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Body shape, diet and ontogenetic diet shifts in young fish of the Sinnamary River, French Guiana, South America

S. MÉRIGOUX* AND D. PONTON†

*Université Lyon 1, ESA CNRS 5023, Laboratoire d'Ecologie des Eaux Douces et des Grands Fleuves, 69622 Villeurbanne, France and †Centre ORSTOM de Cayenne, B.P. 165, 97323 Cayenne Cedex, French Guiana, France

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A total of 1468 young fish representing 66 taxa from the Sinnamary River, French Guiana was classified by complete cluster analysis of mean relative body width and mean relative body height into four groups. These had anguilliform, disciform, flat or intermediate body shapes and belonged chiefly to Gymnotiformes, Perciformes, Siluriformes and Characiformes, respectively. Several of the taxa shifted from one to another body shape during ontogenesis. Seven diet groups were defined by complete cluster analysis. Among these, six groups were represented by carnivorous fish. The three most frequent groups had diets of (1) mainly insect larvae and small crustaceans, (2) insect larvae, and (3) predominantly terrestrial insects. The majority of the fish taxa showed ontogenetic diet shifts. Carnivorous fish usually switched from small-size prey, such as small crustaceans, to intermediate-size prey, such as insect larvae and/or to large-size prey, such as insects and/or fish. However, taxa differed in their capacities to switch from small prey to intermediate and/or to large prey. Taxa of different body shapes had significantly different diets. Disciform fish fed mainly on aquatic insect larvae and terrestrial insects but also, in small amounts, on small curstaceans. Most anguilliform taxa ate insect larvae. Individuals belonging to the depressiform or intermediate morphotype had varied diets ranging from plant debris and substratum to fish.

Key words: neotropical fish; young stages; morphology; food regime; ontogenetic diet shifts; French Guiana.

INTRODUCTION

Studying the early life stages of fish is of major importance for understanding the structure of fish communities, as events that occur during this crucial period determine year-class strength (Snyder, 1983; Balon, 1984; Houde, 1987; Grosberg & Levitan, 1992). Among the different factors influencing survival of young fish, the availability of suitable prey (Hartmann, 1983), feeding efficiency (locating and catching prey) and capabilities of avoiding predators (Webb & Weihs, 1986) are of central importance. These factors are linked strongly to body shape and morphological features that constrain swimming capabilities (Webb, 1984), and thus resource use (Gatz, 1979), or predator avoidance (Keast, 1978; Webb & Weihs, 1986; Bone *et al.*, 1996).

Tropical freshwater fish species exhibit a great diversity of biological and ecological attributes (Lowe-McConnell, 1987). In South America, only Winemiller (1991) has studied freshwater fish morphology while most studies on

*Author to whom correspondence should be addressed. Tel.: +33 04 72 44 62 34; fax: +33 04 72 43 11 41; email: merigoux@cismun.univ-lyon.fr

†Present address: ORSTOM-HEA, Laboratoire Hydrobiologie Marine et Continentale, Université Montpellier II, Case Postale 093, 34095 Montpellier Cedex 5, France.

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fish diets focus only on the adult stages (Knöppel, 1970; Zaret & Rand, 1971; Lowe-McConnell, 1979; Goulding, 1980; Power, 1983, 1984; Carvalho, 1984; Flecker, 1992). Thus, very few detailed studies are available on the food habits of young tropical fish (piscivores: Winemiller, 1989; armoured catfish: Mol, 1995). Consequently, while ontogenetic diet shifts have been studied well in temperate freshwater fish (Keast, 1978, 1980; Hartmann, 1983; Ponton & Müller, 1988; Copp & Mann, 1993; Garner, 1996), few studies exist on ontogenetic diet shifts in neotropical freshwater fish (Angermeier & Karr, 1983; Winemiller, 1989; Mol, 1995). For French Guiana, the area of our study, the few data that have been published on fish diet focused only on a limited number of adult taxa (Boujard *et al.*, 1988, 1990; Rojas-Beltran, 1989; Horeau *et al.*, 1996).

Therefore, from young fish caught regularly in six tributaries of the Sinnamary River, the objectives of this paper were: (1) to identify groups homogeneous by their body form and to document changes in their shape during ontogeny; (2) to describe their food regimes and to detect ontogenetic diet shifts; and (3) to evaluate the relationships between body form and diet. Thereby, the present study is the first step of a larger project aiming to understand the relationships between habitat and life-history strategies of neotropical fish species during their early life. Beyond this fundamental aspect, the present investigations have an applied aspect concerning river regulation in the neotropics, as the Sinnamary River has been subjected to strong hydrological disturbance (Ponton & Copp, 1997) since the construction of the Petit Saut hydroelectric dam in 1994.

