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Diel Pattern of chironomid drift in the Llobregat River (N.E. Spain)

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INTRODUCTION

Drift has received considerable attention in recent times as a method to collect chironomid pupal exuviae (COFFMAN, 1973; LAVILLE, 1979, 1981) for taxonomic as well as water pollution studies (WILSON, 1977). On the other hand the daily drift pattern of chironomids in rivers has been investigated in many occasions (ANDERSON, 1966; ANDERSON & LEHMKUHL, 1968; BISHOP & HYNES, 1969; WATERS, 1972; WARTINBEE, 1979) but data are scarce for the Mediterranean watercourses.

In this paper we make a contribution to the poorly known Spanish chironomid fauna by means of the study of hourly collections of drifting pupal exuviae during a 24-hour period. An attempt to under stand the daily drift pattern is also presented.

SAMPLING SITE, MATERIAL AND METHODS

The sampling site is located 48,8 km from the source of the Llobregat river (fig. 1). At this site the river was 47 m wide with a mean depth of 45 cm. A weir (2 m high) was located upstream of the sampling point. Substrate was composed of stones and pebbles with abundant *Cladophora* and *Potamogeton* among areas with mud and sand.

Samples were taken with a square drift net of 625 cm^2, 1 m long and 500 microns mesh size. The net was on the river bottom with the upper part just emerging from the water, so the complete water column was sampled. As the mean river water velocity was 0,33 m/s, the net filtered 72,1 cubic meters per hour. Every hour the net was taken up from the river and all the collected material was preserved in formalin until laboratory examination. This was done under a stereoscope at 10x. In many cases the species identification was assured by means of the collections and preparation of mature male pupae found in the samples.

The Llobregat at this site is an alkaline river (3,28 meq/l) with some organic pollution although oxygen was abundant during the study period. Water was rich in nutrients thus explaining the abundant *Cladophora* and *Potamogeton* patches on

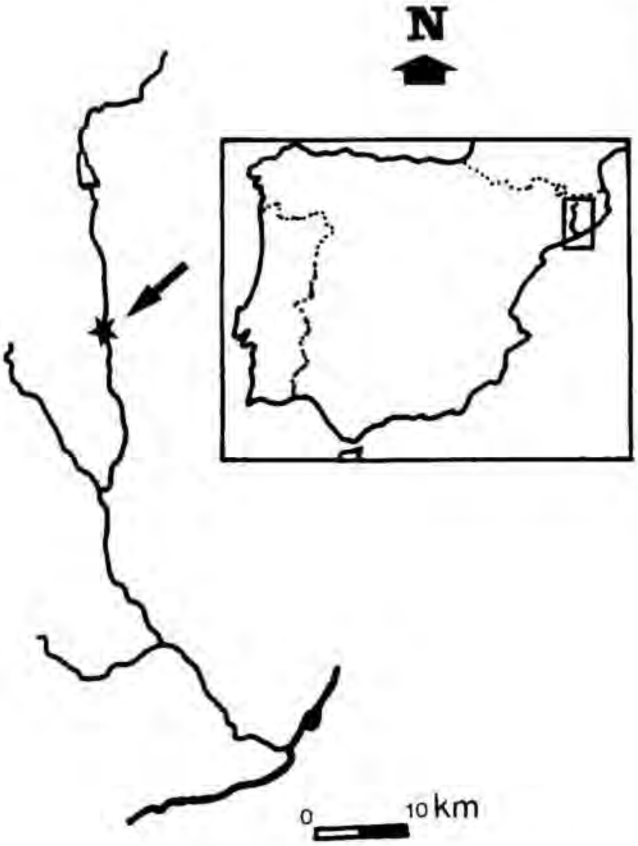

FIG. 1. Location of the sampling site in the Llobregat river. - *Localización de la zona de muestreo en el río Llobregat.*

stones and in the sandy and muddy areas respectively. More data on the river can be found especially in PRAT *et al.* (1982, 1983, 1984) and in MILLET *et al.* (in press).

