinthorn and 2.97 at Nam Ngum) comparable to that of 2.78 and 2.72 in Ubolratana Reservoir during 1968-72 and 1985-88, respectively (Chookajorn et al., 1994). This implies that the zoophagous fishes are targets, where the total catch was composed of more than 55% of the three dominant species in each lake. Interestingly, trophic level of *C. aesarnensis*, which is the main catch in all three lakes, is 3.0 in Sirinthorn and Nam Ngum meanwhile was equal 2.59 in Ubolratana. This is an evident in facultative zooplanktivorous characteristic of this species (Jutagate et al., submitted).

Table 3. Key features of the ECOPATH model

(A) Sirinthorn

Group name	Trophic level	Catch (t $km^{-1}yr^{-1}$)	Biomass (t $km^{-1}yr^{-1}$)	P/B (yr^{-1})	Q/B (yr^{-1})	Production / Consumption
Littoral predator	3.4	0.70	0.617	1.50	7.5	0.200
Channa spp.	3.4	1.14	1.332	1.10	6.5	0.169
Oxyeleotris sp.	3.3	0.73	0.693	1.50	9.0	0.167
M. nemerus	3.3	1.40	1.102	1.70	10.5	0.162
N. notopterus	3.1	0.80	0.870	1.30	9.1	0.143
Hampala spp.	3.6	1.48	1.685	1.70	9.2	0.185
Morulius sp.	2.1	0.32	0.976	1.00	30.0	0.033
Small zoophagus	2.8	1.00	1.307	3.00	22.0	0.136
B. gonionotus	2.4	4.20	9.043	1.70	37.0	0.046
*P. fasciatus*2.7	0.90	1.943	1.50	43.0	0.035	
Small Cyprinids	2.1	1.40	3.256	3.00	50.0	0.060
Tilapiine fish	2.1	4.00	4.322	1.80	32.0	0.056
Clupeids 3.0	4.10	2.875	5.50	38.0	0.145	
Open water ZP	2.0	-	2.013	30.00	200.0	0.150
Littoral ZP2.0	-	7.815	30.00	200.0	0.150	
Aquatic insects	2.1	-	27.976	7.00	50.0	0.140
Crustaceans	2.1	-	25.408	5.00	40.0	0.125
Open water PP	1.0	-	1.280	365.00	-	-
Littoral PP1.0	-	4.616	365.00	-	-	
Macrophtytes	1.0	-	20.280	7.00	-	-
Benthic algae	1.0	-	91.101	15.00	-	-
Detritus	1.0	-	1.000	-	-	-

Note: ZP = zooplankton, PP = phytoplankton

(B) Nam Ngum

Group name	Trophic level	Catch (t km^{-1}yr^{-1})	Biomass (t km^{-1}yr^{-1})	P/B (yr^{-1})	Q/B (yr^{-1})	Production / Consumption
Large predators	3.5	0.10	0.107	1.05	6.5	0.162
N. notopterus	3.1	0.62	0.656	1.05	9.1	0.115
M. nemerus	3.3	1.38	1.384	1.20	9.5	0.126
Hampala spp.	3.6	3.38	3.700	1.30	9.0	0.144
Morulius sp.	2.1	0.24	1.371	1.00	30.0	0.033
Osteocheilus spp.	2.1	0.21	1.253	1.40	38.5	0.036
Puntioplites sp.	2.7	2.56	2.701	2.60	54.0	0.048
Pristolepis sp.	2.8	0.14	0.257	2.20	47.0	0.047
A. truncatus	2.1	0.43	0.806	1.70	41.0	0.041
C. molitorella	2.1	0.51	1.216	1.30	32.0	0.041
Small Cyprinids	2.1	0.86	2.022	2.50	45.0	0.056
*O. niloticus*2.1	0.21	0.152	1.50	29.0	0.052	
Clupeids 3.0	4.30	5.159	5.50	38.0	0.145	
Zooplankton	2.0	-	10.426	30.0	200.0	0.150
Aquatic insects	2.1	-	25.614	7.00	50.0	0.140
Crustaceans	2.1	-	12.087	5.00	40.0	0.125
Phytoplankton	1.0	-	5.828	365.00	-	-
Benthic algae	1.0	-	56.212	15.00	-	-
Aquatic weeds	1.0	-	14.999	7.00	-	-
Detritus	1.0	-	10.000	-	-	-

The efficiency of fisheries (fisheries catch/primary production) was also calculated (Reyes, 1993) and P/B ratios of phytoplankton in both lakes are the similar, at 365 yr^{-1}.

