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Growth, Mortality and Recruitment of Fish Populations in an Asian Man Made Lake Rajjaprabha Reservoir (Thailand) as Assessed by Length Frequency Analysis

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Abstract

Estimates of growth, mortality and recruitment pattern of important commercial species from Rajjaprabha reservoir (Thailand) were obtained from sets of length frequency distributions resulting from field data collected with multimesh size gillnets from July 1993 to April 1994. Data analysis was performed using the FISAT (FAO ICLARM Stock Assessment Tool, version 1.0) software. The maximum theoretical length L_∞ was rather low and the mortalities were high. Overfishing could be suspected. One peak was observed for recruitment indicating recruitment of one cohort per year. The results are discussed and compared to available informations on growth performance of the similar species in other Asian reservoirs.

Introduction

Reservoir fisheries in Thailand are a post-1950 phenomenon, which began with the construction of multi-purpose storage reservoirs (Bhukaswan 1980). The fish yield from Thai reservoirs has shown a significant increase and have surpassed the traditional riverine fisheries by many folds. In most reservoirs, the production fluctuate yearly, and the degree of fluctuation is correlated with changes in environmental conditions and the relative success of fishery management programmes (Bhukaswan 1980; Pawapootanon 1986).

The species composition, distribution, and abundance of fish fauna in Thai reservoirs are variable. Carps (Cyprinidae), however, are the most numerous species and the other important genera are *Osteochilus* and *Cyclocheilichthys*.

Next in importance are catfish (*Pangasius, Kryptopterus, Mystus, Clarias*...), murrels and snakefish (*Ophiocephalus*), gouramy (*Trichogaster, Osphronemus*) and miscellaneous fish. In some reservoirs, introduced species (Tilapia, *Oreochromis niloticus*) are becoming significantly important (Pawapootanon 1991).

Little is known about exploited fish stocks and populations in Thai reservoirs and this paper intends to provide the first picture of the demographical status of some of them in the Rajjaprabha reservoir.

The Rajjaprabha reservoir

The Rajjaprabha reservoir, (latitude 9 00' N, longitude 98 40' E, altitude 95 m. above M.S.L. with an area of approximately 167 km^2) is a large deep and oligotrophic reservoir created by damming the Tapi river in the Surat-Thani Province (Southern Thailand), about 700 km from Bangkok (Bernacsek 1997; Chookajorn et al 1999). The reservoir occupies a narrow valley. It is drawn down yearly for about 6.0 m. and the area shrinks to about 124 km^2. At 89 m. above M.S.L. the mean depth is 34 m. The Rajjaprabha reservoir is a narrow body of water with no specific pelagic zone. The dam was closed in 1986 and reached its equilibrium level three years after. The total electric power generated is 240 MW. The commercial fisheries are quite active (about 150 fishermen are currently catching an average of 316 tonnes) and deal with several fish species among them some introduced: mostly Asian cyprinids which are stocked on a yearly basis (Sricharoendham et al. 1995).

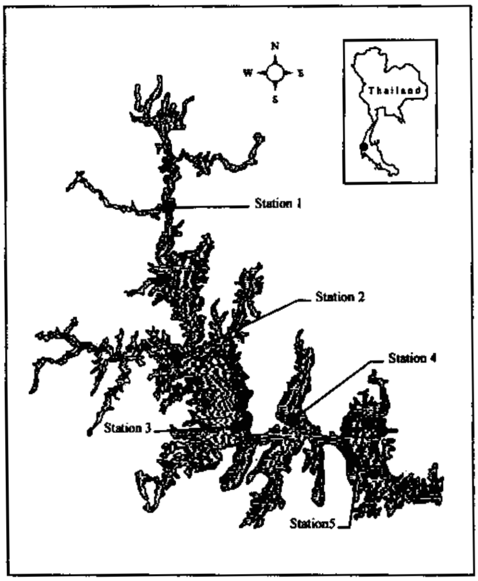


Fig. 1. General map of Rajjaprabha reservoir.

The climate is characterized by a short dry and cool season from December to February and a long wet season because of two directions of wind and rain from the Pacific and the Indian Ocean.

