

# Emergence of aquatic insects and spider abundance in the Balbina Reservoir (Presidente Figueiredo, Amazonas, Brazil) during the phase of declining eutrophication

Emergência de insetos aquáticos e abundância de aranhas no Reservatório de Balbina (Presidente Figueiredo, Amazonas, Brasil) na fase de redução da eutrofização

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**Abstract: Aim:** Between April/91 and December/94 the patterns of insect emergence were assessed by a total of 422 emergence traps that were set for 24 hours periods on the water surface of the riparian zones of two islands in the Balbina Lake; **Methods:** These collections were accompanied by observations of spider densities along the shrubby forest margins of the islands. Furthermore, to characterize the lake ecosystem, casual observations on Odonata and spider abundance within the inundated forest with dead, emergent trees were recorded, and some of the species were identified; **Results:** Insect emergence did not decline during the 4 years of collection, and the Chironomidae and Chaoboridae were dominant throughout, adding up to 70-90% of the catches. There is some indication of seasonal cycles, and the specific pattern of Ephemeroptera emergence is demonstrated in more detail; **Conclusions:** It appears that production of aquatic insects in the Balbina Reservoir, while still in its eutrophic phase, is lower than along the Tarumá-Mirím, an undisturbed Central Amazonian forest stream of nutrient-poor, acid water.

**Keywords:** Amazonas, Balbina Reservoir, insect emergence, spiders.

**Resumo: Objetivo:** De Abril/91 até Dezembro/94 a eclosão de insetos aquáticos foi monitorado por um total de 422 armadilhas de emergência montadas por 24 horas cada, ao longo de duas ilhas no reservatório de Balbina; **Métodos:** No mesmo período foi observada a densidade de aranhas (Aranea) na margem florestada das ilhas, e de odonata e aranhas na floresta morta, inundada, no lago; **Resultados:** Não houve declínio de emergência nos 4 anos de coleta, mas há indicação de ciclos sazonais. Invariavelmente, 70-90% dos indivíduos foram Chironomidae e Chaoboridae, e o padrão extraordinário da eclosão dos Ephemeroptera é demonstrado detalhadamente; **Conclusões:** Os resultados indicam que a emergência de insetos no reservatório de Balbina – enquanto ainda na fase eutrófica – é menor que no Tarumá-Mirím, um riacho de água preta, ácida e pobre em nutrientes, entrando o Rio Negro uns 20 km acima de Manaus.

**Palavras-chave:** Amazonas, Balbina Reservatório, emergência de insetos, aráneas.

## 1. Introduction

The Balbina Reservoir of Eletronorte's powerplant is – for the time being – the only notable artificial lake in the Amazon State (Município Presidente Figueiredo). The dam across the Rio Uatumã was closed in 1987, transforming a hilly landscape covered by primary forest with hundreds of forest streams into the reservoir lake with ca 3300 islands, all being surrounded by a belt of emergent dead, leaf-less trees. According to recent satellite imaging by the National Institute of Space Research (INPE), the inundated area is 4438 km<sup>2</sup> (Rosas et al., 2007), that is – the inundated region is much larger than the former estimates of 2360 km<sup>2</sup> by Eletronorte (Walker, 2007). Sub-aquatic decomposition of the forest biomass caused massive eutrophication, resulting in a dense, floating macrophyte flora, which began shrinking with declining eutrophication since 1990.

The Balbina Project started in 1991 in cooperation between INPA (National Institute of Research in the

Amazon) and Eletronorte, the institution responsible for electric power in northern Brazil. While climate and water quality are continuously monitored along the lake by the scientific staff of Eletronorte (Amaral de Melo, 2003), the process of eutrophication, induced by the decomposition of large areas of submerged forest, called the attention of the biologists, such as the emission of greenhouse gases (Fearnside, 1995), the dynamics of aquatic macrophytes (Walker et al., 1999), and trophic interactions between the aquatic flora and fauna (Walker, 2004, 2007; Rosas et al., 2007; Da Silva et al., 2008).

