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Estimations of Maximum Sustainable Fish Yields and Stocking Densities of Inland Reservoirs of Sri Lanka

By

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ABSTRACT

The Maximum Sustainable Yields of all fish species for nine man-made reservoirs in Sri Lanka were calculated by the simplified version of Schaefer Model. The relationship between the Maximum Sustainable Yield (MSY) and Morpho-edaphic Index, (MEI) for Sri Lankan reservoirs was found to be ;

$$\mathrm{Log}_e\ \mathrm{MSY} = 0.9005 \log_e\ \mathrm{MEI} + 1.9220$$

MSY for these reservoirs were estimated using this relationship. The number of *Tilapia* juveniles needed to be recruited to the fisheries of some reservoirs in addition to the present recruitment to increase the fish production to the level estimated by MEI relationship were calculated by the following equation,

$$S = \frac{\mathrm{MSY}_{est} - \mathrm{MSY}_{cal}}{\overline{W}}\ e^{Z(t_i - t_o)}$$

S = Number of fish fingerlings which must be introduced in addition to the present recruitment to achieve the estimated value of Maximum Sustainable Yield.

Z = Total mortality rate

t_i = Age at capture

t_o = Age at recruitment

$\overline{W}$ = Mean weight of fish at capture

MSY_{est} = Maximum Sustainable Yield estimated using Morpho-edaphic Index relationship

MSY_{cal} = Maximum Sustainable Yield calculated by catch and fishing effort statistics.

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Introduction

The estimated extent of fresh waters in the form of man-made reservoirs available for fisheries development in Sri Lanka is 1385.5km^2. This will be increased by about 15% with the completion of the Mahaweli development program. The importance of proper management of inland reservoir fisheries in Sri Lanka has been discussed by several workers (Anon. 1968; Anon. 1977; Fernando, 1977).

It is well known that primary productivity and fish yield are highly related to morphology of lakes (Rawson, 1952; Fryer and Iles, 1972) and chemistry of water (Moyle, 1956). Combining these factors Ryder (1965) developed a MEI which is the ratio of total dissolved solids to mean depth.

Electrical conductivity of water has later been substituted for total dissolved solids (Henderson and Welcome 1974). MEI has been used to determine potential fish production of inland lakes in Canada (Ryder, 1965, North America (Matuszek, 1978), Africa (Henderson and Welcome, 1974) and Sri Lanka (Wijeyaratne and Costa, 1981). These estimates of potential fish yields can be used to determine stocking densities of fish fingerlings in inland reservoirs as suggested by Welcome (1976). The regression equation proposed by Wijeyaratne and Costa (1981) to estimate potential fish catch from inland water bodies of Sri Lanka using MEI is discussed in this paper and a more precise relationship is suggested. Fresh stocking densities of fingerlings for some inland reservoirs are also presented.

Materials and Methods

The fish catch and fishing effort statistics of nine inland reservoirs were obtained for past 7-10 yrs. from the statistical division of the Ministry of Fisheries. MSY of all fish species for nine tanks were calculated using the simplified version of Schaefer Model (Pauly, 1980). The MEI was calculated by the method described by Henderson and Welcome (1974). Values for electrical conductivity and mean depth were obtained from several sources (Mendis, 1965; Amarasiri, 1973).

The relationship between the MSY and MEI was then calculated and 95% confidence band for the regression equation was estimated.

Stocking densities of *Tilapia mossambica* (*Sarotherodon mossambicus*) fingerlings for some reservoirs were calculated by the following equation.

$$S = \frac{MSY_{est} - MSY_{cal}}{\overline{W}} \; e^{Z(t_i - t_o)}$$

S = Number of fish fingerlings which must be recruited to the fishery in addition to the present recruitment to achieve the estimated value of Maximum Sustainable Yield.

Z = Total mortality rate

t_i = Age at capture

t_o = Age at recruitment

$\overline{W}$ = Mean weight of the fish at capture

MSY_{est} = Maximum Sustainable Yield estimated using Morpho-edaphic Index relationship

MSY_{cal} = Maximum Sustainable Yield calculated by catch and fishing effort statistics.