Materials and Methods

Sampling methodology

The following species *Cyclocheilichthys apogon, Hampala macrolepidota, Osteochilus hasselti, Pristolepis fasciatus*, were considered. They contribute 3%, 13%, 2% and 17% respectively to the current commercial catch

(Sricharoendham et al. 1995; Bernacsek 1997). They are the easiest species to catch with multimesh size gillnets which were used here. Length-frequency data were obtained through the routine survey programme conducted every three months by the Department of Fisheries from July 1993 to April 1994 (Tables 1 to 4). In order to minimize the possible sampling bias, the set of gill nets were deployed by parallel to the shoreline at five stations, which are representing at the surface of littoral zones, the favorite habitat of these species. Total length (cm TL) measurements for the samples were grouped into 1 cm length groups ranging from 5.5 to 42.5 cm. Due to the limited number of fish, samples from different mesh sizes were pooled. For the same reason, the selectivity of each separated mesh size was not assessed but the selectivity of the smallest mesh size has been taken into account for the analysis of fish growth as suggested by Pauly (1983, 1984) and Gayanilo et al (1994).

Data analysis

The "FISAT" (FAO ICLARM Stock Assessment Tool) Software (Gayanilo et al 1994) was utilized. The following operations were performed:

(i) To create the length-frequency data set for use with the program, note that the samples collected in 1993 and 1994 had to be merged into a single file thus constituting a single "artificial year" (Tables 1 to 4).

Estimation of growth parameters

(ii) To estimate the growth parameters based on the von Bertalanffy Growth Formula (VBGF) expressed in the form: (Pauly & Gaschutz, 1979):

$$Lt = L_\infty (1 - \exp(-K^*(t-to))) \quad (1)$$

where:

L_t is the predicted length at age t.
L_∞ is the asymptotic length, or the mean length the fish of a given stock would reach if they were to grow forever.
K is a growth constant, also called «stress factor» by Pauly (1980).
t_0 is the "age" the fish would have had at zero length predicted by the equation.

Given the sets of data and the ecological conditions of the lake, a seasonality could be taken into account by using the VBGF as modified by Somers (1988) which incorporates two more parameters:

C the value of which is between 0 and 1 indicates the magnitude of the seasonal growth pattern

WP the time of the year during which growth rate is minimum. It appeared to be around the end of the year.

It should be noted that FISAT has a routine which allows to improve the quality of the estimates of L_∞ and K by taking into account the possible selectivity of sampling techniques towards small fishes (Pauly 1980, 1984) a

Table 1. Length frequency distributions for *Cyclocheilichthys apogon* in Rajjaprabha reservoir in 1993-1994.

ML/Date	15/01/93	15/04/93	15/07/93	15/10/93
9.00	2.00	1.00		1.00
10.00	14.00	60.00	48.00	1.00
11.00	37.00	144.00	112.00	9.00
12.00	11.00	97.00	59.00	5.00
13.00	3.00	37.00	31.00	9.00
14.00	5.00	7.00	8.00	9.00
15.00	2.00	7.00	19.00	9.00
16.00	4.00	11.00	22.00	7.00
17.00	2.00	8.00	14.00	3.00
18.00	2.00	6.00	13.00	3.00
19.00	4.00	1.00	6.00	1.00
20.00	0.00		1.00	
21.00	1.00		2.00	
22.00			1.00	
Sum	87.00	379.00	336.00	57.00

n = 859.00

Table 2. Length frequency distributions for *Hampala macrolepidota* in Rajjaprabha reservoir in 1993-1994.

ML/Date	15/01/93	15/04/93	15/07/93
11.00	1.00	1.00	
12.00	1.00	3.00	1.00
13.00	1.00	6.00	4.00
14.00	0.00	15.00	4.00
15.00	3.00	9.00	2.00
16.00	4.00	5.00	2.00
17.00	5.00	4.00	1.00
18.00	4.00	3.00	2.00
19.00	3.00	3.00	5.00
20.00	8.00	4.00	6.00
21.00	6.00	2.00	7.00
22.00	2.00	1.00	8.00
23.00	2.00	0.00	5.00
24.00	1.00	0.00	4.00
25.00	0.00	1.00	1.00
26.00	0.00	2.00	3.00
27.00	3.00	1.00	2.00
28.00	1.00	0.00	2.00
29.00	3.00	3.00	4.00
30.00	2.00	4.00	2.00
31.00	2.00	1.00	0.00
32.00	0.00	1.00	1.00
33.00	0.00	1.00	1.00
34.00	0.00	0.00	0.00
35.00	0.00	1.00	1.00
36.00	0.00		0.00
37.00	0.00		0.00
38.00	0.00		0.00
39.00	0.00		0.00
40.00	0.00		0.00
41.00	0.00		1.00
42.00	1.00		
Sum	53.00	71.00	69.00

n = 193.00

Table 3. Length frequency distributions for *Osteochilus hasselti* in Rajjaprabha reservoir in 1993-1994.

