Fish distribution and density investigated by quantitative echosounding - Some ecological aspects of the fish fauna in three Portuguese reservoirs.

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PREFACE

The present work is a part of a larger limnological study of the Alentejo reservoirs conducted by the "Instituto Nacional de Investigação das Pescas", Portugal. The report presents data from field work carried out during the period 2.5 - 12.5.1985. From a professional point of view, it was of special interest to include fishery research in the study, and a joint programme was started between the "Instituto Nacional de Investigação das Pescas and the "Laboratory for Freshwater Ecology and Inland Fisheries", University of Oslo, Norway. We acknowledge financial support from both institutions and for all the facilities providing during this study.

We are very thankful to M.J.C. Pereira and M. Coelho, University of Lisbon, for assistence with fish species identification, and to the excellent Portuguese field team: A. Morais, A.M. Correia and L. Martins. Thanks are also due to J.E. Brittain and to T. Lindem, both at the University of Oslo, for respectively correcting the English and for analysing the hydroacoustic recordings.

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During the period 2-12.5.1985 hydroacoustic research was carried out along selected transects with the echosounder SIMRAD EY-M in three Portuguese reservoirs, Divor, Maranhão and Montargil, in the Tejo river system. The equipment records echosignals on magnetic tapes and enables subsequent analysis on a microcomputer for calculating fish density in different water layers and for interpretation of individual fish size. To relate the relative length-frequency diagrams to known fish species and size classes, fishing was carried out at different water depths using pelagic floating and littoral gill nets. Age and growth, feeding, length/weight regressions are presented for the most abundant fish species. Fish species interactions and behaviour of the most important species are also discussed.

In all three reservoirs, the number of fish species in the pelagic zone was low. Sunfish (Lepomis gibbosus) dominated in Divor and Montargil, while carp (Cyprinus carpio) and nase (Chondrostoma polylepis) dominated in Maranhão. Since the structure of the earlier fish community (river community and period after damming) have not been described, we can only focus on the present fish community and discuss the differences between the investigated reservoirs.

In Divor, the only fish in the pelagic zone was sunfish, documented by pelagic gill nets, and echosounding. Fish were not observed during night in the pelagic zone, reflecting the general day-pelagic activity of this species. The pelagic tendency is confirmed by high zooplankton consumption. The lack of available benthic animals is indicated both by the high consumption of zooplankton even by sunfish caught in the

littoral zone, and by the benthivorous feeding behaviour of carp, confirmed by gut contents containing largely vegetative food items. The one individual of spined loach, Cobitis taenia caught in Divor confirms its expected presence, since this shallow lake allows this species to survive in the substrate due to oxygen requirements and the substrate consistence.

In Montargil fish density was highest during the day along all the investigated transects. During the day, fish density varied between 1312 and 4386 fish ha^{-1} and during the night between 251 and 1840. In Montargil and Divor, sunfish also clearly showed a diurnal horizontal migration between littoral and pelagic parts of the lakes, moving to the littoral zone during the night. In Montargil sunfish was the only species caught in gill nets. However, the presence of larger species (probably carp) was clearly observed by the echosounder.

In Maranhão, fish density varied between 1840 and 3433 fish ha^{-1} during the night. In Maranhão and Montargil reservoirs and along all transects, fish density was clearly highest in the upper 5 m immediatly below the water surface. Dominance of echosignals of target strength dB 40 - dB 38 indicate epi-limnetic distribution of carp, as this dB interval showed fish of size class larger than approx. 25 cm. On the basis of length-weight regressions of the most abundant fish species in the reservoirs, fish density varied between 335 - 513 kg ha^{-1} in Maranhão during the night, while in Montargil between 16 - 111 kg ha^{-1} during the night and between 247 - 1072 kg ha^{-1} during the day.

In the Maranhão reservoir, carp and nase were both planktivorus, their gut contents being completely dominated by zooplankton (>98% Daphnia). Sunfish was only observed in the littoral zone, but fed also here to a large extent on zooplankton, indicating the low availability of other food items. In the Divor reservoir, carp was feeding on the bottom, and food items were mostly plant detritus, with few chironomide larvae. In Divor, largemouth bass, Micropterus salmonoides, fed on 0+ sunfish, probably when sunfish moved into the littoral zone during the night. In Montargil, sunfish were planktivorous mainly feeding on Daphnia.

In Divor, the previously documented shift in zooplankton dominance from Daphnia longispina to the more predation resistent species Bosmina longirostris, and the high planktivorous tendency of sunfish in general, indicate that this fish species are an important regulating factor in zooplankton abundance and species composition.

Fish migration patterns between littoral and pelagic parts of the reservoirs are also discussed in relation to some environmental conditions. During the investigated period, stratification was not yet established, and well oxygenated water was present at all depths in the three reservoirs.

PORTUGUESE ABSTRACT

Durante o periodo de 2-12/5/85 foi efectuado um rastreio hidroacústico com a ecosonda SIMRAD EY-M em 3 albufeiras portuguesas-Divor, Maranhão e Montargil - que fazem parte da bacia hidrográfica do rio Tejo. O respectivo equipamento regista sinais acústicos em fita magnética e a posterior sua análise em microcomputador, permite o cálculo da densidade de peixe em diferentes camadas de água e a interpreção do tamanho individual dos peixes. Foi efectuada pesca a diferentes profundidades, usando redes de emalhar na zona pelágica e no litoral, com o objectivo de relacionar os diagramas de frequências relativas de comprimento com as espécies piscicolas conhecidas e as classes de tamanho.

Apresentam-se regressoes para idade, crescimento, alimentação, comprimento e peso, para as espécies piscicolas mais abundantes. As interacçoes entre as espécies e o comportamento das mais importantes são também discutidas.

A diverdidade de espécies piscicolas na zona pelágica das três albufeiras é baixa. Enquanto a perca sol (Lepomis gibbosus) foi a espécie dominante no Divor e Montargil, a carpa (Cyprinus carpio) e a boga (Chondrostoma polylepis) dominaram no Maranhão. Dado que a estrutura da comunidade piscicola autóctone (comunidade do rio e do periodo após enchimento da albufeira) não se encontra descrita, apenas nos podemos concentrar na comunidade piscicola presente e discutir as diferenças entre as albufeiras estudadas.

A única espécie presente na zona pelágica do Divor, quer registada na ecosonda quer capturada nas redes pelágicas, foi a perca sol. Durante a noite não foi observado peixe na xona pelágica, o que reflecte de um modo geral uma actividade pelágica dessa espécie durante o dia. Este tipo de tendência é confirmado pelo grande consumo de zooplancton. A ausência de organismos bentónicos disponiveis é indicada quer pela quantidade elevada de zooplancton consumida pela perca sol na

zona litoral, quer pela grande quantidade de detritos vegetais encontrados nos conteúdos estomacais da carpa. Foi encontrado no Divor um único indivíduo Cobitis taenia, como se previa, dado a baixa profundidade desta albufeira permitir a sobrevivência desta espécie no sedimento, devido às suas necessidades de oxigénio e à consistência do respectivo substrato.

Em Montargil a densidade de peixes foi mais elevada durante o dia ao longo de todos os perfis investigados. A densidade variou entre 1312 e 4386 peixes ha^{-1} durante o dia, e entre 251 e 1840 durante a noite.

Em Montargil e Divor a perca sol apresentou uma migração diurna horizontal entre o litoral e a zona pelágica, movendo-se para as zonas litorais durante a noite. Em Montargil para além da a perca sol espécies de maior tamanho (provavelmente carpa) foram nitidamente observadas na ecosonda. No Maranhão a densidade de peixes variou entre 1840 e 3433 peixes ha^{-1} durante a noite. Nas albufeiras do Maranhão e Montargil e ao longo de todos os perfis a densidade foi nitidamente mais elevada nos 5m abaixo da superfície da água. A predominância de ecotraços com um-índice de reflexão entre 38-40 dB, indica a distribuição da carpa nas camadas superiores, dada que o intervalo de dB mostra a presença de peixe de classe de tamanho superior a aproximadamente 25 cm. Com base nas regressoes comprimento-peso das espécies mais abundantes nas albufeiras, a biomassa variou no Maranhão, entre 335-513 kg ha^{-1} durante a noite e entre 247-1072 kg ha^{-1} durante o dia.

Na albufeira do Maranhão verificou-se que a carpa e a boga são planctívoros, apresentando-se os seus conteúdos estomacais totalmente dominados por zooplancton (98% Daphnia). A perca sol foi observada apenas na zona litoral, alimentando-se também aqui essencialmente de zooplancton, o que indica fraca disponibilidade de outro tipo de alimento. Por outro lado, na albufeira do Divor a carpa alimentava-se de detritos de fundo, essencialmente detritos de plantas, e algumas larvas de chironomide. Nesta albufeira a perca sol 0+ foi a presa dominante do achigã (Micropterus salmonoides) possivelmente quando durante a noite se deslocava para as zonas litorais. No Montargil a perca sol apresentou-se essencialmente plantivora constituindo a Daphnia a sua presa dominante.

No Divor, a mudança na espécie dominante zooplantónica de D. longispina para a B. longirostris, mais resistente à predação, e em geral a grande tendência planctivora da perca sol, indicam que esta espécie piscicola é um factor importante de controle na abundância e composição do zooplancton.

E também discutida neste trabalho a relação entre os comportamentos migratórios das espécies piscicolas e determinadas condiçoes ambientais. Durante este periodo a ausência de estratificação e as condiçoes de oxigenação nas camadas de água mais profundas apresentam-se como factores favoráveis às tendências migratórias discutidas.

INTRODUCTION

The three reservoirs studied have in common some fish species of their original Iberian river community now adapted to the lentic conditions and the introduced fish species: Mirror carp (Cyprinus carpio) and two centrachid species; sunfish (or pumpkinseed, Lepomis gibbosus) and largemouth bass (Micropterus salmonoides). The wild carp is an original species in these systems.

The dates of the introductions of sunfish and largemouth bass in Portugal and to the present reservoirs is not well documented. However, local fishermen affirmed that introduction to the reservoirs of the sunfish only took place about five years ago, while that of largemouth bass as early as 1965. According to Almaça (1983), sunfish was very common in parts of the Tejo basins based on results from 1962 - 1977. Anyway, its spreading seems very successsful, and may have important impact on competitors as well as on other ecological effects. The development of the populations has occurred under quite different interspecific conditions and abiotic factors such as trophic status and water level fluctuations, which have affected the composition of the fish fauna.

The fish species present have different responses to increased trophic level, anoxic hypolimnion, sediment structure, development of macrophytes and availability of main food items such as zooplankton, zoobenthos and macrophytes. The aim of this study was to describe the pelagic and littoral fish community in the three reservoirs, their diurnal behaviour, especially migration patterns between littoral and pelagic areas or vertical migrations between epi- and hypolimnion. Pelagic fish density was estimated in selected water depth layers by a quantitative echosounding method, and vertical fish distribution related to chemical and physical parameters is discussed. Age structure, growth and feeding of sunfish, largemouth bass, Iberian nase and carp are presented as well as interspesific feeding relationships. These are based only on spring samples.

STUDY AREA

The Divor, Montargil and Maranhão reservoirs are all part of the Tejo river system, draining the central parts of Portugal and the western parts of Spain. All three reservoirs were constructed by damming rivers. The outlines of Montargil and Maranhão reservoirs are quite similar, following the contours of the earlier river valley, while the Divor reservoir is more open (see Fig. 1, Fig. 2 and Fig. 3). The main purpose of the reservoirs is storing water for irrigation and drinking water although Montargil and Maranhão are also used for electric power production.

Table 1. Some characteristic features of the three studied reservoirs during 1985.

	DIVOR	Maranhão	MONTARGIL
Temperature surface (^{0}C)	10.5-26.4	10.0-26.6	9.9-30.5
pH (surface)	6.9-8.8	7.3-8.4	6.6-8.8
Diss. O_2 mg/l (surface)	6.6-11.3	4.2-10.2	7.8-11.0
Tot.P µg/l (surface)	48-230	19-230	14-63
Secchi disc.trans (m)	0.1-1.6	0.2-3.5	0.8-4.5
External loading			
Summer (kg/day)	0.14	73	24
Winter (kg/day)	3.7	6400	330

Divor, (261 m a.s.l.), is the smallest (2.65 km^2) and the newest (from 1965) of the three reservoirs (Fig. 3). Its maximum depth is c. 11 m. Montargil (80 m a.s.l.), is 16.5 km^2 and was first filled in 1958. Its greatest depth is c. 30 m (Fig. 2). Maranhão (130 m a.s.l.) is the largest of the three reservoirs (19.6 km^2). Its maximum depth is c. 40 m and it was initially filled in 1957 (Fig. 1). Some other general characteristics of the reservoirs are given in Table 1.

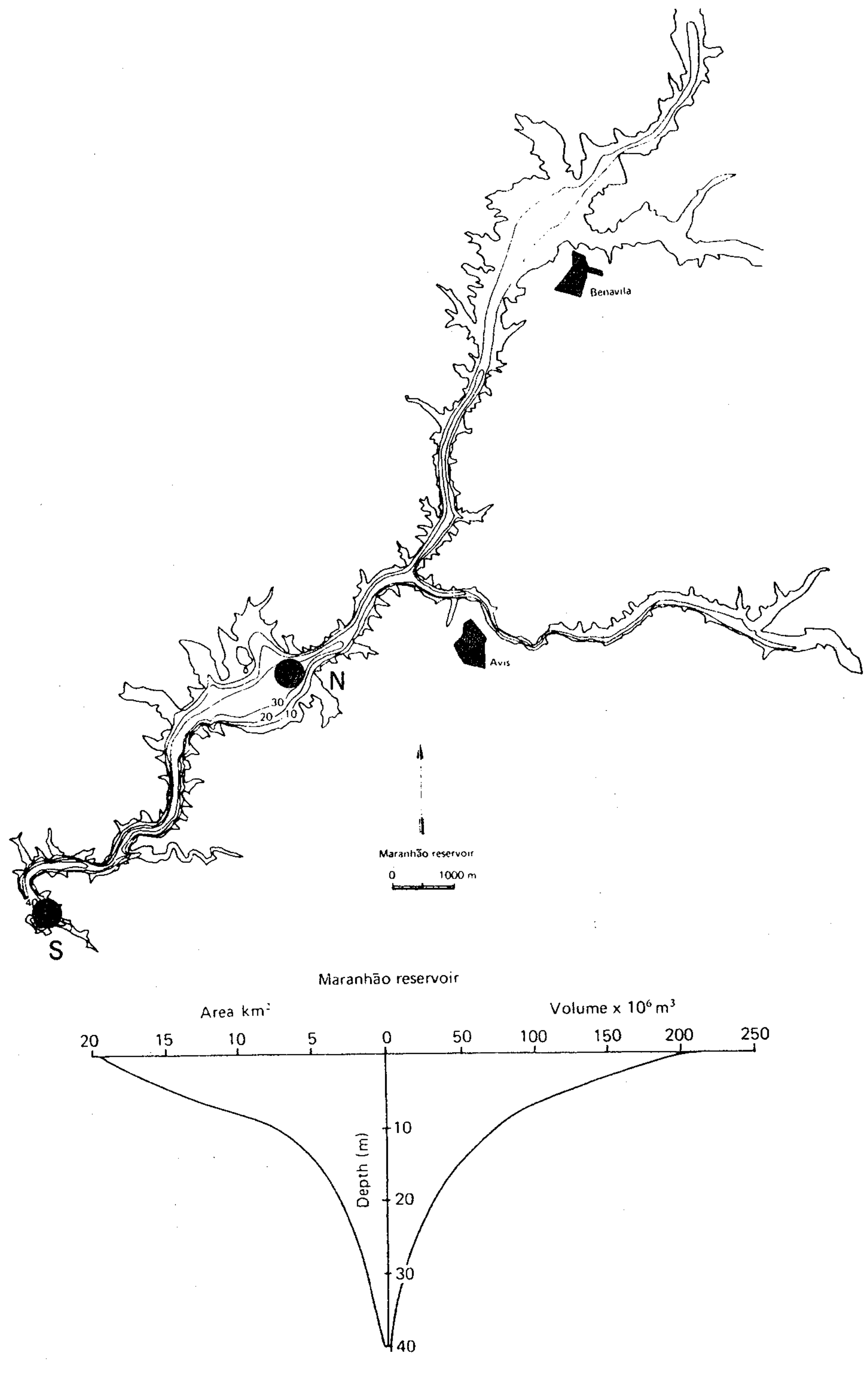


Fig. 1. Map and bathymetric contours of Lake Maranhão. Transects for echosounding and gill net fishing are marked. N - North, S - South.

