The Ecosystem of Broa Reservoir, Sao Paulo State, Brazil, as Described Using ECOPATH

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Abstract

In this paper, a model was constructed using the ECOPATH software, to describe Broa reservoir, Sao Paulo State, Brazil, in terms of material or energy flow that the organisms (compartments) interchange. This reservoir was chosen since it is probably the best-known reservoir in Brazil. The eleven compartments of this model are: phytoplankton; macrophytes; detritus; periphyton; zooplankton; benthos and fish: *Astyanax fasciatus; Geophagus brasiliensis; Gymnotus carapo; Leporinus* spp and *Hoplias malabaricus*. The results show that phytoplankton is the primary producer most used as a food source; there is little cycling of nutrients; total primary production is 40 times greater than total system respiration; there is an accumulation of detritus in the environment; and Broa reservoir is an ecosystem still under development, in terms of its ascendency and overhead. Moreover, one notes that there is a lack of information about the fish community at the reservoir. One should emphasize, however, that it is perfectly possible to construct reasonable mathematical models based only on published data and parameter estimates.

Introduction

The Lobo reservoir, commonly named Broa, was constructed for generating electrical energy in 1936 by the former Central Eléctrica de Rio Claro S.A. (SACERC), now the Centrais Elétricas de Sao Paulo (CESP). It is located in the central-east region of State of Sao Paulo, between the districts of Brotas and Itirapina (Fig. 1).

Calijuri and Tundisi (1990) classify Broa reservoir as oligomesotrophic and identify the following environmental changes caused by human activities: deforestation, domestic and fertilizers used in agricultural areas.

Broa reservoir (22°15'S; longitude: 47°49'W) is small: maximum length: 8 km; maximum width: 2 km; mean width: 0.9 km; maximum depth: 12 m; mean depth: 3 m; surface: 6 km^2; perimeter: 21 km; volume: 22 x 106 m^3. These dimensions, together with the winds and the turbulent features of the water, are responsible for the absence of a thermal stratification and a homogenous distribution of phytoplankton in the water column (Watanabe 1981).

Due to its location and easy access, Broa reservoir has relatively been well studied, mainly by researchers from UFSCar (Universidade Federal de Sao Carlos) and EESC-USP (Escola de Engenharia de Sao Carlos-Universidade de Sao Paulo).

The present study intends to take advantage of the information thus generated to construct a mass-balance model, through the program ECOPATH II (Christensen and Pauly 1993), and to offer a means of comparison with other ecosystems.

Methodology

The ECOPATH II software combines the work developed by Polovina (1984) to estimate the biomass and consumption of various elements of an aquatic ecosystem, with the theory of Ulanowicz (1986) for analysis of the flows among the elements of ecosystems. This union was initially proposed in 1987 by Pauly et al. (1993) and is described by Christensen and Pauly (1992) as a tool for the detailed analysis of mass-balance models of aquatic ecosystems.

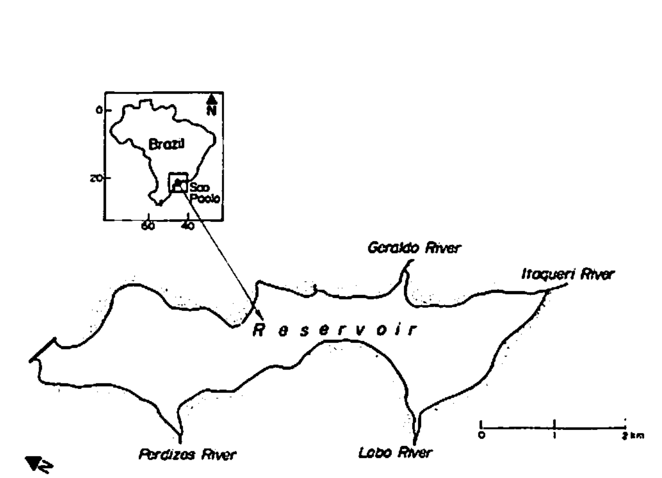

Fig. 1. Broa Reservoir (State of Sao Paulo, Brazil).

The basic concept behind the ECOPATH II model is that of mass-balance, wherein the consumption of a predator (group) generates the mortality by predation of its prey (groups). This was expressed by Christensen and Pauly (1993) as:

Consumption = Production + Respiration + Non-assimilated food

where:

Production = Export + Mortality by predation + Non-predatory mortality

which can be re-expressed as:

$$B_i * P/B_i * Ee_i - \Sigma_j (B_j * Q/B_j * DC_{ji}) - Ex_i = 0 \quad ...1$$

where:

- B_i - biomass of (i);
- P/B_i - production/biomass ratio (i);
- EE_i - ecotrophic efficiency;
- B_j - predator biomass (j);
- Q/B_j - consumption/biomass ratio of predator j;
- DC_{ji} - fraction of prey (i) in the averge diet of predator j;
- EX_i - export of (i);

Therefore, a system with *n* groups ("boxes") will have *n* linear equations. Since ECOPATH II links the different groups, it allows the estimation of one unknown parameter for each group.

