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COMMUNITY STRUCTURE OF ODONATA LARVAE IN TWO STREAMS IN ZIMAPAN, HIDALGO, MEXICO

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Community structure of odon. larvae was investigated at El Saucillo (ES) and San Francisco (SF) streams, from August 1995 to July 1996. Species richness (S), species composition, Margalef's richness index (R), Shannon-Wiener's diversity index (H'), Hill's evenness index (E), and rareness (Rs) were used to describe and compare the communities. Annual variation of the indices was examined within and among streams. Streams were significantly different in terms of physical/chemical variables, and faunistic similarity between the communities was quite low (37%). Mean larval density was highest at ES, but the remaining parameters were highest at SF. Global richness was 31 spp. and some spp. such as *Hetaerina americana, Enallagma civile, Anax junius, Erpetogomphus elaps, Dythemis nigrescens, Aeshna multicolor, A. dugesi, Erythemis plebeja* and the majority of *Argia* spp. were only found at SF. More abundant spp. at SF were *Pseudoleon superbus, Telebasis salva, Libellula saturata* and *Enallagma praevarum*, while those more abundant at ES were *Paltothemis lineatipes* and *Argia anceps.*

INTRODUCTION

Several authors have emphasized the potential of environmental monitoring using Odonata, especially the larval stages (CARLE, 1979; WATSON et al., 1982; SCHMIDT, 1983; MOORE, 1984; TREVINO, 1997). However, few works have described Odonata community structure and related it to environmental characteristics (WATSON et al., 1982; CARCHINI & ROTA, 1985; JOHNSON & CROWLEY, 1989). Furthermore, most of the studies on Odonata larval community structure have been carried out in lentic habitats (JOHNSON & CROWLEY, 1989; CHOVANEC, 1998), and little has been done in lotic environments (SCHRIDDE & SUHLING, 1994; BULÁNKOVÁ, 1997). Moreover, many of these studies have focused on seasonal and habitat segregation (JOHNSON & CROWLEY, 1989; SCHRIDDE & SUHLING, 1994), and structuring of communities through predation (JOHNSON, 1991).

Given the disturbing rate of development and habitat loss going on currently in Mexico, the purpose of this work was to provide a baseline dataset for Odonata larval community structure, describing the community measures throughout a year in two streams in Hidalgo State.

STUDY AREA

The studied streams are located on the boundary between the states of Hidalgo and Queretaro, Mexico (20°40'N and 99°30' W); both streams discharge at Zimapan's reservoir (Fig. 1). The sampling sites were between 1540-1650 m a.s.l. Vegetation is predominantly xerophytic and the climate is of the extreme dry type (GARCÍA, 1988). The rainfall period goes from May to September (341 mm), and during the rest of the year there is no significant precipitation. May is the hottest month (mean air temperature = 19.1°C) and December is the coldest one (mean = 11.7°C).

We selected the San Francisco stream (SF), a tributary of the San Juan stream, and the El Saucillo stream (ES), a tributary of the Tula River, because apparently there are no discharges of domestic and industrial pollutants. Moreover, they are roughly similar in depth but quite different in length, width, discharge and physical setting. The SF is a permanent water body with a basin of variable width (from 50 cm to more than 20 m); its depth is quite heterogeneous (from 0.03 m to more than 2 m in some pools); it runs into a wide canyon and most of its basin is a rocky bed with little slope, at least in the studied area. In some parts of the watershed there exist layers of volcanic rock at the bottom, most of them without any traces of sediments or vegetation. On the other hand, the ES stream is an intermittent, torrential water body which flows into a narrow canyon forming several terraces; its basin´s width ranges from 0.4- 4 m, and its depth ranges from 0.1-2 m in some pools; most of its bed is a rocky plate with a strong slope.

METHODS

Samples were taken monthly from August 1995 throughout July 1996. Representative segments of both streams were selected for sampling, beginning at their confluence to the reservoir. Fifteen (SF) and 10

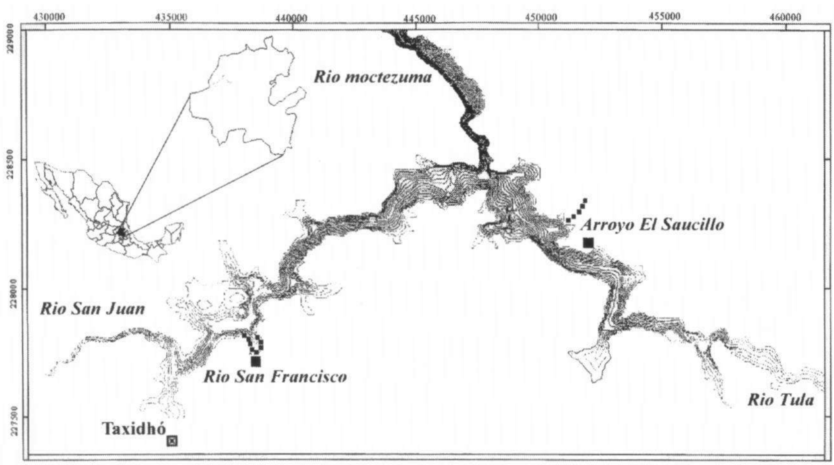

Fig. 1. The study area in Hidalgo and Queretaro states of Mexico.