The results were 0.010 and 0.007 in Sirinthorn and Nam Ngum, respectively, which are comparable to the value in other very productive reservoirs, about 0.005 (Moreau, 1997). The higher value in Sirinthorn means that the utilization of the primary production in this lake is better than in Nam Ngum. This is due, perhaps, to the introduction of the forage species such as *O. niloticus* and Chinese carps from stocking program (Virapat, 1993).

Even the trophic structures of these two reservoirs are quite similar. The box models (Fig.1) show that Sirinthorn 's model is slightly more complicated than Nam Ngum, both in term of boxes and complexity of flow. However, it can also be seen through the coincided results that zooplankton has the highest consumption followed by aquatic insect and crustacean. This is important since theses organisms are the main food resources for the zoophagous species. Therefore, any increase of biomass for both insects and crustaceans would a significant impact, whereas the most important changes within ecosystem might come from the development of phytoplankton and benthic algae or aquatic weeds (Moreau, 2000)

Figure 1a. Trophic ECOPATH box model of Sirinthorn Reservoir

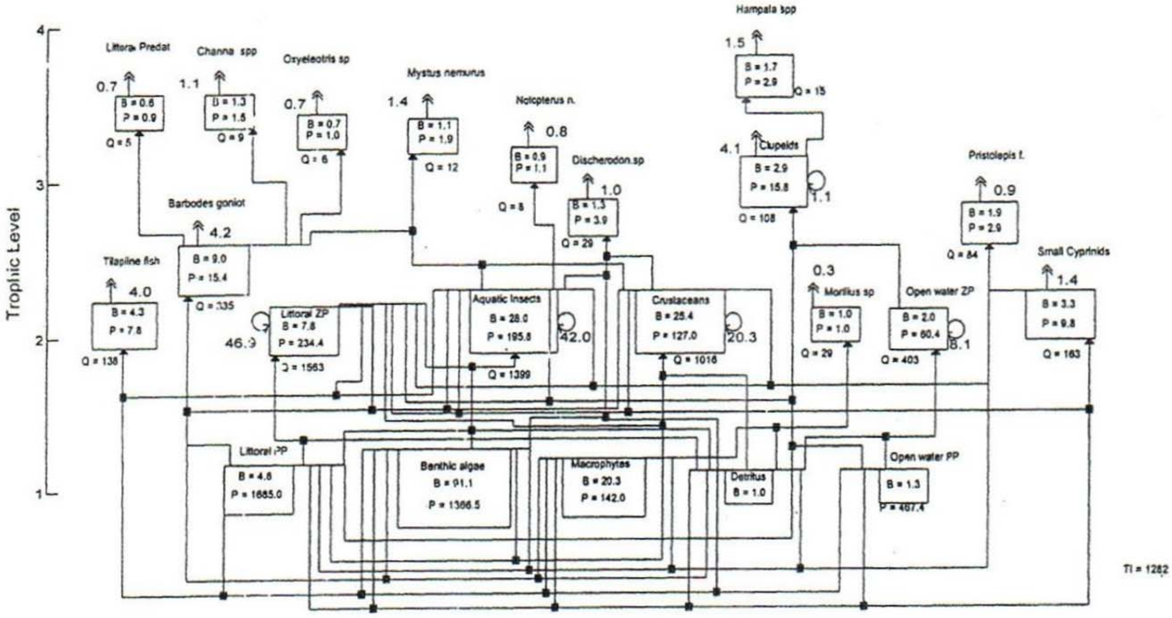


Figure 1b. Trophic ECOPATH box model of Nam Ngum Reservoir

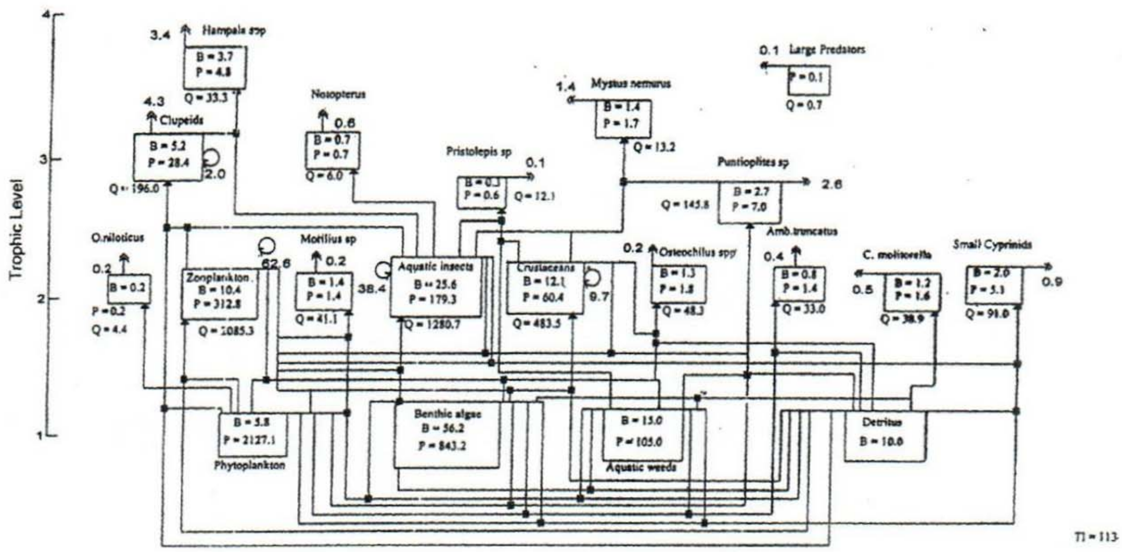


Figure 2a. Mixed trophic impact for Sirinthorn Reservoir
(positive and negative impacts are shown above and under the base line, respectively)