For Broa reservoir, eleven compartments were identified: phytoplankton; macrophytes; detritus; periphyton; zooplankton; benthos and fish: *Astyanax fasciatus; Geophagus brasiliensis; Gymnotus carapo; Leporinus* spp. and *Hoplias malabaricus*. The estimation of parameters for equation 1 for these compartments of the model, from now on called BROA, is described in the following.

Group descriptions

1 - *Gymnotus carapo* (Gymnotidae)

The species usually feeds on larvae of benthos, insects and detritus (Soares 1979). For biomass the data used are from 1979 (Barbieri 1981). The production/biomass ratio was based on the natural mortality, calculated following Pauly (1980), with growth parameters L_∞ = 60 cm, K = 0.3 $year^{-1}$ (Barbieri and Barbieri 1983) and a mean environmental temperature of 24.7°C. The consumption/biomass ratio was calculated based on a gross food conversion efficiency (P/Q) of 0.167.

2 - *Geophagus brasiliensis* (Cichlidae)

The biomass data are from Barbieri (1974); P/B was calculated following Pauly (1980), based on the growth parameters L_∞ = 27 cm, K = 0.35 $year^{-1}$ (Lizama and Vazzoler 1993); Q/B was calculated based on Palomares and Pauly (1989) with W_∞ = 363 g and A = 0.49. The *Geophagus* diet is herbivorous and detritivorous (H_d = 1).

3 - *Leporinus* spp. (Anostomidae)

Two species of the genus *Leporinus* occur in the Broa reservoir: *L. octofasciatus* and *L. friderici*. They were considered as belonging to the same compartment, as Andrian et al. (ms.) demonstrated that four species of *Leporinus* (including *L. friderici*) occupy the same trophic category in the Parana River. This group, as well as being herbivorous, consumes insects; its biomass was estimated using the study of Barbieri and Barbieri (1991) and Barbieri and Garavello (1981). P/B was calculated following Pauly (1980), based on the growth parameters L_∞ = 38 cm, K = 0.25 $year^{-1}$ (Lizama and Vazzoler 1993) while Q/B was calculated using a GE value of 0.16.

4 - *Hoplias malabaricus* (Erythrinidae)

This fish is exclusively carnivorous (and cannibalistic), and its estimate of B refers to 1979 (Barbieri et al. 1982). Q/B was estimated based on Palomares and Pauly (1989), with parameters: W_∞ = 700 g; A = 1; and Hd = 0.1. P/B was calculated using a GE = 0.223.

5 - *Astyanax fasciatus* (Characidae)

Biomass was estimated based on Barbosa (1982) and Barbosa and Matsumura-Tundisi (1984); diet composition is based on the latter paper and is basically zooplanktonic. Q/B was based on Palomares and Pauly (1989), with parameters W_∞ = 98 g and A = 2.56. P/B was estimated based on GE = 0.225.

6 - Benthos

The estimate of biomass was obtained from Strixino (1973), and the P/B ratio is from Jϕrgensen et al. (1979). Value of GE = 0.091 was used to estimate Q/B.

7 - Zooplankton

Matsumura-Tundisi et al. (1989) and Tundisi (1977) found that the biomass of zooplankton in Broa reservoir can be divided in three main groups: Copepoda, representing 81% of the biomass of zooplankton; Cladocera (13.8%) and Rotifera (5.4%). Their P/B ratio was obtained from Angelini et al. (ms.) based on the copepod *Argyrodiaptomus furcatus*, which contributes 79% to biomass, referring to the years 1983-1984 and obtained from Matsumura-Tundisi et al. (1989). GE used for the calculation of QB, was assumed to be 0.154 (mean of values in Christensen and Pauly 1993). The diet of this group is composed exclusively of phytoplankton.

8 - Phytoplankton

The data are from Tundisi et al. (1977) and refer to the period of 1972-1973. P/B was calculated from the ratio of primary production to biomass.

9 - Macrophytes

The importance of macrophytes in Broa reservoir was pointed out by Barbieri (1984) and Silveira-Menezes (1984). The data are from the latter author. P/B was calculated as for the phytoplankton. The macrophytes occur only in one area of Broa reservoir. For simplicity's sake, it was however assumed that they were spread out over the whole reservoir.