MATERIALS AND METHODS

SAMPLING

From January 1995 to October 1996, six tributaries of the Sinnamary River (Fig. 1) were sampled regularly with rotenone (for a complete description of the sampling method see Mérigoux *et al.*, 1998). For each of the 200 samples, all fish were preserved in 90% alcohol in the field and then transferred to 75% alcohol in the laboratory where they were processed later. All specimens were sorted and identified using keys for adults by Géry (1977); Rojas-Beltran (1984); Kullander & Nijssen (1989); Planquette *et al.* (1996), and keys for juveniles by Ponton (unpublished) and measured for standard length (L_s) to the nearest 1 mm. Keys for juveniles are based on series of drawn specimens of variable size and on meristic parameters such as number of rays on the anal fin or position of fins. Juveniles were retained for analysis by separating them from adults according to the minimal size at first maturity observed for each species in the Sinnamary River (Ponton & Mérona, 1998). Depending on the number of individuals available, up to three size classes were separated for each taxon. Size limits were chosen in order to separate roughly early life stages (about 4 to 15–20 mm, depending on species) from young (about 15–20 to 30–50 mm) and older juveniles (about >30–50 mm). Within each of these size classes, three to 10 specimens (depending on their availability) were chosen randomly for analysis without any consideration of the time and place of sampling (Table I).

BODY SHAPE AND DIET

For the description of body shape, three variables were measured on each individual: standard length, maximum height and maximum width. For smaller individuals measurements were taken on fish outlines drawn with the help of a camera lucida set up on a dissecting microscope. Calipers were used for larger individuals. With both techniques measurements were made to the nearest 0·1 mm.

Stomach contents (or contents of the anterior part of the digestive tract for stomachless species) were removed carefully under a dissecting microscope. Fish with an empty

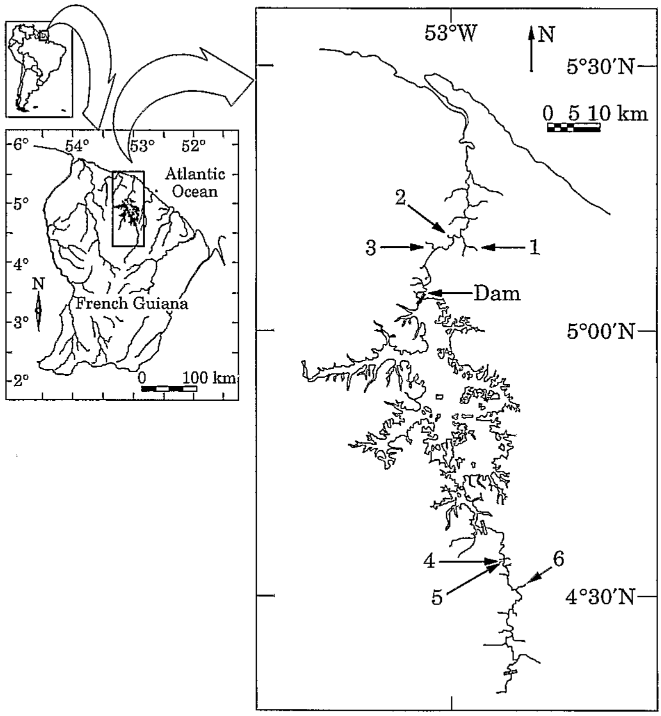

FIG. 1. Map of the Sinnamary River (French Guiana, South America) with the six tributaries sampled.

stomach were replaced randomly by other individuals, if sufficient material was available. Diet items were identified under a dissecting microscope (up to 50 × magnification) or a microscope (100–400 × magnification) and assigned to 10 categories: fish (Fi), molluscs (snails) (Mo), large crustaceans (shrimps) (Cr), small crustaceans (Copepoda, Cladocera and Ostracoda) (sCr), terrestrial insects (TeIn), insect larvae (InLa), water mites (WaMi), rotifers (Ro), vegetative debris (VeDe), and substratum (Su). The relative volumes of each category were estimated following the method of Sheldon & Meffe (1993). For each fish, the most abundant food category was assigned rank 1, the second most abundant rank 2, and so on.

DATA ANALYSIS

Mean relative body width (ratio of maximum width to standard length) and mean relative body height of each size class were calculated. These ratios were treated with cluster analysis by the complete linkage method (Legendre & Legendre, 1979) using Euclidean distances.