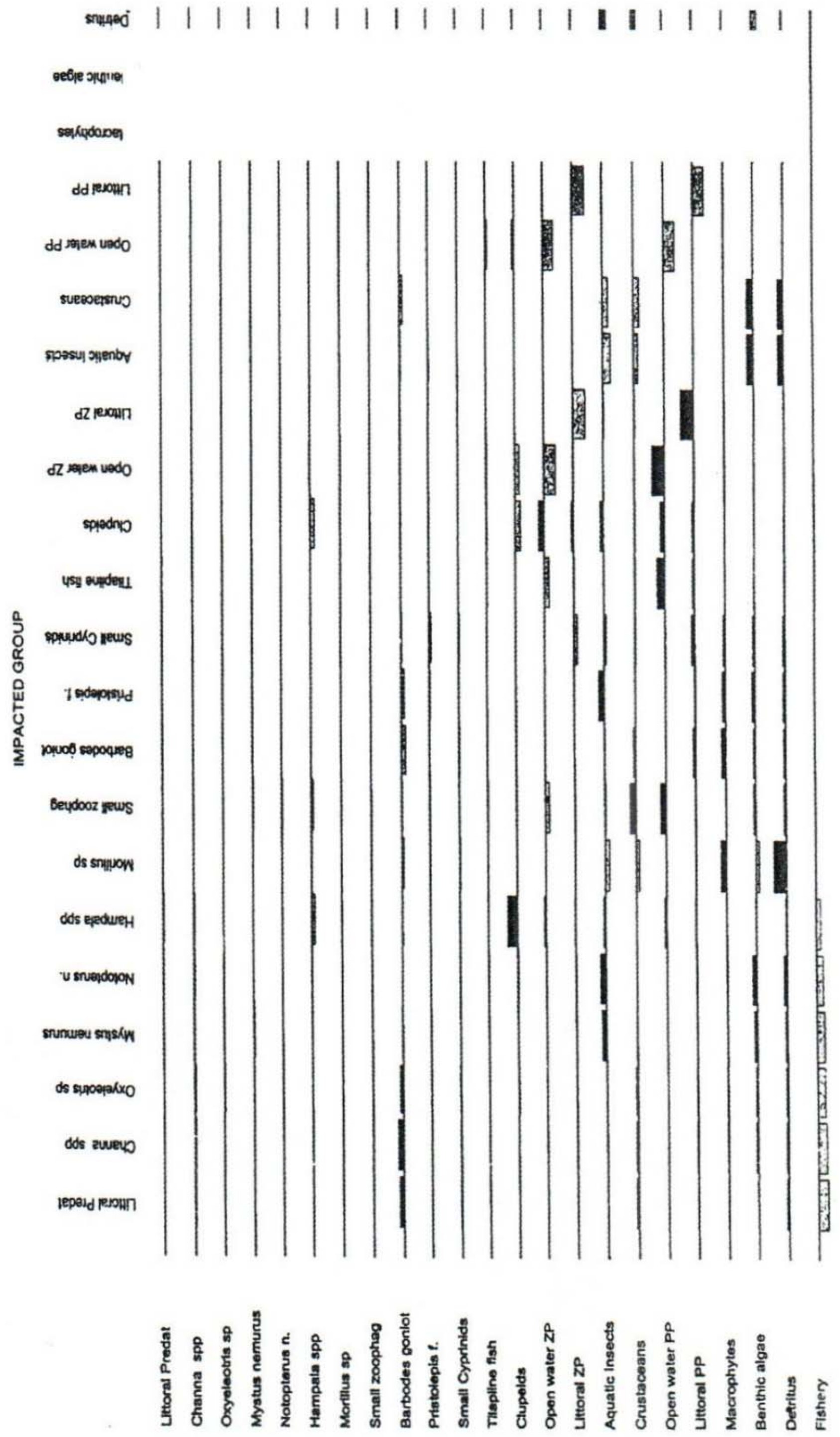