10 - Periphyton

The periphyton of Broa reservoir use the macrophytes as substrate. The data were from Soares (1981) and refer to the years 1978-1979. P/B was calculated as for the phytoplankton.

11 - Detritus

ECOPATH II estimated all parameters for this group.

12- Other Features of the Model

Wet mass (g ww·m^{-2}) was used as unit. Since there was no estimation of fishing and emigration of fish from the reservoir, these elements are not included in the model. Annual primary production,

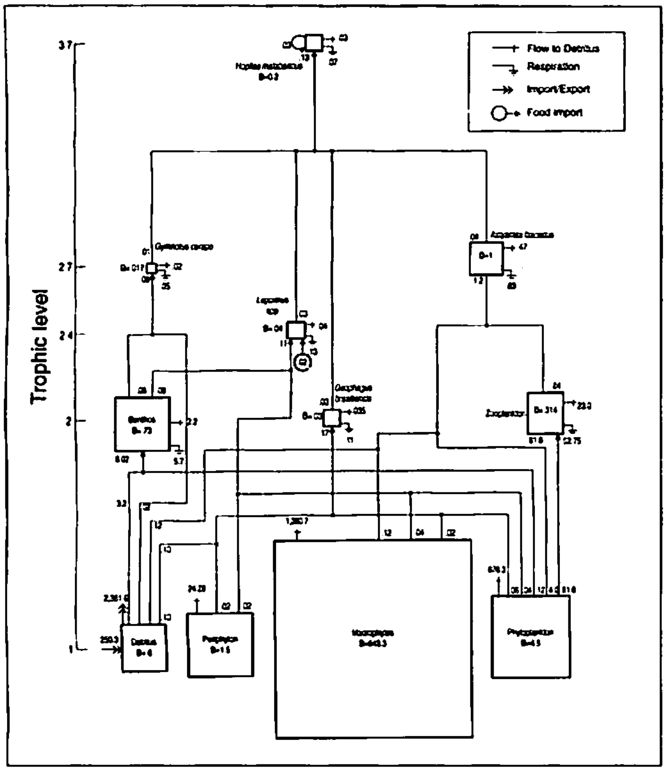

Fig. 2. Food web of Broa reservoir (Brazil). Flows are expressed in g ww·m⁻²·year⁻¹. The Y axis represents the trophic levels. The size of the boxes is proportional to the biomass of the compartments.

which includes the production by macrophytes, phytoplankton and periphyton was 2421 g ww·m^{-2}.

Results and Discussion

The data entered for the compartments are recalled in Table 1, and the diet composition matrix is shown in Table 2. Table 3 and Figs. 2, 3 and 4 show the main output of ECOPATH II.

In general it can be observed that the Ecotrophic Efficiency (EE) of the groups with trophic levels less than or equal to 2.0, is very low. This is due to several reasons:

i) The difference between the Total Primary Production estimated independently (TPP) and the Primary Production calculated by ECOPATH II (TPP') represents a flow to the detritus (251 g ww m^{-2}·year^{-1}). The detritus also receives flows from all the other components (Fig. 2), totaling 2 365 g ww m^{-2}·year^{-1}). A compartment that receives a large amount of energy and does not transfer it to the other part of the trophic web has a low trophic efficiency. It is interesting to note that with such a high import of detritus, the "need" for recycling in the system is low. Finn's Index (of detritus recycling) is thus near zero.

ii) The macrophytes, with the largest biomass of the system (648 g ww·m^{-2}) lose their production to the detritus due to the lack of appropriate herbivores.

iii) Although phytoplankton is the primary producer most utilized as a food source (87 g ww m^{-2}·year^{-1}), it also has a low ecotrophic efficiency (EE=0.11) due to its very high rate of productivity (P/B = 170 g ww m^{-2}·year^{-1}).

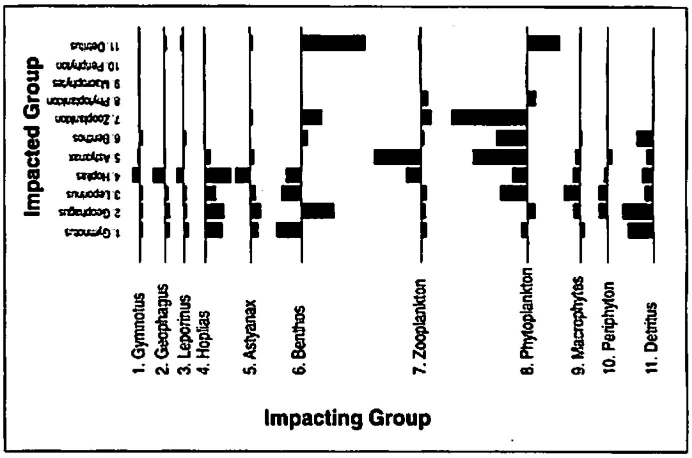

Fig. 3 - Mixed trophic impacts in the Broa reservoir (Brazil) food web. Positive impacts are shown above the baseline, negative below. The impacts are relative and comparable between groups.

