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Fisheries Research 31 (1997) 93–106

FISHERIES RESEARCH

'Three seine nets' sampling applied to the littoral zone of two Brazilian tropical rivers with reduced velocity (Brazil)

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Accepted 18 November 1996

Abstract

Three seine nets (TSN method) laid simultaneously from the bank to form concentric semicircles (enclosing an area of 350 m^2) and hauled one after the other were employed for the removal fishing technique in littoral zones with reduced velocity in the Paraná River catchment. Fish density was estimated using the Zippin maximum likelihood method. The efficiency of this TSN method, estimated by two different indexes was not diminished by the size of the populations, but was limited by the kind and amount of obstacles on the bottom (submerged macrophytes, branches, mud) and the habitat preferences of the fish taxa. TSN was found to give best results for pelagic fishes, slightly less good for bentho-pelagic, and less good again for benthic ones, although it was not altogether unsatisfactory for quantitative research on fish populations.
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Keywords: Large tropical rivers; Littoral zone; Reduced velocity; Fish populations; Three seine nets; Density; Standing crop; Catch-efficiency

1. Introduction

One sampling method applied in a large river cannot provide credible density estimates, or even assessments of fish species richness (Pardue and Huish, 1981; Casselman et al., 1990). Bayley and Dowling (1993) suggest that 'along with fish size, various habitat features strongly affect efficiency, but in different ways, depending on sampling methods and species groups'. The efficiency of a given sampling method decreases with the increase in number of separate habitats in large rivers. In the profile of the Paraná River, in which we also used other sampling methods, their number was very high (Bonetto, 1975), as in other parts of the catchment studied.

Electrofishing, commonly used in temperate zone rivers, will never be fully useful in Latin America due to the frequent low water conductivity (Welcomme, 1985; Zalewski and Cowx, 1990; Penczak and Rodriguez, 1990; Cordiviola de Yuan, 1992; Lasso and Castroviejo, 1992; Menni et al., 1992; Penczak et al., 1994). Conductivity is a convenient measure of the quality of water for electrical transmission. Restrictions in using this method may

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PII S0165-7836(97)00001-5

Table 1
Description of three sampling areas at the time of collection. The lower part of the table shows type and amount of obstacles at sites of sampling. −: none; +: little; + +: common; + + +: abundant; [a] annual mean

Parameters/Area	Ivai (Taquara)	Parana	
		Baia River	Cortado Channel
Bed width (m)	200	300	80
Littoral depth (m)			
maximum	1.5	1.3	1.8
mean	0.7	0.4	0.7
Bottom structure	Sand:mud	Sand:mud	Sand:mud
(Proportion)	(9:1)	(2:1)	(1:2)
Velocity in littoral			
($m\ s^{-1}$)	0.2	0.12	0.06
Conductivity			
($\mu S\ cm^{-1}$)	30.0		
Transparency (cm)	25.0	0.74 [a]	1.01 [a]
Adjacent area	Pastures	Pastures	Arable land

Obstacles/Sites	Ivai				Baia Ch.			Cortado Ch.
	1	2	3	4	5	6	7	8
Pieces of wood	−	+	+ +	+	−	−	−	−
Clumps of macrophytes	−	+	+	+	+	−	−	−
Mud	−	−	−	−	−	+	+	+ +

occur at 100 $\mu S\ cm^{-1}$ according to Reynolds (1983), and below 60 $\mu S\ cm^{-1}$ according to Fisher and Brown (1993). Alabaster and Hartley (1962) claim that for the latter value fishing efficiency is already close to nil. In small tropical rivers of low discharge this problem may be overcome by salting the water and continuously monitoring with an automatic conductometer with an electrode to check if the water conductivity is sufficient for electrofishing. In large rivers this approach would be difficult, and even if possible it would be expensive, because tons of salt would have to be used. Further, the possibility of damage to the fauna prevents the use of such methods.

While searching for solutions to such problems during fish sampling in the habitats of large, low conductivity rivers of the Paraná (littoral zone with small velocity, lagoons, old river arms, oxbow lakes

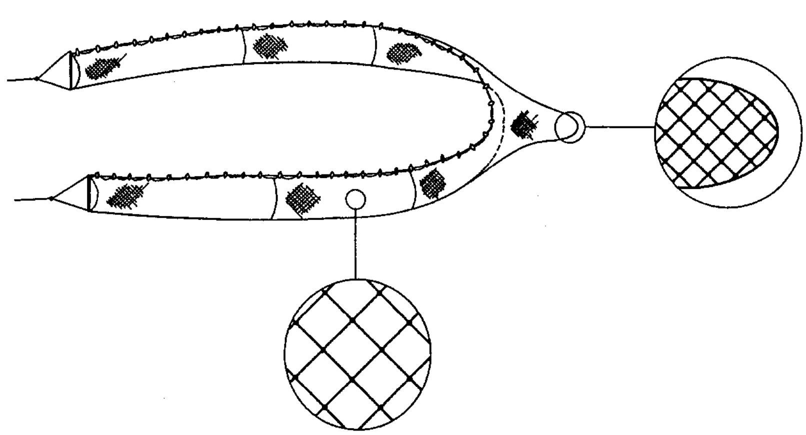

Fig. 1. Seine net with a bag. For net's dimensions see 'Methods'.

