The food of larval Chironomidae (Insecta, Diptera) in submerged litter in a forest stream of the Atlantic Forest (Rio de Janeiro, Brazil)

Alimentação de larvas de Chironomidae (Insecta, Diptera) na liteira submersa em um riacho de floresta da Mata Atlântica (Rio de Janeiro, Brasil)

Sanseverino, AM. and Nessimian, JL.

Laboratório de Entomologia, Departamento de Zoologia, Instituto de Biologia, Universidade Federal do Rio de Janeiro – UFRJ, CP 68044, CEP 21944-970, Rio de Janeiro, RJ, Brazil
e-mail: amsansev@biologia.ufrj.br, nessimia@acd.ufrj.br

Abstract: Gut contents of 23 genera of Chironominae and Orthocladiinae larvae inhabiting aquatic litter were investigated in order to study feeding habits. Submerged litter samples were quantitatively taken from a first-order stream in the Atlantic Forest during autumn, winter, spring and summer. Algae, pollen, fungi, particulate organic matter, silt and plant fibers were observed in the larval guts. Particulate organic matter was the predominant food source and, according to a chi-square distribution test, the proportions of food items consumed by the larvae showed seasonal variation except for *Stenochironomus*. The largest size (280 µm length) of ingested food particle was recorded for *Xestochironomus*, and the smallest (10 µm) for *Lopescladius*. A cluster analysis dendrogram showed that the groups of genera were separated according to the season on which the smallest size of food particle was observed.

Keywords: aquatic insects, ecology, feeding, lotic system, tropical forest.

Resumo: Conteúdos digestivos de 23 gêneros de larvas de Chironominae e Orthocladiinae (Diptera: Chironomidae) habitando litter aquático foram investigados com o objetivo de estudar seus hábitos alimentares. Amostras de litter submerso foram quantitativamente coletadas em um riacho de primeira ordem na Mata Atlântica (Estado do Rio de Janeiro) durante o outono, inverno, primavera e verão. Algas, pólen, fungos, matéria orgânica particulada, silte e fibras de plantas foram observados no tudo digestivo das larvas. Matéria orgânica particulada foi a fonte predominante de alimento e, de acordo com o teste de distribuição do Qui-quadrado, as proporções dos itens alimentares consumidos pelas larvas mostraram variação sazonal, exceto para *Stenochironomus*. O maior tamanho de partícula alimentar ingerida (280 µm de comprimento) foi registrada para *Xestochironomus*, enquanto que a menor (10 µm) para *Lopescladius*. Um dendrograma de análise de agrupamento mostrou que os grupos de gêneros foram separados de acordo com a estação do ano em que o menor tamanho de partícula foi observado.

Palavras-chave: insetos aquáticos, ecologia, alimentação, sistema lótico, floresta tropical.

1. Introduction

Litter accumulations form a dominant habitat in lotic ecosystems and increase the available area for colonization by several organisms. Walker (1987, 1998) indicates that the submerged litter with its decompositors is not only an important link in food webs, but also the shelter niche for large consumers. However, most of the studies on organic matter dynamics in drainage systems do not consider the food and feeding habits of the associated aquatic organisms.

About eighty years ago Leathers (1922) studied the feeding habits of Chironomidae larvae. He tried to assemble those larvae which obtain their food in an essentially similar manner. The author mentioned the difficulty in studying this group: "... The two consecutive seasons devoted to this work, in the absence of any considerable literature on the feeding habits of larvae, are all too short a time to exhaust a study involving such small and relatively obscure organisms."

Studies considering feeding mode and food of larval chironomids were comparatively scarce until the work of Thienemann (1954); since then the interest in chironomids and their role in ecological studies has been improved. Several projects investigated feeding habits and larval food preferences (Baker and MacLachlan, 1979; Roback, 1969), larval feeding habits in relation to available food in the associated environment (Provost and Branch, 1959; Ali, 1990; Ingvason et al., 2004), and the chironomids role on secondary production and food webs (Butler, 1982; Berg and Hellenthal, 1991; Hall et al., 2000) among others. Based on literature published in the past four decades, Berg (1995) discussed feeding modes, types of food materials consumed, food selectivity and feeding behaviour of chironomids.

Information about food of larval chironomids in Brazil is recent. Correia and Trivinho-Strixino (1998) studied the phytofauna associated with a macrophyte rhizosphere and analyzed food items in the larval chironomids guts. Trivinho-Strixino and Strixino (1998) investigated the gut contents of chironomids associated with submerged wood in a flooded gallery forest. Nessimian et al. (1999) analyzed the chironomids food items and discussed trophic relationships and their importance for the foodwebs in a sand dune marsh.