Table 1. Input values and results of ECOPATH II modeling. The P/B and Q/B give production/biomass ratio and consumption/biomass ratios, respectively, both in year⁻¹. EE is the ecotrophic efficiency, i.e., the proportion of the production that is consumed by predators or exported, while GE is the gross food conversion efficiency (P/Q). Flows are in g ww·m⁻²·year⁻¹ and biomass in g ww·m⁻². Input values are without brackets; computed estimates are in brackets.

Compartment	Biomass	PB	QB	EE	GE
1 - *Gymnotus carapo*	0.017	0.8	(4.8)	(0.956)	0.167
2 - *Geophagus brasiliensis*	0.03	0.9	5.7	(0.963)	(0.158)
3 - *Leporinus* spp	0.04	0.8	(5.0)	(0.813)	0.160
4 - *Hoplias malabaricus*	0.02	(1.45)	6.5	(0.897)	0.223
5 - *Astyanax fasciatus*	0.1	(2.7)	12.0	(0.144)	0.225
6 - Benthos	0.729	1.0	(11.0)	(0.188)	0.091
7 - Zooplankton	0.314	40.0	(260.0)	(0.067)	0.154
8 - Phytoplankton	4.5	170.0	-	(0.113)	-
9 - Macrophytes	648.2	2.13	-	(0.000)	-
10 - Periphyton	1.501	16.2	-	(0.002)	-
11 - Detritus	-	-	-	(0.001)	-

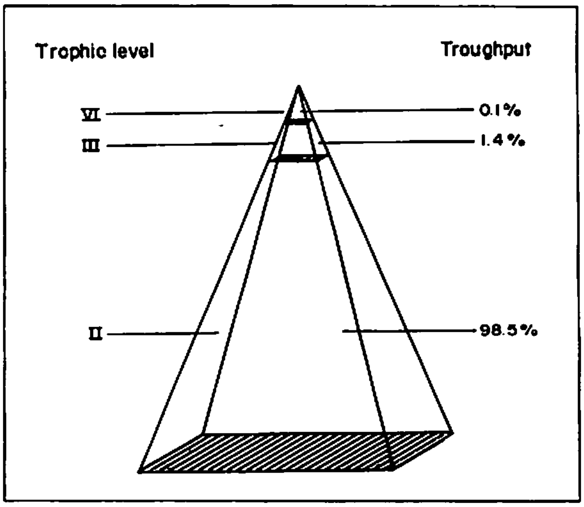

Fig. 4. Modified Lindemann pyramid of the flows in the Broa reservoir (Brazil). The volume of each discrete trophic level is proportional to the throughput (total flow) at that level.

Table 2. Matrix of the diet composition (DCji) of the predator (rows) against the preys (columns) for the BROA model. The sum of the rows is 100%.*

GR	1	2	3	4	5	6	7	8	9	10	11
1	-	-	-	-	-	70	-	-	-	-	30
2	-	-	-	-	-	-	-	20	10	10	60
3	-	-	-	-	-	40	-	20	20	10	10
4	10	20	20	20	30	-	-	-	-	-	-
5	-	-	-	-	-	-	70	10	10	-	10
6	-	-	-	-	-	-	-	60	-	-	40
7	-	-	-	-	-	-	-	-	100	-	-

*The groups are: 1 - *Gymnotus carapo*; 2 - *Geophagus brasiliensis*; 3 - *Leporinus* spp.; 4 - *Hoplias malabaricus*; 5 - *Astyanax fasciatus*; 6 - Benthos; 7 - Zooplankton; 8 - Phytoplankton; 9 - Macrophytes; 10 - Periphyton; 11 - Detritus.

Table 3. Summary statistics of the net flow for the BROA model. Biomass are in g $ww{\cdot}m^{-2}$, flows in g $ww{\cdot}m^{-2}{\cdot}year^{-1}$.