Table 2
Number (numerator) and standing crop (g)(denominator) obtained from sites in the Ivai River by the removal method of applying three successive seine net catches (C_n)

Species and its number	Site 1			Site 2			site 3			site 4		
	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3
1. *Apareiodon piracicabae*	134/54.06	29/12.67	16/6.00	23/8.49	1/0.12	4/0.79	12/2.59	6/1.65	6/2.65	39/10.88	27/5.79	22/5.39
2. *Aphyochorax nasutus*	98/84.39	14/11.39	2/1.86		1/0.83	2/1.79	6/3.95	7/7.79	1/0.86	40/31.38	19/16.92	4/3.69
3. *Astyanax bimaculatus*	34/123.40	3/15.64		3/32.65	1/8.23	2/7.69	1/5.74			10/32.52	6/8.12	1/0.48
4. *Bryconamericus stramineus*	151/68.04	29/11.26	19/4.45	31/40.66	20/6.63	21/5.52	22/6.99	10/3.38	3/0.40	84/25.30	8/2.24	4/0.79
5. *Bryconamericus* sp 1		3/1.89								9/4.23		
6. *Bryconamericus* sp 2							1/0.51					
7. *Catathyridium jenynsii*		1/458.10										
8. *Cheirodon notomelas*	1/0.40											
9. *Crenicichla britskii*	2/1.41		1/0.60								1/0.61	
10. *Farlowella hahni*		1/3.53										
11. *Hemigrammus marginatus*	30/20.95						2/0.64			1/0.66	1/0.79	
12. *Hoplias malabaricus*	1/26.08											
13. *Hyphessobrycon* sp	7/2.76									8/3.02		1/0.20
14. *Iheringichthys labrosus*	6/5.91	13/20.52	5/6.04	1/1.17		2/1.68	7/27.58	1/1.70		3/3.12	3/4.94	1/0.73
15. *Megalonema platanus*		1/16.76					1/23.18					
16. *Moenkhausia intermedia*										1/2.55		
17. *Roeboides paranensis*	10/32.34	3/12.84	2/4.47	4/17.15	1/1.96	1/2.43	1/2.24			7/16.32		
18. *Steindachnerina insculpta*	114/1331.60	25/289.74	9/93.93	1/6.53						13/132.77	3/58.31	
Total	588/1751.30	122/854.34	54/117.40	63/106.65	24/17.80	32/19.90	53/73.42	24/14.52	10/3.91	215/262.75	68/97.72	33/11.28

Table 3
Sampling results in the Baia Channel (Sites 5–7) and the Cortado Channel (Site 8) (see Table 2 for explanation)

Species and its number	Site 5			Site 6			Site 7			Site 8		
	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3
1. *Apareidon affinis*	38/17.46	86/41.43	56/18.15	48/30.69	28/8.20	13/3.98	18/15.10	7/4.69	4/1.73	36/11.43	49/12.72	55/9.35
2. *Aphyochorax nasutus*	142/104.28	17/12.48		112/80.18	15/10.08		45/32.29	2/1.17	3/2.24	12/8.23	8/5.35	4/2.48
3. *Astyanax bimaculatus*	134/311.53	98/220.37	6/14.34	29/52.64	4/3.69	1/0.73	26/25.44	7/7.72	3/3.38	7/54.58	5/48.92	5/26.32
4. *Astyanax* sp				2/3.88								
5. *Bryconamericus stramineus*	362/190.63	41/22.25	27/6.64	30/9.95	16/3.55	4/0.35	27/12.30	2/0.73	5/1.39	1365/478.75	677/80.41	332/27.29
6. *Catathyridium jenynsii*						1/8.23					1/17.18	1/34.80
7. *Characidium* gr *fasciatum*		1/0.35	1/0.32	2/1.04	1/0.50	3/1.41	2/2.74	2/1.17				
8. *Cheirodon notomelas*	615/287.18	9/4.39	24/11.65	302/143.87	21/11.10		89/40.94	8/4.27	2/1.02	40/18.38	15/6.74	
9. *Cheirodon* sp 1	19/4.32	2/0.39	1/0.22	3/0.77	2/0.41		1/0.27					
10. *Cheirodon* sp 2	4921/1697.80	132/45.57	69/22.19	1362/437.02	105/31.45	19/5.71	2634/824.40	206/63.35	71/21.77	8195/2130.90	1140/296.09	325/75.89
11. *Cichla monoculus*										1/0.59		
12. *Crenicichla britskii*	1/12.12						1/11.88					
13. *Cyphocharax modesta*		1/3.46										1/20.94
14. *Cyphocharax nagellii*												
15. *Hemigrammus* sp							2/1.59			98/44.90	14/4.51	1/0.28
16. *Hemigrammus marginatus*	3/1.53			1/0.38	1/0.58		1/0.38	1/0.71		6/1.17	10/2.31	7/1.05
17. *Hyphessobrycon* sp	359/75.80	39/7.44	104/15.85	21/6.90	15/3.12	3/0.51	56/15.94	13/3.88	12/3.15			
18. *Hyphessobrycon callistus*	2/0.98	2/0.91	1/0.60	1/0.40			36/17.13	5/2.46	1/0.04			
19. *Hyphessobrycon* sp 1	4/1.28											
20. *Iheringichthys labrosus*	18/514.20	14/515.30		4/87.22			15/343.97	1/35.86	1/16.72	2/0.51	4/94.78	3/73.87
21. *Jobertina* sp				1/0.36								
22. *Leporinus friderici*				1/49.60								
23. *Leporinus obtusidens*			3/1.44				4/317.35	1/18.14	2/23.80			
24. *Loricariichthys platymetopon*	2/106.25	1/125.19		2/41.92	2/1.40	2/1.51		1/36.62		1/0.09	6/6.28	27/8.95
25. *Moenkhausia intermedia*	5/14.56	1/1.81		1/2.49					9/7.60	2/0.92		
26. *Moenkhausia sanctae-filomenae*	4/3.15	3/1.90		18/16.14	1/0.83	18/14.42		5/4.19				
27. *Odontostilbe microcephala*	5/3.73	1/0.60		2/1.40			3/1.99			29/21.79	4/2.28	
28. *Oligosarcus pintoi*	1/3.47											
29. *Pimelodella gracilis*	2/10.88			2/11.58								
30. *Roeboides paranensis*	4/11.58	1/2.24		3/9.09			5/15.68	1/2.66		1/2.78		1/3.00
31. *Salminus maxillosus*										1/0.32		
32. *Satanoperca pappaterra*	1/1.69		1/0.24	1/0.08			4/89.81	3/1.97	1/0.50	6/4.23	18/6.94	10/6.09
33. *Serrasalmus marginatus*	7/1.04	4/6.77				1/0.28	1/0.41	1/0.70				
34. *Serrasalmus spilopleura*	6/174.45		1/0.54	2/1.08			3/1.15		1/0.05			1/14.55
35. *Steindachnerina insculpta*	385/2068.00	723/3919.4	98/488.80	78/495.26	10/45.16	9/49.24	8/49.20	2/8.87	9/42.99	4/32.38	65/435.70	76/530.50
Total	7040/5617.90	1176/4932.30	392/581.00	2028/1483.90	221/120.07	74/86.37	2981/1820.00	268/199.20	124/126.40	9806/2811.95	2016/1020.20	849/835.40