For each individual, ranks of food categories were first converted into percentages by a modified version of the MacArthur broken stick model (Magurran, 1988). This model gives the expected percentage N_r of each food category when eaten randomly and simultaneously by a fish by:

$$N_r = \frac{100}{S} \sum_{n=r}^{S} \frac{1}{n}$$

with S=total number of food categories, and r=rank number of food category $[r\varepsilon(1, \ldots S)]$.

Thus, a fish feeding on two food categories would have 100/2(1/1+1/2)=75 assigned to category ranked 1 and 100/2(1/2)=25 to category ranked 2. Identically, an individual

TABLE I. Body shape and diet of fish taxa for different ontogenetical stages, with species authority and occurrences of switches between morphological or diet groups

Species	Authority	Early life stages				Young juveniles				Old juveniles				Body shape switch	Diet switch
		n	L_S (mm)	Body shape	Diet	n	L_S (mm)	Body shape	Diet	n	L_S (mm)	Body shape	Diet		
Characiformes															
Hemiodontidae															
Hemiodopsis quadrimaculatus	(Pellegrin, 1908)	10	9–14	Ang	sCr-InLa	10	15–24	Int	InLa					—	—
Parodon guyanensis	Géry, 1959	10	7–16	Int	sCr-InLa									—	—
Curimatidae															
Chilodus zunevei	Puyo, 1945	10	9–13	Int	InLa-sCr	10	14–30	Int	InLa-sCr	7	31–65	Int	InLa-sCr	No	No
Unidentified young Curimatidae		10	5–14	Int	InLa-sCr	10	15–30	Int	VeDe-Su	10	31–75	Int	VeDe-Su	No	Yes
Anostomidae															
Leporinus despaxi	Puyo, 1943									10	30–90	Int	VeDe-Su	—	—
Unidentified young Leporinus		10	8–13	Int	sCr-InLa	10	14–45	Int	InLa-sCr	10	48–115	Int	VeDe-Su	No	Yes
Erythrinidae															
Erythrinus erythrinus	(Schneider, 1801)	10	7–16	Int	InLa-sCr	10	17–50	Int	InLa-sCr					—	—
Unidentified young *Hoplias*		10	4–20	Int	InLa-sCr									—	—
Hoplias aimara	(Valenciennes, 1840)					10	21–50	Int	InLa-Fi					—	—
Hoplias malabaricus	(Bloch, 1794)					10	21–50	Int	InLa-Fi	10	51–160	Int	InLa-Fi	No	Yes
Lebiasinidae															
Copella carsevennensis	(Regan, 1912)	10	6–12	Int	sCr-InLa	10	13–19	Int	InLa-sCr	10	20–24	Int	InLa	No	Yes
Nannostomus beckfordi	Günther, 1872					10	13–20	Int	InLa	10	21–25	Int	InLa	—	—
Pyrrhulina filamentosa	Val. in. Cuv., 1846	10	6–14	Int	InLa-sCr	10	15–30	Int	InLa-sCr	10	31–49	Int	TeIn	No	Yes
Gasteropelecidae															
Gasteropelecus sternicla	(Linnaeus, 1758)	10	6–11	Int	TeIn	10	12–15	Int	TeIn					—	—
Characidae															
Astyanax bimaculatus	(Linnaeus, 1758)	10	9–14	Int	InLa-sCr	10	15–30	Int	InLa-sCr					—	—
Astyanax cf *keithi*	Géry, Planquette & LeBail, 1996	10	6–11	Int	sCr-InLa	10	12–25	Int	InLa-sCr	10	26–55	Disc	TeIn	Yes	No