The striking abundance of the terrestrial adults of aquatic insects and of spiders (Araneae) in the dead, inundated forest and along the live, terrestrial forest edge of the islands, as observed during the fieldwork between 1991-1997 (Walker, 2004, 2007) lead to the decision to include sampling of insect emergence and observation of

spider and Odonata abundance in the project, and these results are presented in this report. Besides standardized sampling, occasional observations of spiders and Odonata in particular situations are also recorded, and – time and conditions permitting – specimens were collected for identification.

As the original landscape of the Balbina area before the closure of the dam was primary closed forest drained by a dense net of forest streams, which is the general pattern of Central Amazonian ecosystems, comparison between the results of the Balbina Reservoir presented in this report with data on insect and spider distribution along Central Amazonian forest streams may show some of the faunal changes induced by the inundation of the area.

## 2. Material and Methods

### 2.1. Sampling areas

Inundation of the originally hilly, forest-covered landscape with a dense net of forest streams resulted in a new, complex, lacustrine landscape. The islands represent the highest former water-divides between neighbor stream-valleys, hence, approaching an island by canoe, water depth decreases: in the peripheral open lake area, water depth exceeds original forest height of ca 45 m; (51 m being the maximum depth maintained by Eletronorte), but getting nearer the islands, the dead forest starts emerging and is getting higher and denser when approaching the islands. Furthermore, floating dead trunks and branches, associated with aquatic macrophytes, are accumulating along the islands' margins, thus reducing the areas of free, open water. The distribution of sampling spots on surface waters along the islands' margins were thus imposed by accessibility. Despite these difficulties, it was always possible to reach the land of the two islands chosen as research areas in 1991: the "Ilha das Aranhas" (a flat, ca 20 ha island some 5 km NE of the dam) and the "Serra do Chocador" (a steep range of hills, area of ca 1 km<sup>2</sup>, ca 35 km upriver from the dam; Walker, 2007). The original, primary forest with its dense, shrubby undergrowth remained intact along the terrestrial margins of the islands.

Observations on the overall-abundance of adult *Odonata* and large spiders (*Araneae*) in the inundated forest were made in the peripheral, deeper water when approaching the islands, with the height of the dead, emerging trees reaching some 2-3 m above the water surface. Insect emergence was assessed along two belts along the margins of the two islands: firstly, a proximal belt of 5-10 m from the water edge with dense, aquatic macrophytes between floating tree trunks (water depth was ca 1m along the flat Ilha das Aranhas and less than 8 m along the Serra do Chocador), and secondly, a more distal belt of 50-100 m distance from the islands with lower densities of macrophytes between the dead, still upright tree trunks of the

submerged forest (Figure 1). Variations of water levels as a result of power plant management and of local precipitation, though, did not permit for a consistent ecological differentiation between the two belts. In fact, the proximal belts of the sampling areas coincide with the ecological zone, i.e. "ecotone", of transition between terrestrial and aquatic habitats (Henry 2003), that is, with the "riparian" zone (Lima, 2003) of the two islands.

*Spider density* in the live, terrestrial forest was sampled in the shrubby forest edge of the two islands that paralleled the aquatic sampling belts.

### 2.2. Sampling periods

*Emergence traps:* Due to the research areas' geographical position near the equator, annual variation of day length varies between  $12 \pm 1$  hour, however, there are two distinct climatic periods: the rainy season from January to June, and the dry season from July/August to December.

The traps were invariably set for 24 hours ( $\pm 1$  hour, depending on weather conditions and obstacles when motoring through the area, such as submerged trees and cover by water plants). The time between sequential sampling periods was ca 1 month, and on occasions, sampling series were repeated by resetting the traps on the same spots on sequential days (see "Results"). The sampling months were the following: 1991: April, July, September, October, November, December; 1992: January, February, April 2<sup>nd</sup> and 30<sup>st</sup>; May, August, September, October; 1993: May only; 1994: January, March, June, July, August 14<sup>th</sup> and 26<sup>th</sup>, October, November, December.

Spider observations in the terrestrial forest edge: 1991: September, October; 1992: April, August, September; 1993: May, August; 1994: May, September, November 10<sup>th</sup> and 22<sup>nd</sup>; 1995: February, March, July, September, November; 1996: March.