RESULTS

CHIRONOMID COMPOSITION

After the sampling period 62 species of chironomids were recorded in the 21 samples as pupal exuviae or pupae (table I). Adults and larvae were not identified. Only in one case a pupae was found without the record of any exuviae (*Eukiefferiella lobifera*). Of these 62 species 19 are new for the Spanish fauna (marked with an * in the table I) and 37 are first records for the Llobregat river despite the fact that this was the best known river in Spain (PRAT *et al.*, 1983b).

TABLE I. List of chironomids collected during de sampling period. New species to the Spanish fauna are noted (*). - *Quironómidos recolectados durante el periodo de muestreo. Las especies nuevas para España se han señalado con un asterisco (*).*

	N
SF. Tanypodinae	
Procladius sp.	20
Ablabesmyia longystila	179
* *Conchapelopia melanops*	21
* *Rheopelopia maculipennis*	6
R. ornata	146
Thienemannimyia laeta	17
T. northumbrica	12
SF. Diamesinae	
Potthastia gaedii	9
SF. Orthocladiinae	
* *Brillia longifurca*	1
Cardiocladius fuscus	1
Cricotopus annulator	115
C. bicinctus	532
* *C. curtus*	28
* *C. ? similis*	13
C. trifascia	272
C. vierriensis	4
C. (Isocladius) sylvestris	36
* *C. (I.) pilitarsis*	3
Eukiefferiella clypeata	7
* *E. ilkleyensis*	83
* *E. lobifera*	1
Limnophyes sp.	6
Nanocladius rectinervis	418
Orthocladius (Euorth.) rivicola	3
* *Orthocladius (O.)* sp. *a*	169
* *O. (O.) saxicola*	17
* *Paracladius conversus*	21
Paracricotopus niger	103
* *Parakiefferiella* sp. I	1
Parametriocnemus stylatus	12
Paratrichocladius rufiventris	23
Rheocricotopus chalybeatus	1737
Smittia sp.	1
Synorthocladius semivirens	1198
* *Thienemanniella obscura*	189
Tvetenia calvescens	876
SF. Chironominae	
Chironomus sp.	743
Ch. gr. riparius	40
* *Cryptochironomus rostratus*	76
Cryptochironomus sp.	91
* *Cryptotendipes nigronitens*	121
* *Demicryptochironomus vulneratus*	2
Harnischia sp.	4
Microchironomus sp.	13
Microtendipes confinis	75
Parachironomus sp.	2
* *Phaenopsectra flavipes*	239
Polypedilum convictum	503
P. cultellatum	30
P. quadriguttatum	3295
P. (Pentapedilum) sp.	2
Stenochironomus sp.	1
Micropsectra atrofasciata	1665
Neozavrelia fuldensis	6
Paratanytarsus bituberculatus	3
P. confusus	19
Rheotanytarsus cf. *ringei*	64
Tanytarsus brundini	261
T. ejuncidus	168
* *T. heusdensis*	59
* *T. usmaensis*	29
Virgatanytarsus arduennensis	39