TABLE I. *Continued*

Species	Authority	Early life stages				Young juveniles				Old juveniles				Body shape switch	Diet switch
		n	L_S (mm)	Body shape	Diet	n	L_S (mm)	Body shape	Diet	n	L_S (mm)	Body shape	Diet		
Characidae (cont'd)															
Bryconops spp		10	8–15	Int	InLa	10	16–35	Int	TeIn	10	36–80	Int	TeIn	No	Yes
Characidium fasciadorsale	Fowler, 1914	10	7–14	Int	InLa-sCr	10	15–30	Int	InLa	10	31–45	Int	InLa	No	Yes
Charax pauciradiatus	Günther, 1864	10	6–13	Int	sCr-InLa									—	—
Hemigrammus ocellifer	(Steindachner, 1882)	10	7–12	Int	sCr-InLa	10	15–19	Int	InLa-sCr	10	20–25	Int	TeIn	No	Yes
Hemigrammus unilineatus	(Gill, 1858)	10	9–12	Int	sCr-InLa	10	13–19	Int	InLa-sCr	10	20–29	Int	TeIn	No	Yes
Hyphessobrycon aff. *sovichthys*	Schultz, 1944	7	7–10	Int	InLa-sCr	10	11–15	Int	InLa-sCr	10	16–20	Int	InLa-sCr	No	No
Melanocharacidium sp.		10	5–13	Int	InLa-sCr									—	—
Microharacidium eleotrioides	(Géry, 1960)	10	5–9	Int	InLa-sCr	10	10–14	Int	InLa					—	—
Moenkhausia chrysargyrea	(Günther, 1864)	10	7–14	Int	InLa-sCr	10	15–30	Int	TeIn	10	31–45	Disc	TeIn	Yes	Yes
Moenkhausia collettii	(Steindachner, 1882)	10	5–12	Int	sCr-InLa	10	13–25	Int	InLa-sCr	10	26–35	Int	TeIn	No	Yes
Moenkhausia georgiae	Géry, 1966	10	7–13	Int	sCr-InLa									—	—
Moenkhausia hemigrammoides	Géry, 1966	10	7–13	Int	InLa-sCr	10	14–25	Int	TeIn	10	26–35	Disc	TeIn	Yes	Yes
Moenkhausia oligolepis	(Günther, 1864)	8	6–13	Int	InLa-sCr	10	14–30	Disc	TeIn	10	31–65	Disc	TeIn	Yes	Yes
Moenkhausia surinamensis	Géry, 1966					10	14–30	Int	TeIn	10	31–60	Disc	TeIn	—	—
Phenacogaster aff. *megalostictus*	Eigenmann, 1909	10	5–12	Int	InLa-sCr	10	13–19	Int	InLa	10	20–29	Int	InLa	No	Yes
Piabucus dentatus	(Köhlreuter, 1761)	10	9–14	Int	InLa-sCr	10	15–40	Int	TeIn					—	—
Poptella brevispina	(Reis, 1989)	10	5–13	Int	InLa-sCr	10	14–30	Disc	TeIn					—	—
Pristella maxillaris	(Ulrey, 1894)	10	7–10	Int	sCr-InLa	10	11–15	Int	InLa-sCr	10	16–19	Int	InLa-sCr	No	Yes
Pseudopristella simulata	Géry, 1960	10	6–11	Int	sCr-InLa	10	12–17	Int	InLa-sCr	9	18–22	Int	sCr-InLa	No	?
Unidentif. young *Acestrorhynchus*		10	9–15	Int	InLa-sCr	10	16–40	Int	InLa-Fi	10	41–120	Int	Fi	No	Yes
Siluriformes															
Auchenipteridae															
Tatia intermedia	(Steindachner, 1876)	10	7–14	Int	TeIn	10	14–25	Int	TeIn	7	26–60	Int	TeIn	No	No

TABLE I. *Continued*

Species	Authority	Early life stages				Young juveniles				Old juveniles				Body shape switch	Diet switch
		n	L_S (mm)	Body shape	Diet	n	L_S (mm)	Body shape	Diet	n	L_S (mm)	Body shape	Diet		
Siluriformes (cont'd)															
Pimelodidae															
Unidentified young *Pimelodella*		10	8–20	Int	InLa-sCr									—	—
Pimelodella cristata	(Müller & Troschel, 1848)					10	21–40	Int	InLa-sCr	10	41–95	Int	InLa-Fi	No	Yes
Pimelodella gracilis	(Val. in Cuv. & Val., 1840)					10	21–40	Int	InLa	3	41–100	Int	InLa-sCr	No	?
Pseudopimelodus raninus	(Valenciennes, 1840)	10	8–13	Dep	InLa-sCr	10	14–30	Dep	InLa	10	31–65	Dep	InLa-Fi	No	Yes
Rhamdia quelen	(Quoy & Gaimard, 1824)					9	18–50	Int	InLa-Fi					—	—
Helogenidae															
Helogenes marmoratus	(Günther, 1863)					5	14–30	Int	TeIn	10	31–60	Int	TeIn	—	—
Aspredinidae															
Bunocephalus coracoideus	Cope, 1874	4	7–14	Dep	InLa	10	15–39	Dep	InLa-Fi	10	40–70	Dep	TeIn	No	Yes
Trichomycteridae															
Trichomycterus guianense	(Eigenmann, 1909)	10	8–14	Int	InLa	10	15–29	Int	InLa	10	30–50	Int	InLa	No	No
Callichthyidae															
Callichthys callichthys	Linnaeus, 1758	7	6–13	Dep	sCr-InLa	10	14–50	Dep	InLa-sCr					—	—
Hoplosternum thoracatum	(Val. in Cuv. & Val., 1840)	8	6–13	Dep	sCr-InLa	10	14–50	Dep	sCr-InLa					—	—
Loricariidae															
Ancistrus aff. *hoplogenys*	(Günther, 1864)	9	11–13	Dep	VeDe-Su	10	14–30	Dep	VeDe-Su	5	31–65	Dep	VeDe-Su	No	No
Gymnotiformes															
Sternopygidae															
Sternopygus macrurus	(Bloch & Schneider, 1801)	10	7–20	Int	InLa-sCr	10	21–60	Int	InLa	8	61–145	Ang	InLa	Yes	Yes
Hypopomidae															
Brachyhypopomus beebei	(Schultz, 1944)	7	8–20	Int	InLa-sCr	10	21–50	Aug	InLa	10	51–100	Ang	InLa	Yes	Yes
Hypopomus artedi	(Kaup, 1856)	10	7–20	Int	InLa-sCr	10	21–50	Ang	InLa	10	51–130	Ang	InLa	Yes	Yes