Total Consumption (CT)	91.4
Total Export (TEX)	2 361.5
Total Respiration Flow (TR)	59.5
Total Detritus Flow (TDET)	2 365.0
Total System Throughput (T)	4 877.4
Total Production (TP)	2 183.8
Primary Production: independent estimate	2 421.0
Primary Production: calculated by ECOPATH II	2 170.2
Total Primary Production/Total Respiration	40.69
Net production of system (PLS)	2 361.50
Total Primary Production/Total Biomass	3.693
Total Biomass/Total Transfer	0.134
Total Biomass (excluding Detritus) (BT)	655.5
Connectance Index	0.22
System Omnivor, Index	0.05

Leontief's matrix

As represented in Fig. 3, Leontief's matrix shows that the impact of the increase of biomass at time t in a group row can cause on the others (column) at time t+1. As it were, this matrix thus ends up working as a sensitivity analysis for the model. One notes, for example, that:

a) 8-Phytoplankton is the group that modifies the others most. In this simulation, even the biomass of group 11-(Detritus) is altered. This is because the increase in phytoplankton enlarges the biomass of detritus consuming fish as well as that of the group 6-(Benthos);

b) An increase in predation by 4-(*Hoplias*) reduces all the biomasses of its prey and drastically decreases its own biomass. This is caused by the diminished prey, a greater intra-group competition and an increase of cannibalism in this group;

c) An increase in 11-(*Detritus*) also augments the biomass of 4-(*Hoplias*). This illustrates the indirect effects that this analysis is able to detect. Thus, there is an increase in the biomass of 4-(*Hoplias* prey) that feed on detritus (1-*Gymnotus*, 2-*Geophagus*, 3-*Leporinus*, 5-*Astyanax*), from which it eventually benefits.

Lindemann's pyramid

Fig. 4 shows the Lindemann's pyramid for BROA. It is large compared to, e.g., Tongoy Bay, Chile (Wolff 1994). As might be seen, the ecosystem of Broa reservoir concentrates 98.5% of its total fluxes in trophic level II, and only 1.1% of the energy which enters in TL II is sent to TL III; from this only 4.6% is sent to TL IV. These values are much lower than the 15% transfer efficiency normally found in lakes (Christensen and Pauly 1993). This is due to the absence of appropriate consumers in the system.

Network analysis

Christensen and Pauly (1991), linked some of the values calculated by ECOPATH with some of the 24 characteristics of Odum (1969), to determine the stage of the evolution of ecosystems. Table 6 shows the results and marks the stage in which BROA is found.

In this context, we propose the use of a new attribute, the ratio TB/TDET, which indicates how much of the biomass is transformed into organic material. If this ratio is close to 1, all the organisms will be

Table 4. Odum's ecosystem attributes, ECOPATH estimates and status of BROA.

Item	Developing*	Mature **	ECOPATH*	BROA
1 - P/R	<1>	=~1~	TPP/TR	40.7*
2 - P/B	high	low	TPP/TB	3.7*
3 - B/E	low	high	TB/T	0.134*
4 - Net Production	high	low	PLS	2170.6*
5 - Food chains	linear	weblike	IC	0.22*
6 - Organic matter	small	=~1~	TB/TDET	0.27*
12 - Niche specializ.	broad	narrow	IO	0.057*
Nutrient cycling				
15 - Mineral cycles	open	closed	IF	0.0*
17 - Detritus	unimportant	important	TDC/CT	3.4%*
selection pressure	developing	mature	ECOPATH	BROA
18 - Growth from	"r"	"K"	TB/T	0.134*
Overall homeostasis	developing	mature	ECOPATH	BROA
21 - Nutrient conserv.	poor	good	IF	0.0*
22 - Stability	poor	good	O	43.3%*
23 - Entropy	high	low	TE/TB	0.09*
24 - Information	low	high	A	56.7%*

*TPP/TR: Total Primary Production/Total Respiration; TPP/BT: Total Primary Production/Total Biomass; TB/T: Total Biomass/Total Transfer; PLS: Net Production of the System; IC: Index of Connectivity; IO: Omnivore Index; IF: Finn Index (recycling); A: Ascendency; O: Overhead; TR/TB: Total Respiration/Total Biomass; TB/TDET: Total Biomass/Total Flow for Detritus; TDC/CT: Total Consumption of Detritus/Total Consumption.

recycling rapidly and the system will have reached a mature state. If the rate differs from 1, the ecosystem is still developing; the value of TB/TDET for BROA confirms its developing status.