The aim of the current study was to investigate the basic resource spectrum and its seasonal variation in larval chironomids inhabiting submerged litter in an Atlantic Forest stream.

2. Material and Methods

Submerged litter samples were quantitatively taken in autumn, winter, spring of 1991 and summer of 1992 from a first-order tributary of Rio Paquequer at about 1100 m altitude (Coastal Range - "Serra do Mar", Teresópolis city, Rio de Janeiro state, Brazil). The area presents many small streams and rivers and is surrounded by the Atlantic Forest. Larvae were sorted, cleared in KOH, mounted in Euparal on microscope slides and identified to genus using taxonomic keys (Cranston et al., 1983; Pinder and Reiss, 1983; Epler, 1995; 2001; Trivinho-Strixino and Strixino, 1995) and generic descriptions. Larval gut contents of 23 genera of Chironominae and Orthocladiinae were examined directly from slides. Some litter fragments were investigated in order to facilitate the identification of food items in the larval guts. The percentage composition of each food item was tabulated per genus and season, and the maximum size of ingested food particles was also recorded. For the twelve genera found in all seasons, a Chi-square distribution test ($\nu = 15$; $\alpha = 0.001$) was used to verify seasonal variations in the proportions of food items consumed. Kendall's coefficient of rank correlation was performed to investigate correlation among these 12 genera according to maximum size of food particles, and a dendrogram was produced by UPGMA (Unweighted pair-group method with arithmetic averages) clustering of this resultant matrix with NTSYS-pc 1.7 (Rohlf, 1992). Chironomini 26 (new, undescribed species) is an unknown chironomini genus deposited at the Zoologische Staatssammlung Munich.

3. Results and Discussion

Gut content analyses showed algae, pollen, fungi, particulate organic matter (POM), silt and plant fibers as food items ingested by the chironomid larvae in submerged litter (Table 1). Particulate organic matter (POM) was the predominant food source, while algae showed the lowest participation in the larval diet.

Table 1. Percentages per season of food items and maximum size of food particle found in gut contents of larval chironomids inhabiting submerged litter in a first order tributary of the Rio Paquequer (Teresópolis, RJ). POM- particulate organic matter; µm - maximum size of food particles; aff. - "affinis"; cf. - "confer"; Chironomini 26 - unknown chironomini genus; Harnischia cpx. 1 - unknown genus of the Harnischia complex.

		Algae	Fungi	Pollen	POM	Silt	Plant fibers	µm
CHIRONOMINAE								
Cryptochironomus Kieffer	Autumn	0	25	25	25	25	0	20
Endotribelos Grodhaus	Autumn	0	7	0	16	0	77	70
	Winter	0	13	7	67	13	0	75
	Spring	0	10	5	50	10	25	50
	Summer	3	23	6	34	6	28	200
Harnischia Kieffer-cpx.1	Autumn	0	8	4	22	28	38	120
Lauterborniella Thienemann and Bause	Autumn	0	8	4	60	7	21	110
	Winter	0	12	8	58	10	12	67
	Spring	0	5	5	60	20	10	70
	Summer	7	5	12	59	7	10	167
aff. *Nilothauma* Kieffer	Autumn	0	0	0	50	50	0	20
	Winter	0	24	2	60	14	0	50
	Spring	0	24	4	24	0	48	180
	Summer	0	0	0	90	0	10	40
Oukuriella Epler	Autumn	0	7	1	56	10	26	88
	Winter	0	13	3	53	11	20	60
	Spring	0	10	10	10	0	70	120
	Summer	5	9	9	61	12	4	50
cf. *Paratendipes* Kieffer	Winter	0	5	9	48	20	18	85
Phaenopsectra Kieffer	Autumn	2	9	3	45	11	30	130
	Winter	5	10	10	39	11	25	130

Table 1. Continued...