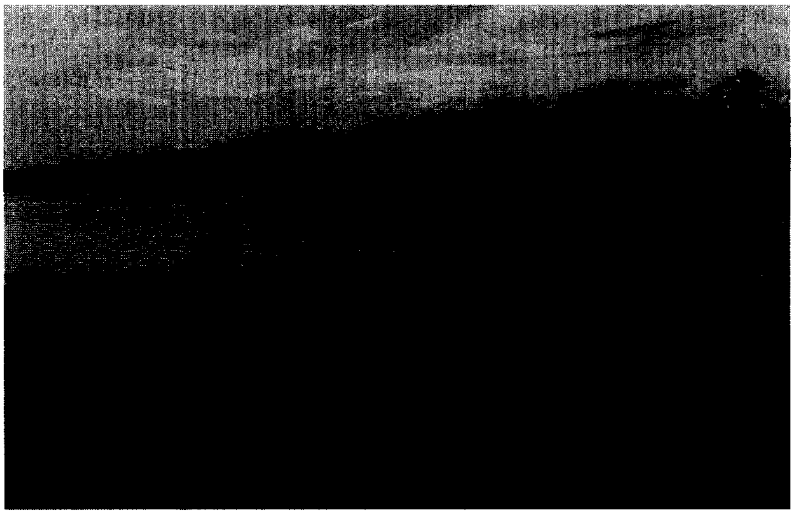

Fig. 2. Three seine nets method employed in the littoral zone of the Ivai River. The first net is just being hauled.

and others with low velocity), we tested the use of three seine nets (TSN) laid simultaneously from the bank to form concentric semicircles and hauled one after the other (Penczak and O'Hara, 1983). Three nets are required, because that number is the minimum for any accurate estimate of density employing a removal technique (Raleigh and Short, 1981).

2. Study area, materials and methods

2.1. Study area

Sampling was carried out in the littoral zone of: (1) the Ivai River; (2) Baia River; and (3) Cortado Channel, which is one part of the braided channel of

Fig. 3. Setting the seine nets in a deeper part of the Ivai River with a boat.

the Paraná. All of these sites are situated in the Paraná River catchment in north-western corner of State Paraná.

The Ivai River, 695 km long, is a left bank tributary of the Paraná River, entering the main river 505 km along its course. The sites are located 611 km downstream of its sources (Table 1), near the mouth of its tributary, the Taquara. They were sampled on 18 November 1994.

The Baia River, located on the right side of the Paraná River floodplain, is 75 km long and runs parallel to the main channel. It flows into the Paraná at the 430 km of the latter's course. The river is highly sinuous and is connected with many lagoons. The upper stretch (17 km) was intercepted by the Porto Primavera dam. The site sampling was in a 'baia' (enlargement of the channel) 65 km down its course (Table 1); the sampling date was 26 November 1994.

The Cortado Channel is part of a typically braided channel of the Paraná River, with a large number of islands and sandy bars. The Paraná River has 810 km within Brazilian territory, excluding the Paranaiba River (1070 km), its natural prolongation. The sampling sites were 435 km down its course, near the confluence of the Cortado Channel. The date of collection was 26 November 1994, and the site description is given in Table 1, which also contains a qualitative and quantitative description of obstacles to nets.