(ES) randomly selected transects across the stream, from a total of 200, were sampled each month, using an aquatic net (45 x 12 cm, mesh 0.5 mm), applying the same unit-effort (≈1 m^2 sampling surface per 2 min). Samples were taken at each side and in the center of the transect, except at narrow transects (≤1 m) where only one sample was taken. Odonata larvae were preserved in 96% ethanol and then identified to species and counted. Dissolved oxygen (ppm), pH, temperature (°C) and conductivity (µS/cm) were simultaneously recorded for each sampling plot in each stream, using a digital water analyzer (model ICM5500, Forestry Suppliers). We described each sampled transect according to stream width, depth, current speed, turbidity, and the characteristics listed in Table I. The community structure was described in terms of number of species (S), species composition, Margalef's richness index (R), the maximum diversity which can possibly occur (H_{max}), Shannon's diversity index (H'), Hill's evenness index (E) (LUDWIG & REYNOLDS, 1988), annual average density (AAD) and monthly average density (MAD) expressed as individuals/unit-effort. Frequency (Fc) of species was calculated as percentage of samples in which each species occurred, and rareness (Rs) as percentage of species with abundance lower than 1% of the total. Species dominance was based on percentage of total numbers collected (also called numerical dominance). All monthly biological variables were plotted to show their annual variation. A Hotelling's test was applied to physical/chemical variables to compare streams (MANLY, 1998). The possible effect of the water body's nature on species density was tested using a one-way ANOVA (ZAR, 1984). Finally, we established the similarity between the communities using a modified Bray-Curtis (BC) index as 100 (1-BC) (LUDWING & REYNOLDS, 1988). All statistical analyses were performed by using STATISTICA ver. AX99.

Table I

Habitat composition based on percentage of annual studied samples. – [SF, San Francisco stream and ES, El Saucillo stream, Hidalgo, Mexico; – n = number of samples]

Fact habitat/stream	SF (n = 409)	ES (n = 109)
Width range (m)	0.5-20	0.4-4
Depth range (m)	0.30-0.50	0.10-0.30
Current	Low	Low
Turbidity	Low	Low
Bottom rocky bed	23%	4%
Sandy	64%	67%
Rough gravel	37%	62%
Fine gravel (Diam< 0.03m)	50%	57%
Big rocks (diam>0.10m)	40%	58%
Detritus	27%	23%
Marginal plants	35%	3%
Emergent plants	17%	3%
Submerged plants	49%	20%
Floating plants	25%	29%
Filamentous algae	53%	43%

RESULTS

PHYSICAL/CHEMICAL DESCRIPTION OF STREAMS

Ranges and 95% confidence intervals for means of all physical/chemical variables are shown in Table II. Multivariate Hotelling's test showed the two streams were quite different ($T^2 = 894.6$; $F_{(4,530)} = 222.4$; $p < 0.0001$). The four variables exhibited significant differences between the streams ($p < 0.05$). ES had significantly lower averages than SF (Tab. II), and more variability in all variables (Fig. 2). pH was high in both streams; in ES alkalinity increased during February-May (Fig. 2a); there was less variation in SF. Temperature was lower in ES throughout the year and in both streams it decreased during October-February (Fig. 2b). Dissolved oxygen was lower in ES, but showed similar annual variation in both streams, reaching a maximum in January and February

Table II

Means ± 95% confidence intervals and ranges (in parenthesis) for physical/chemical features of the streams; data from August 1995 to July 1996

Stream/variable	pH	Dissolved oxygen (ppm)	Conductivity (µS/cm)	Temperature
San Francisco	9.05 ± 0.02	11.16 ± 0.13	608.29 ± 5.39	19.69 ± 0.19
	(8.28 - 11.0)	(4.4 - 21.8)	(142 - 934)	(10.2 - 29.1)
El Saucillo	8.78 ± 0.03	7.44 ± 0.19	394.05 ± 7.99	15.59 ± 0.28
	(7.72 - 10.16)	(0.5 - 16.5)	(177 - 817)	(8.1 - 22.6)

(Fig. 2c). Conductivity was very constant between August and May in SF whereas it tended to increase in ES from August to April, then dropped in May (Fig. 2d); both streams had lowest conductivity in June.

There were important differences in habitat composition between streams: the number of sampled sites that had rocky bottoms was almost six times greater in SF than in ES, and SF had more marginal, emergent, and submerged plants, and less rough gravel than ES (Tab. I).