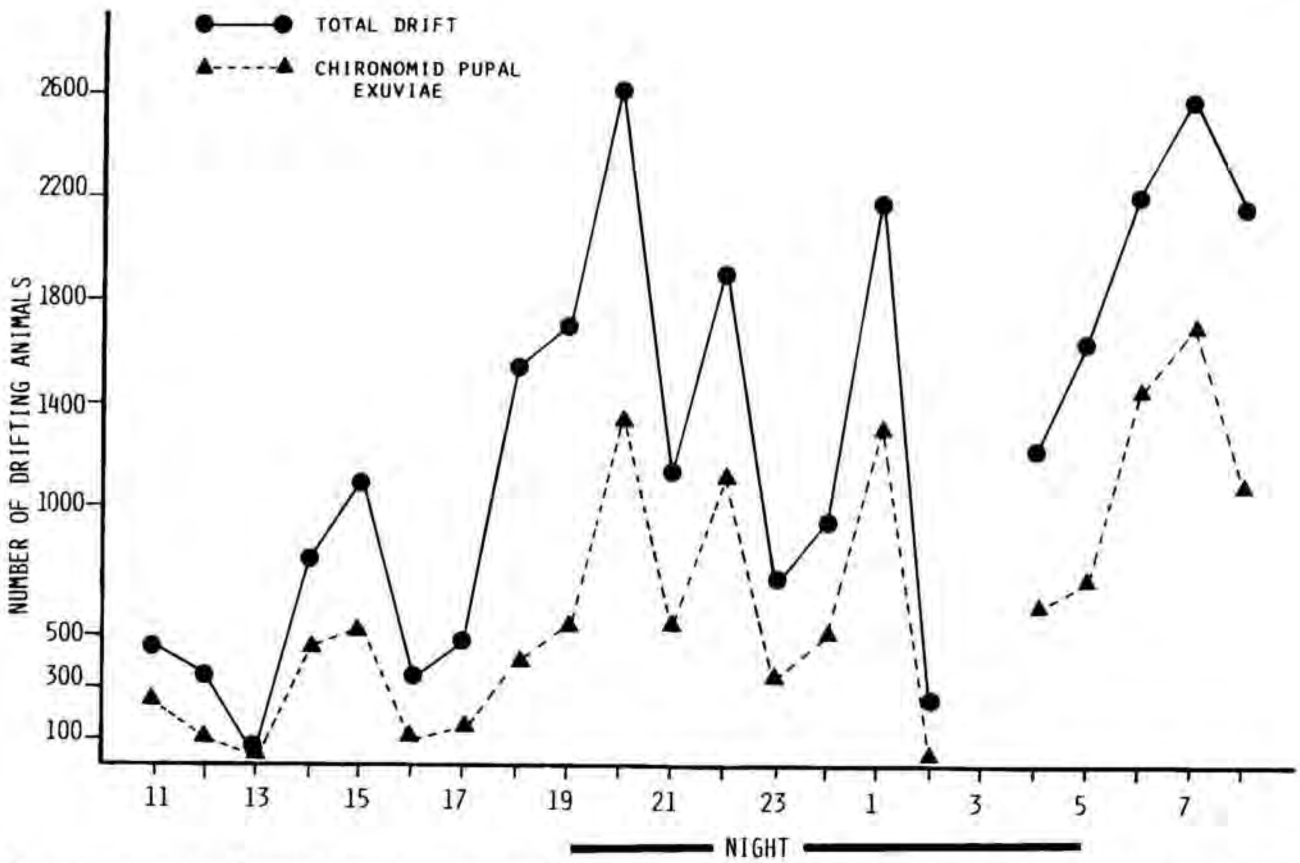

FIG. 2. Hourly fluctuations in the total drifting organisms and chironomid pupal exuviae in the Llobregat river, in August 5 to 6, 1982. - *Cambios en la deriva de todos los organismos y de las exuvias pupales de quironómidos en el río Llobregat, a lo largo de los días 5 al 6 de Agosto de 1982.*

These facts indicate the poor knowledge of Spanish chironomid fauna and the suitability of drift samples to investigate chironomids in rivers.

DIEL PERIODICITY

The hourly drift pattern for August 5-6 1982 of all drifting animals (mainly chironomid exuviae, ephemeroptera exuviae and trichoptera larvae) and the chironomid exuviae is presented in fig. 2. The major percentage of the drift was accounted for the chironomid pupal exuviae except in the afternoon (6 and 7 p.m.) when *Baetis* (nymphs and exuviae) were more abundant (RIERADEVALL & PRAT, in press). At 3 p.m. chironomid larvae and *Hydropsyche exocellata* were also abundant. From figure 2 no definitely clear pattern can be stated as in other drift studies, and peaks in the afternoon, midnight and in the early morning are more or less important.

If the drift pattern of larvae, pupae and adults of chironomids is drawn out some differences appear (fig. 3). For the pupae and imagos a clear afternoon pattern appears with other minor peaks at 1 a.m. and in the early morning. But chironomid larvae were more abundant in the drift at 3, 7 and 10 p.m. and in the early morning (fig. 3). These differences between larvae and pupae-adult patterns appear to be related to the different factors affecting drift of the different life stages. Emergence seems to be the explanation for the adult-pupae pattern while the larvae drift appears to be related to disturbance events upstream as we will discuss later.

The drift pattern for the most abundant chironomid species is presented as the hourly percentages of the total exuviae caught for each species, in figures 4 to 7. When sufficient number of pupae of a given species were collected the absolute diel pattern is also shown (fig. 7).