ML/Date	15/01/94	15/04/94	15/07/94	15/10/94
6.00		1.00		3.00
7.00	3.00	0.00		1.00
8.00	3.00	1.00		2.00
9.00	2.00	0.00		1.00
10.00	5.00	4.00		0.00
11.00	3.00	10.00	4.00	0.00
12.00	7.00	27.00	4.00	1.00
13.00	17.00	34.00	11.00	4.00
14.00	15.00	32.00	5.00	3.00
15.00	11.00	23.00	6.00	6.00
16.00	4.00	14.00	0.00	6.00
17.00	1.00	9.00	1.00	5.00
18.00	4.00	5.00	0.00	8.00
19.00	10.00	4.00	1.00	8.00
20.00	12.00	1.00		2.00
21.00	3.00	1.00		1.00
22.00	1.00			1.00
23.00	1.00			
24.00	4.00			
Sum	106.00	166.00	32.00	52.00

n = 356.00

Table 4. Length frequency distributions for *Pristolepis fasciatus* in Rajjaprabha reservoir in 1993-1994.

ML/Date	15/01/93	15/04/93	15/07/93	15/10/93
6.00		4.00		2.00
7.00		8.00		10.00
8.00	1.00	13.00	5.00	5.00
9.00	5.00	4.00	0.00	2.00
10.00	4.00	1.00	0.00	1.00
11.00	3.00	5.00	3.00	6.00
12.00	2.00	6.00	4.00	13.00
13.00	2.00	9.00	6.00	19.00
14.00	1.00	3.00	4.00	9.00
15.00	1.00	4.00	6.00	11.00
16.00	9.00	5.00	14.00	15.00
17.00	6.00	10.00	17.00	13.00
18.00	5.00	6.00	5.00	11.00
19.00	2.00	5.00	4.00	4.00
20.00	4.00	3.00	2.00	5.00
21.00	1.00	1.00	3.00	3.00
22.00	1.00		2.00	1.00
23.00			1.00	0.00
24.00			1.00	1.00
25.00			1.00	1.00
Sum	47.00	87.00	78.00	132.00

n = 344.00

feature which was of relevance and utilized here because of the use of gill nets.

Estimation of mortality rates

(iii) To obtain an estimate of the instantaneous total mortality coefficient for a definite range of sizes/ages via a length-converted catch curve analysis as described by Pauly (1980, 1983, 1984). In order to compute the natural mortality coefficient M, Pauly (1981) developed a predictive formula using the multiple regression indicated below:

$$\log_{10} M = -0.0152 - \log_{10} L_{\infty} + 0.65431 \log_{10} K + 0.463 \log_{10} T°C \quad (2)$$

This formula was used to obtain the estimate of M, given L_{∞} (total length in cm), K (the growth constant yr-1), and T (the mean environmental temperature i.e. 28°C, here). Once Z and M were obtained, the fishing mortality (F) was derived from the relationship:

$$Z = F + M; \quad F = Z - M \quad (3)$$

and the exploitation rate (E) obtained by the relationship:

$$E = F/Z = F/(F + M) \quad (4)$$

Recruitment pattern

(iv) To obtain expressions of the seasonal changes in recruitment displayed in the graphical form of a recruitment pattern suggestive of the recruitment season, growth parameter estimates L_{∞}, K, C and WP were used as inputs in this analysis in application of the appropriate program in FISAT. For that purpose, the value of t_0 has been set close to 0.

Results

Growth parameters, mortality estimates, and recruitment pattern

Growth curves obtained from files after incorporating the correction of selectivity for the smallest mesh size as suggested by Pauly (1980 and 1984), recruitment pattern and length converted catch curve for the four considered populations are provided on Figures 2 to 4. (see also Table 5).