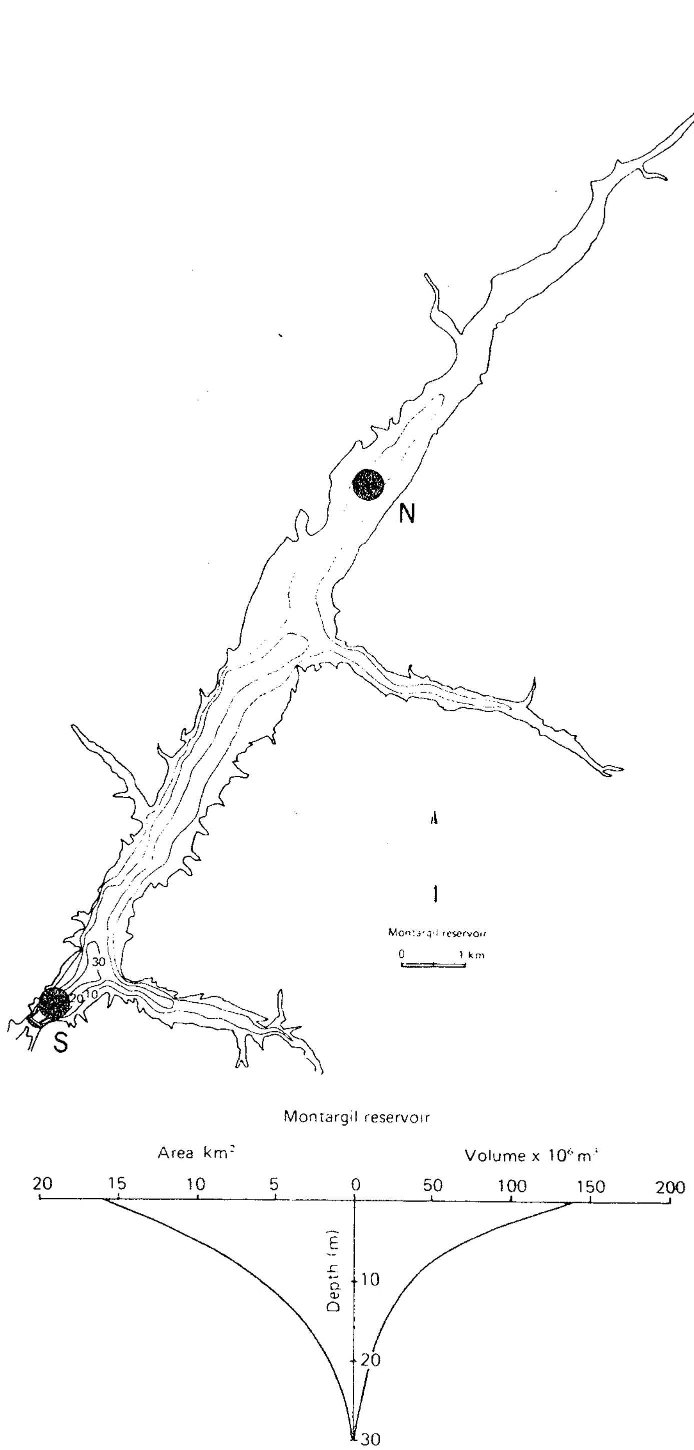


Fig. 2. Map and bathymetric contours of Lake Montargil. Transects for echosounding and gill net fishing are marked. N - North, S - South.

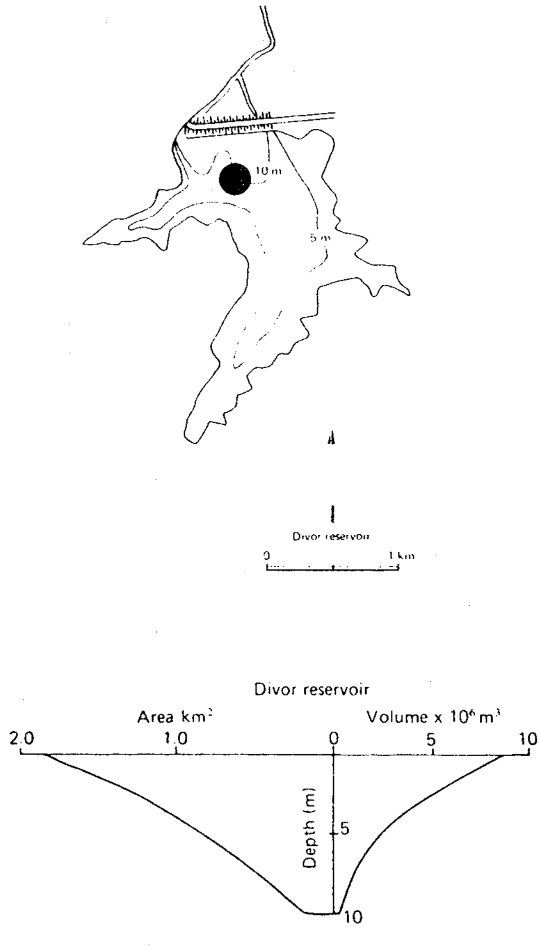


Fig. 3. Map and bathymetric contours of Lake Divor. Transects for echosounding and gill net fishing are marked.

All three reservoirs are influenced by agricultural runoff and domestic sewages. Maranhão is also subjected to industrial effluent effects. Primary production is relatively high in Divor, presenting blooms of Anabaena and Microcystis (Oliveira 1984), see Fig. 4. Fish kills are often reported from this reservoir due to periods of oxygen depletion. The trophic level of Maranhão is slightly higher than Montargil. Summer stratification occurs in both, with oxygen deficit in the hypolimnion during late summer, see Fig. 5.

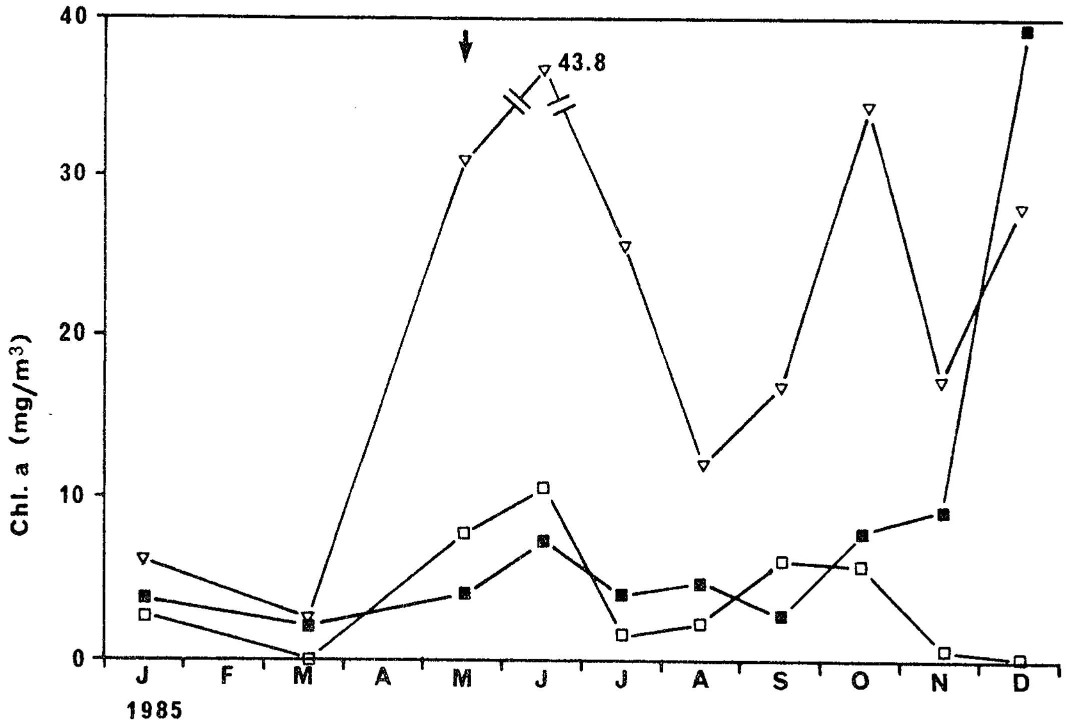


Fig. 4. Chlorophyll a (surface values) of Divor (▽), Maranhão (□) and Montargil (■) during 1985. Arrow indicates fishing period.

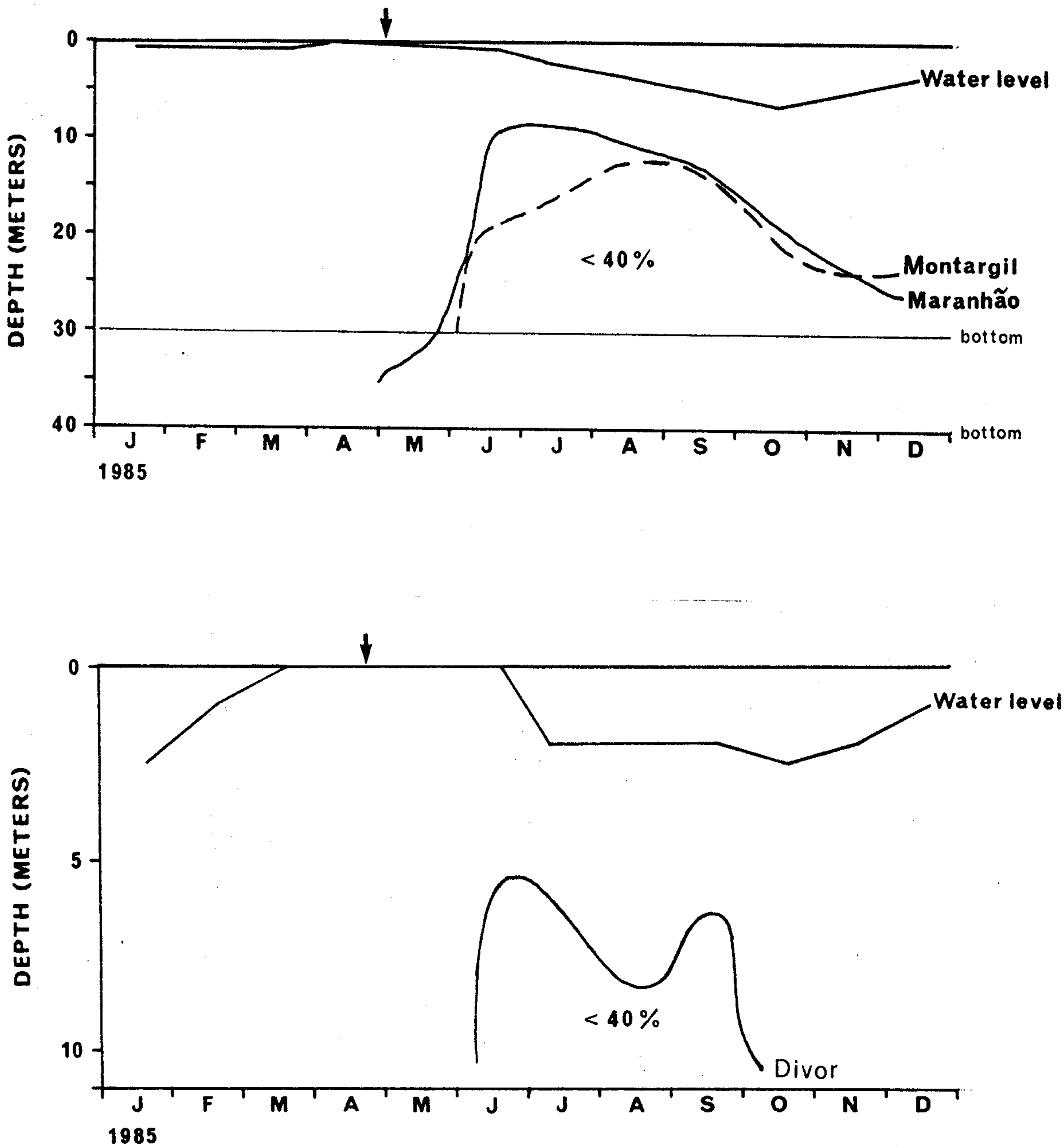


Fig. 5. Isopleths of 40 % oxygen saturation and water level in Maranhão and Montargil reservoirs (above) and Divor (below) during 1985. Arrow indicates fishing period.

MATERIAL AND METHODS

Density of fish and the diurnal behaviour were investigated by using the quantitative echosounder SIMRAD EY-M along selected transects during day and night. The echosounder has been described by Lindem (1979). The echo signals of single fish were recorded on magnetic tape and analysed in a microcomputer according the method described by Craig and Forbes (1969), and further modified by Lindem (1982). The working frequency of the system is 70 kHz, and the duration of the transmitted pulse is 0.6 msec., giving a depth resolution between single fish of about 0.5 m. The echo signals are stepped down from 70 kHz to 10 kHz at the calibrated signal output, making it possible to record the analog signal on a high fidelity tape recorder, Nakamichi 550. All data have been recorded with a 40 * log R time varied gain control, TVG, applied to the preamplifer.

The analysed echosignals were sorted into target strength (TS) categories of 2 dB units, reflecting fish of different size. To transform target strength to fish size in cm (L) the regression equation TS = 20 log L - 68 was used (see Lindem and Sandlund 1984) and Bjerkeng et al. (in prep.). In fish biomass calculations, the regression between fish length and fish weight for the main pelagic fish species from this investigation was used.

To identify the different fish species and the actual size classes of fish, pelagic and littoral gill nets were used. Mesh sizes, water strata sampled and time of the day fishing were decided according to the echosounding data to cover the most probable species and their behaviour. Pelagic zone floating gill nets of total length 25 m and height 6 m and with mesh sizes: 10 mm, 16 mm, 19.5 mm, 22.5 mm, and 35 mm, were used in all three reservoirs. The nets were placed to cover the depth interval 1-7 m and 7-13 below water surface in Maranhão, 1-7 m in Divor and 7 - 13 in Montargil. In Maranhão and Divor floating gill nets were used during the day and the night, while in Montargil only during the day.

Bottom gill nets of total length 25 m, height 1.5 m and mesh size 10 mm, 16 mm, 19.5 mm, 22.5 mm, 29 mm, 35 mm, 45 mm and 52 mm were used in Maranhão and Divor. Single nets were set outwards from the shore.

Each fish was measured to nearest mm (TL), weighed and its sex determined. From a subsample, the stomach gut contents were removed for further analysis. For fish aging, opercula of sunfish, largemouth bass, carp and nase were removed. Fish growth is presented as backcalculated length of individual fish, and 95 % confidence limits are used throughout. Stomach gut contents were analysed according to the volumetric method described by Richer (1969). However, stomach gut contents of cyprinids are often extremely difficult to identify because of the pharyngeal teeth which desintegrate food items. Therefore, for the different zooplankton food items food quantity is difficult to evaluate.

RESULTS

Gill net catches.

The results of the gill net catches are given in Table 2, Table 3 and Table 4. In Montargil only pelagic gill nets were used. A total of seven fish species were caught.

Table 2. Total number of fish caught by bottom gill nets in Lake Maranhão in May 1985. L.bass= largemouth bass. M. carp = Mirror carp.

Mesh size (mm)	Sunfish	Barbe	M.carp	Carp	Nase	L.bass	Rutilus
10	0	3	0	5	0	1	3
16	4	3	0	1	0	10	0
19	2	0	1	1	0	0	0
22	34	1	1	11	47	3	0
29	0	3	3	9	10	1	0
35	0	4	1	5	0	0	0
45	0	3	1	39	0	0	0
52	0	0	0	7	0	0	0

Table 3.Total number of fish caught by bottom gill nets in Lake Divor in May 1985.

Mesh size (mm)	Sunfish	Carp	L.bass
10	22	3	0
16	12	0	0
19	124	0	2
22	61	0	0
29	15	2	8
35	0	1	0
45	3	11	0
52	1	10	0

Table 4. Total number of fish caught by pelagic floating gill nets in Lake Divor, Maranhão and Montargil in May 1985. L.bass - Largemouth bass, M. carp - Mirror carp.

Mesh	DIVOR	Maranhão				MONTARGIL
Size (mm)	Sunfish	Carp	L.bass	Nase	M.carp	Sunfish
10	0	1	0	0	0	0
16	2	7	0	0	0	6
19	128	0	0	0	0	62
22	0	11	0	47	0	37
28	0	1	0	0	0	-
29	0	9	1	7	1	-
31	0	75	0	3	0	-
45	0	1	0	0	0	-

Divor.

Sunfish was the dominating fish species in the catches from Divor both in littoral and pelagic gill nets (Table 3 and Table 4). Most fish were caught in 19 mm mesh size gill nets. Their size was between 82 and 140 mm, and dominated by individuals between 104 and 122 mm (Fig. 6). The largest fish above 114 mm were mainly males, while those smaller were mostly females.