TABLE I. *Continued*

Species	Authority	Early life stages				Young juveniles				Old juveniles				Body shape switch	Diet switch
		n	L_S (mm)	Body shape	Diet	n	L_S (mm)	Body shape	Diet	n	L_S (mm)	Body shape	Diet		
Gymnotiformes (cont'd)															
Gymnotidae															
Unidentified young *Gymnotus*		10	9–19	Int	InLa									—	—
Gymnotus anguillaris	Hoedeman, 1962					10	20–50	Ang	InLa	10	51–185	Ang	InLa	Yes	No
Gymnotus carapo	Linnaeus, 1758					10	20–50	Ang	InLa	10	51–185	Ang	InLa-sCr	Yes	No
Cyprinodontiformes															
Aplocheilidae															
Rivulus agilae	Hoedeman, 1954					10	11–15	Int	InLa-sCr					—	—
Rivulus xiphidius	Huber, 1979	10	5–10	Int	sCr-InLa	10	11–15	Int	InLa					—	—
Poeciliidae															
Poecilia parae	(Eigenmann, 1894)	10	6–12	Int	InLa-sCr									—	—
Synbranchiformes															
Synbranchidae															
Synbranchus marmoratus	Bloch, 1795	9	32–59	Ang	sCr-InLa	7	60–100	Ang	InLa	9	101–200	Ang	InLa	No	Yes
Perciformes															
Nandidae															
Polycentrus schomburgkii	Müller & Troschel, 1848					10	14–19	Disc	InLa-sCr	10	20–30	Disc	InLa-sCr	—	—
Cichlidae															
Cichlasoma bimaculatum	(Linnaeus, 1758)									10	30–70	Disc	InLa-sCr	—	—
Cleithracara maronii	(Steindachner, 1882)	10	10–13	Disc	InLa-sCr	10	14–34	Disc	InLa	10	35–52	Disc	InLa-sCr	No	?
Crenicichla saxatilis	(Linnaeus, 1758)	10	8–20	Int	InLa-sCr	10	21–50	Int	InLa-sCr	10	51–140	Int	InLa-Fi	No	Yes
Krobia guianensis	(Regan, 1905)	10	4–13	Disc	InLa-sCr	10	14–29	Disc	InLa	10	30–75	Disc	InLa-sCr	No	?
Nannacara anomala	Regan, 1905	10	6–12	Disc	InLa	10	13–19	Disc	InLa	10	20–29	Disc	InLa	No	No
Satanoperca aff. *leucosticta*	(Müller & Troschel, 1848)					10	14–30	Int	sCr-InLa	10	31–70	Int	sCr-InLa	—	—
Eleotridae															
Eleotris amblyopsis	(Cope, 1870)	10	10–15	Int	sCr-InLa	10	16–20	Int	InLa	10	21–25	Int	sCr-InLa	No	?

n, Number of individuals; L_S, range of standard length; Disc, disciform body; Ang, anguilliform; Dep, depressiform; Int, intermediate body; Fi, fish; TeIn; terrestrial insects; InLa, insect larvae; sCr, small crustacean; VeDe, vegetative debris; Su, substratum. Body shape and diet shifts are presented only for species with data for the three stages.