LARVAL COMMUNITY COMPOSITION OF THE SAN FRANCISCO STREAM

5617 odonate larvae were captured throughout the sampling year in 409 samples. Annual average density (AAD) of larvae was 13.73/unit-effort. Number of taxa was 30 species (16 Anisoptera and 14 Zygoptera) belonging to 18 genera and 5 families. Not all the species were found throughout the year. The predominant species overall were *Pseudoleon superbus* (17.60%), *Telebasis salva* (15.70%), *Libellula saturata* (13.50%), *Enallagma praevarum* (10.30%), *Argia fumipennis violacea* (9.03%), *Paltothemis lineatipes* (6.55%), *Argia anceps* (5.91%), and *Erpetogomphus crotalinus* (5.84%) (Fig. 3). The most frequently encountered species in the community throughout the year were *L. saturata* (which occurred in 39.5% of the samples), *Pseudoleon superbus* (Fc = 28.10), *Erpetogomphus crotalinus* (Fc = 26.70), *Argia fumipennis violacea* (Fc = 25.70) and *Enallagma praevarum* (Fc = 19.80, Fig. 4).

MONTHLY NUMERICAL VARIATION. — Monthly numerical structure was highly variable. For instance, in some months (August to October) one species out-numbered all others, while in the remainder of the year several species were equally common. Only in August and September was the structure the same (Fig. 5). During August and September sampling was concentrated at the site of the confluence of SF stream and the Zimapan's reservoir (ecotone area). The most abundant species here was *Telebasis salva* (Figs 4, 5) whose abundance, in these two months, comprised to 89.9% of its annual total.

COMMUNITY PARAMETERS FLUCTUATION. — Community measures are given in Table III. Richness (R), diversity (H') and monthly average density (MAD) dropped in

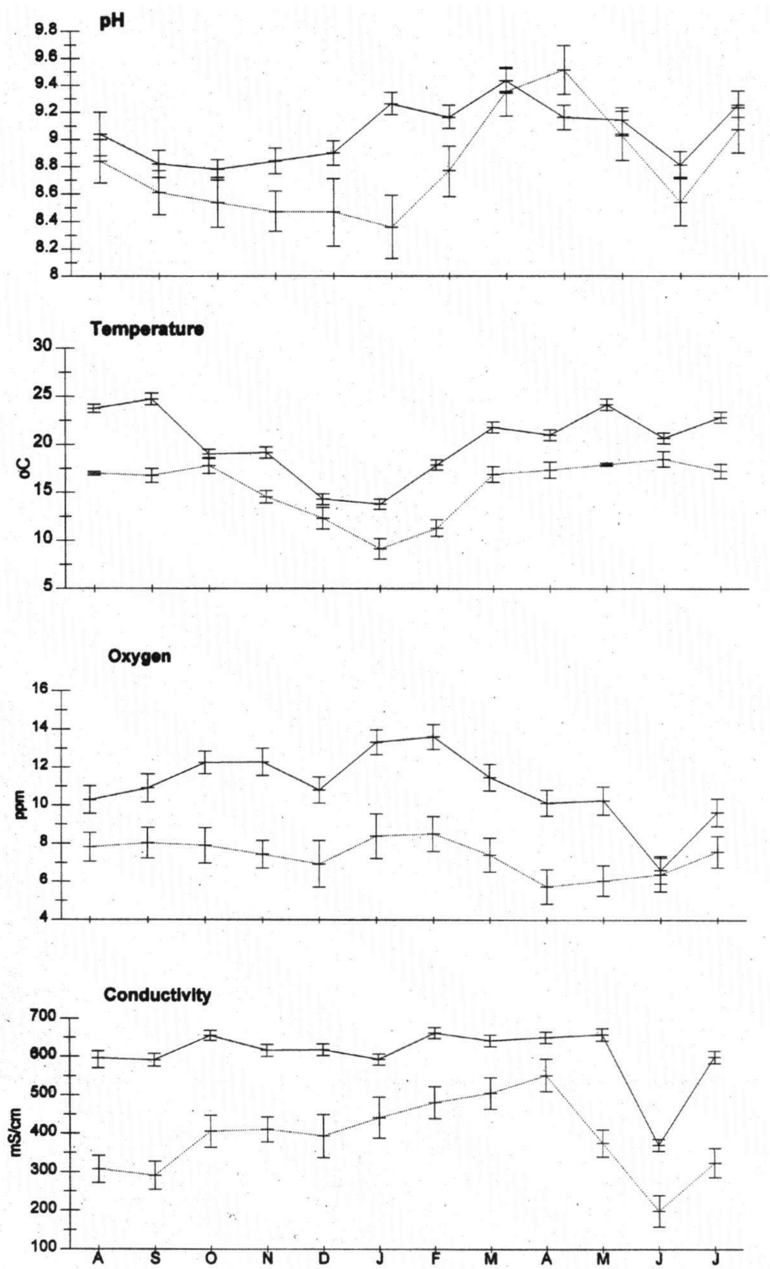

Fig. 2. Annual average variation of physical-chemical factors at San Francisco stream (solid lines) and El Saucillo stream (dashed lines). Error bars indicate 95% confidence intervals.