Carp (C. carpio) was only caught in littoral gill nets and the material only consisted of wild carp. The largest mesh sizes caught most fish (Table 3). Carp in Divor were all of very large size and all were above 29 cm in length. (Fig. 6). The two largest carps were 64 and 70 cm respectively. Besides these two species, five individuals of largemouth bass and one individial of C. taenia were caught in Divor. The largemouth bass were all very small; between 19.4 and 21.2 cm.

Maranhão.

The most diverse fish fauna was found in Maranhão. Five species were caught, but carp and Iberian nase dominated (Table 2 and Table 4). The material of carp, consisted of both carp and mirror carp. Both forms were primary found in the pelagic gill nets, in mesh size 31 and 22 mm. Most of the nase were found in

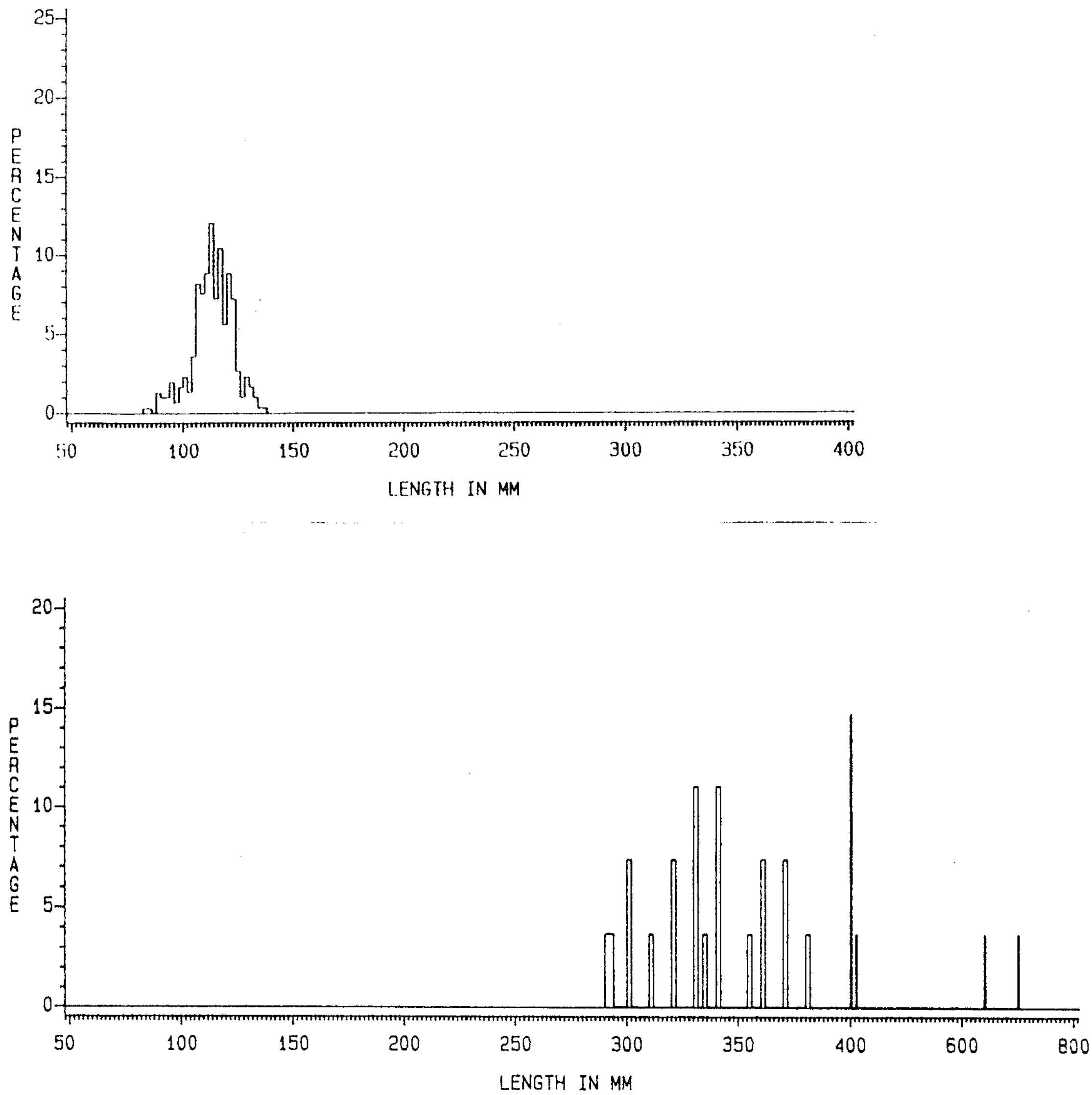


Fig. 6. Percentage length distribution of total numbers of sunfish (Lepomis gibbosus) (above) and carp (Cyprinus carpio) (below) caught by gill nets in Lake Divor.

22 mm. Catches from littoral gill nets consisted mostly of sunfish (Table 2), primarily in 22 mm mesh size.

These species constituted three very distinct length groups in Maranhão (Fig. 7), carp being the largest and sunfish the smallest fish. Carp were between 26 and 46 cm, and dominated by fish between 30 and 35 cm (Fig. 7). Nase did not reach the same size as carp, and most of the material was between 22.5 and 24 cm, although a few specimens were above 25 cm (Fig. 7).

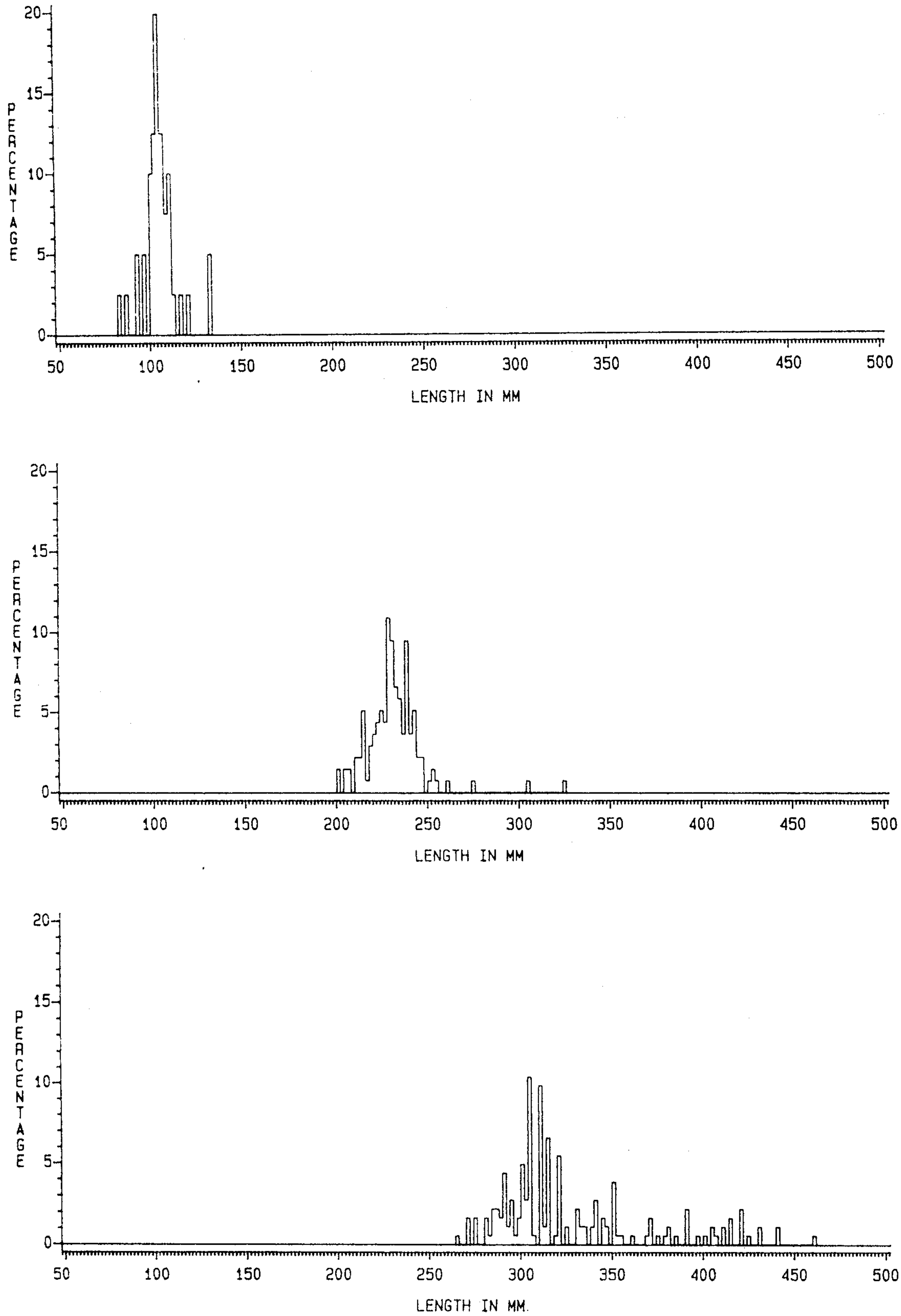


Fig. 7. Percentage length distribution of total numbers of sunfish (Lepomis gibbosus) (above), Iberian nase (Chondrostoma polylepis) (middle) and wild carp (Cyprinus carpio) (below) caught by gill nets in Lake Maranhão.

The sunfish ranged between 8 and 13 cm, although most were between 10 and 11 cm (Fig.7).

Other species found in Maranhão were barbel (Barbus sp.), roach (Rutilus sp.) and largemouth bass, primarily found in the littoral zone (Table 2). They were relatively scarce in catches and no attempt was made to separate the different species of barbel and roach.

Montargil.

Sunfish were the only species caught in Montargil (Table 4). Lack of other species in the catches might be due to the fact that the littoral zone were not studied. The size of the sunfish were between 96 and 132 mm (Fig. 8), and no differences in the size distribution of sunfish from the three reservoirs were observed.

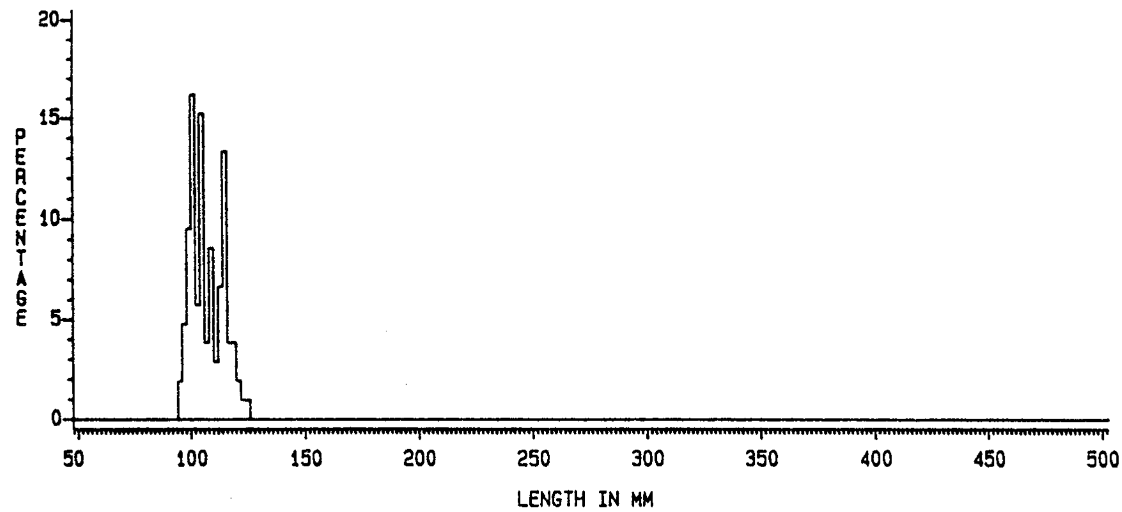


Fig. 8. Percentage length distribution of total numbers of sunfish (Lepomis gibbosus) caught by gill nets in Lake Montargil.

Age and growth

Age and growth in different fish species are illustrated by selecting material from the lakes where the species were most abundant in the catches.

Carp (Cyprinus carpio)

Most of the wild carp (45%) from Maranhão were three years old, but also 4 and 5 year old carps were abundant in the material (Fig. 9). The oldest carp was 8 years old. In Maranhão the carp showed relatively rapid growth the first 3 to 4 years (Fig.10). After 4 years, no significant growth increase occurs in the population, due to large individual size variation. It is possible that females grow larger than males.

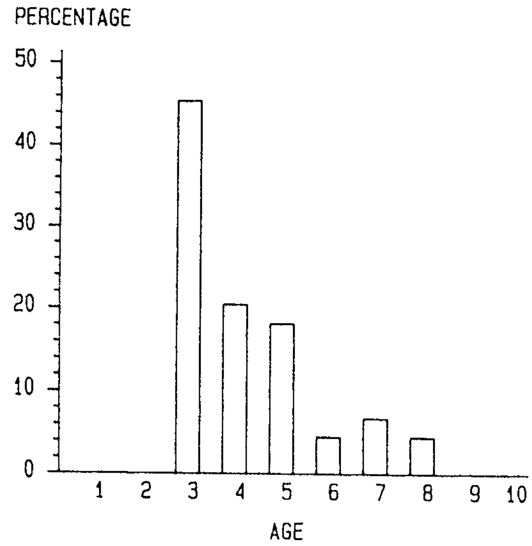


Fig. 9. Percentage distribution of age groups in wild carp (Cyprinus carpio) caught by gill nets in Lake Maranhão.

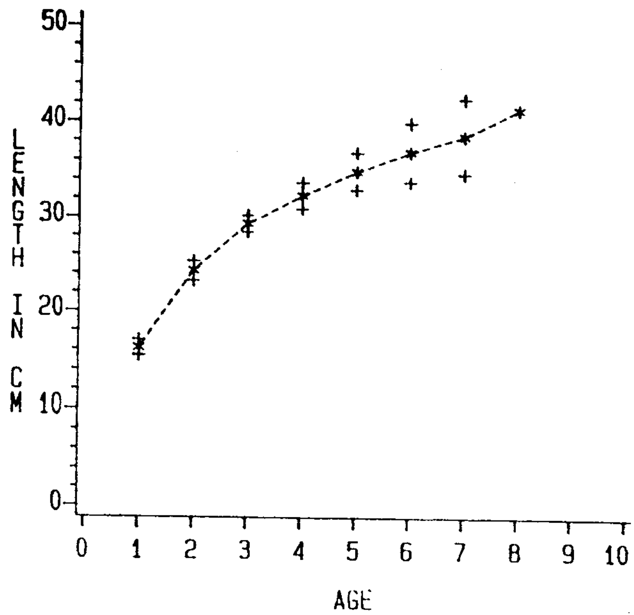


Fig. 10. Backcalculated growth of wild carp (Cyprinus carpio) in Lake Maranhão. 95% confidence limits are marked.

Sunfish (<u>Lepomis gibbosus</u>)

The material of sunfish from Divor was dominated by fish 4 and 5 years old (70%) (Fig.11), but fish up to eight years old were caught. The oldest fishes in the material were all males, and males also dominated in the 4, 5 and 6 year classes (Fig.12). Very few fishes above 5 years were female. However, the occurrence of both larger and older males in the material could be due to differences in spring activity between females and males, making the males more catchable. The blue gill showed a slower growth in Divor. After reaching an age of 4 years, growth stagnates and no further increase in size occurs (Fig.13).

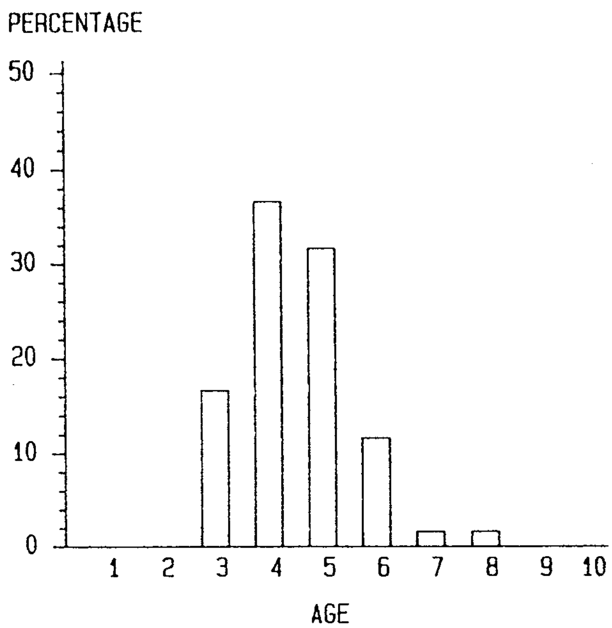


Fig. 11. Percentage distribution of age groups in sunfish (Lepomis gibbosus) caught by gill nets in Lake Divor.