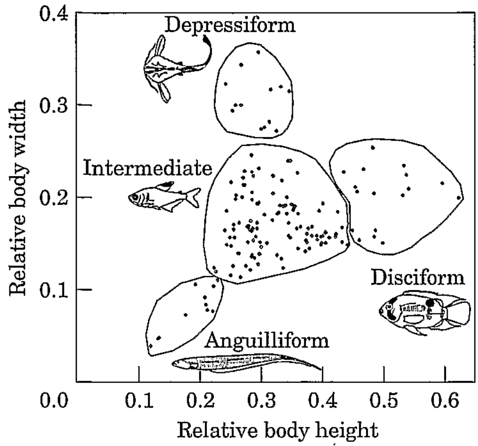

FIG. 2. Relative body width *v.* relative body height, indicating the four groups of body shapes resulting from complete cluster analysis of the 152 size classes of 66 taxa captured in the Sinnamary River (see Table I for the faunistic composition of the different groups).

feeding on three different categories would have 1100/18, 500/18, and 200/18 assigned for categories ranked 1, 2, and 3 respectively. Mean N_r values calculated for all the individuals of each size class were also treated with cluster analysis by the complete linkage method (Legendre & Legendre, 1979) using Euclidean distances. In order to provide a simpler index of prey use, the resulting diet groups were described by the prey items averaging >70% within the individuals of the group. Differences in diet among groups of fish with different body shapes were then tested by $R*C$ test of independence using G-test (Sokal & Rohlf, 1995).

RESULTS

MORPHOMETRY

The total of 1468 fish from 66 taxa grouped in 152 size classes (Table I) was separated by complete cluster analysis on mean relative body width and mean relative body height into four groups of different body shapes (Fig. 2). Disciform fish (*sensu* Holčik *et al.*, 1989) were characterized by high relative body height and medium relative body width values. This group included all stages of the Perciformes *Cleithracara maronii* (Steindachner), *Krobia guianensis* (Regan) and *Nannacara anomala* Regan, and juveniles of the Perciformes *Polycentrus schomburgki* Müller & Troschel and *Cichlasoma bimaculatum* L., and juveniles of the Characidae *Astyanax* cf. *keithi* Géry, Planquette & le Bail, *Moenkhausia chrysargyrea* (Günther), *M. hemigrammoides* Géry, *M. oligolepis* (Günther), *M. surinamensis* Géry and *Poptella brevispina* (Reis) (Table I). Anguilliform fish (*sensu* Holčik *et al.*, 1989) presented low relative body height and low relative body width values and included early life stages of *Hemiodopsis quadrimaculatus* (Pellegrin), juveniles of all Gymnotiformes, and all stages of *Synbranchus marmoratus* Bloch. Depressiform taxa (*sensu* Holčik *et al.*, 1989) were characterized by high relative body width and intermediate relative body height values. All stages of the Siluriformes *Pseudopimelodus raninus* (Valenciennes), *Bunocephalus coracoideus* Cope, *Callichthys callichthys* L.,

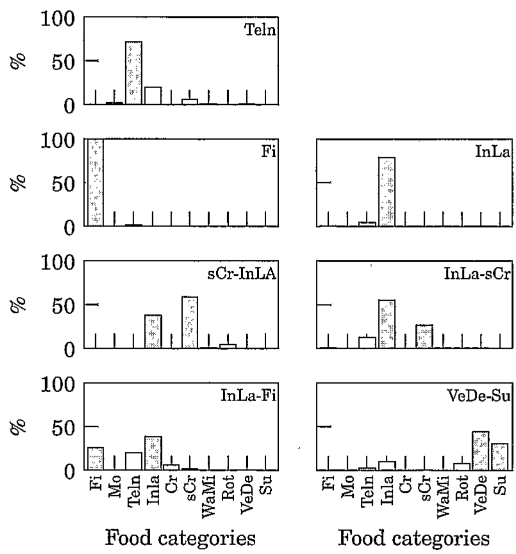

FIG. 3. Food spectra of each of the seven diet groups resulting from complete cluster analysis of Euclidean distances computed from percentages of food categories of the 152 size classes of 66 taxa captured in the Sinnamary River. Diet groups were defined by the categories representing ≥70% of the food items: Fi, fish; TeIn, terrestrial insects; InLa, insect larvae; sCr, small crustacean; VeDe, plant debris; Su, substratum (see Table I for faunistic composition of diet groups).

Hoplosternum thoracatum (Valenciennes) and *Ancistrus* aff. *hoplogenys* (Günther) belonged to this group. The remaining taxa, mainly Characiformes, presented intermediate body shapes.