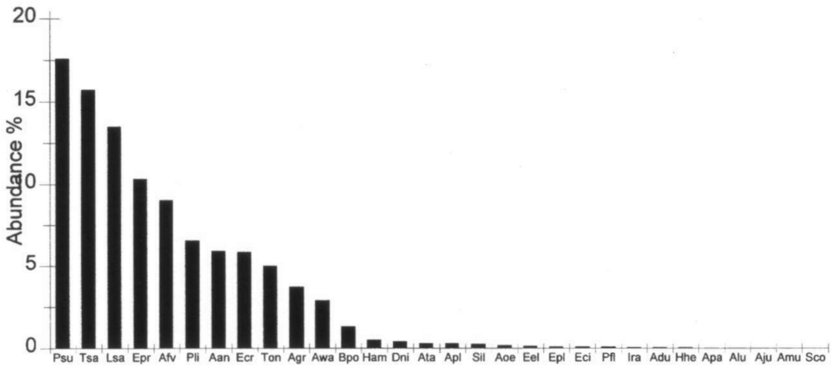

Fig. 3. Percentage of total abundance from August 1995 to July 1996, of odonate species from San Francisco stream. All species to the right of Bpo showed rareness. Key to species in Table III.

October and November (Fig. 6). In contrast, richness and diversity were high in March, whereas MAD reached one of its lowest values. Evenness was relatively constant throughout the year.

DENSITY PATTERNS OF SPECIES. – MAD patterns are shown in Figure 7 for the more abundant and frequently occurring species throughout the collecting year. However, density patterns of other species are also commented upon below. The coenagrionid *Telebasis salva* was very abundant during August and September reaching a maximum density of 10 individuals/unit-effort, the highest value reached by any species during the study. *Pseudoleon superbus*, the commonest odonate at SF, reached peak density during November-January. The abundance of all species was very low in October. The following species were only recorded in 1, 2 or 3 months and at very low density: *Argia lugens* (January), *Sympetrum corruptum* (February), *Enallagma civile* (August and September), *Erpetogomphus elaps* (January, February and June), *Anax junius* (June), *Ischnura ramburii* (April, May and July), *Pantala flavescens* (August),

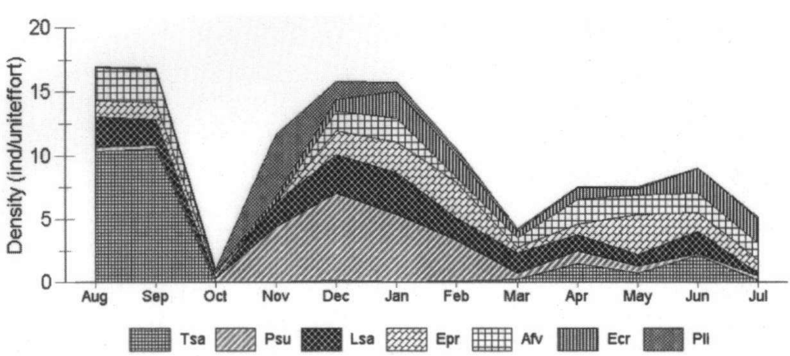

Fig. 4. Species densities throughout the collecting year in San Francisco stream. Key to species in Table III.

Hesperagrion heterodoxum (June, July) and *Argia pallens* (March). All these species were designated as rare.

LARVAE COMMUNITY COMPOSITION OF THE EL SAUCILLO STREAM

A total of 3447 specimens in 109 samples were captured throughout the collecting year, so the annual average density (AAD) of larvae was 31.6 ind/unit-effort. The number of species was 21 (11 Anisoptera and 10 Zygoptera) belonging to 16 genera and 5 families. The most abundant species were *Paltothemis lineatipes* (34.1%), *Argia anceps* (27.9%), and *Archilestes grandis* (13.4%) (Fig. 8). The first two species were common throughout most of the year and *A. grandis* was common from January to July (Fig. 9).

MONTHLY NUMERICAL VARIATION. — As in SF stream, monthly numerical structure varied greatly in ES (Fig. 10). Only 5 species were recorded in August, and 50% of the larvae collected were *Libellula saturata*. From September to January *P. lineatipes* and *A. anceps* were the two commonest species. In February *A. grandis*, *A. anceps* and *P. lineatipes*, were common, and by April 8 species were more or less equally abundant.

COMMUNITY PARAMETERS FLUCTUATION. — All community measures are given in Table III. The patterns of richness, evenness and diversity followed much the same pattern as in SF (Fig. 11). However, MAD was more variable in ES.