		Algae	Fungi	Pollen	POM	Silt	Plant fibers	µm
	Spring	0	5	3	38	7	47	95
	Summer	7	7	18	57	11	0	250
Polypedilum Kieffer	Autumn	0	7	1	56	10	26	88
	Winter	5	13	26	32	7	17	110
	Spring	0	10	10	40	20	20	120
	Summer	0	2	7	48	3	40	105
Stempellinella Brundin	Autumn	0	3	2	45	50	0	15
	Winter	0	3	5	76	10	6	45
Stenochironomus Kieffer	Autumn	0	14	1	17	1	67	100
	Winter	0	10	0	10	0	80	200
	Spring	0	5	0	0	0	95	170
	Summer	0	5	2	13	0	80	130
Tanytarsus van der Wulp	Autumn	0	5	2	75	3	15	65
	Winter	5	16	11	28	12	28	233
	Spring	0	16	11	26	6	41	90
	Summer	0	40	10	13	12	25	200
aff. *Tribelos* Townes	Autumn	1	18	2	56	10	13	75
	Winter	0	14	4	41	30	11	35
	Spring	0	5	8	30	7	50	90
	Summer	0	5	1	12	5	77	190
Xestochironomus Sublette and Wirth	Autumn	0	5	0	10	0	85	150
	Winter	0	10	0	10	0	80	280
	Spring	0	5	0	0	0	95	170
Chironomini sp. 26	Autumn	0	13	3	52	2	30	70
	Winter	0	5	90	0	5	0	30
	Spring	5	10	5	40	20	20	110
	Summer	0	20	5	50	5	20	100
ORTHOCLADIINAE								
Corynoneura Winnertz	Autumn	8	5	3	39	25	20	50
	Winter	0	0	5	82	13	0	30
	Spring	0	3	2	65	30	0	12
	Summer	0	10	0	40	40	10	20
aff. *Georthocladius* Strenzke	Winter	0	15	2	23	0	60	90
	Spring	0	10	3	30	3	54	120
	Summer	0	5	6	20	4	65	135
Lopescladius Oliveira	Autumn	1	0	2	35	37	25	50
	Winter	0	0	0	100	0	0	11
	Spring	0	0	0	50	50	0	10
aff. *Mesosmittia* Brundin	Autumn	0	20	0	80	0	0	120
	Spring	0	50	0	50	0	0	43
	Summer	0	3	2	15	0	80	60
Nanocladius Kieffer	Autumn	3	31	4	49	13	0	60
	Winter	5	50	2	22	8	13	31
	Spring	0	10	3	40	22	25	170
	Summer	0	25	9	54	12	0	27
Parametriocnemus Goetghebuer	Autumn	0	5	2	40	13	40	120
	Winter	3	11	6	60	20	0	75
aff. *Pseudosmittia* Goetghebuer	Winter	0	0	0	100	0	0	35
Rheocricotopus Thienemann and Harnisch	Summer	5	10	5	30	40	10	70

Particulate organic matter was the main food item except for *Harnischia* complex 1, *Stenochironomus*, *Xestochironomus* and aff. *Georthocladius*, whose gut contents were predominated in plant fibers. *Stenochironomus* larvae mine in dead submerged leaves or wood and *Xestochironomus* in dead submerged wood (Borkent, 1984; Epler, 2001).

Although POM was predominant in the guts, some larvae showed other food item prevailing in one or more seasons. In spring, plant fibers were the main food source of aff. *Nilothauma*, *Oukuriella*, *Phaenopsectra* and *Tanytarsus*, in summer of aff. *Mesosmittia*, in autumn of *Endotribelos* and in spring and summer of aff. *Tribelos*. In winter, pollen was the main item in the guts of Chironomini 26, and Fungi were the dominant food of *Nanocladius*. *Tanytarsus*, aff. *Mesosmittia* and *Nanocladius* exhibited the highest percentage of fungi in the guts. *Phaenopsectra* showed algae in more seasons than any other studied genus. Among studied genera found in all seasons, *Stenochironomus* presented the highest percentages of plant fibers and the lowest percentages of pollen and silt in the diet.

These results were expected because detritus is known to be the most commonly recorded food type ingested by chironomids (Pinder, 1986; Berg, 1995). Besides, most of the streams situated in forested areas at the Coastal Range (Atlantic Forest) are shallow, fast-flowing systems shaded by riparian vegetation. The autotrophic production is relatively low and the aquatic biota is mainly sustained by the entrance of allochthonous organic matter such as leaves, wood, seeds, fruits, among others.

The Chi-square distribution test (Table 2) showed that the proportions of food items in the guts of *Endotribelos*, *Lauterborniella*, aff. *Nilothauma*, *Oukuriella*, *Phaenopsectra*, *Polypedilum*, *Tanytarsus*, aff. *Tribelos*, Chironomini 26, *Corynoneura* and *Nanocladius* varied among seasons. *Stenochironomus* did not show any variation in the diet. The presence of plant fibers in the *Stenochironomus* guts and the absence of variation in the food items consumed by them would be expected because this genus exhibits a highly modified habit adapted to a mining mode of life in the larval stage (Borkent, 1984). For the other genera, food variation could mean a low feeding selectivity, confirming that the majority of chironomids are generalists (Berg, 1995). Ali (1990) found similarities between the food of one species of the genus *Chironomus* and the resources available in the aquatic environment, suggesting that the larva is a nonselective feeder and ingests food items in the proportions they occur in the surrounding water. Cummins (1973) mentioned that the ingested food diversity greatly exceeds the aquatic insect diversity and true selective feeding implies the rejection of some of the available food substances.