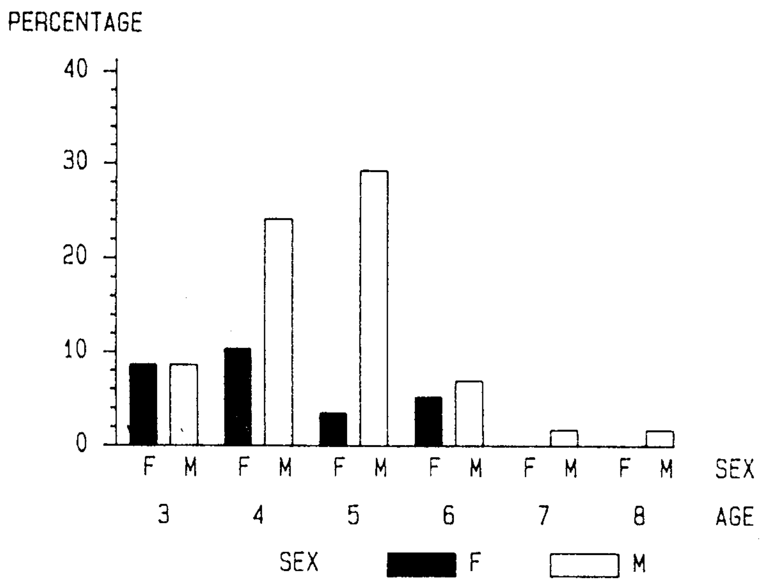


Fig. 12. Percentage distribution of age groups in males and females in sunfish (Lepomis gibbosus) caught by gill nets in Lake Divor.

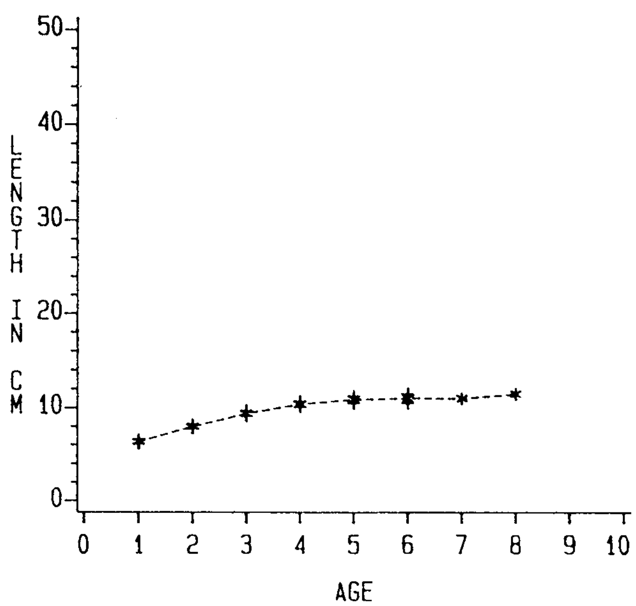


Fig. 13. Backcalculated growth of sunfish (Lepomis gibbosus) in Lake Divor. 95% confidence limits are marked.

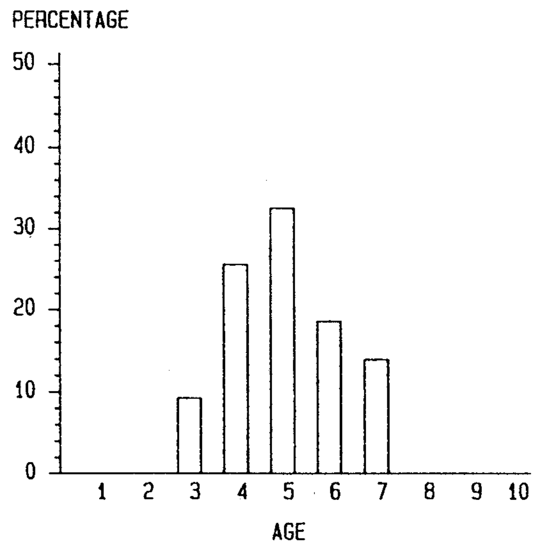


Fig. 14. Percentage distribution of age groups in Iberian nase (<u>Chondrostoma polylepis</u>) caught by gill nets in Lake Maranhão.

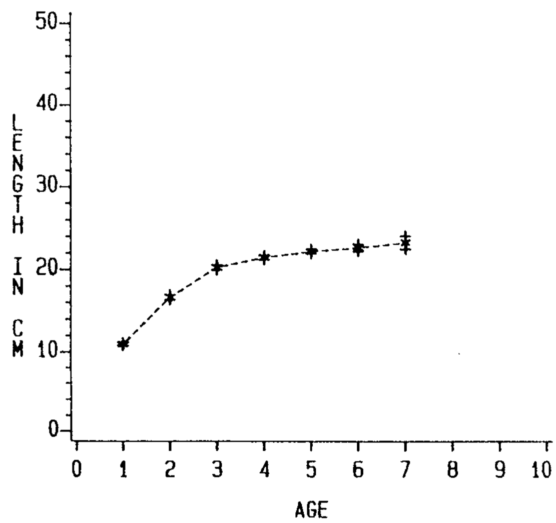


Fig. 15. Backcalculated growth of Iberian nase (<u>Chondrostoma polylepis</u>) in Lake Maranhão. 95% confidence limits are marked.

Iberian nase (Chondrostoma polylepis)

The nase from Maranhão were from 3 to 7 years old, but more than half of the fishes (55%) were 4 and 5 years (Fig.14). The low abundance of young fish in the catches may be due to higher spawning activity in older individuals. After one growth season their body size is approximately 10 cm (Fig.15). After three years and a mean size of c. 20 cm growth stagnates completely.

Largemouth bass (Micropterus salmonoides)

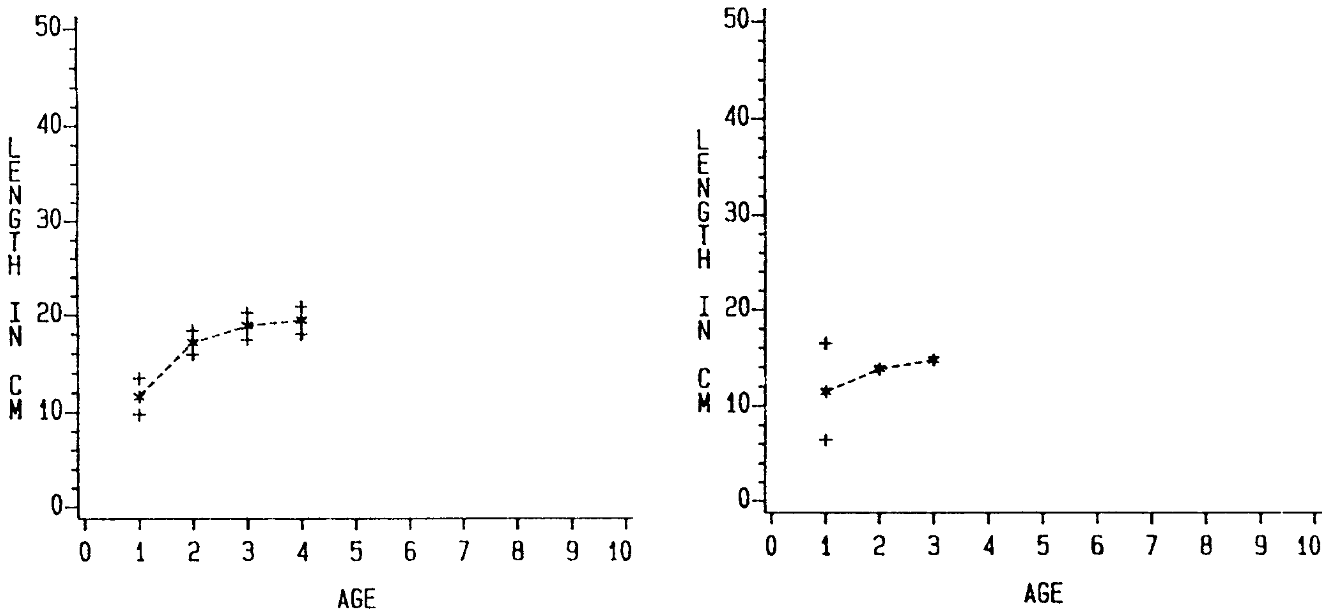


Fig. 16. Backcalculated growth of largemouth bass (Micropterus salmonoides) in Lake Divor (left) and a small material from Lake Maranhão (right). 95% confidence limits are marked.

From the back calculated growth curve (Fig.16), it appears that largemouth bass in Divor probably do not reach a very large size. From growing rather fast the first two years, no further significant increase in size occurs. The oldest fish in the material were 4 years old. In Lake Maranhão, only a small

Length-weight relationships of the dominating fish species in Divor, Montargil and Maranhão is shown in Fig.17 and the significant higher W/L ratio for carp in Lake Maranhão compared to lake Divor probably reflects the general higher trophic level of Divor, as also the scarcity of available food items except of zooplankton in Maranhão. The presence of nase as a planktivore also increase the food competition to the carps in Maranhão. The nearly identical equation of the carp and the sunfish, and further the small deviation to the nase enables the use of the equations in the fish biomass calculations from the echosounding data.

The following regression equations has been calculated (W - weight in g, L - length in mm, SD - standard deviation on the regression coefficient).

Divor, carp :	log W = 3.05 log L- 4.90	r^2 =0.97	SD=0.107
Maranhão, carp:	log W = 2.67 log L- 4.07	r^2 =0.95	SD=0.045
Montargil, sunfish:	log W = 3.92 log L- 6.63	r^2 =0.75	SD=0.224
Divor, sunfish:	log W = 2.81 log L- 4.29	r^2 =0.81	SD=0.174
Maranhão, nase:	log W = 2.70 log L- 4.32	r^2 =0.81	SD=0.114

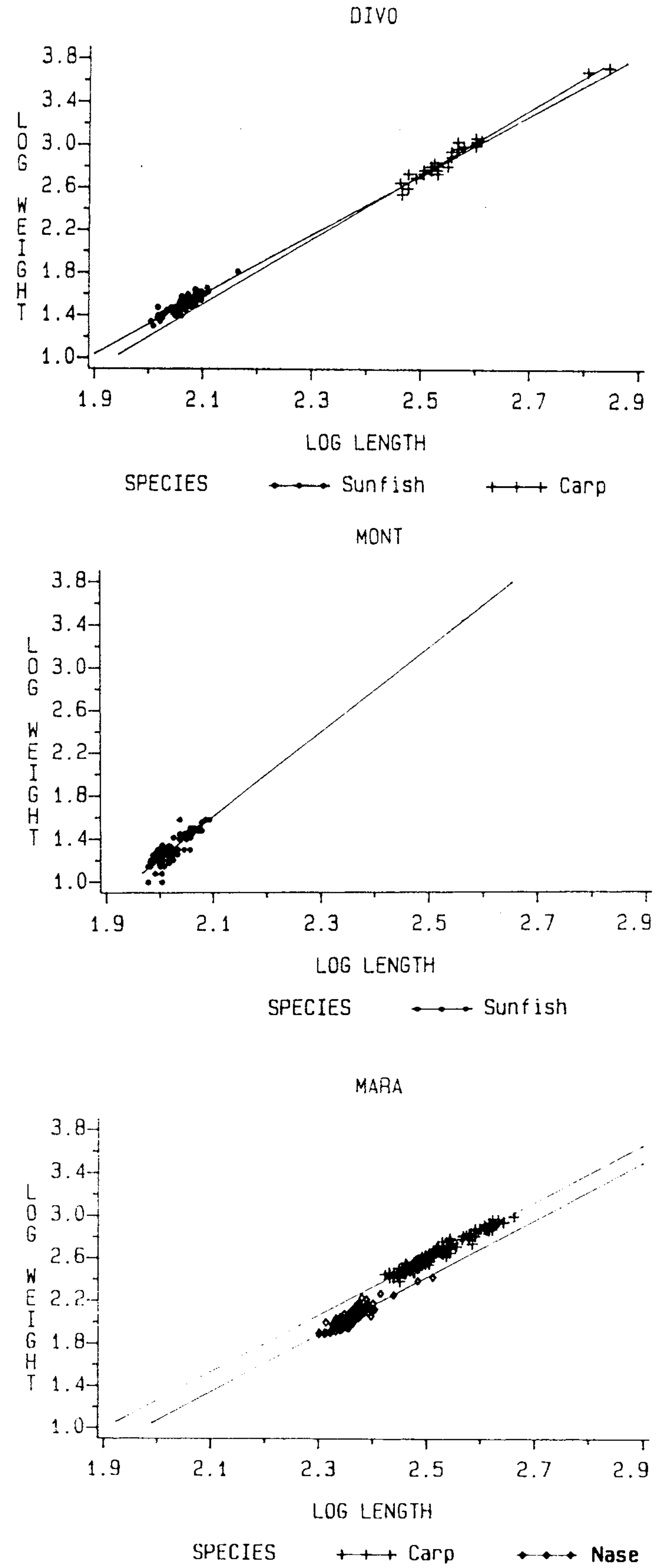


Fig. 17. Length-weight relationship in sunfish (Divor (above), Montargil (middle) and Maranhão (below)), Iberian nase (Maranhão) and

Feeding.

The stomach contents of nase and wild carp from Maranhão are shown in Table 5 only and Table 6 respectively. Both species were pelagic, and their food uptake was almost exclusively zooplankton during the daytime, dominated by Daphnia, probably D. hyalina. Interestingly, nase caught pelagically during night-time had completely empty stomachs indicating a strong diurnal variation in the food consumption. In carp there was no difference either between day and night or in carp caught in the pelagic and littoral zone. Zooplankton therefore seems to be the most important food items available for both fish species and also for fish moving in to the littoral zone. The strong zooplankton component for adult carp also indicates the lack of alternative food items to the zooplankton.

Table 5. Stomach contents of nase (Chondrostoma polylepis) in the Maranhão reservoir in the pelagic and littoral zone 2-4.5.1985. N = 10, body size 20 - 25 cm.

	DAY-TIME			
	Pelagic zone		Littoral zone	
	Freq.	vol.	Freq.	vol.
Cladocera	100	100	100	100
Daphnia	100	++	100	++
Daphnia ephippia	100	+	100	+
Diaphanosoma	40	+	60	+
Copepoda	10	(+)	-	-

In the littoral zone of Divor carp gut contents was dominated by vegetative food components, with small amounts of detritus and sediments. The only animal food items observed were chironomide larvae. The food indicate carp to be a bottom feeders in this reservoir, as is also indicated by their littoral distribution. The diet of sunfish from Divor is shown in Table 7. In the pelagic zone, sunfish increased the uptake of zooplankton, dominated by Daphnia hyalina, while in the littoral zone sunfish seemed to predate largely on available food such as insect larvae, zooplankton, water mites and fish eggs. In the pelagic zone of Montargil (Table 9) and in the

Table 6. Stomach contents of carp (Cyprinus carpio) in the Maranhão reservoir in the littoral zone 2-4.5.1985.

DAY-TIME

LITTORAL ZONE	25-30 Freq	25-30 Vol	30-35 Freq	30-35 Vol	35-40 Freq	35-40 Vol
Cladocera						
Daphnia	100	98	100	99	100	100
Bosmina	25	2	33	< 1		
Diaphanosoma			16	< 1		
Copepoda			33	< 1		
Diptera p.	25	< 1				

Table 7. Gut contents of pelagic (A) and littoral (B) in sunfish (Lepomis gibbosus) from the Divor reservoir during daytime 5.5.1985.

	Pelagic zone N = 12 Freq	Pelagic zone N = 12 vol.	Littoral zone N = 10 Freq.	Littoral zone N = 10 vol.
Cladocera				
Daphnia	58	17	100	36
Bosmina	8	<1		
Ceriodaphnia	58	21	50	10
Copepoda cal.	58	9	80	15
Ostracoda	8	<1		
Corixidae	67	6	40	4
Chironomidae l.	75	23	90	16
Chironomidae p.	92	22	80	22
Chaoborous	8	<1		
Acarina	8	<1		
Fish eggs	8	1		

littoral zone of Maranhão (Table 8), the sunfish fed to a large extent on zooplankton, in Maranhão also on chironomidae larvae.

Table 8. Gut contents of littoral sunfish (Lepomis gibbosus) from the Maranhão reservoir during daytime 5.5.1985. N= 5, body size 98-120 mm.

	Freq.	vol.
Cladocera		
Daphnia	100	57
Copepoda cycl.	60	2
Corixidae	20	<1
Chironomidae l.	80	37
Chironomidae p.	60	1
Other diptera l.	20	<1

Table 9. Gut contents of pelagic sunfish (Lepomis gibbosus) from the Montargil reservoir during daytime 5.5.1985. N= 8, body size 98-130 mm.

	Freq.	vol.
Cladocera		
Daphnia	100	98
Copepoda cycl.	63	1
Copepoda cal.	12	<1
Chironomidae p.	12	1

Echosounding

Echograms.