Table 4

Results of three removal catches in the Ivai River at Site 1 and 2. SIN: species identification number according to Tables 2–3. C_s and B_s are total number and total weight of fish caught, repectively. N is estimated density value with 95%CL. B is estimated standing crop. R is statistic which tests the validity of the Zippin model, $\hat{p}$ is capture efficiency, e fishing efficiency index, * Zippin method not applicable; [a] absolute estimate; p: pelagic, b: benthic, pb: pelagic-benthic (see text for explanations)

SIN	C_s	B_s (g)	N	95%CL	B (g)	R	$\hat{p}$	e	N ha^{-1}	B kg ha^{-1}
Site 1										
1b	179	72.8	185	7	75.2	0.34	0.70	3.8	5286	2.15
2p	114	97.7	115	2	98.6	0.16	0.85	1.7	3286	2.82
3pb	37	139.0	37	0	139.0	0.08	0.92	0.0	1057	3.97
4b	199	83.8	206	7	86.7	0.34	0.70	3.4	5886	2.48
5	3	1.9	3 [a]		1.9				86	0.05
7b	1	458.1	1 [a]		458.1				29	13.09
8pb	1	0.4	1 [a]		0.4				29	0.01
9b	3	2.0	3 [a]		2.0				86	0.06
10b	1	3.5	1 [a]		3.5				29	0.10
11p	30	21.0	30 [a]		21.0				857	0.60
12pb	1	26.1	1 [a]		26.1				29	0.75
13	7	2.8	7 [a]		2.8				200	0.08
14b	24	32.4	26 *		35.1				743	1.00
15p	1	16.8	1 [a]		16.8				29	0.48
17p	15	49.6	16	3	52.9	0.47	0.60	18.8	457	1.51
18b	148	1715.2	152	5	1761.2	0.29	0.74	3.3	4343	50.32
Total	764	2723.1	785		2781.3				22432	79.47
Site 2										
1b	28	9.4	29	3	9.7	0.32	0.71	10.3	829	0.28
2p	3	2.6	3 [a]		2.6				86	0.07
3pb	6	48.6	7 *		56.7				200	1.62
4b	72	52.8	84 *		61.6				2400	1.76
14b	3	2.9	3 [a]		2.9				86	0.08
17p	6	21.6	7	2	25.2	0.50	0.57	28.6	200	0.72
18b	1	6.5	1 [a]		6.5				29	0.19
Total	119	144.4	134						3830	4.72

Table 5
Results of three removal catches in the Ivai River at Site 3 and 4 (see Table 4 for symbols' explanations)

SIN	C_s	B_s (g)	N	95%CL	B (g)	R	$\hat{p}$	e	N ha^{-1}	B kg ha^{-1}
Site 3										
1b	24	9.4	35	32	13.7	0.75	0.32	91.4	1000	0.39
2p	14	12.7	17	9	15.4	0.64	0.43	52.9	486	0.44
3pb	1	5.7	1 [a]		5.7				29	0.16
4b	35	10.8	37	5	11.4	0.46	0.60	13.5	1057	0.33
6	1	0.5	1 [a]		0.5				29	0.01
11p	2	0.6	2 [a]		0.6				57	0.02
14b	8	29.3	8	0	29.3	0.13	0.88	0.0	229	0.84
15p	1	23.2	1 [a]		23.2				29	0.66
17p	1	2.2	1 [a]		2.2				29	0.06
Total	87	94.4	103		102				2945	2.91
Site 4										
1b	88	22.1	113 [a]		28.4				3229	0.81
2p	63	52.0	67	6	55.3	0.43	0.63	9.0	1914	1.58
3pb	17	41.1	18	4	43.5	0.47	0.59	22.2	514	1.42
4b	96	28.3	97	2	28.6	0.17	0.85	2.1	2771	0.82
5	9	4.2	9 [a]		4.2				257	0.12
9b	1	0.6	1 [a]		0.6				9	0.02
11p	2	1.5	2 [a]		1.5				57	0.04
13	9	3.2	9	1	3.2	0.22	0.80	11.1	257	0.09
14b	7	8.7	9	9	11.2	0.71	0.36	100.0	257	0.32
16p	1	2.6	1 [a]		2.6				29	0.07
17p	7	16.3	7 [a]		16.3				200	0.47
18b	16	191.1	16	1	191.1	0.19	0.83	6.3	457	5.46
Total	316	371.7	349		386.5				9971	11.22

2.2. Material

A total of 28 261 fish comprising 41 taxa were caught (Tables 2 and 3). Scientific names of fish in many cases were restricted to genera, or numbered within a given genus because the taxonomic affinity of certain captured fish has not yet been determined, and descriptions of new species are expected.

2.3. Methods

Sampling was carried out using seine nets with a bag (Hayes, 1983). Each net had the same dimensions, 50 m in length, 2.8 m in depth, and 3.5 m in the length of bag (Fig. 1). The wall of the net was made of 8 mm mesh knot to knot multifilament material, and the bag was 4 mm mesh. Plastic floats had been mounted on the floatline and bottom line incorporated lead weights to prevent it lifting on submerged weeds or other fine obstacles.