DENSITY PATTERNS OF SPECIES. — Fluctuation patterns of MAD of the more abundant and more frequently occurring species throughout the collecting year are shown in Figure 12. Although not collected in August, *P. lineatipes* maintained high densities during September-January and then declined through to July. *A. anceps* showed a similar pattern maintaining higher densities during October-March and declining thereafter.

The following species were recorded only occasionally and at very low density: *S.*

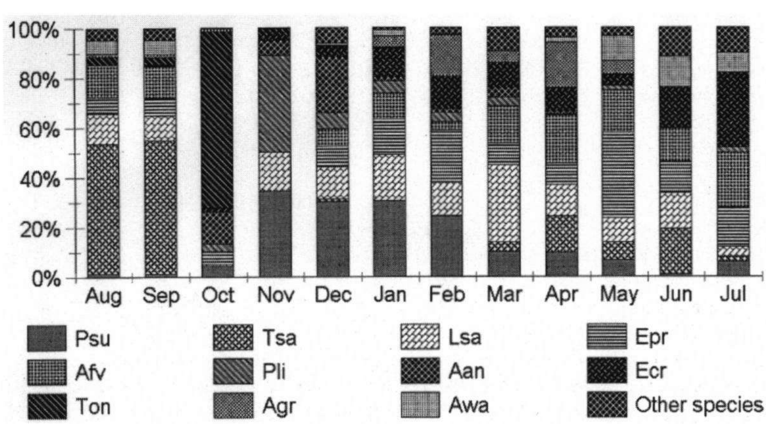

Fig. 5. Monthly proportional abundances of Odonata larvae from San Francisco stream from August 1995 to July 1996. Key to species in Table III.

Table III
Community structure of odonate larva of San Francisco (SF) and El Saucillo (ES) streams; data from August 1995 to July 1996

		SF				ES			
Species	Key	Ab	%	AAD	Fc	Ab	%	AAD	Fc
Hetaerina americana	Ham	28	0.50	0.068	4.94	-	-	-	-
Archilestes grandis	Agr	210	3.74	0.513	10.10	457	13.30	4.19	48.40
Argia anceps	Aan	332	5.91	0.810	13.80	960	27.99	8.81	67.70
Argia fumipennis violacea	Afv	510	9.03	1.240	25.7	92	2.68	0.84	14.00
Argia lugens	Alu	1	0.02	0.002	0.25	-	-	-	-
Argia oenea	Aoe	10	0.18	0.024	1.73	-	-	-	-
Argia pallens	Apa	1	0.02	0.002	0.25	-	-	-	-
Argia plana	Apl	13	0.23	0.032	2.47	7	0.18	0.06	5.38
Argia tarascana	Ata	17	0.30	0.042	2.96	30	0.87	0.27	7.53
Enallagma civile	Eci	6	0.11	0.015	0.49	-	-	-	-
Enallagma praevarum	Epr	580	10.30	1.420	19.80	7	0.20	0.06	1.08
Hesperagrion heterodoxum	Hhe	2	0.04	0.005	0.49	7	0.20	0.06	2.15
Ischnura ramburii	Ira	3	0.05	0.007	0.74	2	0.06	0.02	2.15
Telebasis salva	Tsa	884	15.70	2.160	18.00	126	3.66	1.15	5.38
Anax junius	Aju	1	0.02	0.002	0.25	-	-	-	-
Anax walsinghami	Awa	163	2.90	0.398	14.6	49	1.43	0.45	5.38
Aeshna multicolor	Amu	1	0.02	0.002	0.25	-	-	-	-
Aeshna dugesi	Adu	2	0.04	0.005	0.49	-	-	-	-
Erpetogomphus crotalinus	Ecr	328	5.84	0.802	26.70	3	0.09	0.03	2.15
Erpetogomphus elaps	Eel	7	0.12	0.017	1.48	-	-	-	-
Brechmorhoga p. postlobata	Bpo	74	1.32	0.181	3.95	4	0.12	0.04	3.23
Dythemis nigrescens	Dni	23	0.41	0.056	4.69	-	-	-	-
Erythemis plebeja	Epl	6	0.11	0.015	1.48	-	-	-	-
Libellula saturata	Lsa	759	13.50	1.860	39.50	173	5.03	1.59	31.20
Paltothemis lineatipes	Pli	368	6.55	0.890	17.00	1176	34.20	10.78	81.70
Pantala flavescens	Pfl	5	0.09	0.012	0.25	2	0.06	0.02	1.08
Perithemis domitia	Pdo	-	-	-	-	4	0.12	0.04	3.23
Pseudoleon superbus	Psu	990	17.60	2.420	28.10	162	4.71	1.49	20.40
Sympetrum corruptum	Sco	1	0.02	0.002	0.25	1	0.03	0.01	1.08
Sympetrum illotum	Sil	14	0.25	0.034	1.73	174	5.06	1.59	20.40
Tramea onusta	Ton	281	5.00	0.690	13.60	2	0.06	0.02	1.08
Overall		5617	100	13.700	74.1	3438	100	31.62	92.50
Richness (S)		30				20			
Margalef´s richness index (R)		3.24				1.83			
Shannon´s diversity index (H')		2.42				0.68			
Hill´s evenness index (E)		50.81				57.10			
Rareness (Rs)		58.60				57.10			