Day and night echograms from the three reservoirs are given in Fig.18, Fig.19, Fig.21, Fig.20 and Fig.22. The most obvious diurnal pattern was present in Montargil and in the more shallow parts of Maranhão, where fish showed a more pelagic behaviour during the day. In Montargil fish was more or less evenly distributed in the pelagic zone during the day from lake surface to approx. 12 m depth, although in some areas more concentrated to the water layer 7 - 12 m below water surface. During the night, fish density was in general greatly reduced in the pelagic zone, and a more even vertical fish distribution was observed. In the more shallow Divor, the same diurnal pattern was observed; reduced fish density during the dark period in the pelagic zone.

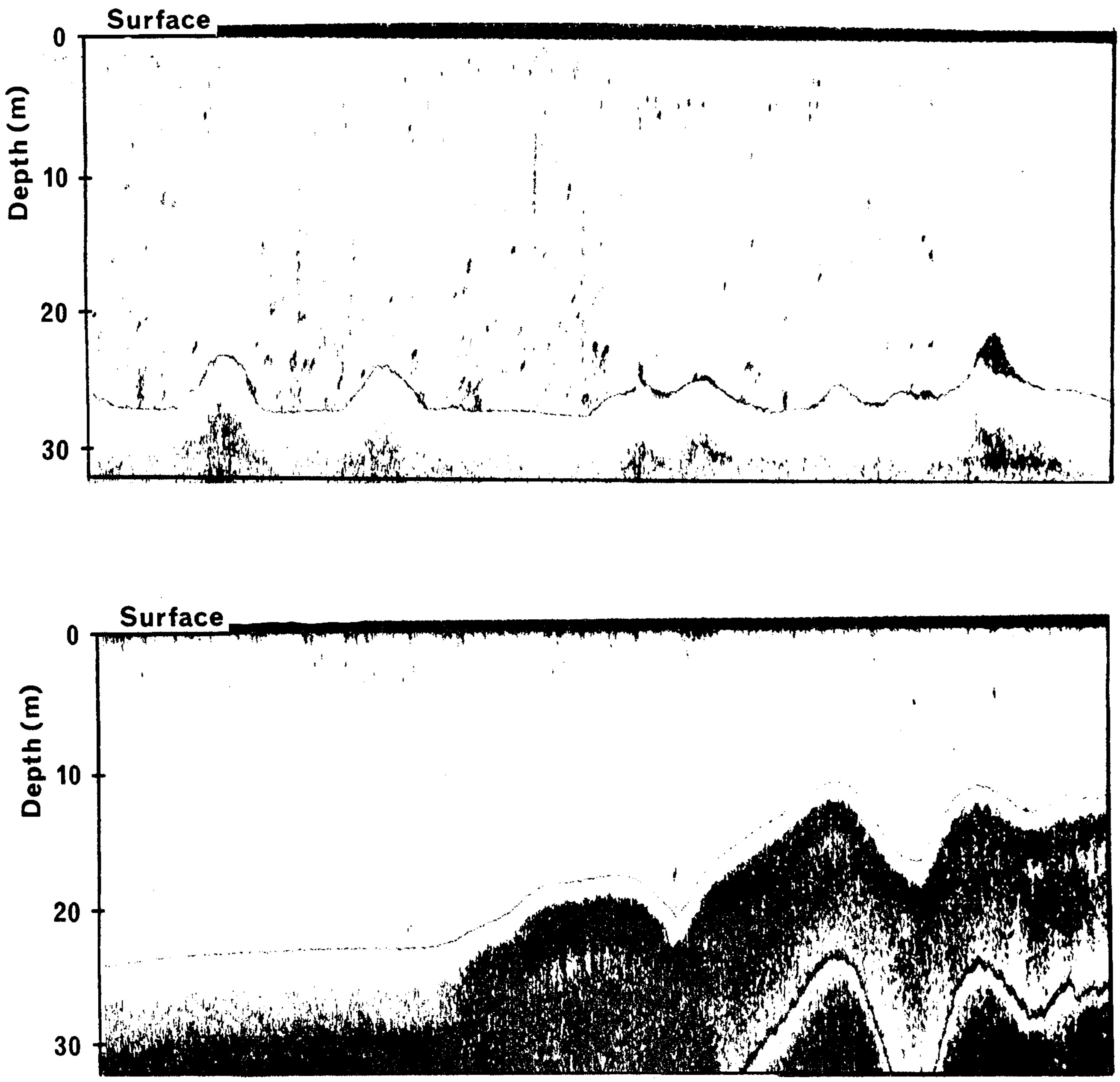


Fig. 18. Selected echograms during the day (above) and night along a transect north in Lake Maranhão.

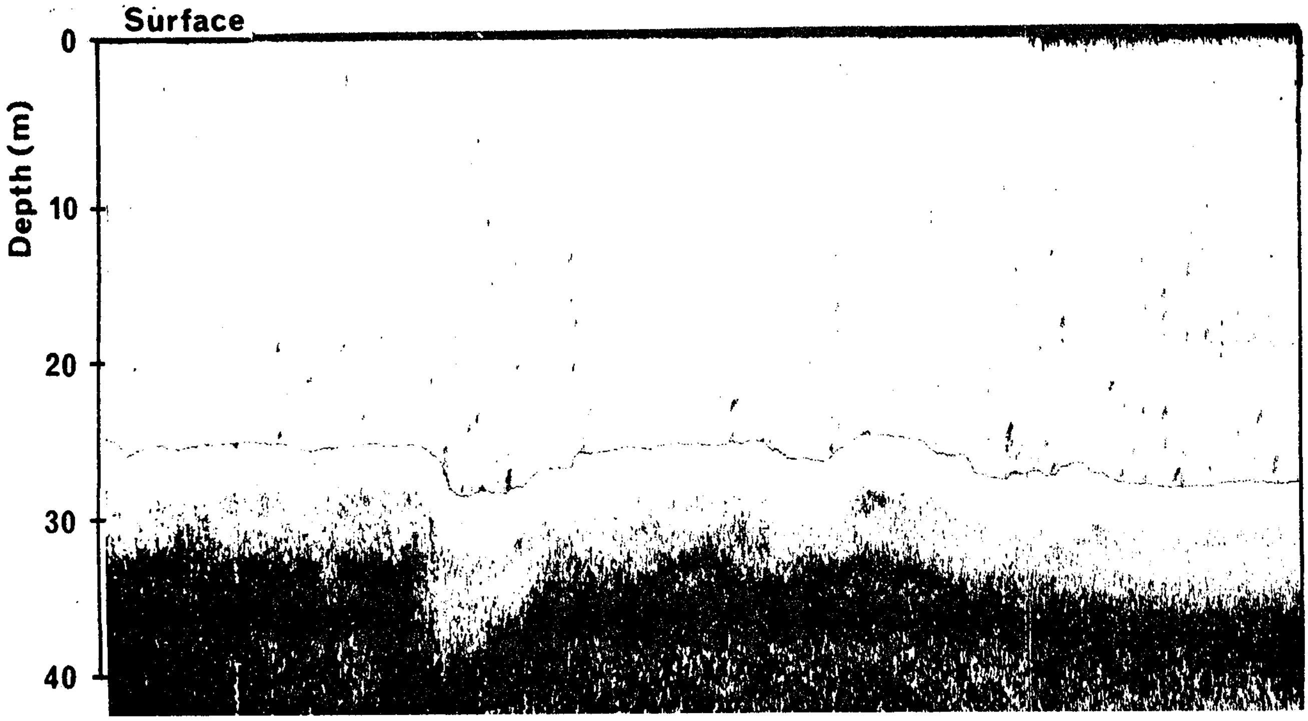


Fig. 19. Selected echograms during the day (above) and night along a transect south in Lake Maranhão.

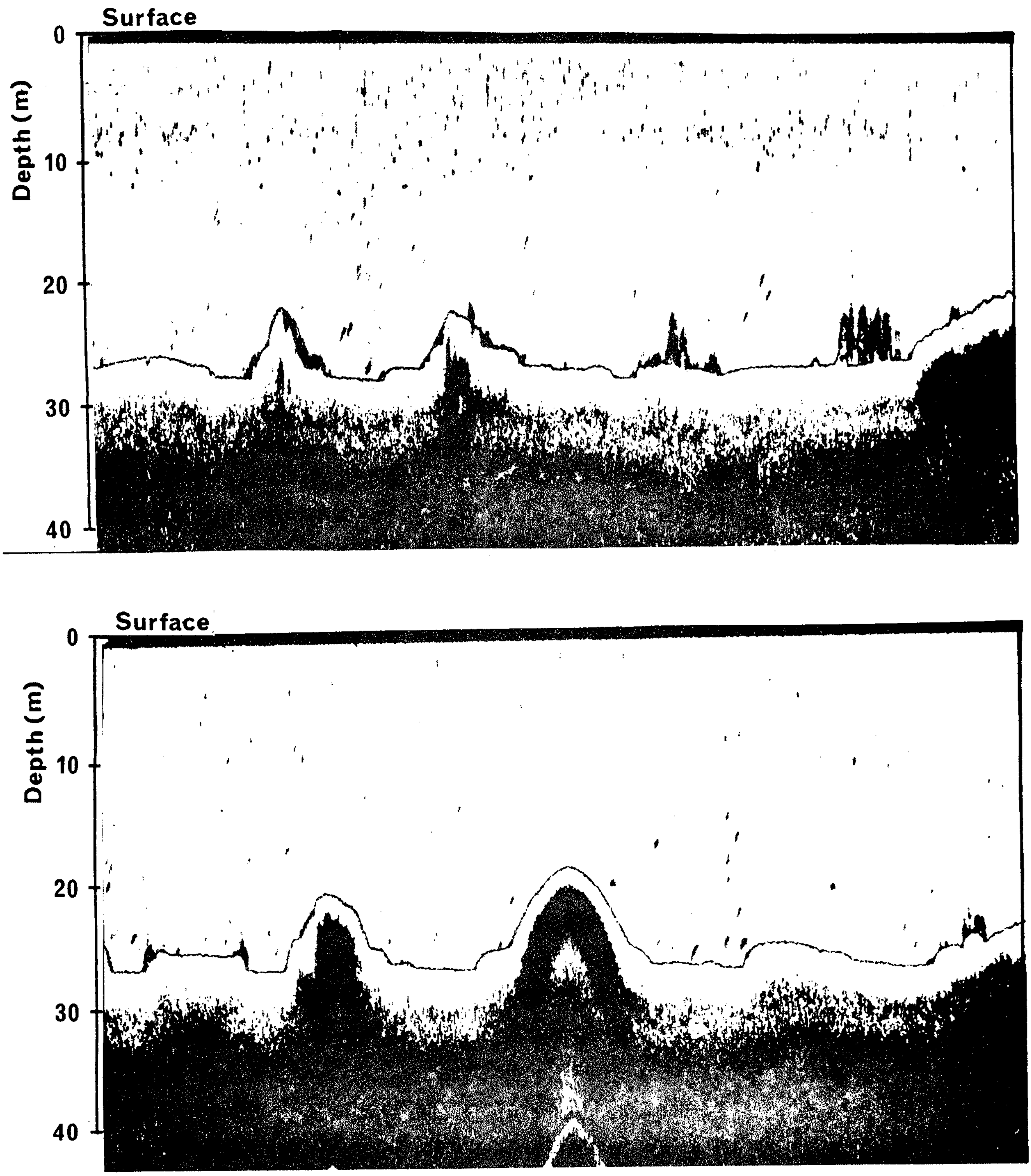


Fig. 20. Selected echograms during the day (above) and night along a transect south in Lake Montargil.

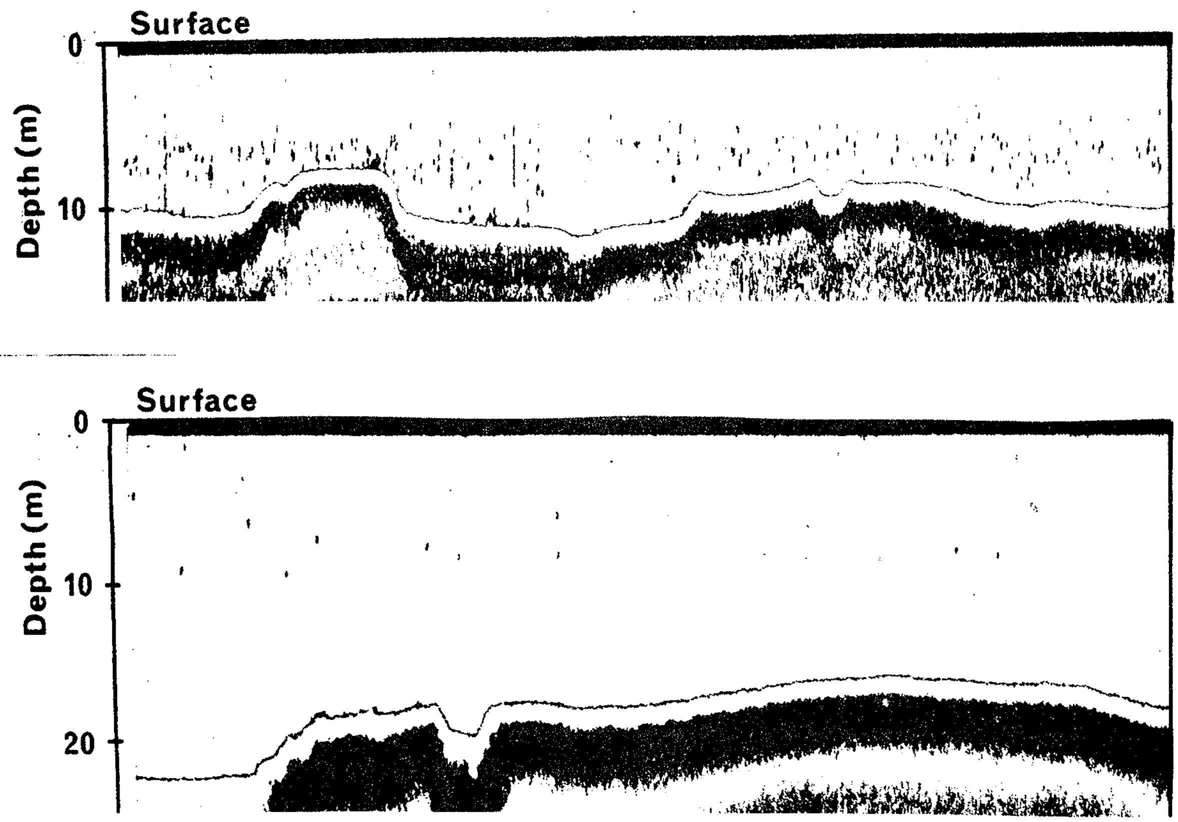


Fig. 21. Selected echograms during the day (above) and night along a transect north in Lake Montargil.

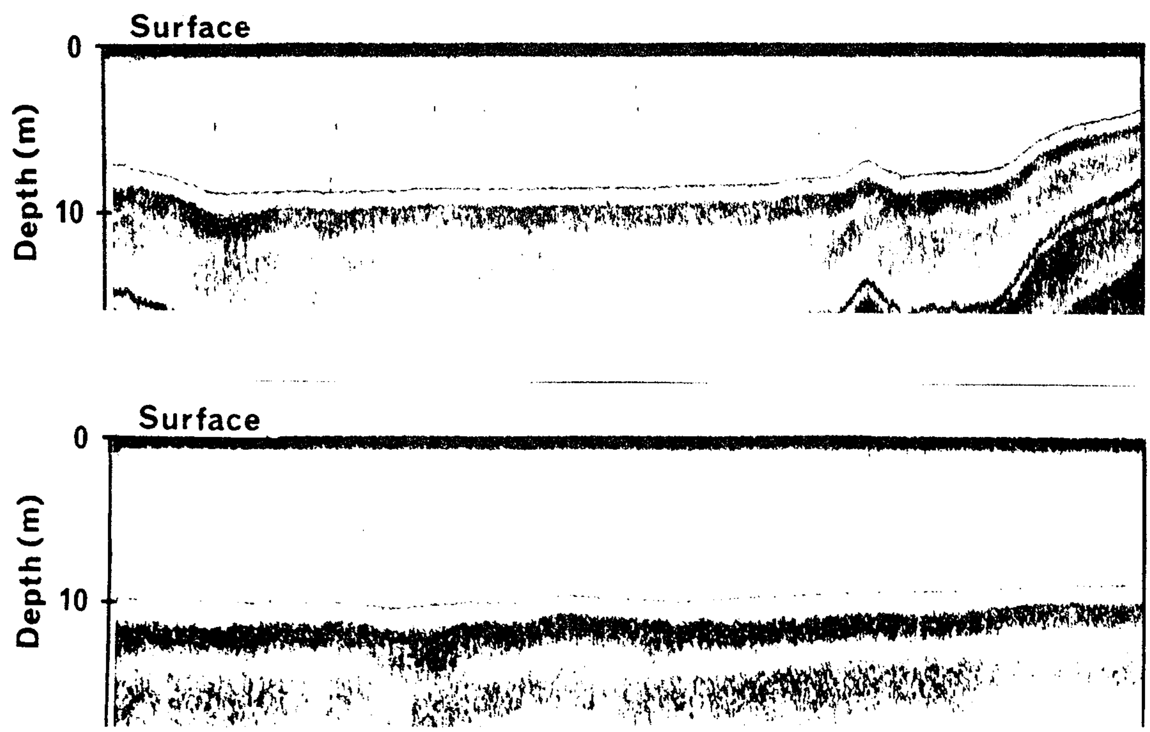


Fig. 22. Selected echograms during the day (above) and night in Lake Divor.