Observations of adult *Odonata* and of spiders in the dead, inundated forest refer to a total of 21 of the above



**Figure 1.** Emergence traps set in the dead emergent forest of the Balbina Reservoir (near the island Serra do Chocador).

noted excursions with the inclusion of two additional excursions on July 14<sup>th</sup> and 24<sup>th</sup> 1997.

Time and conditions permitting, some Odonata and spiders were occasionally collected during the fieldwork for later identification.

### 2.3. Sampling methods

Estimates of *Odonata and Araneae abundance* in the reservoir with dead, emergent tree crowns: As the areas of observation were chosen in deeper water with emergence of trees not more than ca 3 m above the water surface, the majority of *Odonata* that settled on the dead branches could be seen by a person standing in the canoe when very slowly paddling along the trees. Approachable groups of 3-4 trees were chosen for counts, and the lake areas (m<sup>2</sup>) occupied by the chosen group of trees was estimated by counting the number of canoe length when paddling along the two rectangular stretches including the assessed trees. This allowed to calculate an approximate average density of adult Odonata per hectare of the specified habitat on that particular day. *Araneae*: Spiders were more difficult to see, hence, estimates of their abundance is given in observed number of spiders per m<sup>3</sup> within dead tree crowns.

Emergence of aquatic insects. Emerging, adult insects were caught in 1m long, funnel-shaped traps of black cloth mounted on a 50 × 50 cm (=0,25 m<sup>2</sup>) wooden frame (Figure 1). The apex of the funnel consists of a transparent, 1 L plastic bottle, cut in two halves: the upper half with the bottleneck was inverted and inserted into the lower part of the bottle. Emerged insects, climbing up the trap and entering the bottleneck were thus trapped. The bottle was tied to an overhanging tree branch, while the wooden frame was set floating on the water surface, with the cloth funnel moderately stretched, thus allowing for minor water level variation during the 24 hours exposure period. The black colour of the traps was chosen to avoid attraction of emergent insects to lighter spots, as was shown to be the case: more insects were caught in white traps than in black ones (Walker, 1998). The number of individuals caught per area should thus reflect their natural under-water-distribution. Series of 5 or 10 traps were set in linear sequence along the islands margins. The minimal distance between traps was 5 m, but – depending on obstacles such as floating macrophytes and trunks – was generally larger. With the exception of few special series (see Results, Table 2) the traps were set on spots of free water, not including water plants. The animals collected per trap and 24 hours were preserved in separate sampling bottles with 70% alcohol until analysis in the laboratory. A total of 422 trap samples were collected and analysed during the 4 years period (1991-1994).

Spider density in the live forest undergrowth along the terrestrial margin of the two islands: Sample volume was ca 1 m<sup>3</sup> of this shrubby habitat, however, precise measurement was not possible, because this activity would have

disturbed the animals. The webs occupied by spiders – as well as the visible spiders not occupying a web, were counted within this volume. Webs not occupied by spiders were not included in the counts. These counts are probably underestimates, because not all animals may have been visible inside the shrubs. A minimum of 2-3 such counts, with several meters distance between them, were made along the forest margin on any of the respective excursions.

As spider density is probably reflecting prey availability, as indicated by large numbers of Chironomidae and Chaoboridae caught in the spider webs, live chironomids and chaoborids sitting on the leaves nearest to the spider webs were counted as indicators for prey availability. The chironomids and chaoborids sitting on 20 to 30 leaves nearest to occupied spider webs were counted per every spider count within 1 m<sup>3</sup> of forest habitat.

## 3. Results and Comments

### 3.1. Adult Odonata and Araneae abundance in the inundated forest

*Odonata*. A total of 37 counts made during these excursions resulted in a mean estimate of 40-55 adult Odonata/ha of inundated dead forest, and there was no consistent trend of change of abundance during the seven-year period of observation. On a single occasion no Odonata were seen (20 July/94, 8:30 hours, Ilha das Aranhãs), and it may be that this is due to the relatively early hour of the day, because the highest number recorded from this area was 306/ha, between 14:00-16:00 hours (28 November/95). This interpretation is favored by the observation that on May 2<sup>nd</sup> 1993, 37% of emergent tree tops were occupied by Odonata at 9:00 in the morning, as against 68% at midday on the same day in the same place (near the Ilha das Aranhãs). Excessive densities were recorded in July/97 when approaching the Serra do Chocador: 5-15 individuals per 100 m<sup>2</sup>, which amounts to 500-1500/ha. Extension of the 100 m<sup>2</sup> values to hectares, however, may not be realistic, because naiads may accumulate locally for emergence; for example, on March/94, 41 Odonata-exuviae were counted within 1 m<sup>2</sup> of aquatic macrophytes that floated between the dead trees near the Serra do Chocador.