After laying all three nets together on the bank they were drawn simultaneously into the water to form closed semicircular areas of ca 350 m^2. This was done by either using a boat or by wading, depending on the depth of the water. When a boat was used nets were connected by means of long ropes to prevent the boat engine scaring the fish. (Figs. 2 and 3) Each net was then alternately hauled back, onto the bank. The nets were thus hauled to carry out a removal technique in the following order: inner (C_1), middle (C_2), and outer (C_3) and the fish collected in each net were investigated separately. They were preserved in formalin and taken to the laboratory for identification, counting and weighing.

The Zippin (1956) maximum likelihood estimate method was used for density calculation. Density (N) and variance (V_N) were obtained from the equation:

$$N = C_s + 1/(1 - \hat{q}^S),$$

Table 6
Results of three removal catches in the Baia Channel at Site 5 (see Table 4 for symbols' explanation)

SIN	C_s	B_s (g)	N	95%CL	B (g)	R	$\hat{p}$	e	N ha^{-1}	B kg ha^{-1}
1b	180	77.1	288 *		123.4				8229	3.53
2p	159	116.8	159	1	116.8	0.11	0.89	0.6	4543	3.34
3pb	238	546.2	255	13	585.2	0.46	0.60	5.1	7286	16.72
5b	430	219.5	436	6	222.6	0.22	0.80	1.4	12457	6.36
7b	2	0.7	2 [a]		0.7				57	0.02
8pb	648	303.3	648	0	303.3	0.09	0.91	0.0	18514	8.67
9	22	4.9	22	1	4.9	0.18	0.84	4.5	629	0.14
10	5122	1765.6	5122	0	1765.6	0.05	0.95	0.0	146343	50.45
12b	1	12.1	1 [a]		12.1				29	0.35
13b	1	3.5	1 [a]		3.5				29	0.10
16p	3	1.5	3 [a]		1.5				86	0.04
17	502	99.1	544	22	107.4	0.49	0.58	4.0	15543	3.07
18pb	5	2.5	8	125	4.0	0.80	0.27	> 50 [b]	229	0.11
19	4	1.3	4 [a]		1.3				114	0.04
20b	32	1029.5	34	4	1093.8	0.44	0.62	11.8	971	31.25
23pb	2	106.3	2 [a]		106.3				57	3.04
24b	4	126.6	6 *		202.6				171	5.79
25p	6	16.4	6	0	16.4	0.17	0.85	0.0	171	0.47
26pb	7	5.1	7	2	5.1	0.43	0.63	28.6	200	0.15
27p	6	4.3	6	0	4.3	0.17	0.85	0.0	171	0.12
28p	1	3.5	1 [a]		3.5				29	0.10
29b	2	10.9	2 [a]		10.9				57	0.31
30p	5	13.8	5	1	13.8	0.20	0.82	20.0	143	0.39
32b	2	1.9	2 [a]		1.9				57	0.05
33pb	11	7.8	11	2	7.8	0.36	0.68	18.2	314	0.22
34pb	7	175.0	7	1	175.0	0.29	0.74	14.3	200	5.00
35b	1206	6476.2	1825	294	9800.2	0.76	0.31	16.1	52143	280.01
Total	8608	11131.4	9407		14693.7				268772	419.84

and

$$V_N = \frac{N(1-\hat{q}^S)(1-[1-\hat{q}^S])}{(1-\hat{q}^S)^2 - (\hat{p}s)^2(1-[1-\hat{q}^S])/(1-\hat{p})},$$

where C_s is the total number of fish in s catches, $1-\hat{q}^S$ and $\hat{p}$ are determined from the Zippin (1956) graphs for R value (Seber, 1973):

$$R = \sum_{i=1}^{s} \frac{(i-1)C_1}{C_s+1} = \frac{C_2+2C_3}{C_1+C_2+C_3}$$

The 95% confidence limits (95%CL) for N are $\pm 1.96\sqrt{V_N}$. Standing crop (B) (estimated biomass on defined area and time) was calculated from the equation (Mahon et al., 1979):

$$B = B_s N / C_s$$

where B_s in the total weight and C_s total number of fish caught.

When the number of fish caught in three catches was ≤ 3, or if all fish were collected by the first net (the inner) it was assumed that $C_s = N$, and was considered an 'absolute estimate' of fish density and standing crop.

If the Zippin method was not applicable (i.e. no progressive decline in successive catches) the estimated density (N) was obtained by multiplying C_s by the proportion N/C_s for a species characterized by a lower value of catch efficiency $(\hat{p})$ at a given site.

The fishing efficiency and accuracy of density estimates were assessed using two indexes: (1) – $\hat{p}$ the efficiency of first catch read out from the Zippin (1956) model; and (2) $e = 95\%\text{CL} \times 100/N$. The fishing efficiency with TSN using $\hat{p}$ and e were assessed on a 4-point scale (Penczak and Romero, 1990):

	$\hat{p}$	e
Very good	≥ 0.8	$\leq 10\%$
Good	0.79 – 0.60	11 – 25%
Adequate	0.59 – 0.40	26 – 50%
Bad	≤ 0.39	> 50%

Two indices of fishing efficiency were employed because $\hat{p}$ is stimulated by the efficiency of the first net (catch), and e is weighted by the range of 95%CL.