The seasonal growth pattern is always clear and the winter point takes place in early January (most probably in connection to the cool temperatures at this time of the year) The maximum size of the species considered here is low except for *H. macrolepidota*. The recruitment pattern is not clear for *C. apogon* and *P. fasciatus*. There is however one breeding season from March to June for *H. macrolepidota*, from May to August for *O. hasselti* (which could be

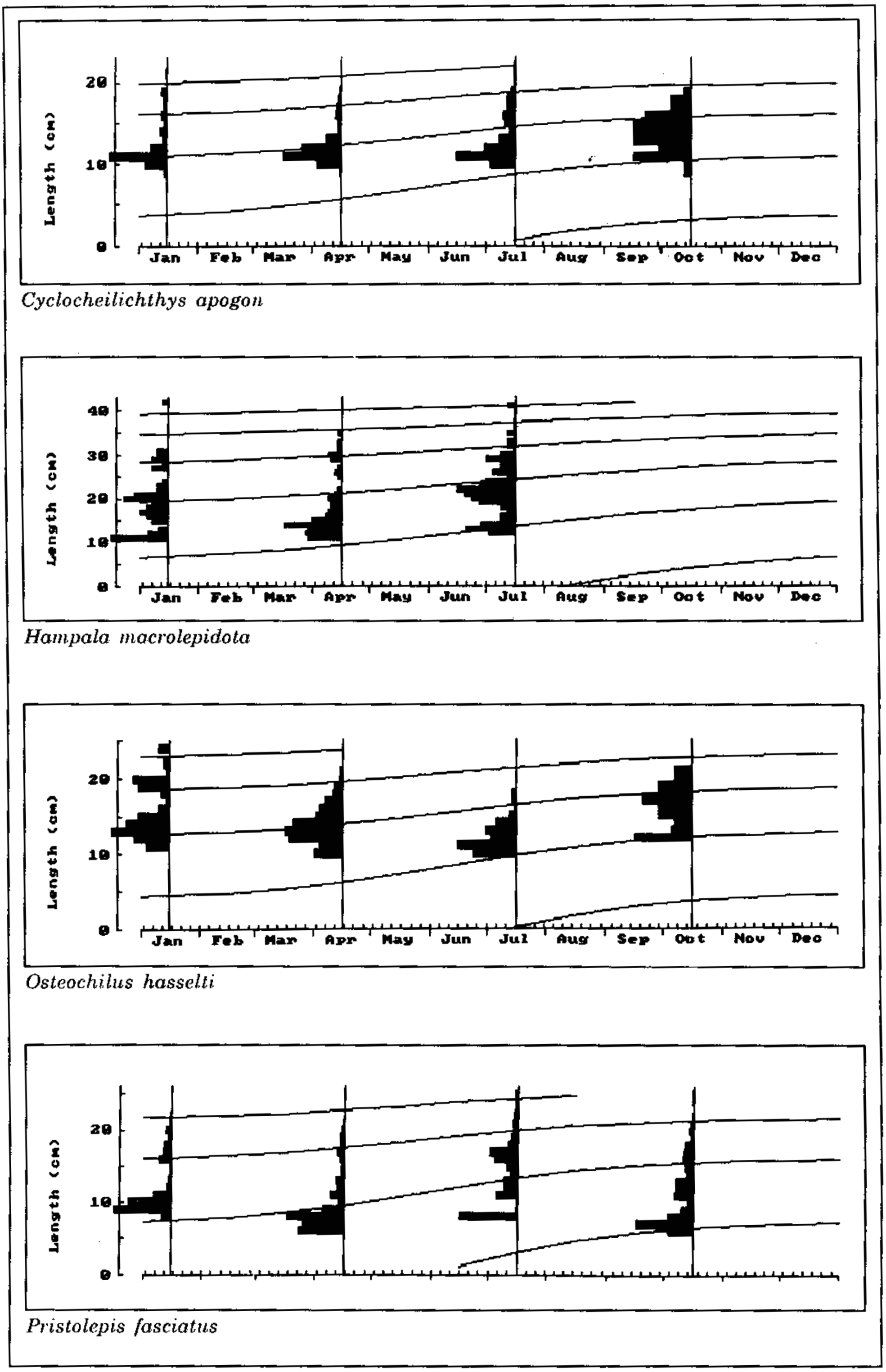
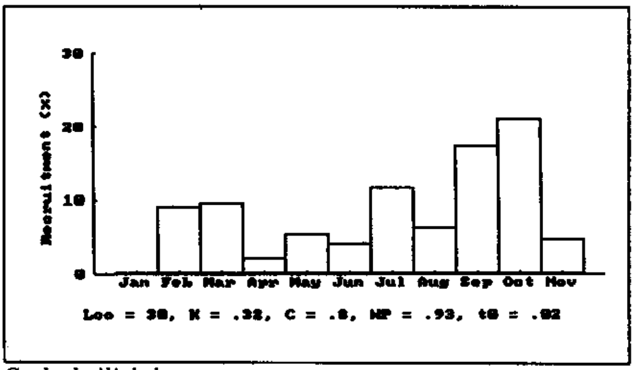
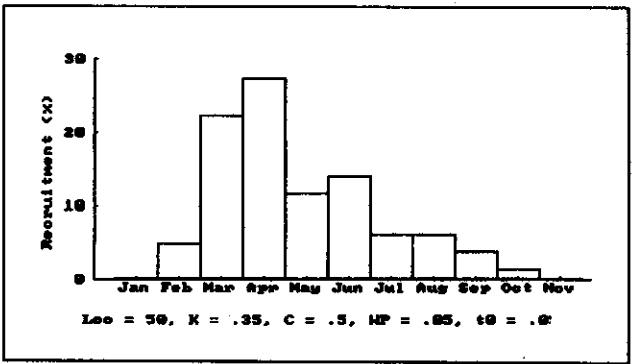