The general picture in Maranhão was somewhat different. During the night, fish were observed from the lake surface to the bottom, while during the day fish were almost absent from the pelagic zone in areas shallower than c. 20 m. In the deeper parts, however, fish were observed from below c. 30 m to the bottom during daytime.

Vertical distribution

The total number of received echosignals at 5 m depth intervals for the two transects in Maranhão are given in Fig.23. In spite of a different total number of signals, the depth distribution seems quite similar, with the highest fish density in the upper water layer (1000 and 1800 fish ha^{-1}, respectively) and with a lower, but more even density varying from 300 to 800 fish ha^{-1} in the water layer below. Echosignals during daytime were not recorded from this reservoir, but echograms showed that fish at this time of the day were more concentrated in the water layers below approx. 30 m in the deep parts of the reservoir (Fig.19). However, gill net fishing and observations showed that fish also moved pelagically very close to lake surface in this reservoir during daytime.

In the Montargil reservoir, two patterns of depth distribution from the analysed daytime echosignals are observed (see Fig. 24 and Fig.25), reflecting the observations from the echograms. In the southern part of the reservoir, the highest fish density was observed in the recorded water layer 1-5 m below the lake surface (approx. 2700 fish ha^{-1}), with decreasing fish density with depth. Along the more shallow and northern transects, fish seemed to show a more even vertical distribution, but with a minor maximum density in the water layer 5 - 10 m. During the night, fish density was in general reduced in all analysed water layers in the southern part(Fig.24), but still reached a maximum close to the water surface.

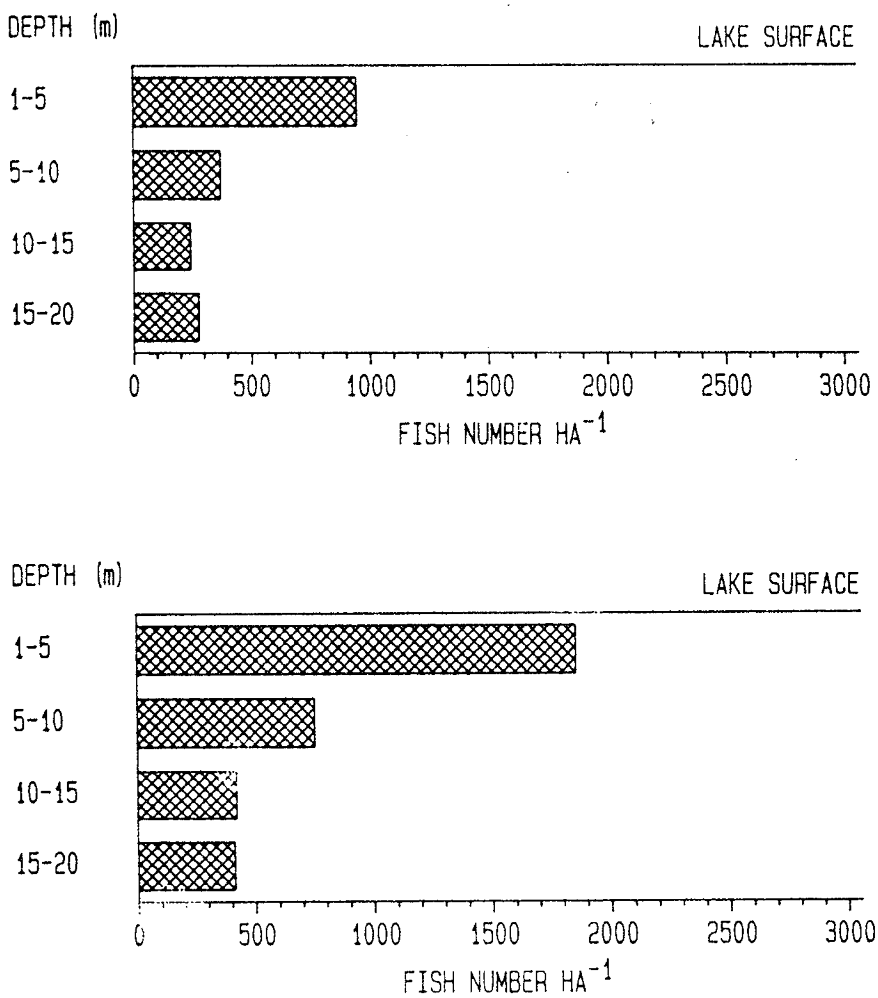
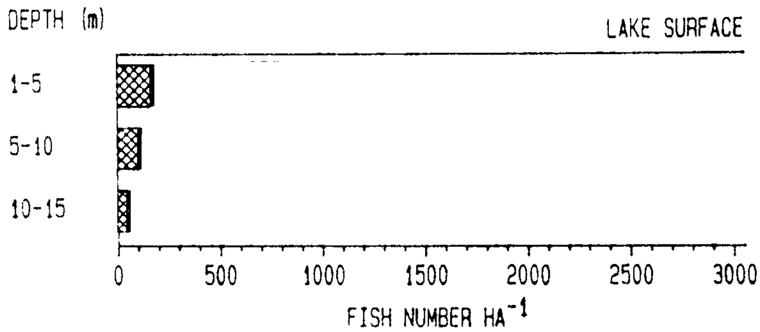


Fig. 23. Depth distribution of received number of echosignals in 5 m depth water intervals in Lake Maranhão during the night along transects north (above) and south.

In the shallow Divor, echo signals were not analysed. However, gill net fishing showed high fish densities (in catch pr. unit effort) in the pelagic zone during the day, corresponding to high fish density observed in the echograms. During the night, the echograms show an almost total lack of fish in the pelagic zone. We therefore conclude the same diurnal pattern of fish distribution exists in Divor as that shown for Montargil.



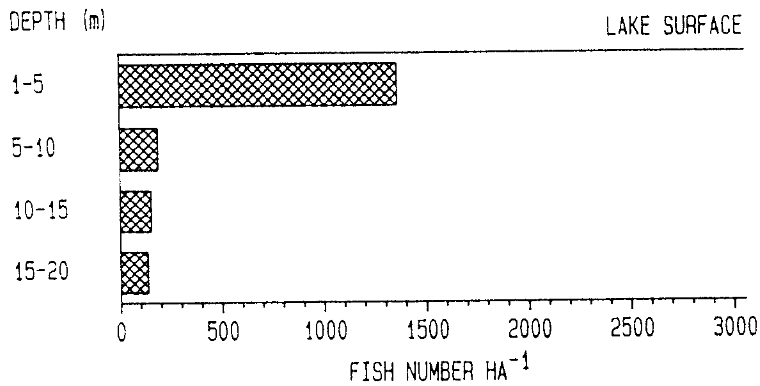


Fig. 24. Depth distribution of received number of echosignals in 5 m depth water intervals in Lake Montargil during the night along transects north (above) and south.

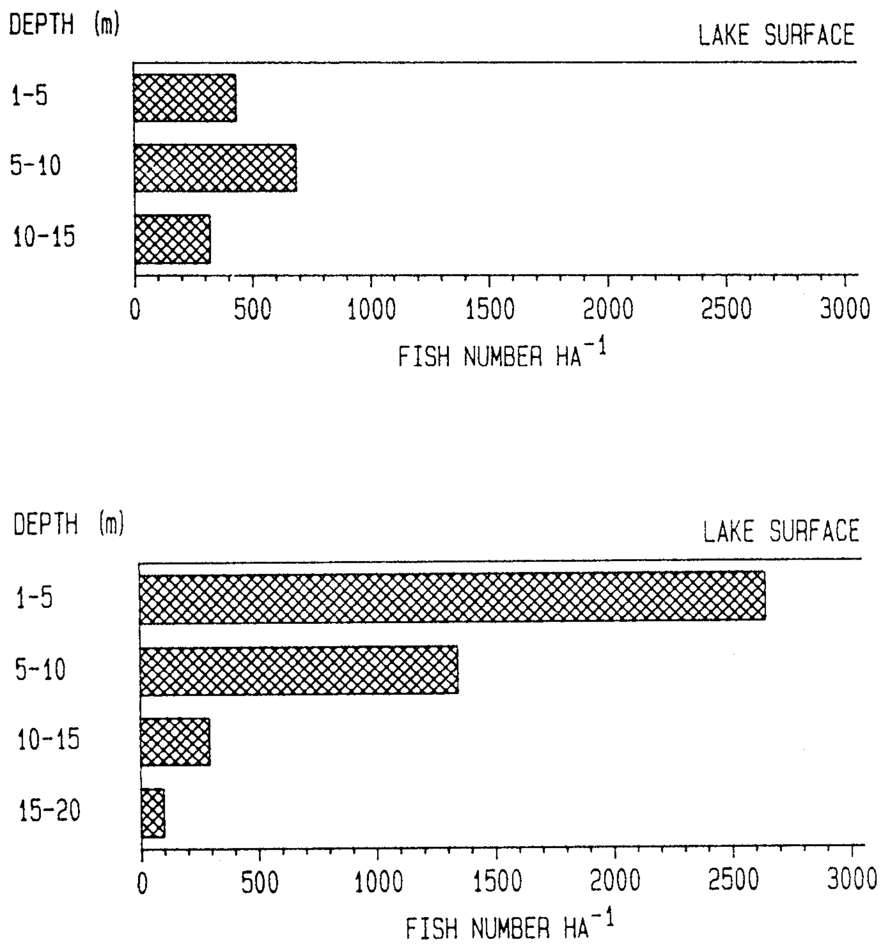
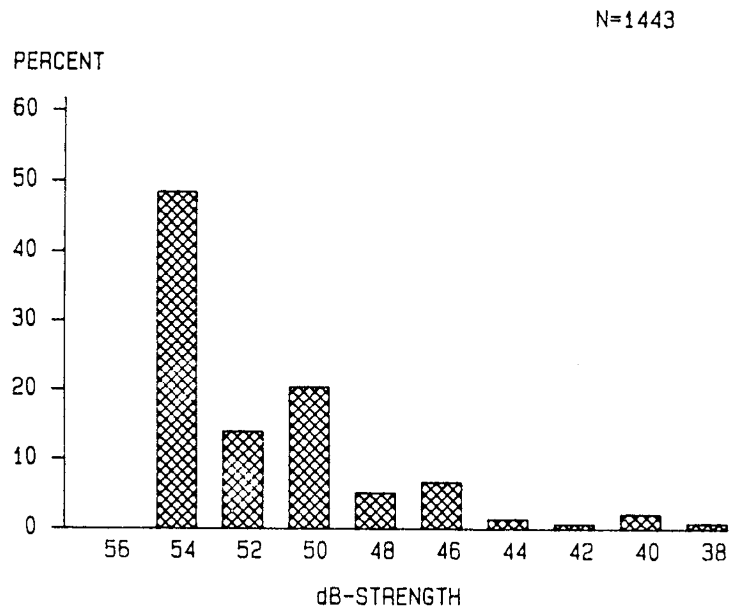


Fig. 25. Depth distribution of received number of echosignals in 5 m depth water intervals in Lake Montargil during the day along transects north (above) and south.

Relative fish size

The received echosignals are classified according to their target strength (TS) and counted for the different transects and for selected depth intervals, reflecting individual fish size on a relative scale (in dB) in the corresponding water layer analysed.

The distribution of target strength of total recorded depth along transect south and north of Maranhão during the night are given in Fig.26, showing an almost identical distribution of target strength along the two transects. Nearly 50 % of the signals were classified in group dB 54, corresponding to an



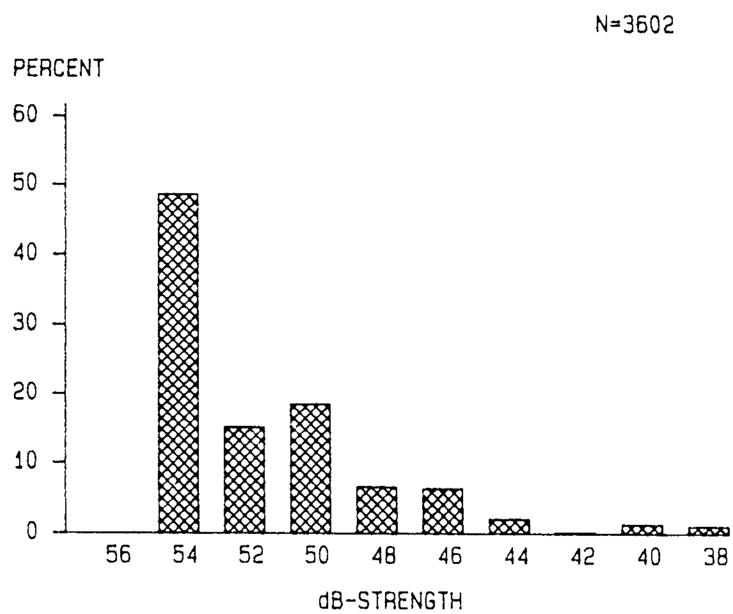


Fig. 26. Distribution of target strength of received echosignals (in - dB) between the bottom and 1 m depth along transects north (above) and south during the night in Lake Maranhão in May 1985.

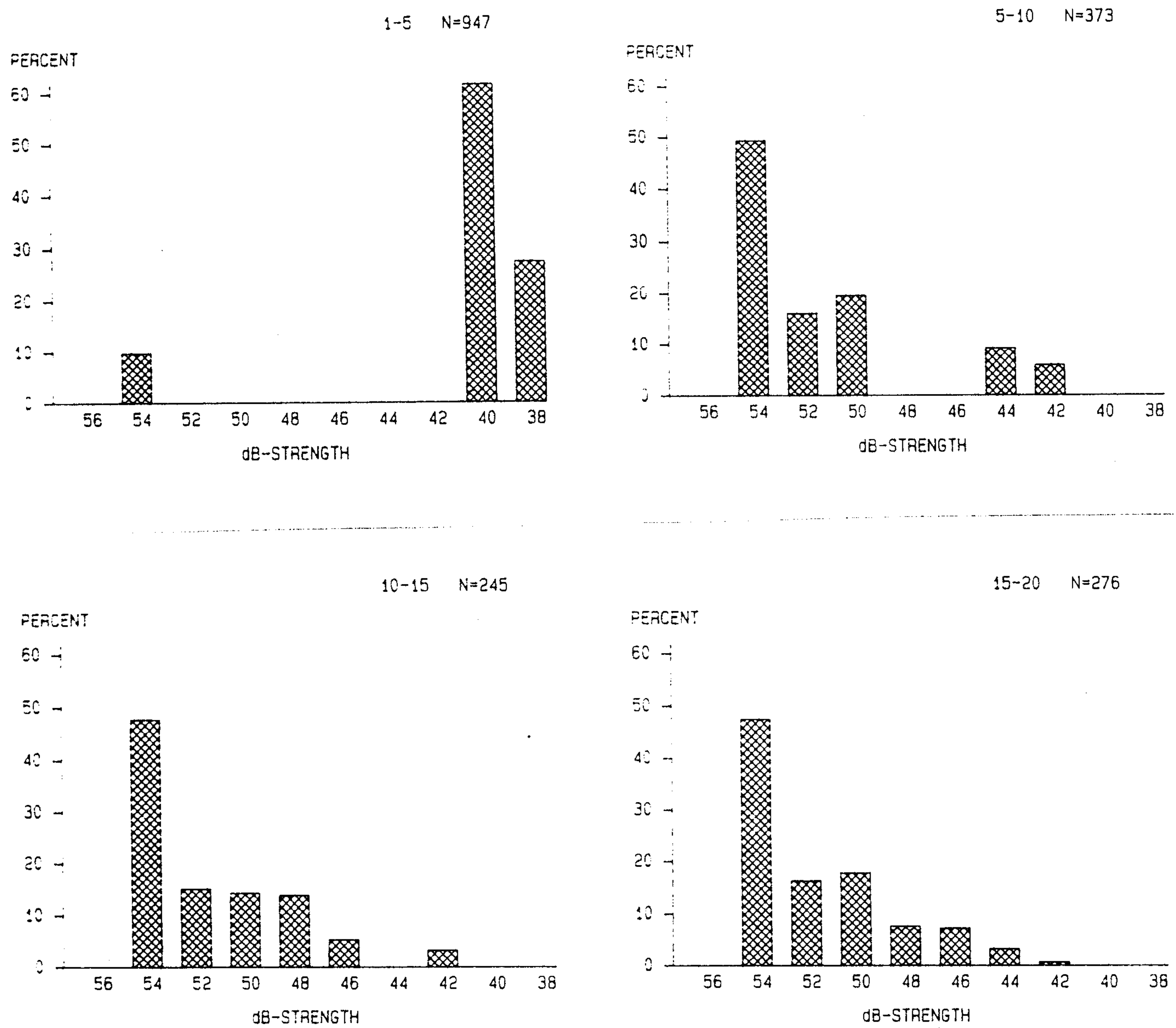


Fig. 27. Distribution of target strength of received echosignals (in - dB) in 5 m's depth strata along transect north during the night in Lake Maranhão in May 1985.