3. Results

Tables 4–9 present data on total number, and total standing crop (SC) of fish caught by TSN, estimated density with 95%CL, estimated SC, statistic which tests the validity of Zippin method (R) and two fishing efficiency indexes ($\hat{p}$, e) at the eight sites in the Paraná River catchment.

A total of 140 estimates of density and SC were made for given taxa. It is noticeable that 'absolute estimates' (59) constituted 42.1% of all estimates, of which in 36 cases a given taxon was captured in the first net (C_1), which constitutes 25.7%, while in 23 cases (16.4%) only ≤ 3 individualsl were captured, but with more than one net.

Particular attention was paid to those taxa that occurred in the first and also in subsequent nets, when their total number was ≥ 4 specimens. A total of 81 such cases were recorded and for them the Zippin method for estimating density was applicable. In 18 (12.9%) of the 81 cases the Zippin method was not applicable. It was applicable in 63 (45%) and this group was further analyzed.

Table 7
Results of three removal catches in the Baia Channel at Site 6 (see Table 4 for symbols' explanation)

SIN	C_s	B_s (g)	N	95%CL	B (g)	R	$\hat{p}$	e	N ha^{-1}	B kg ha^{-1}
1b	89	42.9	105	19	50.6	0.61	0.46	8.1	3000	1.45
2p	127	90.3	127	1	90.3	0.12	0.89	0.8	3629	2.58
3pb	34	57.0	34	1	57.0	0.18	0.84	2.9	971	1.63
4	2	3.9	2 [a]		3.9				57	0.11
5b	50	14.0	54	7	15.1	0.48	0.59	13.0	1543	0.43
6b	1	8.2	1 [a]		8.2				29	0.23
7b	6	2.9	7 *		3.4				200	0.10
8pb	323	155.0	323	0	155.0	0.07	0.94	0.0	9229	4.43
9	5	1.2	5	2	1.2	0.40	0.65	40.0	143	0.03
10	1486	474.2	1486	0	474.2	0.10	0.90	0.0	42457	13.55
16p	2	1.0	2 [a]		1.0				57	0.03
17	39	10.5	44	9	11.8	0.54	0.53	20.5	1257	0.34
18pb	1	0.4	1 [a]		0.4				29	0.01
20b	4	87.2	4 [a]		87.2				114	2.49
21	1	0.4	1 [a]		0.4				29	0.01
22pb	1	49.6	1 [a]		49.6				29	1.42
24b	6	44.8	7 *		52.9				200	0.51
25p	1	2.5	1 [a]		2.5				29	0.07
26pb	37	31.3	44 *		36.9				1257	1.05
27p	2	1.4	2 [a]		1.4				57	0.04
29b	2	11.6	2 [a]		1.6				57	0.33
30p	3	9.1	3 [a]		9.1				86	0.26
32b	1	0.1	1 [a]		0.1				29	0.00
33pb	1	0.3	1 [a]		0.3				29	0.01
34pb	2	1.1	2 [a]		1.1				57	0.03
35b	97	589.7	99	4	661.9	0.29	0.74	4.0	2829	17.20
Total	2323	1690.6	2359		1787.1				67403	49.34

Table 8
Results of three removal catches in the Baia Channel at Site 7 (see Table 4 for symbols' explanation)

SIN	C_s	B_s (g)	N	95%CL	B (g)	R	$\hat{p}$	e	N ha^{-1}	B kg ha^{-1}
1b	29	21.5	32	7	23.7	0.52	0.55	21.9	914	0.68
2p	50	35.7	50	1	35.7	0.16	0.85	2.0	1429	1.02
3pb	36	36.5	37	4	37.5	0.36	0.68	10.8	1057	1.07
5b	34	14.4	35	3	14.8	0.35	0.69	8.6	1000	0.42
7b	4	3.9	4	2	3.9	0.50	0.57	50.0	114	0.11
8pb	99	46.2	99	1	46.2	0.12	0.88	1.0	2829	1.32
9	1	0.3	1 [a]		0.3				29	0.01
10	2911	909.6	2917	5	911.5	0.12	0.88	0.2	83 343	26.04
12b	1	11.9	1 [a]		11.9				29	0.34
15	2	1.6	2 [a]		1.6				57	0.05
16p	2	1.1	2 [a]		1.1				57	0.03
17	81	23.0	86	7	24.4	0.46	0.61	8.1	2457	0.70
18pb	42	19.6	42	1	19.6	0.17	0.85	2.4	1200	0.56
20b	17	396.6	17	1	396.6	0.18	0.84	5.9	486	11.33
23pb	5	335.5	5	1	335.5	0.20	0.82	20.0	143	9.59
24b	3	60.4	3 [a]		60.4				86	1.72
26pb	14	11.8	18 *		14.8				514	0.42
27p	3	2.0	3 [a]		2.0				86	0.06
30p	6	18.4	6	0	18.4	0.17	0.85	0.0	171	0.52
32b	8	92.3	10	6	115.4	0.63	0.45	60.0	286	3.30
33pb	2	1.1	2 [a]		1.1				57	0.03
34pb	4	1.3	4	2	1.3	0.50	0.57	50.0	114	0.04
35b	19	101.1	24 *		126.4				686	3.61
Total	3373	2145.8	3400		2204.1				97 144	62.97