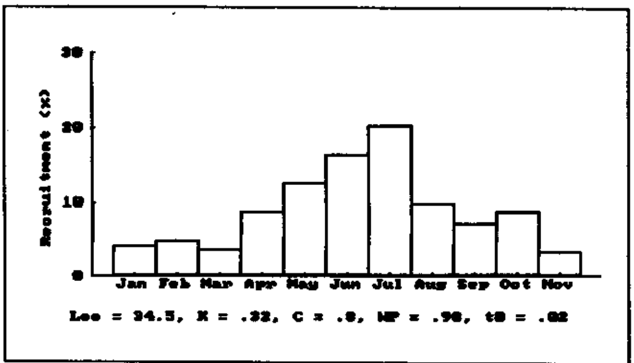
Fig. 2. Direct fit of length-at-age using length frequency distributions for four fish populations in Rajjaprabha reservoir. It should be noted that the selectivity of the multimesh size gill nets towards small size of fish has been taken into account resulting in very abundant small size fish in some samples.



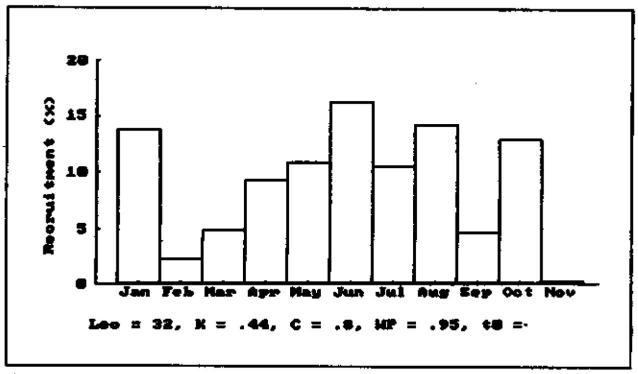
Cyclocheilichthys apogon



Hampala macrolepidota



Osteochilus hasselti



Pristolepis fasciatus

Fig. 3. Recruitment patterns for four fish populations in Rajjaprabha reservoir (inputs are growth parameters as estimated here).