Ascendency

Ulanowicz (1986), developed a new interpretation on the structure and dynamics of ecosystems. According to this, the growth of the system is not due to a simple increase in biomass, but to the number of compartments and mainly, to the amount of flows between them. He developed the concepts of ascendency, overhead and development capacity to quantify the development stage of ecosystems. BROA presented the following results: Ascendency (A) = 56.7% and Overhead (O) = 43.3%. Since these values are intermediate, both for the energy used (A) and for the so-called reserve energy of the system (O), this confirms that BROA is an ecosystem under development. The BROA concentrates its reserve energy on the internal flows (O = 33.8%). For the compartments, the greatest value of Overhead belongs to the phytoplankton and macrophytes. It is as if these compartments were not being used adequately, and constitute a reserve of energy for the system.

Conclusion

The following generalizations can be offered to describe BROA: phytoplankton is the most important primary producer of the reservoir; the cycling of nutrients is low; the energy from the primary producers is not used adequately by the system; an accumulation of detritus, originating mainly from the macrophytes, is occuring in the reservoir.

The Total Biomass/Total Flow for Detritus (TB/TDET), is a good estimator of the importance of the organic material of the system; the Total Consumption of Detritus/Total Consumption (TDC/CT), can be used to quantify attribute 17 of Odum (1969); Broa reservoir is an ecosystem under development; however it possesses a great amount of reserve energy (Overhead), showing that it is a system that can support unpredictable disturbances, for example, it may be colonized by detritivores or herbivores species feeding at Trophic Level I. So, the system may allow the installation of fishpens (enclosures for culturing fish) with herbivorous fishes, as in Laguna de Bay, Philippines (Delos Reyes 1993).

In order to improve the BROA model, the following monthly work should be conducted:

FISH: Identification of all the species of fish in the reservoir through experimental fisheries at different localities of the reservoir for one annual cycle; determination of the diet of the fish by analysis of stomach contents; collection, during a period of 24 hours, of fish with the purpose of using the changes in the stomach contents for estimating food consumption (i.e., Q/B).

OTHER COMPARTMENTS: Intensify the studies for the compartments of bacterioplankton; protozoans, oligochaetes, in terms of biomass, growth and in relation to other compartments.

Though they have shortcomings, models such as that presented here are extremely useful. Without them, interdisciplinary studies are not possible, as the different projects of the same program may stay unconnected, without the possibility of organic linkages.

References

Andrian, I.F., C.R.C. Doria, G. Torrente, C.M.L. Ferreti. Espectro alimentar e similaridade na composiçao da dieta alimentar de quantro especies de *Leporinus* (Characiformes, Anostomidae) do Rio Paraná (22 10' - 22 50' S e 53 40' W). (Ms.)

Angelini, R., M.A.P. Abuabara, C. Rietzler. Application of De Bernardi and Di Cola's model in a *Argyrodiaptomus furcatus* population (zooplankton - copepod) from Broa Reservoir (Sao Carlos, Sao Paulo, Brazil). (Ms.)

Barbieri, G. 1974. (Quoy & Gaimard *Crescimento do Geophagus brasiliensis, 1824)* na Represa do Lobo. IB - Universidade de Sao Paolo, Sao Paulo, Brazil. 111 p. Dissertaçao de Mestrado.

Barbieri, G. and J.C. Garavello. 1981. Sobre a dinamica da reoriduçao e da nutriçao de *Leporinus friderici* (Bloch, 1794) na represa do lobo, Brotas-Itirapina (SP), (Pisces, Anastomindae). II Sem. Reg. Ecol. 347-387.

Barbieri, G., J.R. Verani, M.C. Barbieri. 1982. Dinamica qantitativa da nutriçao de *Hoplias malabaricus* (Bloch, 1794), na rpresa do lbo (Brotas-Itirapina, SP). (Pisces, Erythrinidae). Rev. Brasil. Biol. 42(2):295-302.

Barbieri, G. and M.C. Barbieri. 1983. Growth and first sexual maturation size of *Gymnotus carapo* (Linnaeus, 1758) in the Lobo reservoir (State of Sao Paulo, Brazil) (Pisces, Gymnotidae). Rev. Hydrobiol. Trop. 16(2):195-201.

Barbieri, G. and M.C. Barbieri. 1991. Biologia reprodutiva de femeas de *Leporinus octofasciatus* Steindachner, 1915 (Characiformes, Anostomidae) da Represa do Lobo, Sao Paulo. Notas Preliminares. An. Sem. Reg. Ecol. VI:293-301.

Barbieri, M.C. 1981. Contribuiçao ao estudo da biologia de *Gymnotus carapo* (Linnaeus, 1758) na Represa do Lobo, Estado de Sao Paulo (Pisces, Ostariophysi, Gymnotidae). Departamento de Ciencias Biológicas, Universidade Federal Sao Carlos, Sao Paulo. Tese de Doutorado.