SF = San Francisco River; – ES = El Saucillo stream; – Ab = total abundance; – AAD = annual average density; – % = percentage of abundance; – Fc = frequency based on all year samples; – Key = key to species

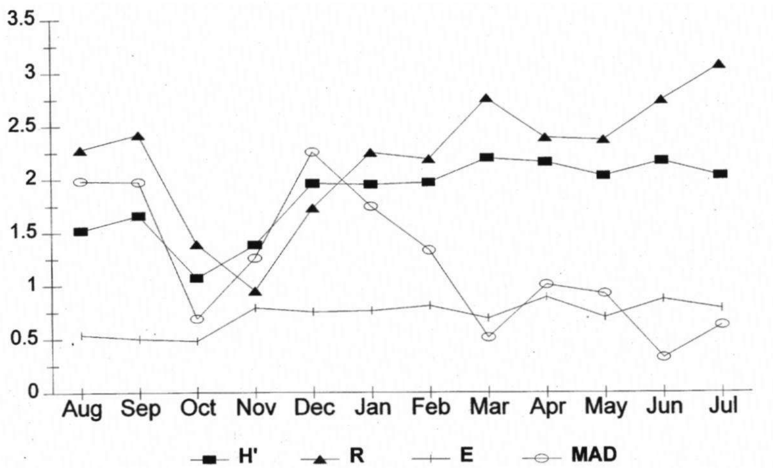

Fig. 6. Annual variation in community parameters in San Francisco stream. H' = Shannon's diversity index; – R = Margalef's richness index; – E = Hill's evenness; – MAD = monthly average density. Density was divided by 10 to be more comparable to other parameters. Key to species in Table III.

corruptum and *P. flavescens* (September), *T. onusta* (November), *Ischnura ramburii* (March, April), *E. crotalinus* (January, March and July), *A. tarascana* (September and April), *H. heterodoxum* (April, May) and *Brechmorhoga praecox postlobata* (August, September, November and July).

EFFECT OF THE WATER BODY'S NATURE ON SPECIES DENSITY

MAD values showed that the streams were significantly different in larval density (ANOVA: $F = 10.96$, $gl = 22$, $p < 0.01$) and monthly variation in larval density was

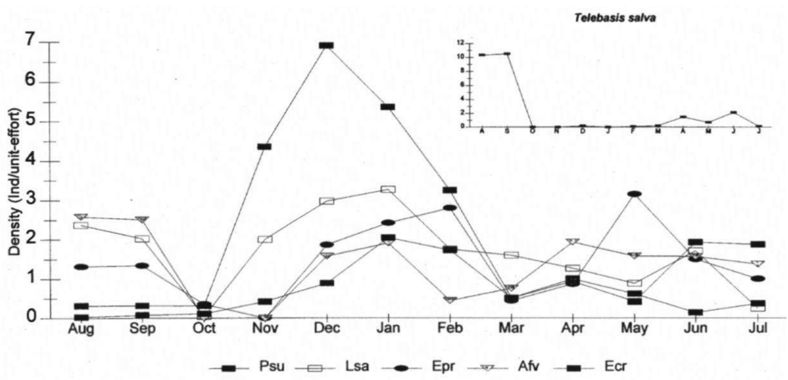

Fig. 7. Species densities in San Francisco stream from August 1995 to July 1996. *Telebasis salva* has been treated separately for scaling reasons. Key to species in Table III.

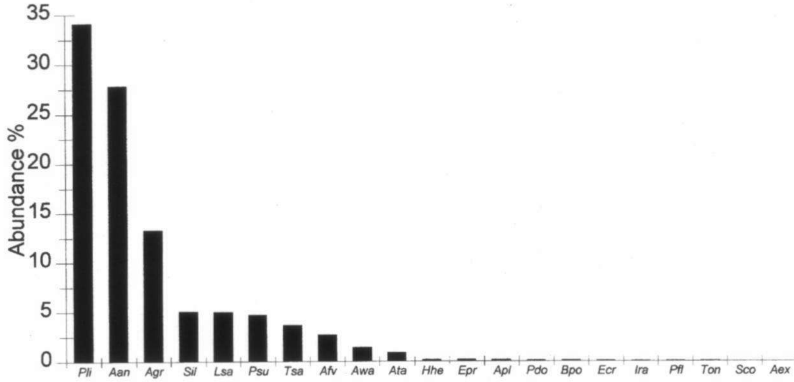

Fig. 8. Percentage of total abundance of Odonata species from El Saucillo stream from August 1995 tot July 1996. Key to species in Table III.

greater at ES (Std. Dev. = 16.15 vs. 5.82 from SF). This difference is mainly due to the high density of larvae of *Sympetrum illotum*, *Paltothemis lineatipes* and *Archilestes grandis* recorded during March and April at ES, as well as to the relatively low density of larvae (< 7 ind/unit-effort) recorded during March, July and October at SF.