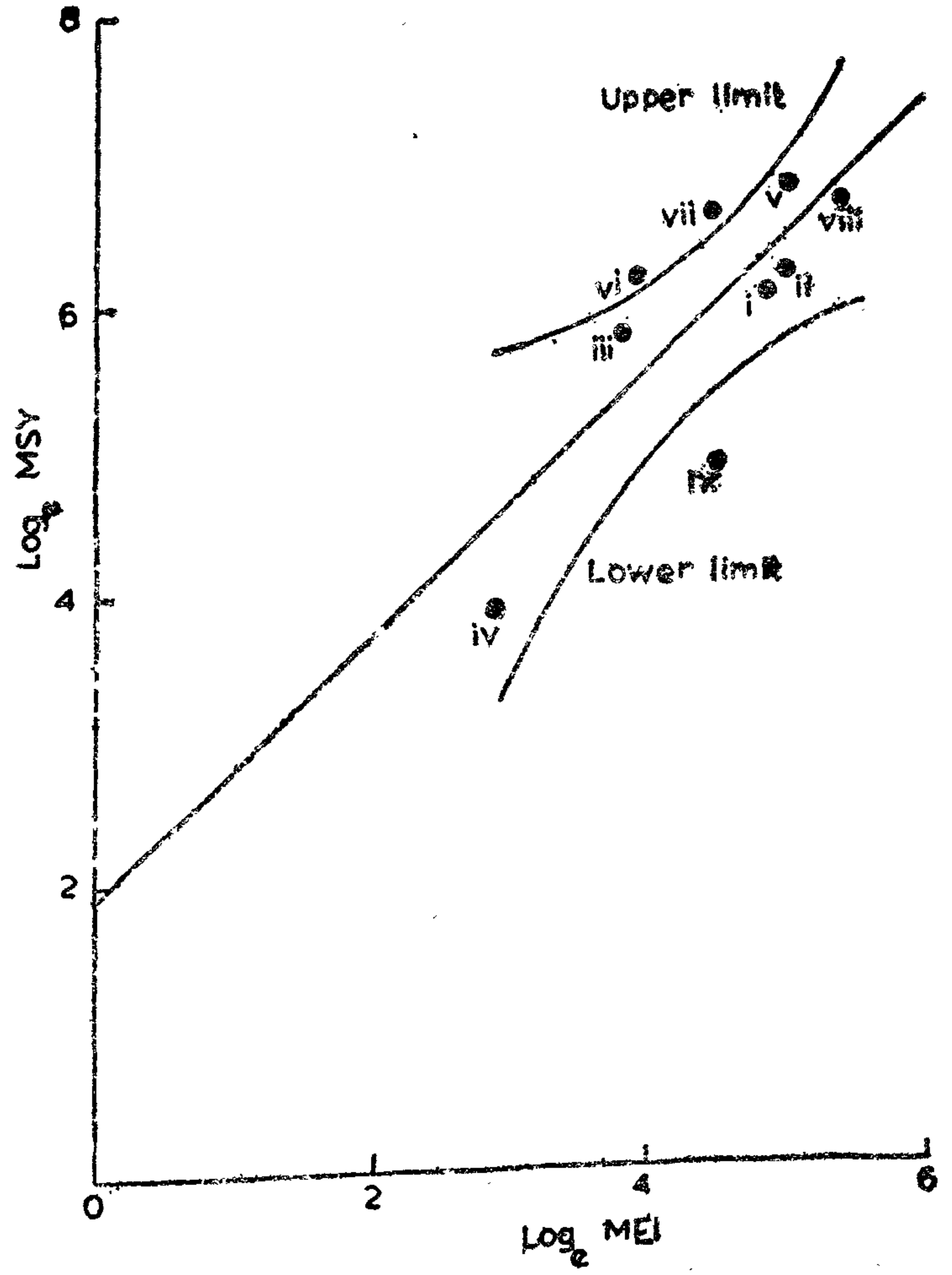
The mean weight of *Tilapia* at capture has been calculated to be 394 gm. (Wijeyaratne and Costa, 1981).

Results and Discussion

The values of conductivity, mean depth, surface area and Morpho-edaphic Induces for the nine reservoirs are given in Table 1. Table 2 summarises the Maximum Sustainable Yields calculated by catch and fishing effort statistics, average number of fishing days per year and the amount of fishing effort needed to obtain the MSY of all species of those nine reservoirs.