Only 11 taxa presented a body shape that switched from one group to another during their ontogeny (Table I). Most of these shifts were from an intermediate body shape during early life to an anguilliform shape (*Sternopygus macrurus* (Bloch & Schneider), *Brachyhypopomus beebei* (Schultz), *Hypopomus artedi* (Kaup), *Gymnotus anguillaris* Hoedeman and *G. carapo* L., or a disciform shape (*A.* cf. *keithi*, *M. chrysargyrea*, *M. hemigrammoides* and *M. surinamensis*) during the juvenile period.

DIET

Among the 1468 full fish stomachs analysed (Table I), seven groups of diet were obtained by complete cluster analysis (Fig. 3). All these groups were defined by one or two main sources of food: terrestrial insects (TeIn, 16·5% of the groups; Table I, Fig. 3), fish (Fi, 0·7% of the groups), mostly small crustaceans and also insect larvae (sCr-InLa, 12·5%), mostly insect larvae and also fishes (InLa-Fi, 5·9%), insect larvae only (InLa, 23·0%), and mostly insect larvae and also small crustaceans (InLa-sCr, 36·8%) for the carnivorous fish and mostly plant debris and also substratum (VeDe-Su, 4·6%) for the other fish.

Most taxa showed ontogenetic diet shifts (Table I). Carnivorous fish switched usually from small-size prey such as small crustaceans to intermediate-size prey such as insect larvae and/or to large-size prey such as insects and/or fish (Table I). However, taxa differed in their capacities to switch from small prey to intermediate and/or to large prey. Some fish even started feeding directly on

TABLE II. Relative dietary abundance (in %) for the different fish body shapes

Body shape	n	Diet groups						
		VeDe-Su	sCr-InLa	InLa-sCr	InLa	TeIn	InLa-Fi	Fi
Disciform	19	0·0	0·0	36·8	26·4	36·8	0·0	0·0
Aguilliform	13	0·0	7·7	15·4	76·9	0·0	0·0	0·0
Depressiform	13	23·1	15·4	7·6	15·4	23·1	15·4	0·0
Intermediate	107	3·7	14·0	42·1	16·8	15·9	6·6	0·9

n, Number of size groups of the 66 species; Fi, fish; TeIn, terrestrial insects; InLa, insect larvae; sCr, small crustacean; VeDe, vegetative debris; Su, substratum.

insect larvae and switched to insects and/or fish (Table I). Only seven taxa belonged to the same diet groups from early life stages to older juveniles: *Chilodus zunevei* Puyo and *Hyphessobrycon* sp. aff. *sovichthys* Schultz fed mainly on insect larvae and also on small crustaceans, *Tatia intermedia* (Steindachner) fed mainly on terrestrial insects, *Ancistrus* aff. *hoplogenys* on plant debris and substratum, *Trichomycterus guianense* (Eigenmann), *G. anguillaris* and *N. anomala* on insect larvae.

RELATIONSHIPS BETWEEN BODY SHAPE AND DIET

Taxa of different body shapes had significantly different diets (Table II; G-value=46·131, d.f.=18, $P<0{\cdot}001$). Disciform fish fed mainly on aquatic insect larvae and terrestrial insects but also, in small amounts, on small crustaceans. Most anguilliform taxa specialized on insect larvae. Individuals belonging to the depressiform of intermediate morphotype presented varied diets ranging from plant debris and substratum, to fish.

DISCUSSION

In a study based on 17 temperate fish species, Douglas & Matthews (1992) argued that interrelationships between body shape, diet, and taxonomic status are predictable. They demonstrated that often studies on eco-morphology reflect only taxonomic or phylogenetic aspects. Phylogenetic systematics is increasingly used to interpret morphological and ecological data in an evolutionary context (Westneat, 1995). Unfortunately, the systematic relationships between neotropical fish species of entire families are still largely unknown (see Montoya-Burgos *et al.*, 1997, for an example in Loricariidae). However, the importance of the systematic position of a fish species for the determination of its body shape is suggested in our study: 69·2% of taxa with an anguilliform body belonged to Gymnotiformes, 63·2% of the taxa with a disciform body were Perciformes, all flat fishes were Siluriformes and 71% of the taxa with an intermediate body shape belonged to Characiformes.

