

# Aquatic macrophytes shape the foraging efficiency, trophic niche breadth, and overlap among small fishes in a Neotropical river

Water

Quirino, B.A.; Thomaz, S.M.; Jeppesen, E.; Sondergaard, M.; Dainez-Filho, M.S.; Fugi, R.

\*Corresponding author. Email address: barbara\_aq@hotmail.com

**Table S1** Macrophyte species sampled in the Baía River, Brazil.

<b>Taxa</b>	<b>Growth form</b>
<b>Araceae</b>	
<i>Pistia stratiotes</i> L.	free floating
<b>Araliaceae</b>	
<i>Hydrocotyle ranunculoides</i> L.	free floating
<b>Cyperaceae</b>	
<i>Eleocharis</i> sp.	emergent
<i>Oxycaryum cubense</i> (Poepp. & Kunth) Lye	epiphyte
<b>Hydrocharitaceae</b>	
<i>Limnobium laevigatum</i> (H. B. K. ex Willd.) Heine	free floating
<b>Menyanthaceae</b>	
<i>Nymphoides indica</i> (L.) Kuntze	rooted floating
<b>Poaceae</b>	
<i>Paspalum repens</i> Berg.	rooted floating
<b>Polygonaceae</b>	
<i>Polygonum acuminatum</i> Kunth.	emergent
<i>Polygonum ferrugineum</i> Weed.	emergent
<i>Polygonum stelligerum</i> Cham.	emergent
<b>Pontederiaceae</b>	
<i>Eichhornia crassipes</i> (Mar.) Salsus.	free floating
<i>Eichhornia azurea</i> Kunth.	rooted floating
<b>Ricciaceae</b>	
<i>Ricciocarpos natans</i> (L.)	free floating
<b>Salviniaceae</b>	
<i>Azolla filiculoides</i> Lam.	free floating
<i>Salvinia auriculata</i> Auble.	free floating
<i>Salvinia biloba</i> Raddi.	free floating
<i>Salvinia minima</i> Bak	free floating

**Table S2** Fish species sampled in aquatic macrophyte stands in the Baía River, Brazil.

Taxa
<b>CHARACIFORMES</b>
<b>Anostomidae</b>
<i>Leporinus lacustris</i> Campos, 1945
<b>Characidae</b>
<i>Astyanax lacustris</i> (Lütken, 1875)
<i>Aphyocharax anisitsi</i> Eigenmann, Kennedy, 1903*
<i>Aphyocharax dentatus</i> Eigenmann, Kennedy, 1903
<i>Hemigrammus ora</i> Zarske, Le Bail, Géry, 2006*
<i>Hyphessobrycon eques</i> (Steindachner, 1882)*
<i>Hyphessobrycon moniliger</i> Moreira, Lima, Costa, 2002*
<i>Moenkhausia bonita</i> Benine, Castro, Sabino, 2004*
<i>Moenkhausia forestii</i> Benine, Mariguela, Oliveira, 2004*
<i>Moenkhausia sanctaefilomenae</i> (Steindachner, 1907)*
<i>Psellogrammus kennedyi</i> (Eigenmann, 1903)*
<i>Roeboides descalvadensis</i> Fowler, 1932*
<i>Serrapinnus calliurus</i> (Boulenger, 1900)
<i>Serrapinnus notomelas</i> (Eigenmann, 1915)
<i>Serrapinnus</i> sp. 1
<i>Serrapinnus</i> sp. 2
<b>Crenuchidae</b>
<i>Characidium</i> sp.
<b>Curimatidae</b>
<i>Steindachnerina brevipinna</i> (Eigenmann, Eigenmann, 1889)
<b>Erythrinidae</b>
<i>Hoplias mbigua</i> Azpelicueta, Benítez, Aichino, Mendez, 2015
<b>Lebiasinidae</b>
<i>Pyrhulina australis</i> Eigenmann, Kennedy, 1903*
<b>GYMNOTIFORMES</b>
<b>Hypopomidae</b>
<i>Brachyhypopomus gauderio</i> Giora, Malabarba, 2009
<b>CICHLIFORMES</b>
<b>Cichlidae</b>
<i>Apistogramma combrae</i> (Regan, 1906)*
<i>Crenicichla britskii</i> Kullander, 1982
<i>Laetacara araguaiae</i> Ottoni, Costa, 2009*
<b>CYPRINODONTIFORMES</b>
<b>Poeciliidae</b>
<i>Pamphorhychties hollandi</i> (Henn, 1916)

\*Species used in trophic niche analyses.