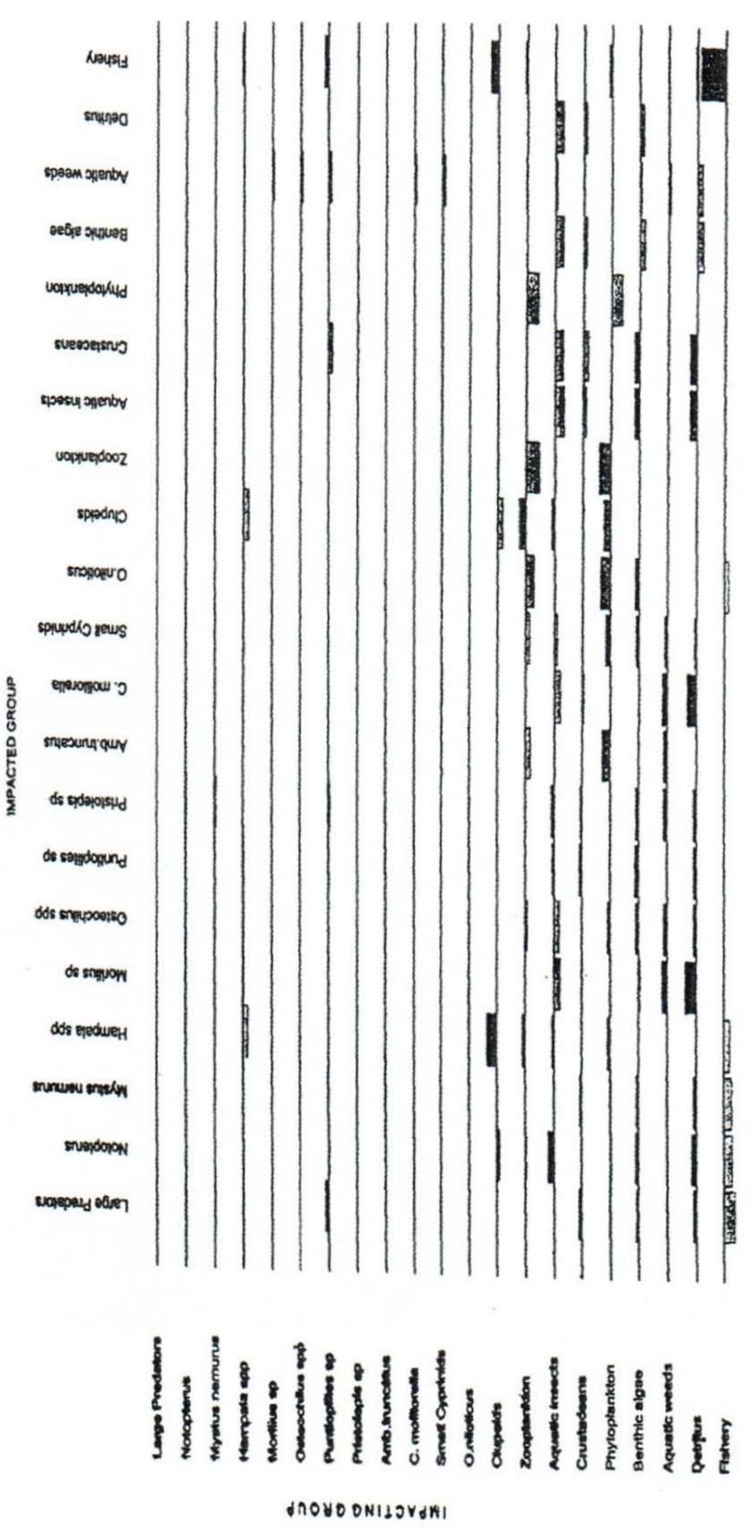