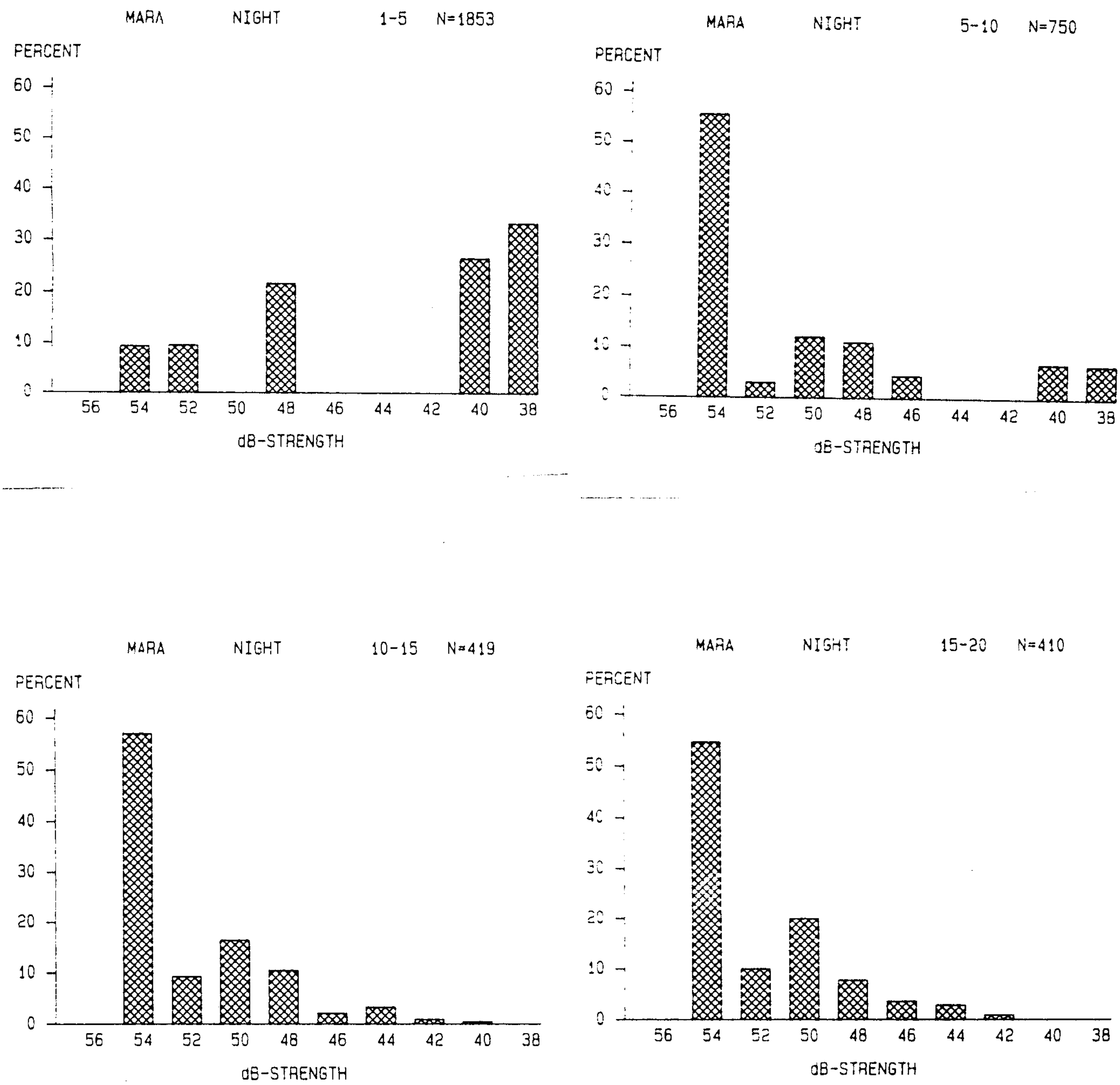
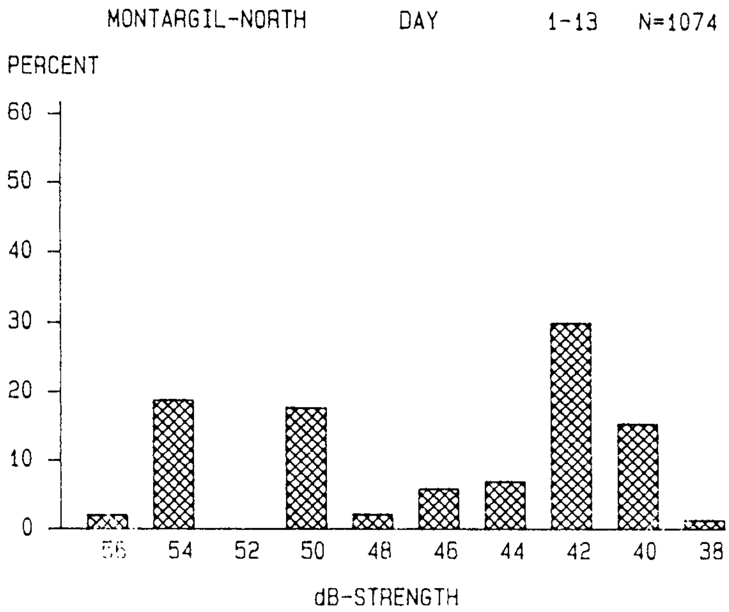


Fig. 28. Distribution of target strength of received echosignals (in dB) in 5 m's depth strata along transect south during the night in Lake Maranhão in May 1985.

individual fish size of approx. 5 cm. The second largest group was the target strengths dB 52 - dB 44, corresponding to a fish size from approx. 8 to 18 cm. Along both transects almost no fish were classified as dB 42, while there was a small peak at dB 40 and dB 38, reflecting fish larger than 24 cm. However, showing the target strength distributions for the different depth intervals gives a quite different picture (Fig. 27, 28). In the water layer 1-5 m below water surface, fish classified as group dB 40 and dB 38 dominated, while at greater depths these dB-groups were absent or much reduced. We therefore conclude that fish larger than approx. 25 cm are restricted to the upper water layer, while smaller fish occur at greater depths.

The distribution of target strength of echosignals from Montargil are shown in Fig.29 and Fig.30. As in Maranhão the target strength distribution at different water layers in Montargil show a dominance of the dB - groups 40 and 38, indicating fish size larger than approx. 25 cm in the water layer 1 - 5 m below water surface (Fig.31 and Fig.32). In the deeper water strata, there was generally no systematic dominance of any dB group. However, the lack of signals in the dB interval 52 - 50 showed the absence of fish of size 5 - 8 cm.



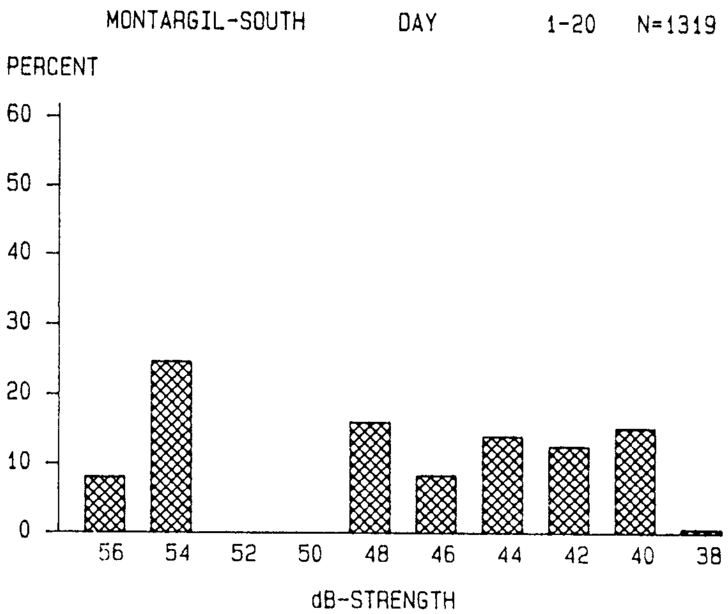
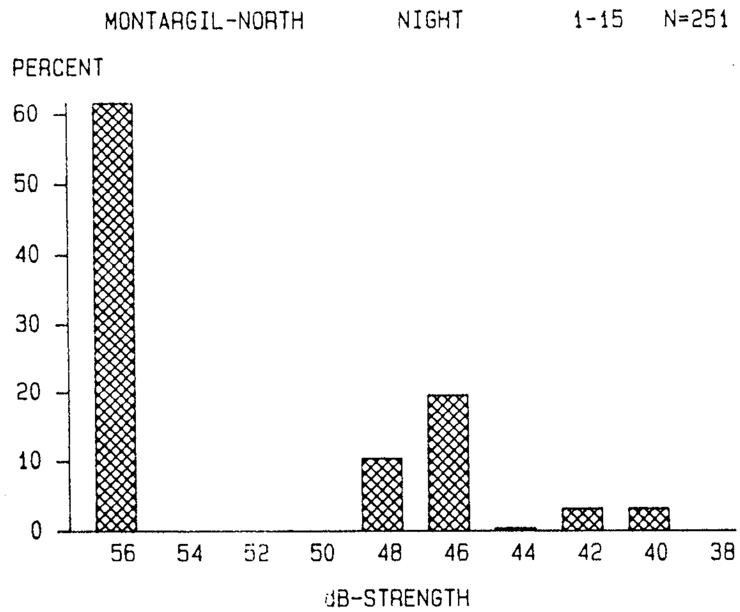


Fig. 29. Distribution of echosignals (in - dB) between the bottom and 1 m depth along transects north (above) and south during the day in Lake Montargil in May 1985.



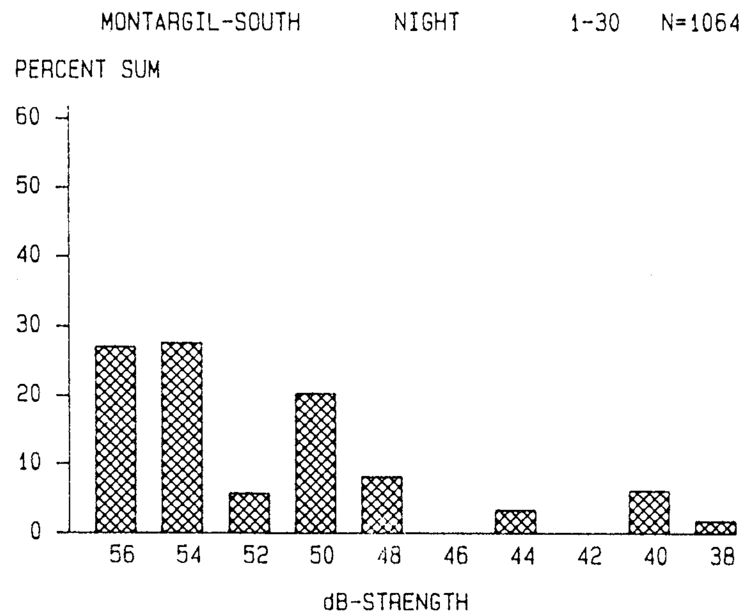


Fig. 30. Distribution of echosignals (in - dB) between the bottom and 1 m depth along transects north (above) and south during the night in Lake Montargil in May 1985.

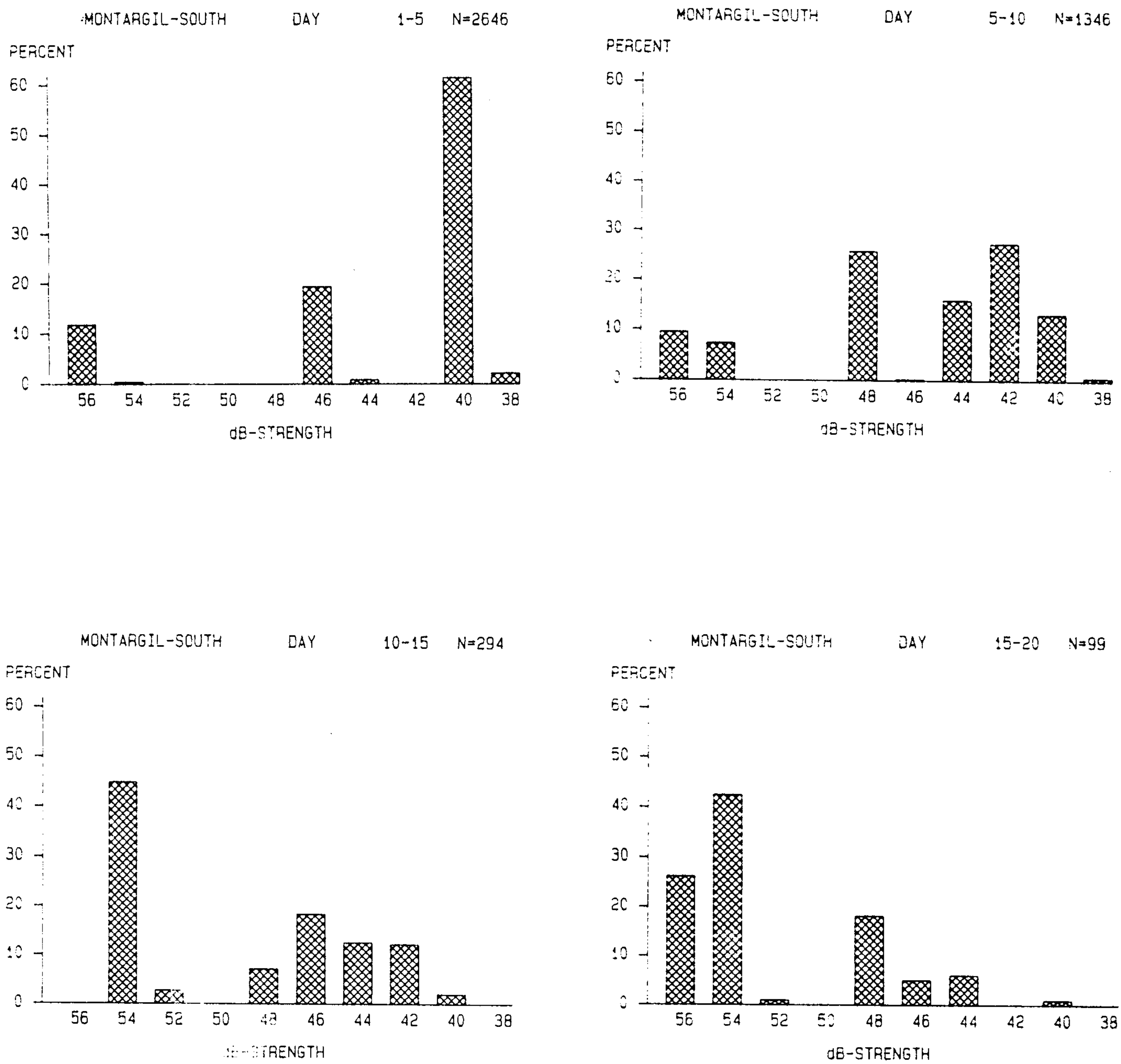


Fig. 31. Distribution of target strength of received echosignals (in - dB) in 5 m's depth strata along transect south during the day in Lake Montargil in May 1985.