Four differents patterns can be dedu-

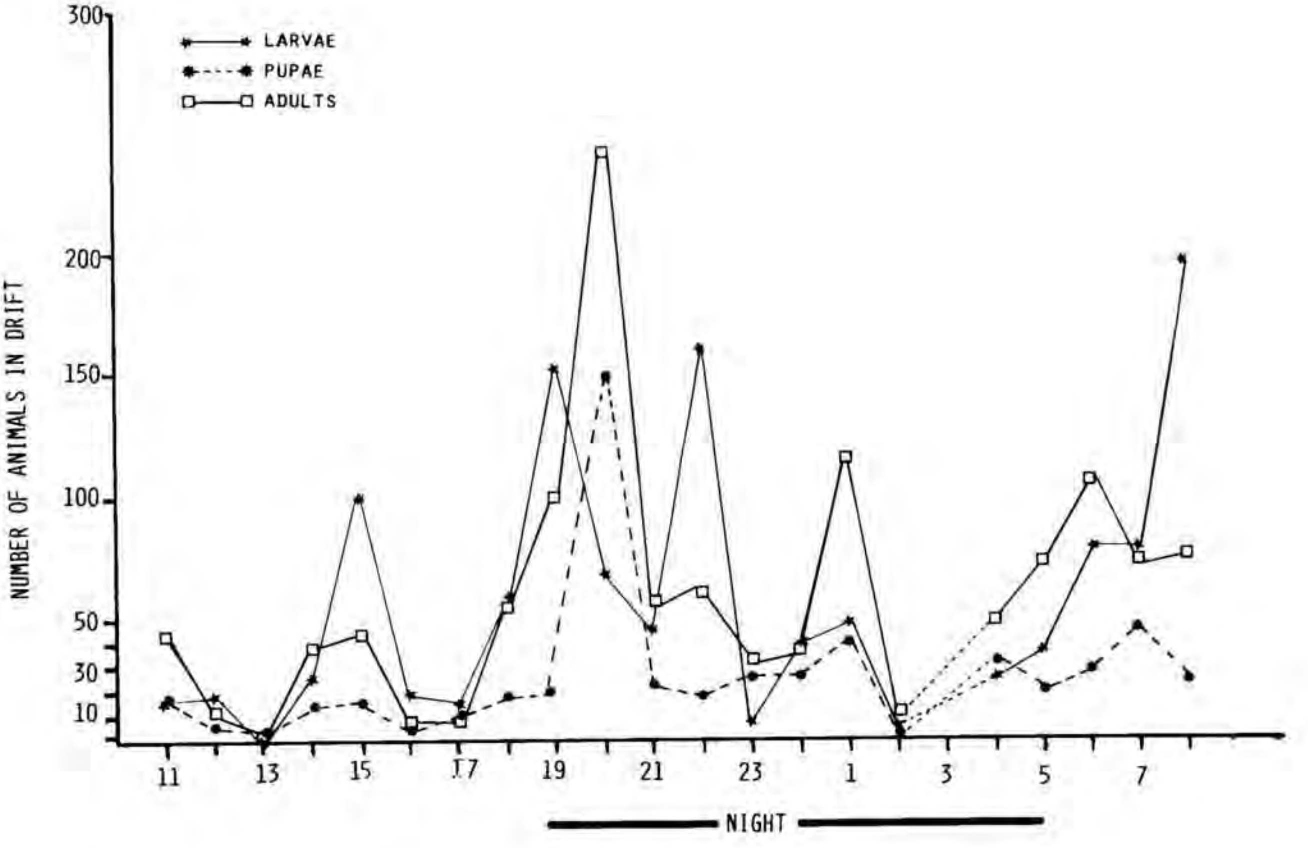

FIG. 3. Numbers of drifting larvae, pupae and adults of chironomids during the daily cicle investigated. - *Abundancias de larvas, pupas y adultos quironómidos en la deriva durante el periodo estudiado.*

ced from these figures. First a pattern with two equivalent peaks in drifting exuviae, one in the afternoon and another in the early morning as in *Nanocladius rectinervis*, *Chironomus* spp., *Rheopelopia ornata* and *Ablabesmyia longistyla*. This pattern is clearly related to the general drifting pattern of all the chironomid exuviae (fig. 2).

