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Composition and Phenology of Ephemeroptera from a Tropical Rainforest Stream at El Verde, Puerto Rico

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ABSTRACT: Seven mayfly species were caught by emergence trap from February 1990 through February 1991 at Quebrada Prieta, a second-order high-gradient stream, and a tributary of the Rio Sonodora in the Luquillo Experimental Forest, Caribbean National Forest, El Verde, Puerto Rico (18°18′N and 65°47′W). Six mayfly species collected from the study site belong to the austral genera *Cloeodes, Borinquena,* and *Neohagenulus* and one to an unidentified baetid Genus A. Six species emerged throughout the trapping period, and one species, *Borinquena* n. sp., was restricted to October through early December. The two dominant species, *Cloeodes* (*C.*) *maculipes* Traver and *Neohagenulus julio* Traver, showed pronounced emergence fluctuations that may be seasonal. The other four species, *Neohagenulus luteolus* Traver, *Borinquena* (*B.*) *carmencita* Traver, *Cloeodes* (*Cloeodes*) sp. and baetid Genus A, displayed similar patterns of emergence but were less abundant. Moon phases showed no obvious correlations to emergence patterns of mayflies in the area. Quebrada Prieta appears to have a low diversity of mayfly fauna when compared to streams from higher latitudes.

Data on the seasonality of mayflies in the tropics are scarce compared to the temperate region. Our study represents only the second set of mayfly seasonality data from tropical areas with an indistinct dry season. The first was the study by Wolda and Flowers (1985) in Panamá.

This study has the following objectives: 1, to investigate the emergence patterns of mayflies in a tropical rain forest; 2, to compare the diversity of the mayfly fauna of Quebrada Prieta, El Verde, with mayfly data from other tropical and temperate areas; and 3, to gain knowledge of the probable zoogeography of the mayfly fauna of El Verde, Puerto Rico.

Materials and Methods

The hydrology and physico-chemical features of Quebrada Prieta, and methods of sampling and calculating daily emergence of aquatic insects caught by emergence traps were briefly discussed by Masteller and Buzby (1993). Mayfly adults were sorted and preserved in 70% ethanol. Individuals of each species were counted and the totals graphically plotted on a monthly interval. The specimens are deposited in the collections of Florida Agricultural and Mechanical University, U.S. National Museum of Natural History, and Pennsylvania State University.

Species diversity was calculated using Fisher's alpha of the log series (Wolda, 1981). Unlike the Shannon-Weaver, Simpson's, and other better known diversity indices, alpha is independent of sample size and it does not give excessive weight to the most common species in a sample (Flowers, 1991; Wolda, 1983).

Results

The 3324 mayfly adults caught in 52 weeks of emergence trap samplings in Quebrada Prieta represented seven species (Table 1, Fig. 1). Two of the seven species belong to the widespread baetid genus *Cloeodes,* one to an unidentified

Table 1. List of mayfly species and number of specimens caught by emergence trap from Feb. 1990 to Feb. 1991, Quebrada Prieta, Luquillo Experimental Rain Forest, Puerto Rico.

Taxa	Specimens
Baetidae	
Cloeodes (*C.*) *maculipes*	1558
Cloeodes (*C.*) sp.	155
Baetid Genus A	78
Leptophlebiidae	
Borinquena (*B.*) *carmencita*	169
Borinquena (*B.*) n. sp.	7
Neohagenulus julio	1152
N. luteolus	205

baetid Genus A, and two species to the leptophlebiid genera *Borinquena* and *Neohagenulus*.