Although adult Odonata were not specified when monitoring to the research sites, the abundance of *Brachymesia herbida* in the emergent dead forest of the reservoir between the dam and the research islands was noted during the whole period of the project.

*Araneae* frequency was estimated at 0.6-0.9 individuals per m<sup>3</sup> of dead, emergent tree crowns. Spider webs and nests were more obvious and were estimated at 3.0-3.6 units.m<sup>-3</sup>. Collection of some of these oval white nests showed that most were empty, and on some occasions were colonized by micro-hymenoptera and by pseudoscorpions, possible parasites of spider eggs.

Spider density, though, was much higher on the aquatic macrophytes floating between the emergent branches and growing over the floating tree trunks that accumulated along the islands. On 4 days between May/94 and March/96 mean spider density in this habitat ranged between 4 and 17/m<sup>2</sup>. One of the obvious prey of these spiders were the Odonata, thus, Libellulidae killed on floating macrophytes during emergence were noted on several occasions.

### 3.2. The fauna collected in emergence traps

The fauna collected in emergence traps in the years 1991 to 1994 along the two islands Ilha das Aranhãs and Serra do Chocador are presented in Table 1. The tables summarize all data, irrespective of distance from the islands margins and of annual periods, with the exception of the special series of traps that were set over floating macrophytes (Table 2). Still, statistical analysis of the monthly data allowed for the fol-

**Table 1.** The fauna collected by emergence traps set along the island Ilha das Aranhãs during the years 1991-1994. Given are numbers (Nr) and percent (%) of individuals collected. Traps/Series = total number of traps assessed in total number of series set on different days and/or in different places.  $\bar{x}$  = mean number of individuals per trap, i.e. per 0.25 m<sup>2</sup> (see p.). Chiron. + Chaob. = total sum of Chironomidae and Chaoboridae collected, and in brackets the ratio between the two, as not 100% of the individuals were separated. A) dominant types; B) taxa that were usually present, but in low numbers; C) rare occurrences. The fauna collected by emergence traps along the island Serra do Chocador. Explanations as for Table 3.

Taxa	1991		1992		1993		1994		
	Nr	%	Nr	%	Nr	%	Nr	%	
<b>Ilha das Aranhãs</b>									
A	Chiron.+ Chaob. (Chiron.:Chaob.)	666 (1:0.16)	71.77	408 (1:0.6)	87.6	107 (1:0.9)	96.4	422 (1:1.1)	86.7
B	Ephemeroptera	198	21.34	1	0.21	0	-	0	-
	Trichoptera	17	1.83	29	6.2	1	0.9	30	6.13
	Hemiptera	16	1.72	10	2.14	0	-	5	1.02
	Diptera*	1	0.11	3	0.64	1	0.9	15	3.06
	Coleoptera	12	1.29	3	0.64	1	0.9	2	0.41
	Collembola	5	0.54	3	0.64	1	0.9	1	0.2
	Araneida	8	0.86	8	1.71	0	-	12	2.45
C	Odonata	2	0.21	0	-	0	-	0	-
	Plecoptera	0	-	1	0.21	0	-	0	-
	Orthoptera	0	-	0	-	0	-	0	-
	Lepidoptera	0	-	0	-	0	-	0	-
	Hymenoptera	2	0.21	0	-	0	-	0	-
	Thysanoptera	1	0.11	0	-	0	-	0	-
	Total Nr	928 = 100%		466 = 100%		111 = 100%		487 = 100%	
	Traps/series	66/12		68/15		10/2		50/10	
	Nr/Trap = x	14	-	6.9	-	11.1	-	9.8	-
<b>Serra do Chocador</b>									
A	Chiron. + Chaob. (Chiron. : Chaob.)	579 (1:0.57)	70.35	638 (1:0.58)	92.46	18 (1:0.5)	72	723 (1:0.58)	91.98
B	Ephemeroptera	97	11.79	1	0.14	0	-	2	0.25
	Trichoptera	20	2.43	14	2.03	2	8	16	2.04
	Hemiptera	72	8.75	14	2.03	0	-	20	2.54
	Diptera*	12	1.46	1	0.14	0	-	17	2.16
	Coleoptera	3	0.36	2	0.29	0	-	0	-
	Collembola	2	0.24	6	0.87	5	20	3	0.38
	Araneida	29	3.52	12	1.74	0	-	5	0.64
C	Odonata	4	0.49	1	0.14	0	-	0	-
	Plecoptera	0	-	0	-	0	-	0	-
	Orthoptera	1	0.12	0	-	0	-	0	-
	Lepidoptera	1	0.12	1	0.14	0	-	0	-
	Hymenoptera	3	0.36	0	-	0	-	0	-
	Thysanoptera	0	-	0	-	0	-	0	-
	Total Nr	823 = 100%		690 = 100%		25 = 100%		786 = 100%	
	Traps/series	42/6		63/12		10/2		45/9	
	Nr/Trap = x	19.6	-	11	-	2.5	-	17.5	-