A second pattern seems to enhance the early morning dominance of exuviae in drift with a minor percentage in afternoon as in *Cricotopus bicinctus*, *Orthocladius*, sp.a PINDER 1978, *Phaenopsectra flavipes*, *Polypedilum convictum* and *Synorthocladius semivirens* (fig. 5).

One species seems to conform to a single peak in drifting exuviae in the afternoon (*Thienemanniella obscura*) and another to a constant drift rate (*Cricotopus trifascia*) (figure 6).

A comparison between the percentage of hourly drifting exuviae and the total number of pupae caught of the five dominant species shows some interesting facts. This comparison is only possible in these species because only for these a sufficient number of pupae were collected (fig. 7).

Firstly there are differences between the patterns of drifting exuviae and the pupae as in *Polypedilum quadriguttatum* and *Tvetenia calvescens*. In both cases the pupae were more abundant in the afternoon (although some pupae can be collected at any hour during the day); specially in the case of *P. quadriguttatum*. But the drifting pattern of pupal exuviae of both species shows a high percentage of exuviae collected in the early morning also (specially in the case of *T. calvescens*) (compare in fig. 7 the left and right columns).

In the case of *Micropsectra atrofasciata* (fig. 7) although the exuviae pattern seems to suggest a major drift in the early

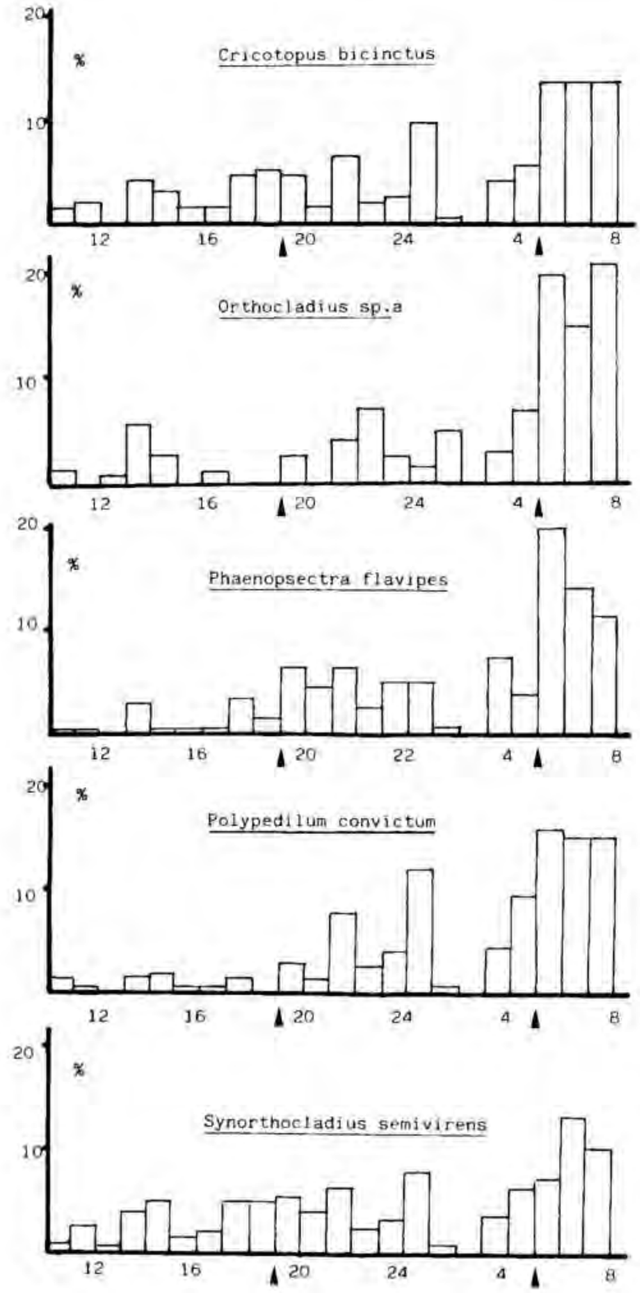

FIG. 4. Patterns of drifting exuviae (as % of the exuviae collected for any species). Afternoon-early morning patterns. Arrows indicate sunshine and sunrise. - *Ritmo de deriva de las exuvias (en % de las exuvias recolectadas cada hora respecto al total capturado de cada especie). Especies con máximos de deriva al atardecer y al amanecer. Las flechas indican la puesta y salida del sol.*