Figure 2b. Mixed trophic impact for Nam Ngum Reservoir
(positive and negative impacts are shown above under the base line, resptively)



The trophic transfer efficiencies, Table 4, by discrete levels can be estimated as the percentage of flow entering a trophic level that is ultimately harvested or transferred to the next trophic level (Christensen and Pauly, 1992b). It can be seen that the transfer efficiency is between 10% and 15% at all trophic levels, which is seemingly low and implies that the food webs in both lakes are intact. However, it can be seen that at the fifth trophic level and above the transfer efficiencies in Sirinthorn are higher than Nam Ngum. This result caused from the abundance of predator species in Sirinthorn.

Table 4. Transfer efficiency

(A) Sirinthorn

Source/ Trophic level	**II**	**III**	**IV**	**V**	**VI**	**VII**
Producer	10.4	9.1	10.8	14.1	14.1	
Detritus	10.1	7.2	13.1	14.1	14.2	
All flow	10.3	7.6	11.2	14.1	14.1	14.3

Note: 1) Proportion of total flow originating from detritus: 0.26

2) Transfer efficiencies: (a) from primary producers: 10.1% (b) from detritus: 9.8% (c) Total: 10.0%

(B) Nam Ngum

Source / Trophic level	**II**	**III**	**IV**	**V**	**VI**	**VII**
Producer 10.8	10.4	10.5	11.7	11.6		
Detritus 10.1	8.3	11.5	11.6			
All flow 10.6	9.9	10.7	11.7	11.6	12.5	

Note: 1) Proportion of total flow originating from detritus: 0.27

2) Transfer efficiencies: (a) from primary producers: 10.6% (b) from detritus: 9.9% (c) Total: 10.4%

Figure 2 shows the mixed trophic impact the various group/species had on the other group in the system. It is seen that the largest impacts are caused by the lower trophic levels whereas the predator groups only influence few other groups. The most important changes within the ecosystem might come from development of phytoplankton and benthic algae. As described above, fisheries have a great impact on the zoophagous species. It is seen that clupeid fish has a positive impact on the *Hampala* spp. and *vice versa*. This is shown the obvious predator-prey relationship of these two species. It can be concluded that the increase in biomass of clupeids would contribute to the slight increase of the abundance of its key predator, *Hampala* spp. Such an increase in abundance of clupeids could come from an increase of zooplankton biomass. In term of biomass, the ratio between predators and their preys in Sirinthorn is 0.33, which indicates an abundance of prey species while the ratio is 0.40 in Nam Ngum. Despite huge prey biomass, the high P/B values of the prey compared to those of predator, which allow the sustained ecosystem in this lake. Change in ratio between predators and prey biomass was observed in Ubolratana. There were about 0.5 before impoundment (Sidthimunka et al., 1978), 0.66 in early 1970s and 0.16 in 1980s (Chookajorn et al., 1994).

The former change maybe the well occupied and proliferated of the predatory species after impoundment while the latter (1970s-1980s) most likely due to overfishing of predators which have high market demand (Chookajorn et al

CONCLUSION

The ECOPATH model displayed the seemingly quite similar ecosystem in Sirinthorn and Nam Ngum Reservoirs. It can be concluded that both man-made lakes are the productive reservoirs, which the zoophagous fish species are the main targets for fishing operations.

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