lowing conclusions: 1) As regards distance, there was no difference of emergence frequency between the proximal and the distal belts: mean emergence (individuals/trap/24 hours) over the 4 years was  $10.06 + 6.34$  along the proximal belt, and  $11.2 \pm 7.35$  along the distal belt ( $p > 0.1 \chi^2$ -Test), nor was there a consistent reduction of emergence over the four years. 2) There is some indication of annual cycles of emergence: significantly fewer animals emerged during the rainy season from January to June than during the dry season between July and December: the range of mean monthly emergence over the 4 years from January to June varied between 4.0-17.5 individuals/trap, and from July to December between 8.0-25.0 individuals/trap, (Range-test,  $p < 0.05$ ). The reduction of emergence between 1991 and 1992 along both islands (Tables 1) appears to be due to this seasonality, because in 1991 only one collection occurred during the rainy season (April) as against 5 collections in 1992 (January-June). The same argument may explain the exceptionally low emergence along the Serra do Chocador in 1993 (Table 1), because the data refer to a single day during the rainy season (May 1<sup>st</sup>). The maximum number of individuals - including all types - caught in a single trap during the 4 years of the project, was 153 (26 August/92, Serra do Chocador, proximal belt).

The general pattern of emergence is remarkably similar along the two islands: In principle, we can distinguish three groups of abundance:

- The invariably dominant group with frequencies of 70 -> 90% of the total numbers caught in each year: the sum of Chironomidae + Chaoboridae. Thereby the ratio of the chaoborids remained stable throughout this period along the Serra do Chocador, but increased continuously along the Ilha das Aranhás.
- Orders that may reach several % of the total catch, Ephemeroptera and Trichoptera being the most frequent. The Diptera (exclusive chironomids and chaoborids) were mostly Ceratopogonidae and Doli-chopodidae, only 7 individuals of Culicidae were captured, while *Anopheles* was completely absent. The

Hemiptera were mostly Notonectidae and Corixidae. Group B also includes the spiders (Araneae), which climbed into the traps.

- Rare types that were caught sporadically only in one or the other year. However, it must be considered that emergence of adults may not occur in the open water, but that naiads may leave the water by climbing up shrubs and trunks, as is the case of the Odonata, for instance.

There are remarkable patterns that call ones attention, particularly as regards the relatively frequent Ephemeroptera (Table 1). Of a total of 299 individuals collected during the 4 years period, all but 4 individuals, - i.e. 98.7% - emerged on July 5<sup>th</sup> and 6<sup>th</sup> 1991 along both Islands in two traps each, set on the free water (Table 2), only two individuals emerged over water plants, and all individuals were of the same species (*Asthenopus* sp.). Considering that oviposition of up to several thousand eggs per single female occurs within few hours after emergence of the adult Ephemeroptera (Imms, 1970), this coincidence of Ephemeroptera emergence on the same day along the edge of two islands some 30 km apart may be explainable by the simultaneous emergence of the parental adults. Furthermore, climatic conditions may have contributed to the phenomenon: it was noted in the field report that July 3<sup>rd</sup> and 4<sup>th</sup> were cool and rainy, thus, the inversion between cooling surface waters and warmer deeper waters may have triggered the simultaneous emergence of mature naiads.