The relationship between MSY of all species MEI was as follows:

$$\log_e \text{MSY} = 0.9005 \log_e \text{MEI} + 1.9220$$



i. Badagiriya wewa. ii. Mahawilachchiya wewa. iii. Minneriya wewa. iv Muruthawela wewa. v. Nachchiyaduwa. wewa vi. Parakrama Samudra. vii. Rajanganaya wewa. viii. Tissa wewa. ix. Udukiriwela wewa.

Fig 1, Relationship between Maximum Sustainable Yield (MSY) and Morpho-edaphic Index (MEI)

TABLE 1

SURFACE AREA, MEAN DEPTH, CONDUCTIVITY AND MORPHO-EDAPHIC INDICES OF SOME INLAND RESERVOIRS OF SRI LANKA

Reservoir	*Surface area at FSL ha.*	*Mean depth (m.)*	*Conductivity (umhos cm^{-1})*	*MEI*
Badagiriya wewa	477.9	2.3	323.75	139.67
Mahawilachchiya wewa	971.3	4.2	632.68	150.64
Minneriya wewa	2549.0	5.3	240.00	45.28
Muruthawela wewa	517.5	8.5	150.80	17.72
Nachchiyaduwa wewa	1783.9	3.1	461.40	148.84
Parakrama Samudra	2262.0	4.5	221.00	49.11
Rajanganaya wewa	1598.5	6.4	593.09	92.67
Tissa wewa	282.8	1.5	371.30	224.70
Udukiriwela wewa	261.0	1.5	143.80	95.80

TABLE 2

MSY CALCULATED BY THE SIMPLIFIED VERSION OF SCHAEFER MODEL, FISHING EFFORT NEEDED TO ACHIEVE THE CALCULATED MSY AND THE AVERAGE NUMBER OF FISHING DAYS FOR SOME INLAND RESERVOIRS OF SRI LANKA.

Reservoir	*MSY kg/ha/yr*	*Fishing effort needed to obtain MSY in fishermen days*	*Average number of fishing days per year*
Badagiriya wewa	449.44	11648	262.3
Mahawilachchiya wewa	486.03	36450	300.4
Minneriya wewa	336.56	57050	321.0
Muruthawela wewa	50.17	1800	203.0
Nachchiyaduwa wewa	953.53	27710	318.8
Parakarama Samudra	512.15	75880	327.5
Rajanganaya wewa	758.28	280750	303.5
Tissa wewa	830.31	20850	239.7
Udukiriwela wewa	134.11	3295	253.1

Students t-test indicates that this relationship is significant at 5% level. This relationship and the 95% confidence band are shown graphically in Figure 1. Estimated values of Maximum Sustainable Yield of all species using this regression equation and 95% confidence limits of these values for the nine reservoirs are given in Table 3. Recent statistics on fish catch and fishing effort of these reservoirs are given in Table 4.

When the estimated fishing effort needed to achieve Maximum Sustainable Yield (Table 2) is compared with present fishing effort (Table 4), over exploitation is evident in Badagiriya, Muruthawela and Nachchiyaduwa reservoirs. Adjusting fishing effort in these reservoirs to the level required for obtaining MSY may increase production. Conversely in Mahawilachchiya, Parakrama Samudra, Rajanganaya, Tissa and Udukiriwela reservoirs there is potential for increasing fishing effort beyond the level that existed in 1981. Although the fish catch in Minneriya reservoir during 1980 has been above the calculated value of MSY the fishing effort in 1980 is less than the calculated optimum effort. However mathematical relationship suggests that the fishing effort in this rservoir can be increased and MSY may be achieved.

Consideration of fishing effort suggested that the fish yield may be increased by adjusting fishing effort to the MSY. However the relationship between MSY and MEI suggests that there is a potential for raising fish production further by biological means in Badagiriya, Mahawilachchiya, Muruthawela, Tissa and Udukiriwela reservoirs where Maximum Sustainable Yields calculated by catch and fishing effort statistics are lower than those estimated using MEI relationship. In that event, the same fishing effort as to obtain MSY may be sustained and the number of juveniles in the population can be increased. This can be done either by releasing hatchery rared juveniles of *Tilapia sp.* or by establishing reproducing populations of *Tilapia sp.* in these reservoirs to produce required number of juveniles since the percentage of *T. mossambica* in fish catches in Sri Lanka reservoirs is over 90% (Fernando, 1971; Costa and Liyanage, 1978). The number of juveniles of *Tilapia sp.* needed to be recruited to the fish populations different reservoirs, in addition to the present recruitment, to achieve the estimated value of MSY are shown in Table 5.