FAUNISTIC SIMILARITY

The modified Bray-Curtis index indicated a 37% similarity between the two communities. The communities shared 69.3% of the species, although some of them were better established in SF (*E. praevarum*, *E. crotalinus*, *A. fumipennis violacea*, *P. superbus*, *T. salva* and *T. onusta*) while others (*A. grandis*, *A. anceps*, *P. lineatipes* and *S. illotum*) had higher densities in ES. Eleven species occured only at SF (*Hetaerina*

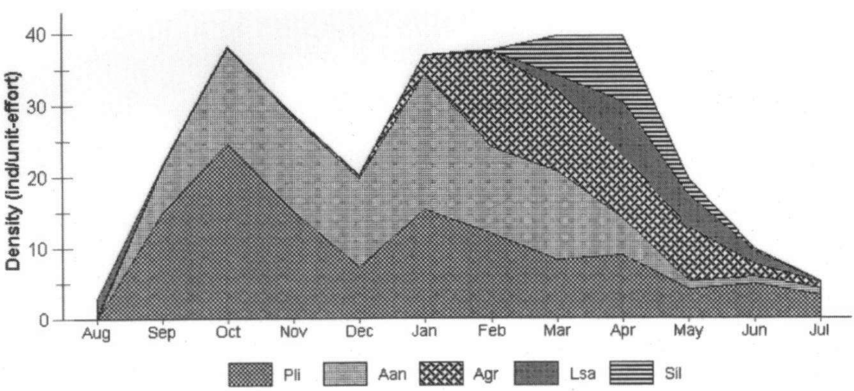

Fig. 9. Species densities in El Saucillo stream from August 1995 to July 1996. Key to species in Table III.

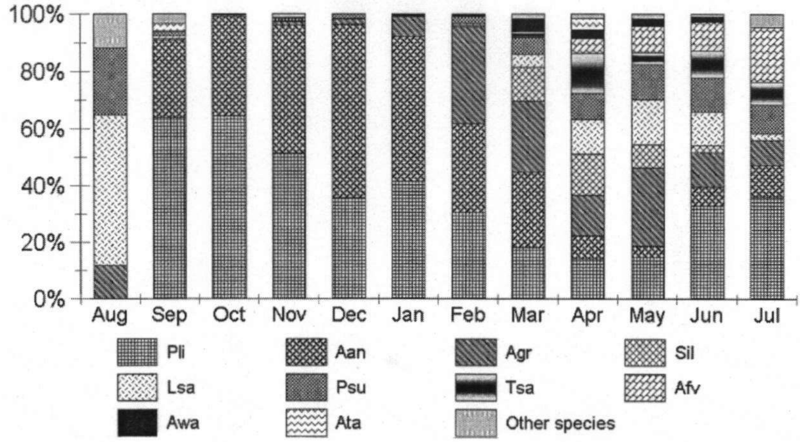

Fig. 10. Monthly proportional abundances of Odonata larvae in El Saucillo stream from August 1995 to July 1996. Key to species in Table III.

americana, A. lugens, A. oenea, A. pallens, E. civile, A. junius, A. multicolor, A. dugesi, E. elaps, D. nigrescens and *E. plebeja)*, while *P. domitia* was an exclusive species at ES.

DISCUSSION

PHYSICO-CHEMICAL VARIABLES. — Although the streams were significantly different in their physico-chemical variables, we did not find a correlation between these and community parameters. However, some factors such as water temperature could be determining a lower odonate density in ES.

LARVAL COMMUNITY COMPOSITION. — The most speciose genus at the studied site was *Argia* with seven species; other genera had only one or two species (Tab. III).

The commonest odonate species in each stream was a member of the Libellulidae: *Pseudoleon superbus* at SF and *Paltothemis lineatipes* at ES, and the next most abundant was a coenagrionid, *Telebasis salva* and *Argia anceps* respectively. In both streams we find a variable monthly numerical structure and a similar fluctuation in the community parameters, with richness and diversity dropping in October-November and increasing in March-April (see Figs 6, 11). The decrease during October and November could be related to the timing of emergence as indicated by the frequent encountering of larval exuviae (unfortunately we did not collect and count all of them). Also, probably we lost many of the very young instars at this time because they could escape through the mesh or were difficult to see. By contrast, larvae were medium- to large-sized and easily captured during March-April.