Table 9
Results of three removal catches in the Baia Channel at Site 7 (see Table 4 for symbols's explanation)

SIN	C_s	B_s (g)	N	95%CL	B (g)	R	$\hat{p}$	e	N ha^{-1}	B kg ha^{-1}
1b	140	33.5	175 *		41.9				5000	1.20
2p	24	17.1	30	12	21.4	0.67	0.40	40.0	857	0.61
3pb	17	129.8	18 *		162.3				514	4.64
5b	2374	586.5	2725	86	673.2	0.56	0.51	3.2	77 857	19.23
6b	2	52.0	2 [a]		52.0				57	1.49
8pb	55	25.1	56	3	25.6	0.27	0.75	5.4	1600	0.73
10	9660	2503.0	9743	22	2524.5	0.19	0.83	0.2	278 371	72.13
11pb	1	0.6	1 [a]		0.6				29	0.02
14b	1	20.9	1 [a]		20.9				29	0.60
16p	113	49.7	113	2	49.7	0.14	0.87	1.8	3229	1.42
17	23	4.6	29 *		5.8				829	0.17
20b	9	169.2	11 *		211.5				314	6.04
24b	34	15.4	43 *		19.3				1229	0.55
25p	2	0.9	2 [a]		0.9				57	0.03
27p	33	24.1	33	1	24.1	0.12	0.88	4.3	943	0.69
30p	2	5.8	2 [a]		5.8				57	0.17
31p	1	0.3	1 [a]		0.3				29	0.01
32b	34	17.2	43 *		21.5				1229	0.61
34pb	1	14.6	1 [a]		14.6				29	0.42
35b	145	998.6	181 *		1248.3				5171	35.67
Total	12 671	4468.9	13210		5124.2				377 430	146.43

Table 10
Evaluation of the efficiency with the TSN method according to stock density using indexes e (above) and $\hat{p}$ (below)

Population size	Zippin not applicable		Bad estimates		Adequate estimates		Good estimates		Very good estimates		Total	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
≤ 20	7	24.1	4	13.8	5	17.2	7	24.1	6	20.7	29	100
21–100	7	24.1	1	3.5	1	3.5	7	24.1	13	44.8	29	100
101–400	4	28.6					2	14.3	8	57.1	14	100
> 400							1	11.1	8	88.9	9	100
≤ 20	7	24.1	2	6.9	6	20.7	5	17.2	9	31.0	29	100
21–100	7	24.1	1	3.5	4	13.8	9	31.0	8	27.6	29	100
101–400	4	28.6			1	7.1	4	28.6	5	35.7	14	100
> 400			1	11.1	2	22.2			6	66.7	9	100

Estimates of which $e = 0$ (because 95%CL = 0) and $C_s = N$ also were considered 'very good' (Tables 4–9). There were nine such density estimates, including three at the highest density values (Table 6, Table 7), while estimates at $e > 0$, but with $C_s = N$ were 18, which indicates a high and proportional decrease in the number of fish of a given population in successive seine nets. For density values with $e = 0$ the value of $\hat{p}$ was always high with a narrow range ($\bar{x} \pm SD = 0.89 \pm 0.04$, range: 0.85–0.95). In contrast, for cases when $C_s = N$, but $e > 0$, $\hat{p}$ was lower and amounted to 0.78 ± 0.11 at a wide range: 0.57–0.89.

Accuracy of fishing efficiency ($\hat{p}$, e), estimated with TSN and taking into account the population size, is presented in Table 10. When the Zippin method was apllicable, 'very good estimates' for all four categories of population size for two indexes constituted the highest percentage of estimates, the next lower being 'good estimates' (Table 10). 'Bad estimates' constituted the lowest percent of all estimates and appeared most frequently in the case when population size ≤ 20 individuals.

An evaluation of the efficiency of the TSN method for species from different habitats (Table 11) showed that the best results were obtained for pelagic taxa; the Zippin method was also always applicable. Slightly worse results were found for pelagic-benthic taxa and the worst for benthic species. It should be noted that the highest number of 'absolute estimates' was recorded for benthic species (Table 11).

A contribution to the knowledge of fish density and standing crop of fish populations in some littoral zones of the Paraná River catchment is included in Tables 4–9. In the reduced velocity sites of the littoral zone of the Ivai River all fish population density is considerable and expressed in thousands per ha, and once in tens of thousands per ha (Tables 4 and 5), but standing crop was low because of the domination of small individuals, 1–3 g in weight. A similar situation but with an even greater number of fish was found in the littoral zones of the Paraná River.