The MEI can be used to estimate fish production in the lakes where the volume and temperature are fairly constant throughout the year and the ionic composition of water is dominated by carbonate and bicarbonate ions (Welcomme, 1976). Previous work has shown that these conditions prevail in the Sri Lankan reservoirs (Mendis, 1965; Amarasiri, 1973; personal observations and communications). The MEI has been considered as a very useful index to determine productivity because it can be calculated very easily. This method becomes very useful especially when detailed data on fish populations are not available.

The relationship between fish yields and MEI for some Sri Lankan reservoirs, calculated by Wijeyaratne and Costa (1981) recently, is not significant at 5% level. Another limitation of their regression relationship is that they have not used MSY for their calculations.

In all reservoirs except Parakrama Samudra, Rajanganaya and Udukiriwela, MSY calculated from catch and effort statistics are within the 95% confidence limits of the estimated MSY using MEI relationship. In the first two it is above the upper limit and in the latter it is below the lower limit. One of the reasons for this low value for Udukiriwela reservoir may be the low population densities of fish species inhabiting it. In Parakrama Samudra and Rajanganaya reservoirs, there seem to be more factors affecting the fish yields other than the chemical constitution of water and mean depth of the reservoir. The high fishing pressure and/or gradual slope of these lakes may have an effect on the fish yields. The basins of these reservoirs have very low gradients due to large surface areas and relatively low mean depths. Such slopes in shallow water provide ideal nesting habitats for *Tilapia* populations which will eventually result in an increase in the fish production in these reservoirs.

Stocking densities of *Tilapia* fingerlings calculated by Wijeyaratne and Costa (1981) Sri Lankan reservoirs, as they themselves have indicated, need to be revised when more accurate statistics on catch and effort are available. A more precise relationship between MSY and MEI and more accurate stocking densities to achieve MSY are presented here.

TABLE 3

ESTIMATED MSY USING MEI WITH 95% CONFIDENCE LIMITS FOR THE NINE RESERVOIRS.

Reservoir	*Estimated MSY kg/ha/yr*	*95% Confidence intervals of MSY kg/ha/yr.*	
		Upper limit	*Lower limit*
Badagiriya wewa	584.06	1107.32	308.06
Mahawilachchiya wewa	625.21	1223.04	319.61
Minneriya wewa	211.80	427.73	104.87
Muruthawela wewa	90.99	317.25	26.09
Nachchiyaduwa wewa	618.48	1203.63	317.82
Parakrama Samudra	227.86	443.77	116.99
Rajanganaya wewa	403.66	691.18	235.76
Tissa wewa	896.22	2148.87	373.79
Udukiriwela wewa	415.91	717.37	234.23

TABLE 4

FISH CATCH AND EFFORT STATISTICS OF THE NINE RESERVOIRS FOR 1981

Reservoir	*Fish catch kg/ha/yr.*	*Number of fishermen*	*Fishing effort fishermen days.*
Badagiriya wewa	361.92	55	14465
Mahawilachchiya wewa	483.31	112	34048
Minneriya wewa*	375.09	150	48150
Muruthawela wewa	15.73	17	3451
Nachchiyaduwa wewa	293.31	166	50796
Parakrama Samudra	251·35	195	65520
Rajanganaya wewa	331.00	231	69993
Tissa wewa	553.44	34	8306
Udukiriwela wewa	39.55	21	4977

*data for 1980

TABLE 5

ESTIMATED NUMBER OF *TILAPIA* FINGERLINGS NEEDED TO BE RECRUITED TO THE FISHERY OF SOME RESERVOIRS IN ADDITION TO THE PRESENT RECRUITMENT TO ACHIEVE THE ESTIMATED MAXIMUM SUSTAINABLE YIELDS.

Reservoir	*Number of fingerlings per hectare* at 12.5% survival	at 25% survival	at 50% survival
Badagiriya wewa	2732	1366	683
Mahawilachchiya wewa	2824	1412	706
Muruthawela wewa	828	414	207
Tissa wewa	528	264	132
Udukiriwela wewa	2860	1430	715

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