The mayfly fauna of Quebrada Prieta was dominated by the baetid species *Cloeodes* (*Cloeodes*) *maculipes* Traver and the leptophlebiid species *Neohagenulus julio* Traver, representing 46.9% and 34.7% of the total mayfly samples, respectively (Fig. 1). *Borinquena* (*Borinquena*) n. sp. had the least number of individuals (0.2%), followed by *B. carmencita* Traver and baetid Genus A, with 5.1% and 2.3% of the specimens (Fig. 1), respectively. All specimens of baetid Genus A were females. Using the alpha of the log series to calculate the species diversity, the mayfly fauna represents an index value of 0.84 ± 0.32, which is quite low compared to published data from temperate and some other tropical environments (Table 2). In *Borinquena* n. sp., adults were collected only from mid-October through early December (Fig. 4), while the rest of the species had continuous emergence patterns or were in flight throughout the year. The three leptophlebiid species, *Neohagenulus julio, N. luteolus* and *Borinquena carmencita,* had similar phenology, with the most emergence from September to December and least from June through August (Figs. 2, 4). The combined emergence data of all four lep-

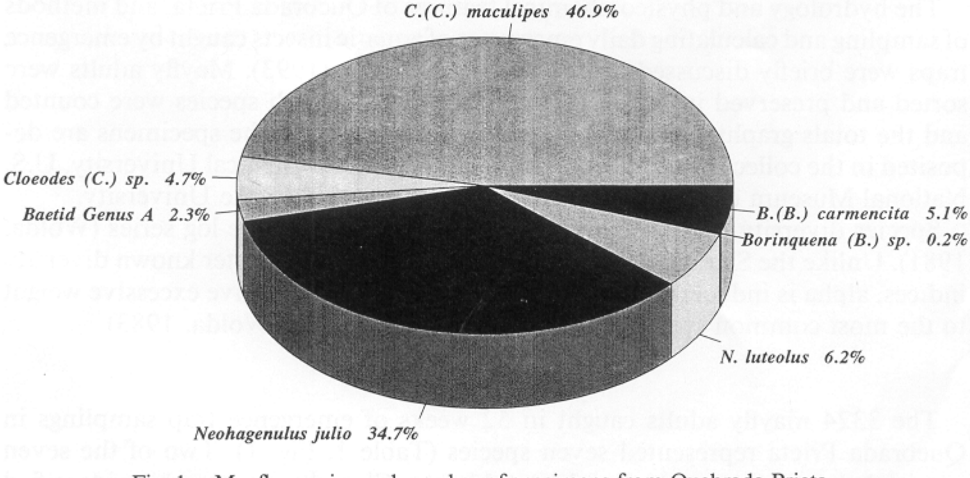

Fig. 1. Mayfly species and number of specimens from Quebrada Prieta.

Table 2. Diversity of tropical and temperate samples of adult Ephemeroptera. Em = emergence trap, LT = light traps, NS = net samples, Var = a combination of different methods, *n* = number of individuals, S = number of species, Alpha = diversity index with standard deviation, MC = number of individuals of most common species as a % of total number in sample. Data ordered according to the value of Alpha. (Data from Wolda and Flowers, 1985).

Source	Method	Country	*n*	S	MC	Alpha
Jazdzewska, 1984	Var	Poland	349	25	22.7	5.93 ± 1.19
Carlson, 1971	Var	USA, SC	11,815	45	37.4	5.92 ± 0.88
Peters and Warren, 1966	LT	USA, AR	3456	34	60.7	5.21 ± 0.89
Ulftrand, 1969	LT	Sweden	532	17	63.3	3.36 ± 0.81
Ulftrand, 1969	Ns	Sweden	2915	22	13.7	3.24 ± 0.69
Wolda and Flowers, 1985	LT	Panama Mir	29,120	30–35	73.0	3.30 ± 0.60
						3.92 ± 0.66
Kopelke, 1981	Em	Zaire	29,892	21	29.5	2.21 ± 0.48
Langford, 1975	Em	England	2620	15	37.8	2.10 ± 0.54
Illies, 1980	Em	Austria Tb	17,737	12	48.4	1.26 ± 0.36
Flannagan and Lawler, 1972	Em	Canada	193	5	49.2	0.94 ± 0.42
Illies, 1980	Em	Austria Sb	1725	—	81.1	0.93 ± 0.35
Brittain, 1978	Em	Norway	3071	—	53.6	0.86 ± 0.32
Present study	**Em**	**Puerto Rico**	**3324**	7	**45.7**	**0.84 ± 0.32**
Illies, 1982	Em	Germany	127,744	9	84.0	0.70 ± 0.24
Illies, 1978	Em	Germany	67,730	—	79.4	0.60 ± 0.23