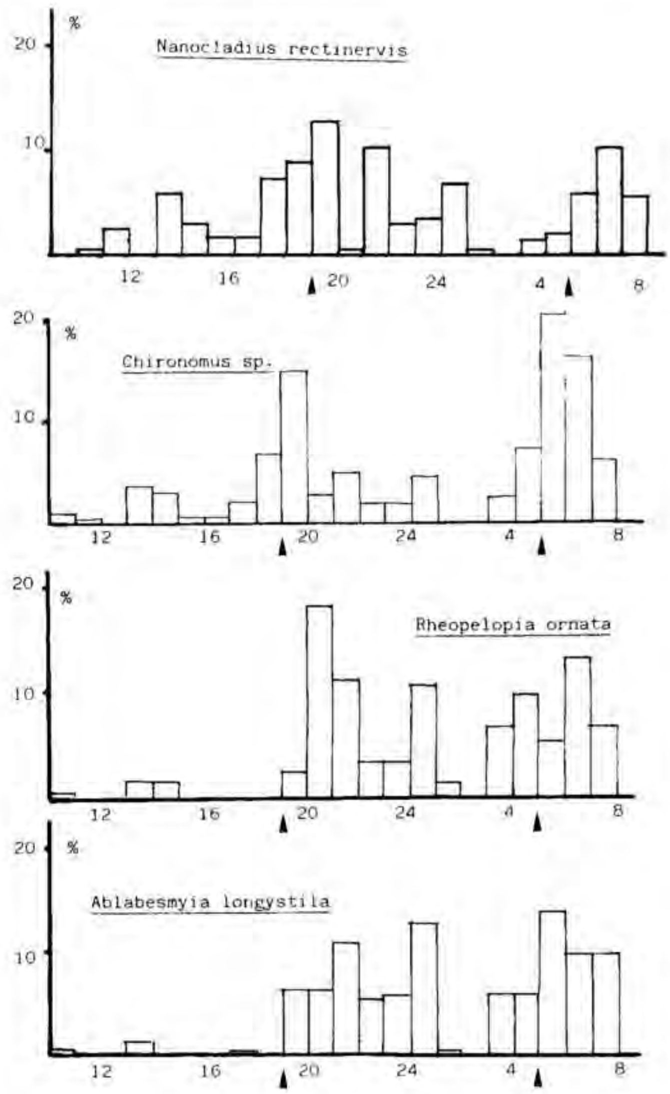

FIG. 5. Pattern of drifting exuviae (as % of exuviae collected for any species). Early morning drifting species. Arrows as in fig. 4. - *Especies con máximos de deriva al amanecer. Las flechas como en la fig. 4.*

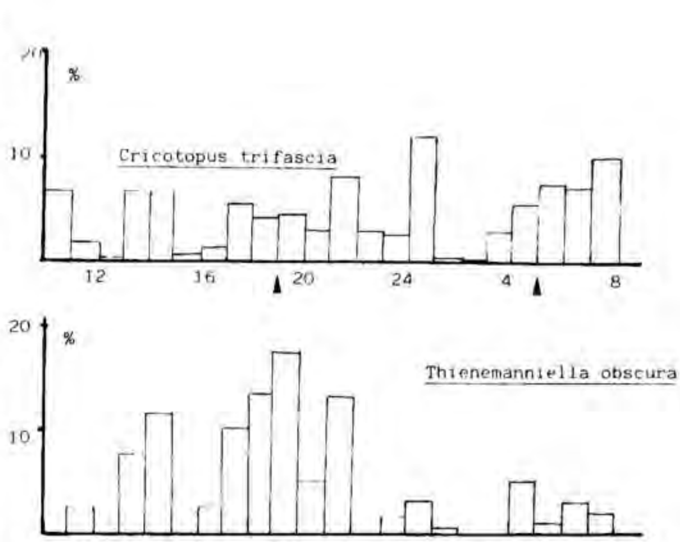

FIG. 6. Patterns of drifting exuviae (as % of exuviae collected for any species). Constant drift rate (*Cricotopus trifascia*) and afternoon pattern (*Thienemanniella obscura*). Arrows as in fig. 4. - *Especies con ritmos constantes de deriva* (Cricotopus trifascia) *o con máximos al atardecer* (Thienemanniella obscura). *Flechas como en la fig. 4.*

morning, the pupae are equally abundant during the day and the night but scarce at the beginning of the night.