**Table S3** The number of stomachs of each fish species analyzed in each macrophyte stand to calculate trophic niche breadth and overlap.

Macrophyte stand	<i>A. anisitsi</i>	<i>A. combrae</i>	<i>H. ora</i>	<i>H. eques</i>	<i>H. moniliger</i>	<i>L. araguaiae</i>	<i>M. bonita</i>	<i>M. forestii</i>	<i>M. sanctaeofilomenae</i>	<i>P. kennedyi</i>	<i>P. australis</i>	<i>R. descalvadensis</i>	Total
1						3		18			2		23
2		2		10		3		25	2		3		45
3	6	2	4	19	3			20		2	4		60
4	17	3	8	31			30	30	6	5			130
5		4		3				4			2		13
6							14	4					18
7		9	6	7		9		29	3		11		74
8	6		26	17			30	30	5				114
9		3	15	29			31	30	7	2	3		120
10						2		9	2		4		17
11			2	22		2		3					29
12			8	18	5	6	4	30	2	8	5		86
13							2	12	2				16
14				14			8	9					31
15							3	3					6
16			2	11	2			20					35
17			5	3			19	17					44
18							7	6				2	15
19				7				30			2		39
20		3						30	2	5			40
21				2			23	30	4		3		62
22				10				29	2		9		50
23		2					9	6	2				19
24		3		12		3		21			5		44
25		2		31		9		30			8		80
26				15				24	4		7		50
27				2		6		30	2		9		49
28	3			2			30	25		12	5		77
29		10					4	17	5	2	3		41
30							30	30	7	6	6		79
<b>Total</b>	<b>32</b>	<b>43</b>	<b>76</b>	<b>265</b>	<b>10</b>	<b>43</b>	<b>244</b>	<b>601</b>	<b>57</b>	<b>42</b>	<b>91</b>	<b>2</b>	<b>1506</b>

**Table S4** Limnological parameters and biotic communities in each macrophyte stand sampled in the Baía River. NA= No available data.

Stand	Water temperature (°C)	pH	Conductivity (µS/cm)	Dissolved oxygen (mg/L)	Water depth (cm)	Fish diversity (Shannon Index)	Fish density (Individuals / 3 traps)	Fish richness (Species / 3 traps)	Macrophyte diversity (Shannon Index)	Macrophyte density (g DW/m <sup>2</sup> )	Dominating macrophyte species (>70% of the total density)
1	19.3 ± 0.4	6.75 ± 0.55	0.03 ± 0.009	4.89 ± 1.23	125	1.43	59	9	2.03	1140.5	<i>E. azurea</i> (24.1%) <i>E. crassipes</i> (48.8%)
2	19.2 ± 0.4	6.61 ± 0.64	0.02 ± 0	4.07 ± 0.24	135	1.63	100	9	2.22	1404.9	<i>E. azurea</i> (45.3%) <i>O. cubense</i> (14.3%) <i>P. stelligerum</i> (15.7%)
3	19.1 ± 0.7	6.61 ± 0.33	0.02 ± 0.001	6.00 ± 2.05	65	1.67	305	13	1.95	1752.1	<i>E. azurea</i> (29.1%) <i>O. cubense</i> (34%) <i>S. biloba</i> (21%)
4	19.3 ± 0.5	6.74 ± 0.35	0.02 ± 0.001	4.23 ± 1.25	60	1.61	464	14	0.68	1370.1	<i>E. azurea</i> (87.9%)
5	19.2 ± 0.4	6.93 ± 0.14	0.02 ± 0.001	5.32 ± 1.89	70	1.6	17	6	0.49	1886.8	<i>E. azurea</i> (92.5%)
6	19.3 ± 0.3	7.07 ± 0.06	0.02 ± 0.001	5.02 ± 1.19	130	1.32	44	8	0.73	1508.5	<i>E. azurea</i> (18.9%) <i>E. crassipes</i> (80.7%)
7	19.7 ± 1.1	6.63 ± 0.66	0.03 ± 0.01	6.42 ± 1.39	55	1.69	157	9	0.58	1659.7	<i>E. azurea</i> (92%)
8	19.8 ± 1.0	7.04 ± 0.6	0.02 ± 0.002	6.74 ± 0.85	75	1.47	395	12	0.34	1503.6	<i>E. azurea</i> (94.8%)
9	19.8 ± 1.1	6.98 ± 0.53	0.02 ± 0.003	6.34 ± 1.34	45	1.91	563	14	0.71	2210.2	<i>E. azurea</i> (84.2%)