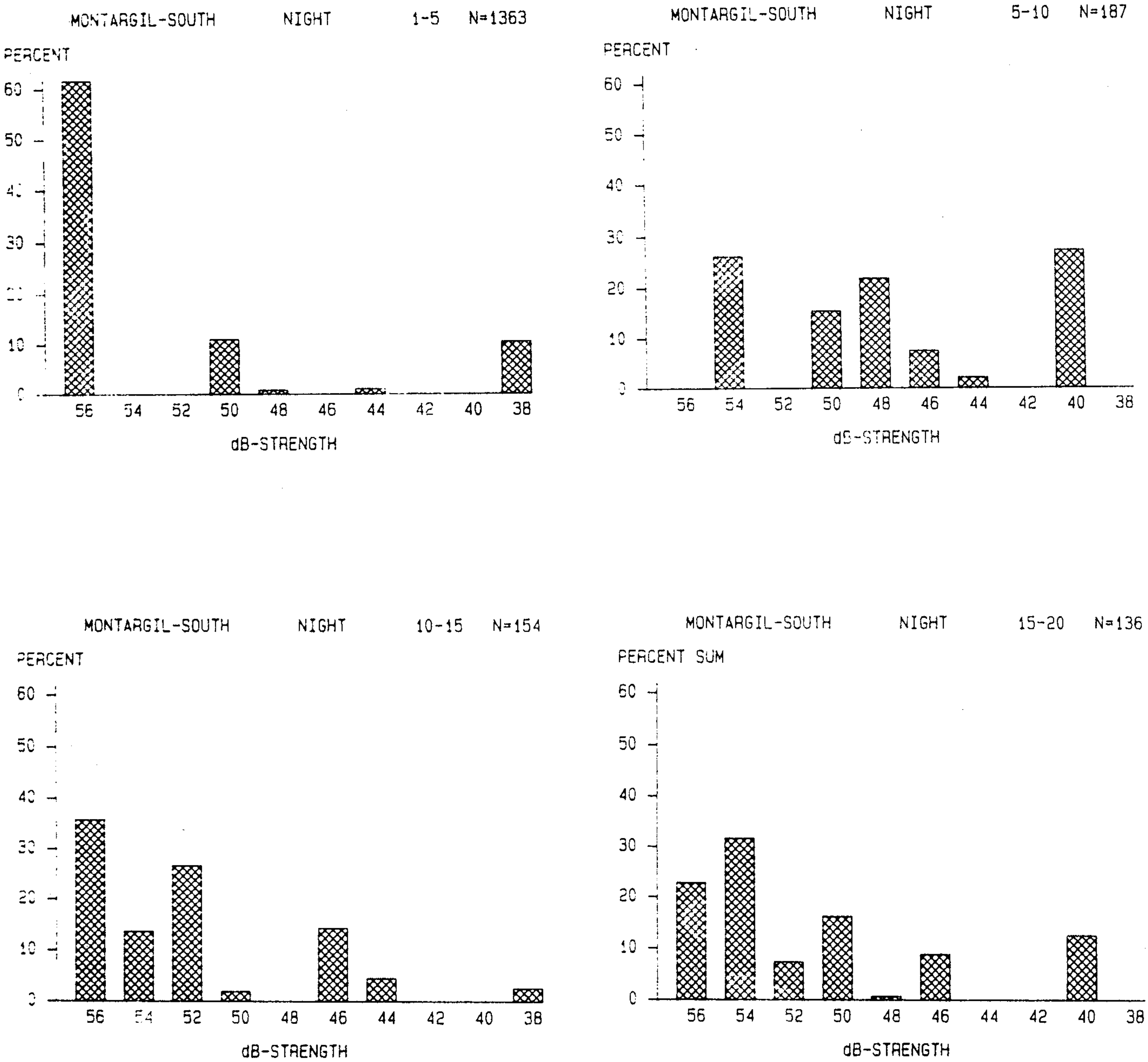


Fig. 32. Distribution of target strength of received echosignals (in - dB) in 5 m's depth strata along transect south during the night in Lake Montargil in May 1985.

DISCUSSION.

Total estimated fish densities along the analysed transects are given in Table 10. In Maranhão, the two night-time transects varied between 1840 to 3433 fish/ha, the highest number being in the deepest part of the lake. The same regional pattern was also observed in Montargil, fish number varying from 251 (night) to 1312 (day) over the northern shallow transect, while the corresponding values were 1840 to 4386 close to the deepest area. In the total biomass calculations, it is suggested that fish in the size interval 10-20 cm follow the length/weight regression equation for sunfish, and larger fish the equation for carp (see Fig.17). Fish smaller than 10 cm contribute very little to total fish biomass, but we suggest following the regression for sunfish/carp. The exact point of change from sunfish to carp regression seems unimportant, since the regression equations are quite similar. The lack of nase in the estimates can be argued against this interpretation. However, the potential error reflecting the difference in weight/length ratio between carp and nase seems small, specially when compared to the possible boat disturbance effects on large fish close to the surface. We therefore consider that our estimates provide a good indication of the level of total fish biomass as well as the difference between the two reservoirs and the diurnal variation in Montargil.

The biomass of pelagic fish population in Divor is suggested to be of the same order as that of Montargil, transect south. This consideration is based on the relative difference in the caught number of sunfish per hour.

The probable dominance of the different fish species and size groups in the three reservoirs is summarized in Fig.33. The corresponding dB values are also indicated. The main problem in the interpretation of the echosounding data is to separate the different species of small sized fish, since the size distribution of young carp and nase overlap that of adult sunfish. However, the main pattern of species and size

Table 10. Echo intergrated number of fish ha^{-1} lake surface along day night analysed transects in Maranhão and Montargil. Total fish biomass is based in total fish number, target strength/fish length regression (Lindem and Sandlund 1984) and fish length/weight regression from this investigation for probable pelagic fish species. N - North, S - South.

	<10cm	10-20cm	>20cm	N	Biomass $(kg)ha^{-1}$
	Number of fish			tot.	Estimated
Maran Night N	824	130	886	1840	335
Maran Night S	1574	642	1216	3433	513
Mont Night N	158	76	16	251	16
Mont Night S	1496	129	216	1840	111
Mont Day N	410	301	601	1312	247
Mont Day S	758	1245	2383	4386	1072

composition is presented in the figure, leaving more detailed studies for future investigations.

In all three reservoirs, the numbers of fish species in the pelagic zone were low, with dominance of sunfish in Divor and Montargil, and carp and nase in Maranhão. Since the structure of earlier fish community have not been described, we can only focus on the present fish community and discuss the difference between the investigated reservoirs . In Divor, the only fish in the pelagic zone was sunfish. Fish were not observed at night in the pelagic zone, reflecting the general day-pelagic activity of this species. The pelagic tendency is confirmed by the high zooplankton consumption. The scarcity of available benthic invertebrates in the lake is indicated by high consumption of zooplankton even by sunfish caught in the littoral zone, and the benthivorous feeding behaviour of carp, with its gut contents mainly containing vegetative food items. The one individual of C. taenia caught in Divor confirms its expected presence, since this shallow lake allows this species to survive in the substrate due to oxygen and substrate requirements (Robotham 1982).

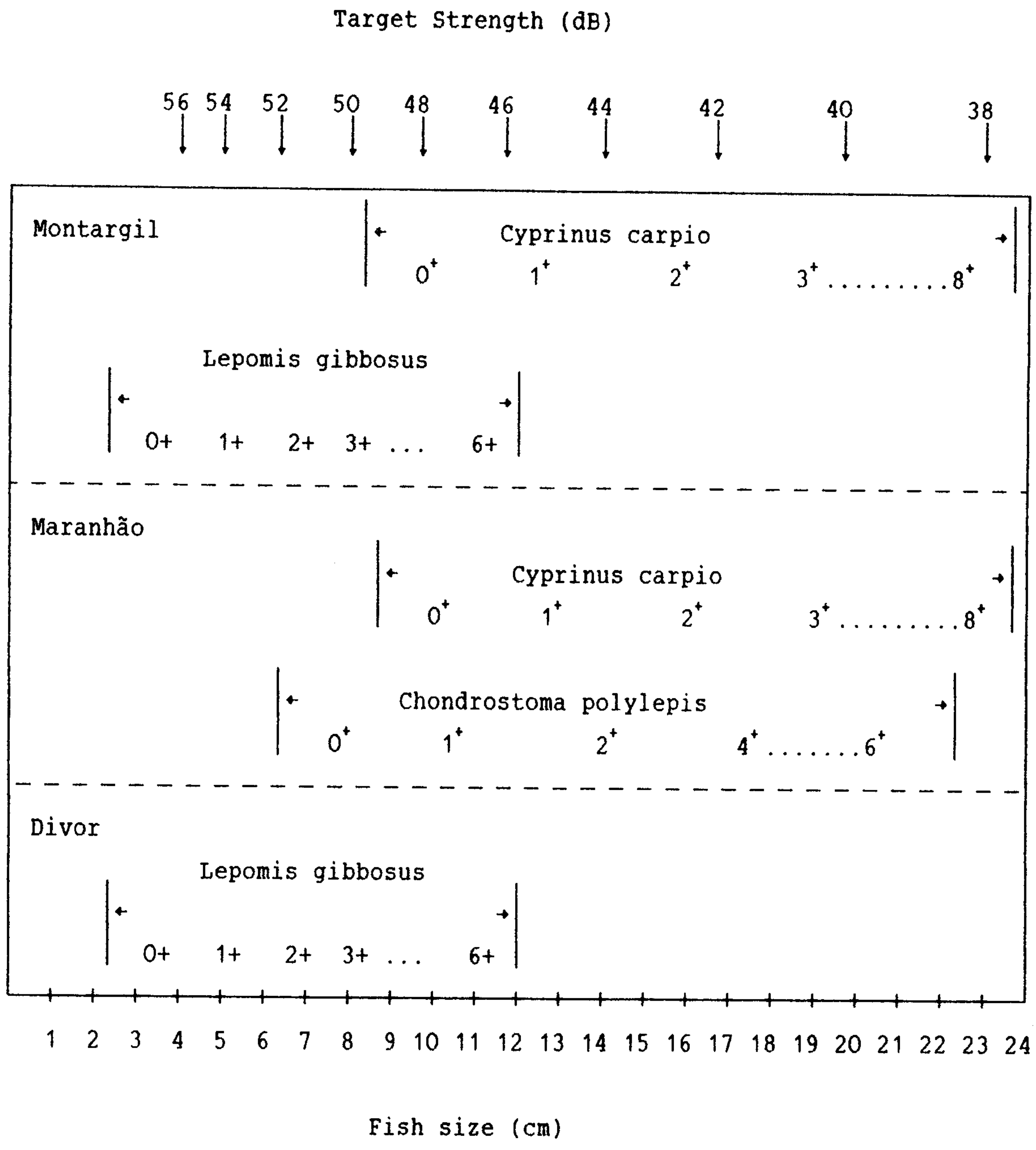


Fig. 33. Probable size distribution of the dominant pelagic fish species in Lakes Maranhão, Divor and Montargil based on echosounding and gill net catches. Target strength values (in -dB) of corresponding single fish size are based on length-dB regression given by Lindem (1980).

The general planktivorous tendency of sunfish both in Divor and Montargil is interesting, since adult sunfish in environments with more complex fish communities are largely restricted to shallow areas (Keast 1978). The lack of severe pelagic food competitors, as well as true pelagic predators in these reservoirs clearly demonstrate the difficulties of predicting the habitat utilization of introduced species into new environments with vacant food niches. More data concerning habitat utilization and feeding of the non predatory allopatric centrarchid sunfish should therefore be given attention in future fish research.

The lack of pelagic sunfish in Maranhão is an interesting feature, as we only caught planktivorous carp and nase, both feeding on zooplankton in this lake. It is too early to conclude if this can be explained by food competition alone, forcing the sunfish as a weaker planktivorous species into littoral habitats. The feeding of littoral sunfish clearly demonstrates the planktivorous tendency also in this lake, and make interpretation of selected habitat in Maranhão more difficult.

More "balanced" coexistence of pelagic sunfish and carp seems to occur in Montargil, since fish larger than approx. 20 cm were observed by echosounding in the upper 10 m water strata during the day. However, the vertical diurnal migration behaviour of sunfish clearly demonstrated in Divor, is also observed to occur in Montargil, since the integrated number of fish of sunfish size (approx. 8-12 cm) increased during the day. This behaviour may contribute to reduced competition for food.

To discuss the habitats utilized by the different fish species, evaluation of available food components in the environments is obviously very important. The zooplankton communities have been well described by Monteiro (1984), and show the presence of relatively predation resistent species in Divor and Maranhão. The shift in cladoceran dominance from <u>Daphnia</u> <u>longispina</u> in an earlier study to the more predation resistent species *Bosmina longirostris* at the present time (Monteiro 1984) is probably related to greater predation pressure from increased sunfish densities in recent years. Further studies concerning sunfish, carp and nase behaviour, their feeding and effects on zooplankton community should therefore be carried out. The omnivorous tendency of carp is well documented by Ramos (1985) also from other parts of the Tejo river, carp feeding to a large extend both on green algae and cladocerans.

Several authors have documented the influence of fish in the lake eutrophication process through zooplankton predation (Shapiro et al. 1975, Andersson et al. 1978, Wurtsbaugh et al. 1981) and nutrient recycling (Andersson et al. 1978, Kitchell et al. 1975, Brabrand et al. in press). An interesting aspect of the investigated lakes is the dynamics of external nutrient loading, which decreases to minimum values in early summer and early autumn when phytoplankton peaks occur. Since water level at this time of the year is at its lowest, and lake area is reduced by 40-60%, a relative increase in fish biomass will occur. Also oxygen depletion in the hypolimnion, which occurs in Maranhão and Montargil, as well as availability of planktivorous food items, will force fish to remain in the phototrophic water stratum and increase the "ecological" fish density, during periods of maximum nutrient demands from the phytoplankton. The high temperature during this period will also enhance metabolic rates and increase the recycling of algal nutrients. Where feeding was investigated in this study, sunfish, nase and carp, moved and fed in a planktivorous manner.

Several factors may increase the relative importance of fish in stabilizing the eutrophic conditions, or influence the increase in phytoplankton biomass. One obvious factor is through the influence of the zooplankton, reducing the abundance of the important filterfeeder *Daphnia*. Another aspect is the excretion of nutrients when fish feeds on detritus or sediments rich in phosphorus. The uptake of low-energy food is well known in different fish species when animal food supply is scarce (Persson 1983). It has been documented from other lakes a P loading from fish excretion on 4.4 kg P ha^{-1} yr^{-1} (Brabrand et al. in press.), based on an estimated fish biomass of 200 kg ha^{-1}, which seems to be lower than the estimated fish biomass in these reservoirs. When the characteristics mentioned above are established during late summer, any P intrusion into the upper water strata will have a decisive importance to the phytoplankton developement. Also, if fish is feeding on sediments or detritus rich in phosphorous, possibly occurring when the water levels are low, increased fish influence may result. Considering the three lakes studied, one can assume a relatively higher contribution from fish on the eutrophication process in Montargil and Maranhão compared to the more shallow Divor, where the contribution of released P from the sediments is estimated to 8.0 kg P ha^{-1} yr^{-1} (Cabeçadas et al. 1986).

Data concerning the relative importance of benthic food animals has not been investigated in the present reservoirs so far, but densities of littoral benthic animals are probably low in Montargil and Maranhão, since water fluctuations and loose sandy substrate provide unsuitable conditions for most benthic animals. Low values of phosphorus input in late summer from the inlet rivers, low water levels and fish behaviour restricted to the phototrophic water stratum will maximize the eutrophications effects by fish.

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APPENDIX 1

Relationship between target strength of received echosignals (TS) and fish size (L), calculated according to the regression equation: <u>TS = 20 log L - 68</u> (Lindem & Sandlund, 1984). Recent investigations indicate fish larger than approx. 25 cm all to be classified in dB-group 38.

Fish size (cm)	Target strength (dB)
3 cm =	.... - 58 dB
4 cm =	.... - 56 dB
5 cm =	.... - 54 dB
6 cm =	.... - 52 dB
7 cm =	.... - 51 dB
8 cm =	.... - 50 dB
9 cm =	.... - 49 dB
10 cm =	.... - 48 dB
11 cm =	.... - 47 dB
12 cm =	.... - 46 dB
13 cm =	.... - 46 dB
14 cm =	.... - 45 dB
15 cm =	.... - 44 dB
16 cm =	.... - 44 dB
17 cm =	.... - 43 dB
18 cm =	.... - 43 dB
19 cm =	.... - 42 dB
20 cm =	.... - 42 dB
21 cm =	.... - 42 dB
22 cm =	.... - 41 dB
23 cm =	.... - 41 dB
24 cm =	.... - 40 dB
25 cm =	.... - 40 dB
26 cm =	.... - 40 dB
27 cm =	.... - 39 dB
28 cm =	.... - 39 dB
29 cm =	.... - 39 dB
30 cm =	.... - 38 dB
31 cm =	.... - 38 dB
32 cm =	.... - 38 dB
33 cm =	.... - 38 dB
34 cm =	.... - 37 dB
35 cm =	.... - 37 dB
36 cm =	.... - 37 dB
37 cm =	.... - 37 dB
38 cm =	.... - 36 dB
39 cm =	.... - 36 dB
40 cm =	.... - 36 dB