Emergence of the sum of Chironomidae + Chaoboridae, on the other hand, was significantly more frequent in traps set over floating macrophytes (mean = 26.47 individuals/trap) than set over free water (4.67 individuals/trap;  $\chi^2$ -test,  $p < 0.05$ ).

### 3.3. Spider density along the terrestrial forest edge of the islands (Table 3)

Along the Ilha das Aranhás with its shallow marginal waters, there is a significant decrease of spider abundance and of the sum of chironomids+chaoborids in the later

**Table 2.** Specific patterns of emergence: Trap identification = linear sequence of 5 traps set along the margins of the two islands, either over free water or over water plants, on same and/or on consecutive days. Empty fields: no traps were set on the respective spots and days; 0 = zero emergence in the respective traps.

Place	Conditions	Ilha das Aranhás										Serra do Chocador									
		Free water					On water plants					Free water					On water plants				
Trap-identification	Date	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Ephemeroptera	5 July/91	104	84	-	-	-	0	-	-	-	-	0	85	12	-	-	0	0	0	-	-
Ephemeroptera	6 July/91	7	1	-	-	-	2	-	-	-	-	0	0	0	-	-	0	0	0	-	-
Ephemeroptera	21/22 July/91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chir. + Chaob.	21 July/94	-	-	-	-	-	-	-	-	-	-	0	2	0	9	0	23	36	33	20	40
Chir. + Chaob.	22 July/94	2	1	0	2	1	0	6	103	25	4	-	-	-	-	-	-	-	-	-	-
Chir. + Chaob.	26 July/94	2	33	15	1	2	27	12	0	3	65	-	-	-	-	-	-	-	-	-	-

**Table 3.** Mean number of spiders (Araneae) counted per m<sup>3</sup> (Araneae/m<sup>3</sup>) in the marginal shrub habitat along the two islands Ilha das Aranhãs and Serra do Chocador, and mean number of chironomids + chaoborids counted per single live, green leaf in this habitat (Chr/leaf). n/ser = total number of samples (n) taken in number of series (ser) ; given are means of series-means and standard deviations ( $\bar{x} \pm SD$ ).

Islands		Ilha das Aranhãs		Serra do Chocador	
Years	Data	Aran/m <sup>3</sup>	Chr/leaf	Aran/m <sup>3</sup>	Chr/leaf
1991 to 1994	$\bar{x} \pm SD$	5.39 ± 3.14	8.19 ± 7.55	2.81 ± 1.54	0.24 ± 0.31
	Range	1.67-11.2	0.05-19.50	1.0-6.25	0-1.0
	n/ser	19/6	191/6	31/9	280/8
1995 to 1996	$\bar{x} \pm SD$	1.77 ± 2.40	0	1.55 ± 2.19	0.16 ± 0.35
	Range	0-6.50	0	0-6.30	0-0.95
	n/ser	18/5	>100/5	16/6	>200/6

years (Spiders/m<sup>3</sup>,  $P \sim 0.05$ ; Chr./leaf,  $P < 0.05$ ;  $\chi^2$ - test). As chironomids and chaoborids were the major prey caught by the spider webs, this simultaneous decline may show the immediate effect of resource limitation (prey insects) on the consumer populations (spiders).

Conditions along the Serra do Chocador appeared to be more stable. The a-priori much lower density of the prey insects did apparently not allow for excessive spider density. This may be due to the relatively steep bank with unfavorable habitats for the larvae of the chironomids and chaoborids, such as low density of submerged litter and stronger impacts of the waves along the steep bank.