											<i>E. crassipes</i> (17.7%)
10	19.9 ± 1.1	6.42 ± 0.45	0.02 ± 0.003	4.47 ± 2.56	53	1.55	25	6	0.85	7066.3	<i>E. crassipes</i> (75.5%) <i>O. cubense</i> (23.7%)
11	19.8 ± 0.8	6.71 ± 0.80	0.02 ± 0.001	6.93 ± 2.28	60	1.34	42	7	0.89	1288.1	<i>E. azurea</i> (83.2%)
12	19.9 ± 1.0	6.69 ± 0.48	0.02 ± 0.001	5.71 ± 1.48	50	1.96	133	15	1.67	2106.6	<i>E. azurea</i> (68.3%) <i>P. repens</i> (10.6%)
13	19.3 ± 0.8	6.41 ± 0.37	0.02 ± 0.001	6.23 ± 3.36	55	1.12	27	7	1.75	3062.9	<i>E. azurea</i> (53.3%) <i>E. crassipes</i> (31.2%)
14	19.2 ± 0.7	6.57 ± 0.17	0.02 ± 0.001	7.9 ± 1.03	NA	1.39	45	6	0.25	366.2	<i>E. azurea</i> (96.1%)
15	19.2 ± 0.8	6.53 ± 0.29	0.02 ± 0.001	7.24 ± 1.42	75	1.54	15	6	0.79	1909.6	<i>E. azurea</i> (83.9%)
16	19.2 ± 0.7	6.33 ± 0.43	0.02 ± 0	8.66 ± 1.49	60	1.75	67	9	0.005	940.3	<i>E. azurea</i> (99.9%)
17	19.0 ± 0.9	6.69 ± 0.32	0.02 ± 0.001	8.89 ± 1.38	50	1.79	108	9	0	1066.7	<i>E. azurea</i> (100%)
18	19.2 ± 0.9	6.58 ± 0.37	0.02 ± 0.001	9.19 ± 1.08	60	1.57	58	8	0	900.3	<i>E. azurea</i> (100%)
19	18.5 ± 0.7	6.42 ± 0.18	0.02 ± 0	7.77 ± 0.29	135	1.09	82	6	0.23	2299.8	<i>E. azurea</i> (96.3%)
20	18.3 ± 0.3	6.33 ± 0.20	0.02 ± 0.004	8.96 ± 2.89	95	0.96	86	6	0.62	3551.5	<i>E. crassipes</i> (87.2%)
21	18.4 ± 0.5	6.22 ± 0.35	0.02 ± 0.012	7.78 ± 1.93	110	1.48	303	9	0.76	1310.5	<i>E. azurea</i> (79.1%)
22	18.7 ± 0.4	6.45 ± 0.11	0.02 ± 0.001	7.92 ± 1.48	180	1.24	64	7	0.54	1683.5	<i>E. azurea</i> (87.5%)
23	18.7 ± 0.2	6.48 ± 0.20	0.03 ± 0.007	7.90 ± 1.47	75	1.05	97	8	0.1	650.9	<i>E. azurea</i> (98.6%)
24	18.9 ± 0.2	6.21 ± 0.26	0.03 ± 0.012	6.20 ± 3.57	220	1.69	72	8	1.88	1369.5	<i>E. azurea</i> (37.9%)