The sites in the Paraná River floodplain were dominated by *Cheirodon* sp_2, which were found at densities of 83 343, 146 343 and 278 371 indiv. ha^{-1} in Sites 7, 5 and 8, respectively, while it was rare at sites on the Ivai River. Other species that occurred in

Table 11
Evaluation of the TSN method efficiency for taxons from different habitas within a river. p: pelagic, b: benthic, p-b: pelagic and benthic; [a] number of estimates; for $\hat{p}$ and e mean ± SD values are calculated; in brackets estimates for $\hat{p}$ and e% are included (see text for explanation)

	p	p-b	b
Absolute estimates [a]	20	11	21
Zippin not applicable [a]	0	3	12
$\hat{p}$	0.75 ± 0.17	0.73 ± 0.17	0.63 ± 0.18
e	12.03 ± 16.71 (15)	17.56 ± 25.82 (16)	29.93 ± 29.21 (21)

high density were *Bryconamericus straminensis* (77 857 indiv. ha^{-1}, Site 8) and *Steindachneria insculpta* (52 143 indiv. ha^{-1}, Site 5).

4. Discussion

Readers may feel confused by the number of unidentified taxa in this and other studies devoted to the ecology of tropical fishes (Watson and Balon, 1984; Lowe-McConnell, 1991; Cordiviola de Yuan, 1992; Lasso and Castroviejo, 1992; Menni et al., 1992). In recent times new fish species are being described by the thousand, while taxonomists are on the decrease because the 'taxonomic component is not always appreciated by government, and other bodies who provide the funds for its execution' (Greenwood, 1992). Under these circumstances long-term investigations on the identification of collected taxa as well as on describing those that are new to science, should not constitute a barrier to publishing ecological studies connected with sampling, diversity, community, populations or when a holistic approach to investigating nature is assumed.

Seine netting, included by some fisheries biologists amongst older technologies 'should not be neglected in the repertoire of techniques, because putting aside the fact that it is 'the more economical technique' (Pygott et al., 1990) one has to remember that only 'a standardized combination of several nonlethal techniques appeared to be the most accurate techniques' in large ecosystems composed of numerous various habitats (Pardue and Huish, 1981). To investigate fish populations in the littoral sites we have selected the TSN method (Penczak and O'Hara, 1983) as a highly qualitative and quantitative tool (Leslie and Timmins, 1992), because three seine nets employed simultaneously are particularly useful in obtaining quantitative data.

While investigating the impact of population size in fluvial zones of rivers on electrofishing efficiency measured with e (always on the same scale as that employed in this paper) 'good' and 'adequate' estimates dominated over 'very good' and 'bad' (Penczak and Romero, 1990). In reduced velocity English navigation canals, where a net technique was also applied, 29 of 46 estimates were 'very good' and there were no 'bad' estimates. Moreover, the highest

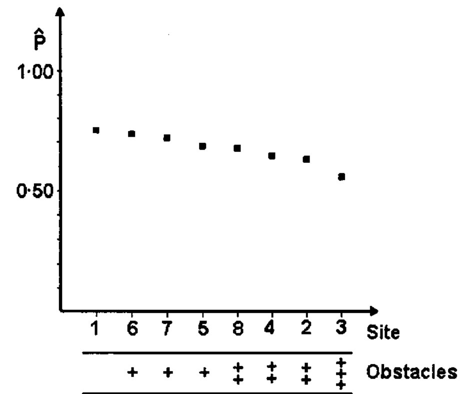

Fig. 4. Efficiency of the first net (inner, C_1) measured with the $\hat{p}$ index, in the investigated sites sequenced according to increasing obstacles (see Table 1 and explanations).

fishing efficiency was measured with $\hat{p}$ and e for pelagic roach and the lowest for benthic gudgeon (Penczak and O'Hara, in press), which is congruent with the present research (Table 2). A lower efficiency for benthic taxons is related to the kind and number of obstacles, which was shown for the TSN method in Frankiewicz et al. (1986), and also confirmed in our investigations (Fig. 4).

Summing up, the experience gathered above allows us to recommend TSN as one of the better methods for estimating density, diversity and standing crop of fish stock in certain habitats of large rivers with reduced velocity. TSN is not, however, free of all limitations, nor are any such methods (Treasurer, 1978; Leslie and Timmins, 1992).

Also, as was the case with Cordiviola de Yuan (1992), our attention was attracted by a high diversity of fish populations in lentic environments of the Paraná River, and by the fact that most of the fishes were small, which is a cause of moderate standing crop results, despite a high number of individuals. It seemed to us that densities (*Cheirodon* sp_2) of 146 343 and 278 371 individuals ha^{-1} (Tables 6 and 9) are close to world records of freshwater fish density, while Naiman (1976), investigating for a year the density of *Cyprinidon nevadensis* in a warm desert stream at measured time intervals (no predator, plenty of food), ranged 133 000–1960 000 indiv. ha^{-1}. Our density measurements were, however, one or two orders of magnitude higher than those calculated by Watson and Balon (1984); Cordiviola de Yuan (1992) and Lobón-Cerviá et al. (1993), also for dominant fishes living in tropical rivers.

Acknowledgements

The authors are very grateful to Rosemary Lowe-McConnell and Ian Cowx for English and other improvements. They also thank Ł. Głowacki and two anonymous reviewers for help in preparing the English version of the draft manuscript as well as compiling/editing numerous tables, and H.A. Britski, C.S. Pavanelli, H.F. Julio Jr. and C.M.L. Ferreti for identification of fish taxa, counting and weighing fish, and S.R. Rodrigues and G. Gherrard for sampling in hard conditions. The project was sponsored by COPEL (Brazil) and the State Committee for Scientific Research, Poland (KBN).

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