The dominance of *P. lineatipes* and *A. anceps* at ES, and *P. superbus* at SF may be due to the fact that they are apparently multivoltine species (they showed 6-9 instars in

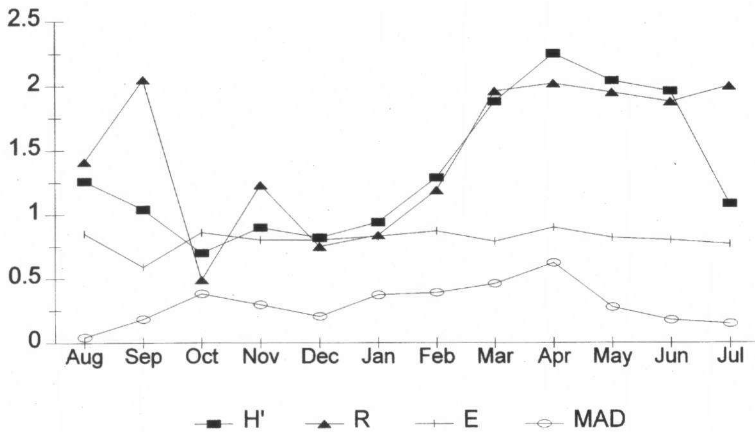

Fig. 11. Annual variation in community parameters in El Saucillo stream. H' = Shannon's diversity index; – R = Margalef's richness index; – E = Hill's evenness; – MAD = monthly average diversity. Density was divided by 10 to be more comparable to other parameters.

each sampling month, thus behaving as "summer species" [sensu BENKE & BENKE, 1975]). These species were always present throughout the collecting year at relatively high densities. Adults of *P. superbus* were observed on the wing from August 1995 to February 1996 and again from April to July 1996, and reproductive activity of this species was observed from August to November 1995 and from June to July 1996 at SF. Adults of *P. lineatipes* at ES were observed flying from August 1995 to January 1996 and again from May to July 1996, and reproductive activity was recorded from August to December 1995 and in July 1996. The long reproductive period of these two species establishes a developmental asynchrony in the larval populations, providing a wide size range of individuals at any time (WISSINGER, 1988) and an overlapping of generations. The codominance of *T. salva* at SF we think is biased by the sampling method: during August and September collections were mainly at sites covered with floating aquatic macrophytes, a substrate preferred by *T. salva.*

The highly variable monthly numerical structure may also reflect the influence of other factors such as seasonality and habitat partitioning (see CROWLEY & JOHNSON, 1982; JOHNSON, 1991), species with similar microhabitats having a distinct temporal separation (BENKE & BENKE, 1975) resulting from competitive and intra-guild predatory interactions (WISSINGER, 1992). For example, in Figure 10, *A. anceps* dominates from September 1995 to March 1996, then declines in April 1996, being outnumbered by *A. fumipennis violacea* from May to July 1996.

EFFECT OF THE WATER BODY'S NATURE ON SPECIES DIVERSITY AND DENSITY. – Although both communities follow similar ecological patterns (monthly numerical dominance, community parameters, and density), they differ in their community structure (mainly diversity), as well as physical/chemical features. We think that the

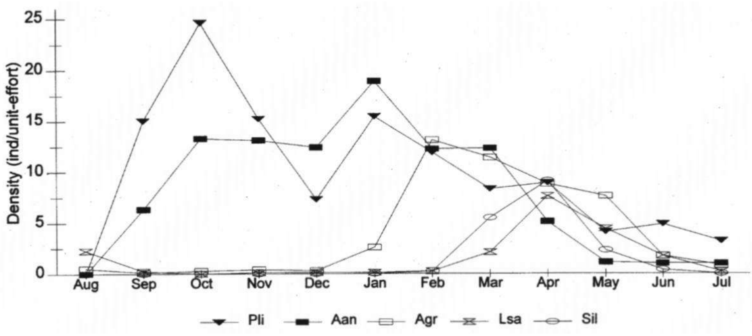

Fig. 12. Species densities in El Saucillo stream from August 1995 to July 1996. Key to species in Table III.

lower diversity at ES was largely due to the macro- and microhabitat conditions. In this stream the steep gradient and its repetitive terraces (with pools) provides a series of homogeneous microhabitats which evidently simplified the environment, favoring the establishment and dominance of species such as *P. lineatipes, A. anceps* and *A. grandis*, while excluding others such as *Argia oenea*, which requires a constant and moderately turbulent water flow (pers. obs.). Likewise, because ES runs into a narrow canyon, it receives less insolation than SF, and its discharge becomes intermittent during the dry period. Both conditions probably affect the establishment of species with higher temperature requirements and a permanent water flow. The proportion of several substrates was notably different between the two streams (see Tab. I), particularly in substrates such as bottom rocky bed, rough gravel, and marginal, emergent and submerged plants, which were more abundant at SF, the stream with the higher diversity.

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