Finally, only in the cases of *Tanytarsus brundini* and *Rheocricotopus chalybeatus* does there seem to be a concordance between the two drifting patterns, the exuvial and pupal ones. In the first case with a night-early morning pattern and in the second case with a constant drift rate (fig. 7).

DISCUSSION

The daily drift pattern of macroinvertebrates has been investigated in many rivers and a general trend has been proposed by different authors, especially WATERS (1962) and MÜLLER (1963). Three main types of drift can be distinguished according to WATERS (1965): the catastrophic drift, the constant drift and the behavioral drift. Many causes can be responsible for these drift patterns, such as dispersal mechanisms (KROGER, 1973), COWELL & CAREW, 1976; WARTINBEE, 1979), substrate recolonization (MÜLLER, 1954), flow floods and changes in water velocity (ELLIOT, 1967; ULFSTRAND, 1968; ANDERSON & LEHMKUHL, 1968), oxygen consumption (KOVALAK, 1978), or disturbance events as children playing (WATERS, 1962), pollution or insecticides (FROST & SINNIAH, 1982; BACK *et. al.*, 1983) or others.

The emergence of aquatic insects in many cases shows a clearly daily pattern (TANAKA, 1960; WATERS, 1962; MÜLLER, 1963) with peaks of adults, pupae and exuviae close to the afternoon and or early morning (WATERS, 1972). In other cases the emergence seems to take place in the dark period but not in hours of light (MÜLLER, 1966). This pattern seems to be originated in the existence of a biological clock with a 24 hour period («behavioral drift»). The «zeitgeber» of this biological clock would be the changing light-dark conditions (HOLT & WATERS, 1967; PEARSON & FRANKLIN, 1968; CHASTON, 1969; MÜLLER, 1974). Laboratory studies of the emergency in *Chironomus riparius* have shown the importance of light as a «zeitgeber» (KURECK, 1980). However very low temperatures or steep fluctuations of these can change the emergence pattern and the temperature can act as a «zeitgeber» (KURECK loc. cit.).

For this reason, although we suppose that the daily pattern of drift in pupae or exuviae in river chironomids is related firstly with the emergence pattern, other factors can be responsible as it seems to occur in the Llobregat in August 5-6 1982.

In figs. 2 and 3 a daily peak is clear at 3 p.m. of which chironomid larvae and *Hydropsyche exocellata* larvae (RIERADEVALL & PRAT, in press) are the major components. This can be related to a disturbance effect caused by a car being washed upstream but close to the sampling point. This was a case of catastrophic drift in the sense of WATERS (1965).

Adult and pupal drift were, in general terms (fig. 3), related to the afternoon with minor peaks at 1 a.m. and in the early morning. For the bulk of chironomids the emergence seems to take place in the changing light-dark conditions at 8 p.m. of August 5. But while *Polypedilum quadriguttatum* and *Tanytarsus brundini* had a high percentage of pupae collected in the afternoon, the most riverine species (*Rheocricrotopus chalybeatus, Micropsectra atrofasciata*) had a nearly constant pupal drift rate throughout the day-night period (fig. 7).