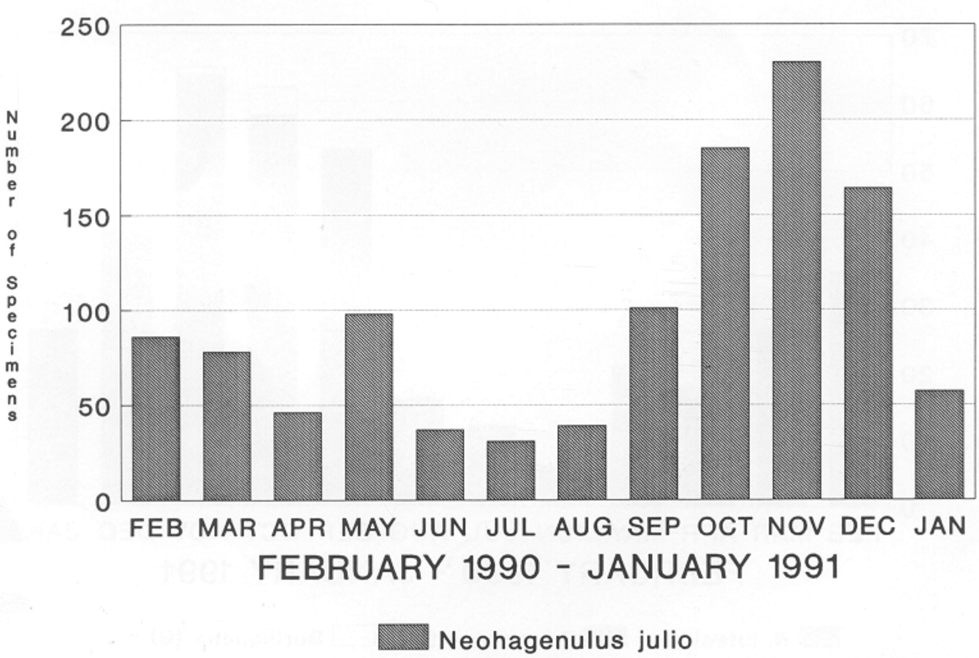

Fig. 2 Monthly emergence of Ephemeroptera from Quebrada Prieta, Luquillo Experimental Rain Forest, Puerto Rico.