## 4. Discussion

### 4.1. Effects of eutrophication?

As noted in relation to the fauna associated with *Eichhornia* roots in the research areas of the two islands (Walker, 2007), eutrophic conditions declined between the years 1989-1995 by some 20-50%, which resulted in a decline of macrophyte cover and in a drastic reduction of plankton density in the free water along the islands; during 1995 conductivity ranged between 10.6-14.9  $\mu S.cm^{-1}$  (Amaral de Melo, 2003). However, neither the macrofauna collected from *Eichhornia* roots (Walker, 2007) nor the quantity of insects caught by the emergence traps (present study), show any tendency of decline. This means that, despite the reduction of chemical fertility and plankton densities in the lake, the riparian zones maintained the resource niches for the subsistence of the aquatic insects. Spider abundance (Table 3) seems to be dependent on local conditions, the data differ between islands and between the years of collection.

### 4.2. Faunal composition

The rate of emergence of the Chironomidae and Chaoboridae in the Balbina Reservoir conforms to the general entomological pattern of artificial lakes in South America. Several investigations of the insect fauna of artificial lakes showed the dominance of these Families (Poi de

Neiff and Carignan, 1997; Poi de Neiff and Neiff, 2006; Bezerra-Neto and Pinto-Coelho, 2002; Santos and Henry, 2001; Corbi et al., 2002).

The complete absence of *Anopheles* is not in contradiction with the investigations of Tadei et al. (1993) in Balbina, because these collections of adult *Anopheles* were made near the dam and in the village (Tadei, personal communication), where reproduction occurs in water tanks and small, accidental pools.

### 4.3. Comparison with stream data

During the years 1988-1992, emergence trap collections, using the same methodology as in Balbina, were also made over the benthic litter habitat along the Central Amazonian forest stream Tarumã- Mirim, which joins the Rio Negro 20 km up-river from Manaus (Walker 1998, 2003). Furthermore, the distribution of Odonata along this stream (Oliveira Da Silva, 1992) and of the Araneae in its lower stretch in the inundation forest (Hofer, 1990) were also documented. As the original landscape of the Balbina region before the closure of the dam consisted of innumerable forest stream basins, comparison between the data of the Taruma-Mirim Basin and the Balbina lake indicate possible effects on insect and spider distribution after the closure of the dam.

The most remarkable difference is the abundance of Chaoboridae in the Balbina Reservoir, while Chaoboridae were invariably absent in the Tarumã- Mirim; chaoborids appear only in the stream bay joining the Rio Negro (Irmiler, 1975). The principle resource of chaoborid larvae is the zooplankton (Arcifa, 2000), and the mineral poverty of Central Amazonian forest streams (Schmidt, 1972; Leenheer, 1980; Walker, 1987) does not allow for substantial presence of zooplankton, which may explain the absence of chaoborids in the forest stream. Recent investigations of the insect fauna of Central Amazonian forest streams, including the Urubu Basin near Balbina (Fidelis et al., 2008), confirm the absence of Chaoboridae. Even in urban streams of Manaus with sewage input, chaoborids are absent (Couceiro et al., 2007). The abundance of Chaoboridae along the forested

islands in the Balbina lake, therefore, must be due to immigration from the larger rivers and their floodplains during the period of inundation. By contrast, the *Chironomidae* were more abundant in the Tarumã-Mirím stream than in the Balbina Reservoir: In the stream mean chironomid emergence was 38.77 (individuals/trap/24 hours) and mean density of chironomid larvae in the benthic litter was 5908/m<sup>2</sup> (Walker, 1998; 2003), this is about twice the maximum density of chironomid larvae reported from the benthos of the Jurumirim Reservoir (Rio Paranapanema, SP, 2345 ind/m<sup>2</sup>; Santos and Henry, 2001). The basic resource input into the food web of nutrient-poor Amazonian forest streams are the fungi that decompose the submerged litter (Walker, 1987), while in Balbina the richer waters permitted the growth of floating macrophytes along the islands' margins, which prevented the accumulation of submerged litter. This may explain the relatively lower density of chironomids in Balbina (<20/trap; Tables 1).

As regards the *Odonata*, the dominant species *Brachymesia herbida* (Libellulidae) (Table 4) in the Balbina Reservoir is not present in the inventory of the Odonata species of the Tarumã-Mirím Basin (Oliveira da Silva, 1992). Thus, this species may be restricted to open waters with reduced flow, and therefore may have immigrated after the closure of the dam.