According to detritus size categories (Cummins, 1974), all genera presented fine particulate organic matter (FPOM < 1000 μm) in the guts. The largest food particle (280 μm) was found in *Xestochironomus* and the smallest (10 μm) in *Lopescladius*. This result could be explained by the type of ingested food and because large larvae generally ingest larger food materials than smaller ones. *Lopescladius* larvae are small (Cranston et al., 1983; Epler, 1995), feeding on ultra-fine particulate organic matter (Nessimian and Sanseverino, 1998). *Xestochironomus* larvae are larger, mining in submerged wood (Borkent, 1984).

The dendrogram for the cluster analysis of 12 genera according to the maximum size of food particles is shown in Figure 1. The groups were separated according to the season on which the smallest size of food particle was observed. Group A is characterized by genera which presented the smallest particle in summer (group 1: *Oukuriella* and *Nanocladius*) and in autumn (group 2: aff. *Nilothauma*, *Polypedilum*, *Stenochironomus* and *Tanytarsus*), group B in winter (group 3: *Lauterborniella*, aff. *Tribelos* and Chironomini 26) and in spring (group 4: *Endotribelos*, *Phaenopsectra* and *Corynoneura*). These results could mean a resource selection and partition according to food particle size. Food resources are divided based on the particle size, and specific utilization is determined by temporal and microspatial isolation of potential competitors (Cummins, 1973). As food selection based on the particle size is primar-

Table 2. Chi-square distribution with 15 degrees of freedom and probability under the null hypothesis, based on food items consumed by the twelve genera of Chironomidae found in all seasons in submerged litter stream.

Chironomidae	Chi-square (X^2)	Probability (p)
Endotribelos	169,444	< 0,001
Lauterborniella	47,400	< 0,001
aff. *Nilothauma*	307,484	< 0,001
Oukuriella	155,138	< 0,001
Phaenopsectra	78,932	< 0,001
Polypedilum	89,559	< 0,001
Stenochironomus	34,054	0,0034
Tanytarsus	138,072	< 0,001
aff. *Tribelos*	163,196	< 0,001
Chironomini tipo 26	340,242	< 0,001
Corynoneura	114,671	< 0,001
Nanocladius	110,840	< 0,001

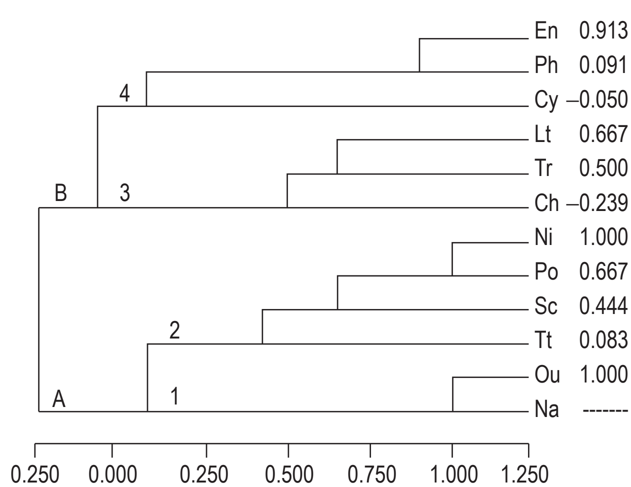

Figure 1. Dendrogram of the clustering of Kendall's coefficient (τ) matrix using UPGMA. En - *Endotribelos*; Lt - *Lauterborniella*; Ni - aff. *Nilothauma*; Ou - *Oukuriella*; Ph - *Phaenopsectra*; Po - *Polypedilum*; Sc - *Stenochironomus*; Tt - *Tanytarsus*; Tr - aff. *Tribelos*; Ch - *Chironomini* 26 (unknown chironomini genus deposited in Zoologische Staatssammlung Munich); Cy - *Corynoneura*; Na - *Nanocladius*; aff. – "affinis".

ily a larval body size function (Berg, 1995), these clusters could represent seasonal differences on larval stages or sizes. Some aquatic insects change their feeding habits and food preferences as they grow, or as seasons change. Many of early instar larvae, simply by virtue of their size, are microvores, and only become macrovores when they grow larger (MacCafferty, 1983). Taking into account that different utilization of microhabitats depending on developmental stage might contribute to resource separations of similar feeding guilds in the chironomid community (Schmid, 1992), such differences in feeding modes and resource utilization could be important in reducing competition and allowing coexistence between larval chironomids.

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