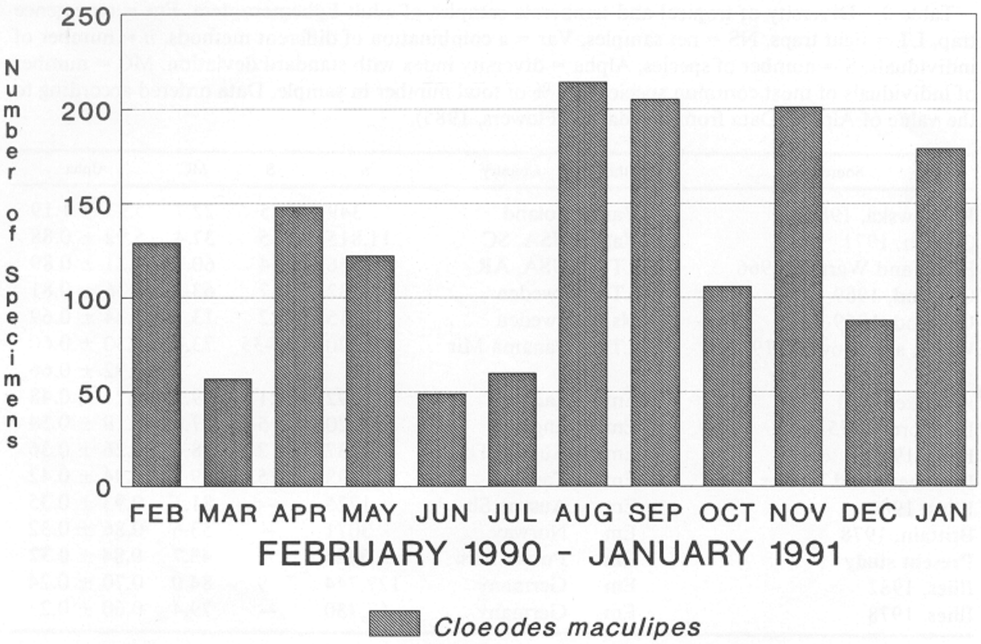

Fig. 3. Monthly emergence of Ephemeroptera from Quebrada Prieta, Luquillo Experimental Rain Forest, Puerto Rico.

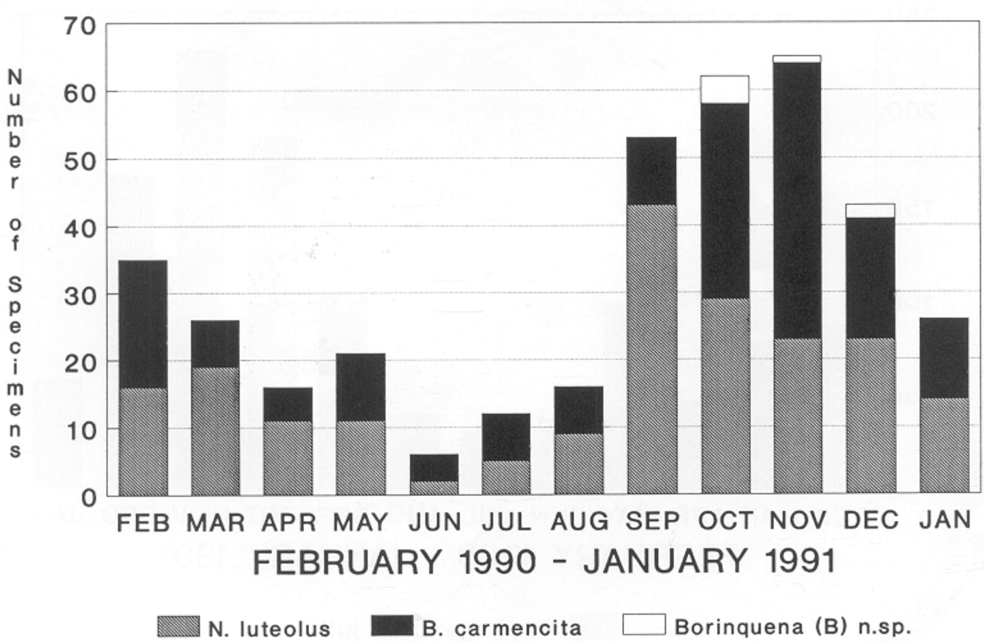

Fig. 4. Monthly emergence of Ephemeroptera from Quebrada Prieta, Luquillo Experimental Rain Forest, Puerto Rico.

tophlebiid species is shown in Fig. 6, indicating that emergence of this group occurs between September and December. *Cloeodes* (*C.*) *maculipes* dominated the baetid mayflies and manifested a more or less rhythmic emergence pattern. Emergence fluctuations occurred practically every other month, with peak emergence between August and November (Fig. 3). The two less abundant baetid species, *Cloeodes* (*C.*) sp. and baetid Genus A, emerged throughout the year, but the low number of specimens caught during the trapping period gave little indication of an emergence pattern (Fig. 5). The emergence pattern of the baetid fauna in the study area is shown in Fig. 6. It appears that the mayfly fauna at Quebrada Prieta displays an abundance of emergence from August to December and reduced abundance in June and July (Fig. 6). The average daily mayfly emergence also showed a similar pattern, with June and July recording the lowest daily emergence (Fig. 7).

The average monthly precipitation records in the Luquillo Mountains, especially in 1990 indicate that the area has indistinct wet and dry seasons. Rainfall was more or less evenly distributed throughout the year, with January through March averaging slightly less (Masteller and Buzby, 1993).