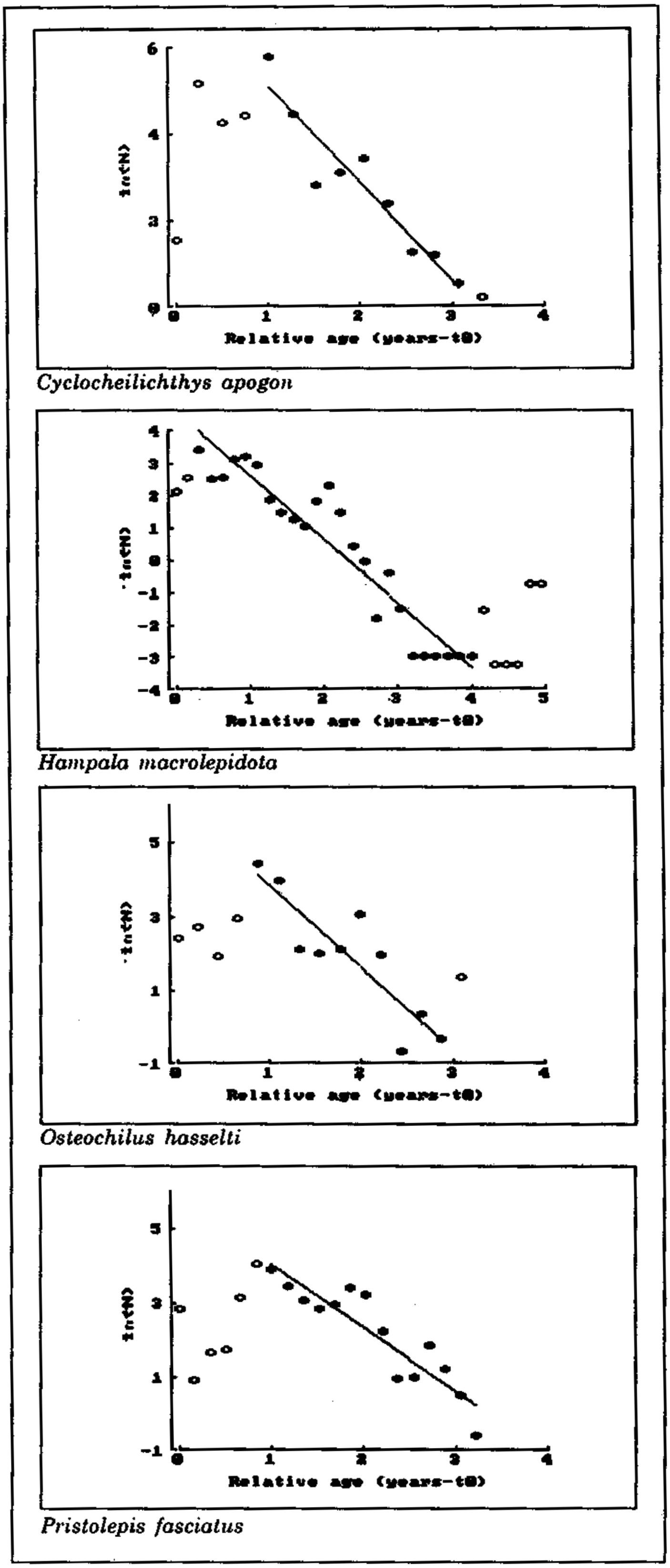


Fig. 4. Length converted catch curves for four fish populations in Rajjaprabha reservoir (inputs are growth parameters as estimated here).

related to the rainy season). The "length-converted catch curve" analysis produced total mortality estimates of Z = 1.73 to 2.27 which are high values within a limited range of ages (0.5 to 4 years as a maximum).

The level of exploitation

The level of exploitation has been assessed by computing the exploitation rate E = F/Z as summarized in Table 6. It appears that, except *P. fasciatus*, the fish stocks under investigation here are quite highly exploited, independently of their relative contribution to the actual catch.

Discussion

FISAT was used on four sets of length-frequency data for fish populations of a Thai reservoir in order to estimate the growth parameters L_∞, and K, also the recruitment pattern and mortality. The seasonality of the growth is clear for the four sets of samples. The variations in C and WP from one set to another allow to disregard a possible effect of the selectivity of each separated gillnet on the fitting of the growth curve. This gives credit to the routine sampling programme operated in Thai reservoirs by the Department of Fisheries.

For *P. fasciatus* and *H. macrolepidota*, the strong polymodality of the lengths could have been dealt with by using other types of length analyses available in FISAT such as the separation of mode classes as representative of year classes and fitting growth curves accordingly. We tried these methods in order to confirm the results of the direct length-at-age fitting. The result was not convincing but it might have come from the fact that the separation of mode classes is operated on the basis of the hypothesis of the gaussian distribution of length frequencies for each year class, an assumption which is not necessary when using the direct fitting.

To some extent, these populations are overexploited as suggested by the high value of E and also the small maximum size. This is particularly clear

Table 5. Demographical status of four fish populations in Rajjaprabha reservoir.

Species	L_∞ (cm)	K(yr-1)	C	WP	Z (yr-1)	Range of ages
C. apogon	30.0	0.32	0.80	0.98	2.27	1 to 3 yr
H. macrolepidota	50.0	0.35	0.50	0.05	1.99	0.5 to 4 yr
O. hasselti	34.5	0.32	0.80	0.98	2.25	1 to 3 yr
P. fasciatus	32.0	0.44	0.80	0.95	1.73	1 to 3 yr

Table 6. Exploitation level of four fish populations in Rajjaprabha reservoir.