25	19.6 ± 1.3	6.93 ± 0.13	0.05 ± 0.008	8.78 ± 1.82	190	1.39	146	8	1.01	1787.9	<i>L. laevigatum</i> (74.5%) <i>S. biloba</i> (33.1%)
26	19.6 ± 0.9	7.07 ± 0.16	0.06 ± 0.003	9.43 ± 1.63	260	1.53	119	9	1.09	1562.3	<i>E. azurea</i> (79.8%)
27	19.5 ± 0.9	7.09 ± 0.16	0.05 ± 0.005	8.86 ± 1.21	300	1.49	161	9	1.56	1705.7	<i>E. azurea</i> (66.3%) <i>H. ranunculoides</i> (13.9%)
28	19.6 ± 0.6	7.28 ± 0.07	0.06 ± 0.001	8.62 ± 1.04	135	1.26	533	13	2.03	1056.5	<i>E. crassipes</i> (17.9%) <i>P. ferrugineum</i> (40.1%) <i>P. stelligerum</i> (27%)
29	19.7 ± 0.6	7.51 ± 0.11	0.06 ± 0.001	8.76 ± 0.88	270	1.88	102	10	1.27	933.2	<i>E. azurea</i> (65.9%) <i>S. auriculata</i> (18.2%)
30	19.7 ± 0.5	7.43 ± 0.13	0.06 ± 0.002	8.56 ± 1.21	290	1.6	259	11	1.1	1429.1	<i>E. azurea</i> (47.5%) <i>H. ranunculoides</i> (50.9%)

**Table S5** Diet composition (volume percentage) and trophic guild of fish species inhabiting aquatic macrophytes of Baía River, Brazil. N= number of stomachs analyzed.

Species	N	Higher plant	Algae	Insects	Other invertebrates	Fish	Detritus	Trophic guild
<i>Aphyocharax anisitsi</i>	33	1.19	0.89	85.91	11.13	0.73	0.15	Insetivore
<i>Apistogramma combrae</i>	51	2.77	1.08	54.39	31.77	-	9.99	Invertivore
<i>Astyanax lacustris</i>	2	40	-	60	-	-	-	Omnivore
<i>Crenicichla britskii</i>	4	0.36	-	97.82	1.82	-	-	Insetivore
<i>Hemigrammus ora</i>	77	55.05	3.82	33.79	6.65	0.69	-	Omnivore
<i>Hyphessobrycon eques</i>	267	2.58	0.49	25.97	70.7	0.11	0.15	Invertivore
<i>Hyphessobrycon moniliger</i>	13	31.88	1.87	63.13	3.12	-	-	Insetivore
<i>Laetacara araguaiae</i>	46	26.3	0.78	64.95	7.8	-	0.17	Insetivore
<i>Moenkhausia bonita</i>	278	1.04	0.55	73.19	25.21	-	0.01	Insetivore
<i>Moenkhausia forestii</i>	612	35.98	3.2	51.66	8.22	-	0.94	Omnivore
<i>Moenkhausia sanctaefilomenae</i>	61	49.93	3.93	38.89	7.07	0.18	-	Omnivore
<i>Psellogrammus kennedyi</i>	50	66.27	12.8	11.53	9.12	0.07	0.21	Herbivore
<i>Pyrrhulina australis</i>	92	1.31	0.12	85.53	12.96	0.04	0.04	Insetivore
<i>Roeboides descaltvadensis</i>	5	-	-	75.49	10.78	10.78	2.95	Insetivore
<i>Serrapinnus calliurus</i>	119	10.47	49.94	4.66	27.53	0.46	6.94	Herbivore
<i>Serrapinnus notomelas</i>	142	15.61	45.98	14.15	19.94	0.24	4.08	Herbivore

**Table S6** Results of likelihood ratio test for models regressing fish foraging efficiency assessed by the mean of the degree of stomach fullness (mDF) for macrophyte and fish attributes.

<b>Models</b>	$\chi^2$	<b>P</b>
First order vs. Second order model	0.01	0.92
First order vs. Third order model	0.35	0.84
Second order vs. Third order model	0.34	0.56

**Table S7** Results of likelihood ratio test for models regressing trophic niche breadth assessed by the mean of the distance from the centroid (mDC) for macrophyte and fish attributes.

<b>Models</b>	$\chi^2$	<b>P</b>
First order vs. Second order model	2.07	0.15
First order vs. Third order model	3.41	0.19
Second order vs. Third order model	1.34	0.25

**Table S8** Results of likelihood ratio test for models regressing trophic niche overlap assessed by the mean of the distance from the centroid (mDC) for macrophyte and fish attributes. \* = significant value.

<b>Models</b>	$\chi^2$	<b>P</b>
First order vs. Second order model	4.91	0.03*
First order vs. Third order model	4.98	0.08
Second order vs. Third order model	0.07	0.78