Discussion

Six of the seven mayfly species caught by emergence traps were in flight throughout the 51 weeks of sampling, which is basically in concert with the general ecological expectation that most aquatic insects in the tropics, including mayflies, emerge throughout the year. Lack of a cold season in the tropics apparently allows uninterrupted growth and development of aquatic insects and the likelihood of year-round adult flight periods.

The genus *Cloeodes* includes species from southeastern Asia, southwestern United States, and Central and South America, but the other two mayfly genera collected in Quebrada Prieta, *Borinquena* and *Neohagenulus,* are presently limited geographically to the West Indies. The predominantly Western Hemisphere *Cloeodes* is neotropical in origin and represents two major phyletic lines recognized as subgenera: the monotypic *Notobaetis* from Argentina, and *Cloeodes* s.s., which includes species from Asia (China and Sri Lanka), southwestern United States (Arizona, New Mexico), Mexico (Baja California), West Indies (Puerto Rico) and South America (Paraguay, Uruguay, Venezuela) (Waltz and McCafferty, 1987; McCafferty and Waltz, 1990). All three species of *Neohagenulus* are endemic to Puerto Rico, and two of the three known species of *Borinquena* as well (Peters, 1971).

Fluctuations in abundance of mayflies in Quebrada Prieta were evident among the two dominant species, *Cloeodes maculipes* and *Neohagenulus julio* (Figs. 2, 3). This might indicate seasonal variation in abundance if similar patterns could be shown year after year. One year's data, however, provides inadequate evidence of seasonality. Similar observations were noted in a study of the seasonality of mayfly adults in Panamá, in which Wolda and Flowers (1985) indicated that most taxa occurred year-round, and some species showed within-year fluctuations in abundance that could be interpreted as seasonal. Use of only a year's data to extrapolate seasonality was cautiously exercised, although Wolda and Flowers (1985) stipulated that, based on their experience with tropical insects elsewhere in Panamá, a clearcut variation in abundance within a year is often repeated year

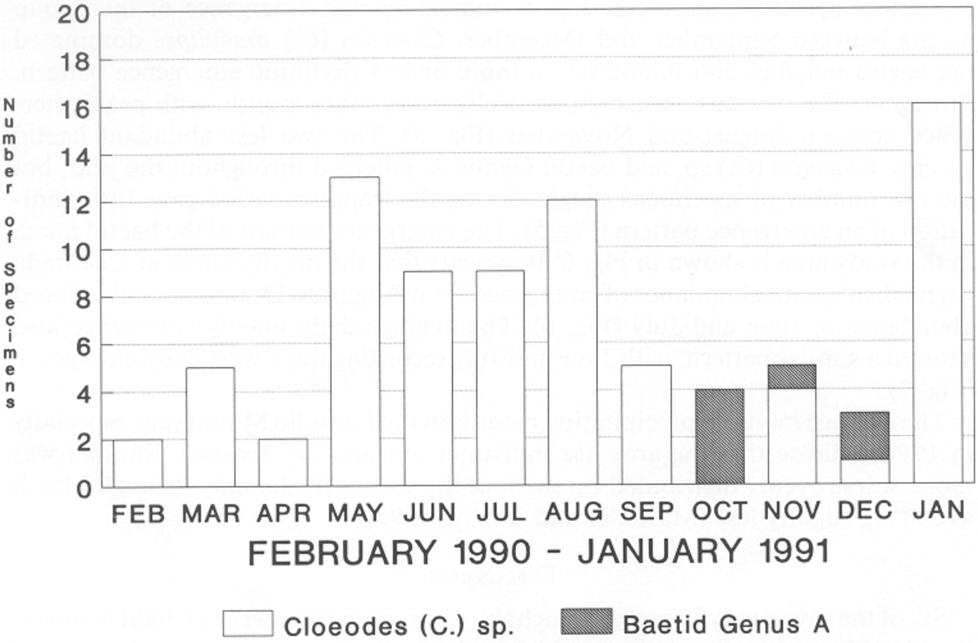

Fig. 5. Monthly emergence of Ephemeroptera from Quebrada Prieta, Luquillo Experimental Rain Forest, Puerto Rico.