Independent of their systematic position, most of the young fish inhabiting the tributaries of the Sinnamary River feed mainly on small crustaceans, insect larvae, and terrestrial insects. For most fish taxa, the importance of small crustaceans in the diet decreased with increasing age and size and small crustaceans were replaced progressively by terrestrial insects. These results correspond well to those of Horeau *et al.* (1996), who highlighted the importance of allochtonous inputs in the diets of several adult fish of the Sinnamary River. In rivers, flooding cycles modify on a regular basis food resource availability and thus feeding specializations of fish tend to appear poorly (Winemiller, 1990). However, two types of specialization were detected for early stages in Guianese fish: piscivory and use of plant debris and substratum (Table I). Indeed, several young taxa presented piscivorous feeding habits at a very small size: young of *Acestrorhynchus* spp. were able to ingest fish occasionally, and juveniles of *Hoplias aimara* (Valenciennes) and *H. malabaricus* (Bloch) preyed upon fish as soon as they had reached >20 mm (Table I). Thus, the young stages of these species have diet spectra identical to those of the adults (Planquette *et al.*, 1996). Piscivorous tendency during early life stages was also noted for other species known to eat fish later in their lives: *Pimelodella cristata* (Müller & Troschel) and *P. gracilis* (Valenciennes) (Planquette *et al.*, 1996), *Rhamdia* sp. and *Crenicichla saxatilis* (L.) (Knöppel, 1970; Angermeier & Karr, 1983; Winemiller, 1989), and *Synbranchus marmoratus* (Winemiller, 1989). The young of Curimatidae, *Leporinus despaxi* Puyo, *L.* spp. and *Ancistrus* aff. *hoplogenys* ate mainly plant debris and substratum. The adults of several species of Curimatidae such as *Cyphocharax spilurus*, *C. helleri*, *Curimata cyprinoides* (Planquette *et al.*, 1996, *C. pristigaster* (Carvalho, 1984) are known to be detritivores and Angermeier & Karr (1983) found that adults of species of *Ancistrus* fed exclusively on algae in Panamanian streams. Similar to what has been demonstrated for the adults (Power, 1983, 1984), young *A.* aff. *hoplogenys* might have ingested large amounts of substratum in order to ingest the algae it contains.

Wainwright & Richard (1995) argued that all fish species change prey use during ontogeny. In our study, the majority of the fish taxa showed ontogenetic diet shifts and young fish were usually able to feed on larger prey at a larger size (Table I). However, taxa differed in their capacities to switch from small prey to intermediate and/or to large prey. So far, evidence for diet changes with age for neotropical freshwater fishes are scarce in the scientific literature. Mol (1995) observed for the two armoured catfish *Callichthys callichthys* and *Hoplosternum thoracatum*, a diet shift from small crustaceans and rotifers to a mixed diet dominated by insect larvae when individuals reached 8·4 mm, a pattern that agrees well with our results. Identically to Winemiller's (1989) results in the Venezuelan Llanos, Guianese *G. carapo* of <50 mm preyed mainly upon insect larvae and switched later to a food regime composed of insect larvae and terrestrial insects. Dietary shifts are induced usually by changes with growth of morphological features correlated to body size (Wainwright & Richard, 1995). The enlargement of the mouth gape (Keast, 1978, 1985; Hartman, 1983; Dabrowski & Bardega, 1984), the development of fins, muscles and swimbladder (Bone *et al.*, 1996) and body shape (Keast, 1978) influence prey selection and catch efficiency.

With data for 66 of the 126 freshwater and 18 euryhaline fish taxa recorded in the Sinnamary River (Lauzanne *et al.*, 1995), our work forms the largest database ever gathered and published for body shape and diet of young neotropical Guianese fish. The large percentage of young fish with intermediate body shapes stresses the need for complementary morphological variables as indicators of ecological fish groups. As the most useful morphological variables are those that affect behavioural performances (Wainwright, 1996), further investigations should relate size and position of fins, mouth gape, development of dentition, development of the digestive system, among other variables, to feeding habits during ontogeny. Moreover, future studies should also define if young fish exhibit seasonal variability in their diets as shown for adult fish in other freshwater tropical systems (Lowe-McConnell, 1979; Zaret & Rand, 1971; Goulding, 1980; Boujard *et al.*, 1990). Comparisons of seasonal variability of diets between sites situated downstream of the dam and upstream of the reservoir would allow evaluation of the impacts of flow disturbances on food resource use by fish during their early life. Beyond these topics, body shape and diet described in this work will be used together with other biological traits related to reproduction to define aspects of life history strategies of fishes in the Sinnamary River. The understanding of the relationships between these life history strategies and environmental parameters will enable us in future to link general community characteristics to the environment (Statzner *et al.*, 1994) beyond the systematic details of the different fish taxa. This approach should provide insights into the fundamental factors structuring fish communities as well as the broader applications of the impacts of hydroelectric dams on neotropical fish assemblages.

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