Species	% catch	Z(yr-1)	Range of ages	M(yr-1)	F(yr-1)	E
C. apogon	3.0	2.27	1 to 3 yr	0.85	1.42	0.62
H. macrolepidota	13.4	1.99	0.5 to 4 yr	0.78	1.21	0.61
O. hasselti	2.0	2.25	1 to 3 yr	0.81	1.44	0.64
P. fasciatus	17.2	1.73	1 to 3 yr	1.02	0.71	0.41

for *H.macrolepidota* which reaches 50 cm only instead of 70.5 cm in the Nam Ngum reservoir, Mekong river basin in Laos (Moreau unpublished). For other species, the only available data are the maximum observed length in Ubolratana reservoir (Sricharoendham, pers. obs.) For *O. hasselti* and *P. fasciatus* the value is the same as here whereas it is much lower for *C. apogon* (16 cm TL). Growth performance of other species considered here are the first ones made available and no comparison with already existing data can be made.

Concerning recruitment, minor pulses observed at the beginning or at the end of the year in two populations seem to be an artifact due to the structure of the samples either with or without the correction taking into account the theoretical selectivity of the set of gill nets for small fish.

Conclusion

For the first time, a length frequency analysis was performed on exploited native fish populations of Thai reservoirs. This exercise showed rather similar demographical situations (as assessed by the value of the exploitation rate E) of the four concerned stocks. However, high values of Z show that further investigations are needed to monitor the demographical evolution and to prevent the occurrence of overfishing for a long period of time.

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References

Bernacsek G. 1997: Management of Reservoir Fisheries in the Mekong Basin project. Publ. Mekong River Commission, Bangkok Thailand var.pag.

Bhukaswan T. 1980: Management of Asian reservoir fisheries, FAO Fish. Tech. Pap. 207: 69 p.

Chookajorn T., S. Duangsawadi, B. Chansawang, Y. Leenanond and B. Sricharoendham 1999: The fish populations in Rajjaprabha reservoir, Thailand p 95-102 in W.L.T. Van Densen and M.J. Morris (eds.) Fish adn Fisheries of lakes and reservoirs in South-east Asia and Africa. Westbury Publishing, Otley, U.K.

Gayanilo F.Jr, P. Sparre and D. Pauly 1994: The FISAT User's Guide. FAO Comput. Inform. Ser. (Fisheries) 99: 125 p. Publ. FAO/ICLARM/DIFMAR

Pauly, D. & G. Gaschutz 1979: A simple method for fitting oscillating length growth data, with a program for pocket calculator. ICES CM 1979/G: 24 Demersal Fish Ctee, 26p.

Pauly, D. 1980: A selection of simple methods for the assessment of tropical fish stocks. FAO. Fish. Circ., No. 729

Pauly, D. 1981: On the interrelationship between natural mortality, growth parameters and the mean environmental temperature in 175 fish stocks. J. Cons. Explor. Mer. 39 (3): 175-192.

Pauly, D. 1983: Length-converted catch curve. A powerful tool for fisheries research in the tropics (part 1) Fishbyte 1 (2): 9-13.

Pauly, D. 1984: Length-converted catch curve. A powerful tool for fisheries research in the tropics (parts 3). Fishbyte 2 (3): 9-10.

Pauly D. 1986: On improving operation and use of the ELEFAN programs. Part II. Improving the estimation of L_∞. Fishbyte 4 (1): 18-20.

Pawapootanon O. 1986: Fisheries and fishery management of large reservoirs in Thailand p. 389-392. In Maclean J., L.B. Dizon and D. Hosillos (Eds). Proc. of the First Asian Fisheries Society Forum. The Asian Fisheries Society, Manila Philippines.

Pawapootanon O. 1991: Current contribution of Tilapia to capture fisheries in Thailand p. 238-243 in Baluyut E.(Ed.) Papers contributed to the workshop on Tilapia in capture and culture-enhanced fisheries in the Indo-Pacific fishery Council.

Somers I.F. 1988: On a seasonally Oscillating Growth Function. Fishbyte 6 (1): 8-11.

Sricharoendham B., Y. Leenanond and P. Poomikong 1995: Fishery Activity and Catches in Rajjaprabha reservoir. Thailand. NIFI Technical Report 171; 66 p. Department of Fisheries Bangkok Thailand.

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