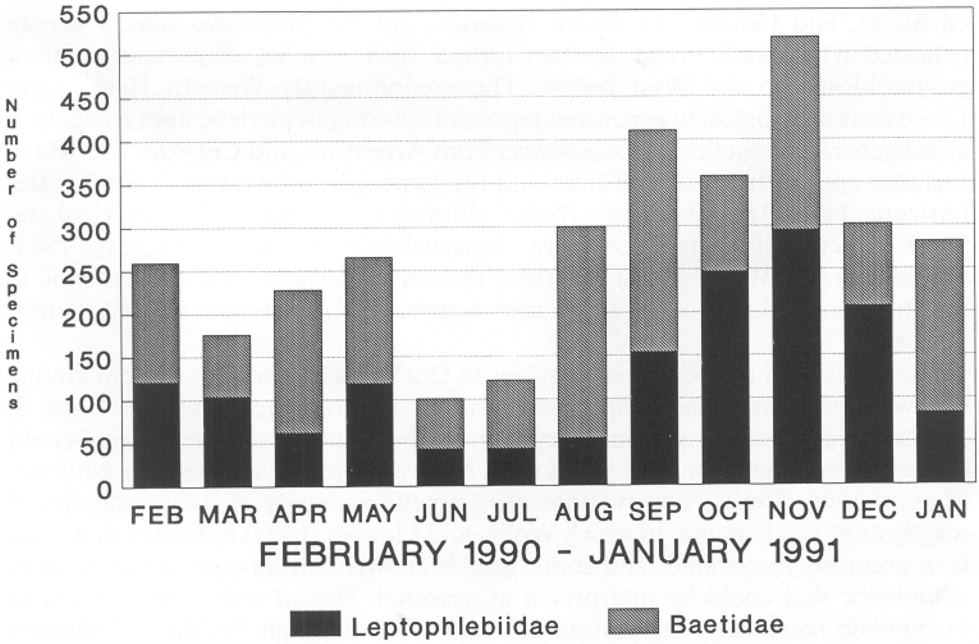

Fig. 6. Monthly emergence of Ephemeroptera from Quebrada Prieta, Luquillo Experimental Rain Forest, Puerto Rico.

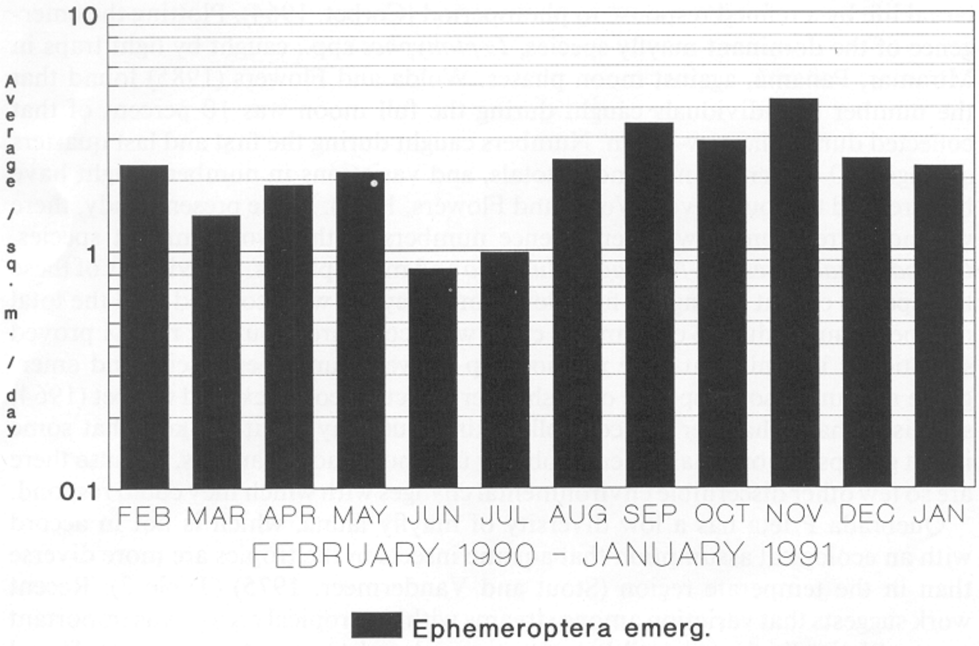

Fig. 7. Monthly emergence of Ephemeroptera from Quebrada Prieta, Luquillo Experimental Rain Forest, Puerto Rico.