Barbieri, R. 1984. Estudo da composiçao quimica de algumas espécies de macrófitas aquáticas e suas implicaçoes no metabolismo da represa do Lobo (Broa). Departamento de Biociencias, Universidade Federal Sao Carlos, Sao Paulo. 225 p. Dissertaçao de Mestrado.

Barbosa, P.M. 1982. Predaçao dos organismos zooplanctônicos pelo *Astyanax fasciatus* Cuvier, 1819 (Osteichthyes, Characidae) na represa do Lobo ('Broa') Sao Carlos. Departamento de Biociencias, Universidade Federal Sao Carlos, Sao Paulo. Dissertaçao de Mestrado.

Barbosa, P.M. and T. Matsumura-Tundisi. 1984. Consumption of zooplanktonic organisms by *Astyanax fasciatus* Cuvier, 1819 (Osteichthyes, Characidae) in Lobo (Broa) Reservoir, Sao Carlos, SP, Brazil. Hydrobiologia 113:171-181.

Calijuri, M.C. and J.G. Tundisi. 1990. Limnologia comparada das represas do Lobo (Broa) e Barra Bonita - Estado de Sao Paulo: mecanismos de funcionamento e bases para o gerenciamento. Rev. Brasil. Biol. 50(4): 893-913. R.J.

Christensen, V. and D. Pauly. 1991. A guide to the ECOPATH II Software System (version 2.0). ICLARM Software 6, 72 p.

Christensen, V. and D. Pauly. 1992. ECOPATH II - a software for balancing steady-state ecosystem models and calculating medeval characteristics. Ecol. Modelling 61:169-185.

Christensen, V. and D. Pauly, Editors. 1993. Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26, 390 p.

Jørgensen, S.E., M.B. Friis, J. Henriksen, L.A. Jørgensen and H.F. Mejer, Editors. 1979. Handbook of environmental data and ecological parameters. Pergamon Press, Oxford. 1162 p.

Lizama, M.L.A.P. and A.E.A.M. Vazzoler. 1993. Crescimento em peixes do Brasil: uma sintese comentada. Rev. UNIMAR 15 (supl.): 141-173.

Matsumura-Tundisi, T., A.C. Rietzler and J.G. Tundisi. 1989. Biomass (dry weight and carbon content) of plankton crustacea from Broa reservoir (Sao Carlos, S.P. - Brazil) and its fluctuation across one year. Hydrobiologia. 179:229-236.

Odum, E.P. 1969. The strategy of ecosystem development. Science 104: 262-270.

Palomares, M.L.D. and D. Pauly. 1989. A multiple regression model for predicting the food consumption of marine fish populations. Austral. J. Mar. Freshw. Res. 40:259-273.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. J. Cons. CIEM 39(3):175-192.

Pauly, D., M. Soriano and M.L. Palomares. 1993. Improved construction, parametrization and interpretation of "steady-state" multispecies models, p. 1-13. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystem. ICLARM Conf. Proc. 26, 390 p.

Polovina, J.J. 1984. Model of a coral reef ecosystem. Part I. The ECOPATH model and its application to French Frigate Shoals. Coral Reefs 3:1-11.

Delos Reyes, M.L. 1993. Fishpen culture and its impact on the ecosystem of Laguna de Bay, Philippines, p. 74-84. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26, 390 p.

Silveira-Menezes, C.F. 1984. Biomassa e productividade primária de 3 espécies de macrófitas aquáticas da Represa do Lobo (Broa), SP. Departamento de Ciências Biológicas. Universidade Federal Sao Carlos, Sao Paulo. 250 p. Dissertaçao de Mestrado.
Soares, J.J. 1981. Estudos sobre a biomassa e produtividade de perifiton em marcófitas na represa do Lobo, Sao Carlos (SP). Departamento de Ciências Biológicas, Universidade Federal Sao Carlos, Sao Paulo. 223 p. Tese de Doutorado.
Soares, M.G.M. 1979. Aspectos ecológicos (alimentaçao e reproduçao) dos peixes do Igarapé do Porto, Aripuana, M.T. Acta Amazôn. 9(2):325-352.
Strixino, G.B.M.A. 1973. Sobre a ecologia dos macroinvertebrados do fundo na represa do Lobo. Departamento de Biologia, Universidade de Sao Paulo, Sao Paulo. Tese de Doutorado. 188 p.
Tundisi, J.G. 1977. Produçao primária, "standing-stock", fracionamento do fitoplancton e fatores ecológicos em ecossistema lacustre artificial (represa do Broa, Sao Carlos). Departamento de Biologia - Ribeirao Preto, Universidade de Sao Paulo, Sao Paulo. 409 p. Tese de Livre-Docência.
Tundisi, J.G. 1986. The Lobo (Broa) ecosystem. Cienc. Interam. 25: 18-31.
Tundisi, J.G.; T.M. Tundisi O. Rocha, J.G. Gentil and N. Nakamoto. 1977. Primary production, standing-stock of phytoplankton and ecological factors in a shallow tropical reservoir (Represa do Broa, Sao Carlos, Brasil). Sem. Medio Ambient. Rep. (1)138-172.
Ulanowicz, R.E. 1986. Growth and development: ecosystem phenomenology. Springer Verlag, New York. 203 p.
Watanabe, T. 1981. Flutuaçao sazonal e distribuiçao do nano e microfitoplancton na represa do Lobo (Broa), Sao Carlos (SP). Depto. de Ciência Biológicas, Universidade Federal Sao Carlos, Sao Paulo. Dissertaçao de Mestrado. 157 p.
Wolff, M. 1994. A trophic model for Tongoy Bay - a system exposed to suspended scallop culture (Northern Chile). J. Exp. Mar. Biol. Ecol. 182:149-168.