The few data on Aranea (Table 4) imply that spider communities – at least on the level of Genera and Families – show similar patterns in the riparian zones of the Central Amazonian inundation forests (igapó) and of the Balbina Reservoir. Two species, *Alpaida veniliae* and *Plesiometa argyra* from Balbina, were not found by Hoefer (1990) in the igapó of the Tarumã - Mirím river.

From a general point of view we may note that in order to arrive at valid evaluation of the ecological changes induced by an artificial lake, detailed knowledge on the species level would be necessary. The few data so far available of the Balbina Reservoir are not indicative for catastrophic reduction of species diversity. Insect communities changed, but may not be impoverished. As the headwater streams remained intact, and consequently, also their aquatic fauna, the transition of the lower courses of their basins to the lacustrine ecosystem of the Reservoir resulted in the colonization of the lake by new species and thus, may actually have resulted in an increased overall - biodiversity of the region.

As a rule, research on aquatic insects refers to the larval, benthic phase, this, for obvious reasons: the benthic stages are far more stable, and hence, easier to characterize than the ephemeral terrestrial phases. However, the terrestrial adult phases may facilitate species identification, and for the characterization of the ecosystem as a whole, including aquatic-terrestrial foodweb interrelations, the terrestrial phases of the life cycles must be known. An interesting proposition as regards monitoring adult, aquatic

**Table 4.** Some of the most frequent adult Odonata observed along the Balbina Reservoir. + the same Genus, and ++ the same species were also recorded for the forest stream Tarumã – Mirím (Manaus, Amazonas; Oliveira da Silva, 1992). Spiders collected along the two islands (see Table 2). + members of the same Family, and ++ of the same Genus, were also collected by Hoefer (1990) along the mouthbay of the stream Tarumã – Mirím.

Anisoptera	
Fam. Libellulidae	
	<i>Brachymesia herbida</i> +
	<i>Erythemis hematogaster</i>
	<i>Erythemis vesiculosa</i> ++
	<i>Orthemis ferruginea</i> (?) +
	<i>Perithemis lais</i> ++
Zygoptera	
Fam. Coenagrionidae	
	<i>Ischnura fluviatilis</i>
Fam. Protoneuridae	
	<i>Protoneura</i> sp.
Spiders collected in live shrubs along the forest edge	
Fam. Tetragnathidae:	
	<i>Tetragnatha</i> sp.
	<i>Plesiometa argyra</i>
	<i>Leucauge</i> sp. ++
Fam. Theiidae: <i>Chrysso</i> sp.	
	(and two unidentified species)
Fam. Sparassidae: (1 sp.) +	
Fam. Trechaleidae: <i>Trechalea amazonica</i> (F.O.P. Cambridge)	
Fam. Pisauridae: <i>Thaumasia</i> sp. +	
Spiders collected on <i>Eichhornia</i> , in the shallow water along the islands	
Fam. Tetragnathidae: <i>Tetragnatha</i> sp.	
Fam. Araneidae: <i>Alpaida veniliae</i> Keyserling	
Fam. Corinnidae: <i>Castianeura</i> sp. ++	
Fam. Clubionidae: <i>Cheiracanthum</i> sp. +	
Fam. Lycosidae: (? 1 species) +	
Fam. Pisauridae: <i>Thaumasia</i> sp. +	
Fam. Salticidae: (1 species) +	
Spiders collected on emergent, dead tree crowns	
Fam. Tetragnathidae, <i>Tetragnatha</i> sp.	
Fam. Araneidae:	
	<i>Alpaida veniliae</i> Keyserling ++
	<i>Araneus</i> sp. ++
	<i>Metazygia</i> sp. ++
Fam. Salticidae: (not identified) +	

insects was recently published by Chovanec and Waringer (2005): The quantitative distribution of 60 species of adult Odonata along the Danube river (Austria) is formalized as the "Odonata Habitat Index" (OHI) to assess the effects of human activities in the areas. Analogous methods might be practicable to measure ecological effects of human interference along Amazonian rivers and floodplains.

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