after year. Kopelke (1981) observed year-round emergence of mayflies in northeastern Zaire, and although some species showed rather large fluctuations in abundance, there was no obvious correlation with the alternation of wet and dry seasons. Northeastern Zaire has distinct long wet and short dry seasons, compared to the indistinct dry season in Puerto Rico.

Based on the average monthly precipitation in the Luquillo Mountains, the emergence of mayflies in the area showed no clearcut correlation with rainfall. Fluctuations in abundance of the two dominant species, *N. julio* and *C. maculipes,* were very much evident despite the more or less equable average monthly rainfall. *Neohagenulus julio* had greatest emergence in October through December (Fig. 2), and for *C. maculipes* this occurred in August, September and November (Fig. 3). Fluctuations in abundance of some mayflies in the tropics have been attributed at least in part to rainfall, but available data have only been based on nymphal observations (Bishop, 1973; Bright, 1982). Bishop (1973) also reported that part of the fluctuations in nymphal abundance of mayflies and other aquatic insects in a Malayan river were due to the scouring of the streambed during spates. Similarly, Bright (1982) found that the densities of nymphs in a Palau stream appeared to be correlated with current speed and discharge.

Lunar phases have been known to influence the emergence patterns of some species of mayflies and other aquatic insects in the tropics (Hartland-Rowe, 1955; Corbet, 1958; Corbet, 1964; Corbet et al., 1974; Wolda and Flowers, 1985). In the mayfly *Povilla adusta* Navás, emergence is closely synchronized and occurs shortly after full moon (Hartland-Rowe, 1955; Corbet et al., 1974), and this phenomenon may be under the control of an endogenous rhythm fixed in early larval life by a refined response to photoperiod (Corbet, 1964). Plotting the emergence of the dominant mayfly species, *Leptohyphes* spp., caught by light traps in Miramar, Panamá, against moon phases, Wolda and Flowers (1985) found that the number of individuals caught during the full moon was 10 percent of that collected during the new-moon. Numbers caught during the first and last quarters averaged 50 percent of new-moon totals, and variations in numbers might have been related to cloud cover (Wolda and Flowers, 1985). In the present study, there was no correlation between emergence numbers of the two dominant species, *Cloeodes maculipes* and *Neohagenulus julio* and moon phases. Individuals of these two species caught during the first eleven moon cycles were counted, and the total numbers caught during each moon cycle were compared, but the results proved statistically insignificant. The relationship between lunar periodicity and emergence rhythm in some species of freshwater insects is complex, and Corbet (1964) surmised that, whatever the controlling time-cue may be, it is likely that some insect groups in non-tidal waters probably use endogenous variants, because there are so few other discernible environmental changes with which they could respond.

Quebrada Prieta has a low diversity of mayfly fauna, which is not in accord with an ecological assumption that aquatic insects in the tropics are more diverse than in the temperate region (Stout and Vandermeer, 1975) (Table 2). Recent work suggests that variation among streams within a tropical region is as important as any "latitudinal gradient" between tropical and temperate streams in faunal diversity (Flowers, 1991). Obviously data from a long period of study will provide a better understanding of the faunal dynamics of mayflies in the El Verde area. Additionally, emergence traps have certain limitations for collecting adults, particularly if there are different habitats outside the trap that may harbor other mayfly species. Light traps or sweep nets appear to collect more diverse samples than emergence traps. As shown in Table 2, samples caught by emergence traps, regardless of latitude, appear to have lower alpha diversity values than samples caught by light traps or sweep nets. The low diversity of the mayfly fauna in Quebrada Prieta could also be related to the relatively small size and insular nature of Puerto Rico.

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