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Fishbyte News Items

Announcements

The Spanish version of the stock assessment manual, *Introducción a la evaluación de recursos pesqueras tropicales*, is ready for distribution. Copies have already been distributed to FAO (or UNDP) representatives of Spanish-speaking countries in Latin America. Those who have received Part 2 (Exercises) should automatically get Part 1 (Manual). A surplus stock of the English version of the Manual and exercises will be distributed to NTFS members in English-speaking countries. There are less copies of Part 2, so preference will be given to those from developing countries. For NTFS members who are interested to obtain copies of the Spanish version, please contact your local FAO or UNDP office, or the FAO Regional Office in Santiago, Chile (Fax: 0056-2-6961121; e-mail: FAO-RLC@field.fao.org), or Mr. Siebren Venema, Project Manager, Fishery Resources Training Project, FAO/DANIDA Project GCP/INT/575/DEN, FAO Fisheries Department, Via delle Terme di Caracalla, 00100 Rome, Italy (e-mail: Siebren.Venema@fao.org). The English version is also available from these sources.

The Second World Fisheries Congress titled, "Developing and Sustaining World Fisheries Resources: the State of Science and Management", will be held on 28 July to 2 August 1996 at the Brisbane Convention & Exhibition Centre, Brisbane, Queensland, Australia. Congress activities will include poster presentations, oral presentations of papers, and a scientific trade and services exhibition. Papers presented will be published in Volume II of the congress proceedings. Representatives from all fisheries professions are invited to attend, as well as associated groups interested in sustainable fisheries resources development and management around the world. For more information, contact the Congress Secretariat, Second World Fisheries Congress, PO Box 1280, Milton Brisbane, Qld 4064, Australia. Tel. +617 369 0477; Fax: +617 369 1512; e-mail: im@cc.uq.oz.au.

With the objective of bringing together scientists and managers together to exchange knowledge about the processes and consequences of stock enhancement and sea ranching, and to identify the most important priorities for future research, the First International Symposium on Stock Enhancement and Sea Ranching will be held in Bergen, Norway on 8-11 September 1997. The organizers invite papers on stock enhancement and sea-ranching that contribute to knowledge of the application, cost-benefit and ecological impact of these fisheries management measures, as well as contributions on marine fish, crustacea and molluscs, and salmonids. For more details, please contact the Convener, E. Moksness, Institute of Marine Research, Flødevigen Marine Research Station, N-4817 His, Norway; Fax: +47 37 05 90 01; e-mail: erlend.moksness@flode.imr.no.

News on NTFS Members

Drs. Daniel Pauly and John McManus have been nominated to join the new Working Group (WG 105) on The Impact of World Fisheries Harvest on the Stability and Diversity of Marine Ecosystems, established by the Executive Committee of the Scientific Committee on Oceanic Research (SCOR). WG 105 will be chaired by Dr. Michael Sinclair of the Bedford Institute of Oceanography, Dartmouth, Canada.

Recent Publications by NTFS Members

Siddeek, S.M. and R.M. Baldwin. 1996. Assessment of the Oman green turtle (*Chelonia mydas*) stock using a stage-class matrix model. Herpetological J. 6:1-8.

Pauly, D. 1996. ITQs: the assumptions behind the meme. Rev. Fish Biol. Fish. 6(1):109-112.

Pauly, D. 1996. One hundred million tonnes of fish, and fisheries research. Fish. Res. 25(1):25-38 (25th anniversary issue).