Changes in flow, disturbance events,

FIG. 7. Patterns of drifting exuviae (as % of collected exuviae for any species) and number of pupae for the same species at each hour. (Left and right column respectively.) Arrows as in fig. 4. - *Ritmos de deriva de las exuvias (en % de las exuvias recolectadas cada hora respecto al total capturado de cada especie) y abundacias de pupas para las mismas especies. Flechas como en la fig. 4.*

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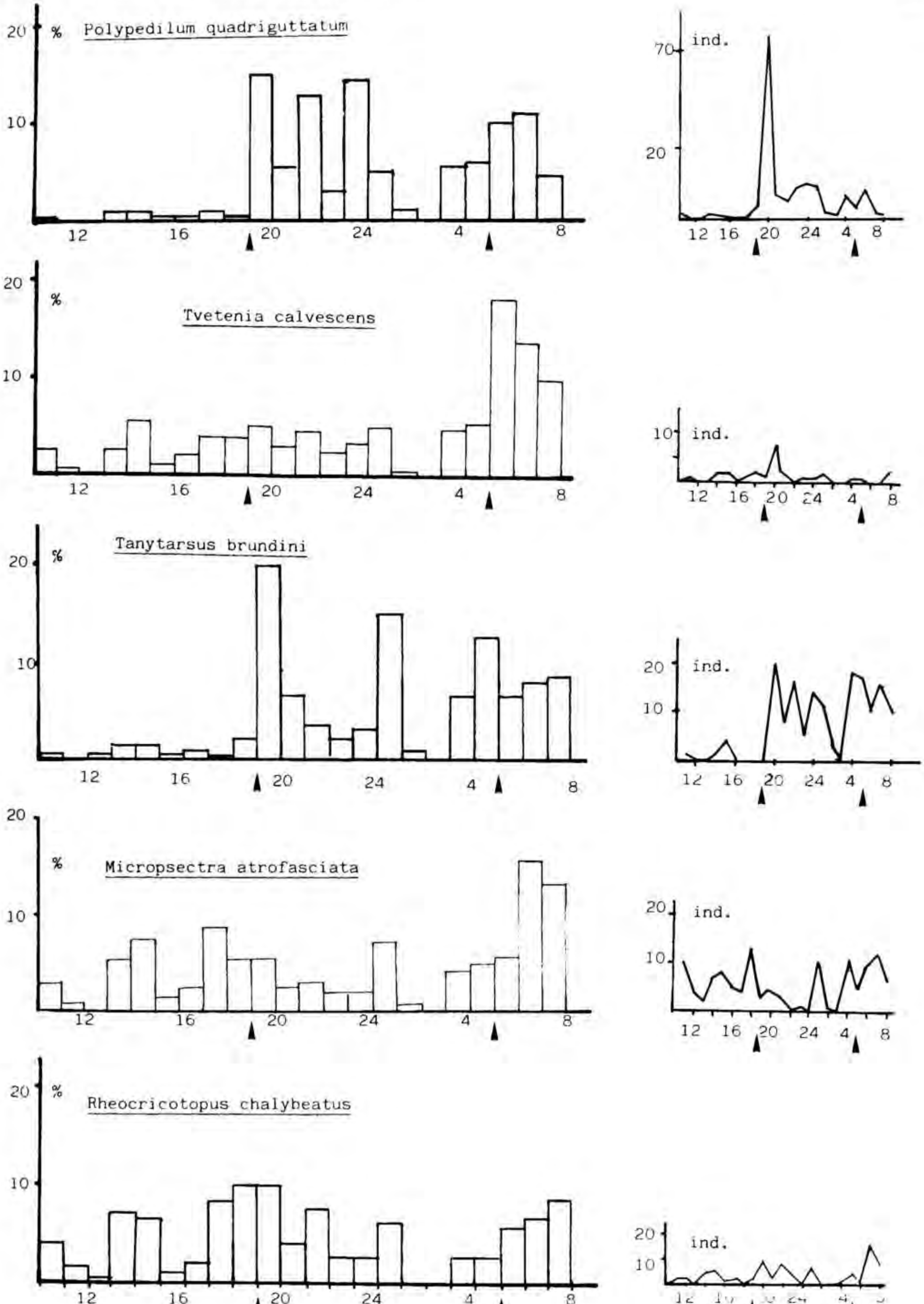

Polypedilum quadriguttatum
Tvetenia calvescens
Tanytarsus brundini
Micropsectra atrofasciata
Rheocricotopus chalybeatus
%
ind.
20
10
70
12
16
20
24
4
8

high water temperature (24 °C nearly constant), high contents in nutrients (and therefore high biological productivity) seem to produce a framework of conditions in which many species are able to emerge continuously from the river.

In the case of *P. quadriguttatum* (which accounts for more than 50 % of the pupae collected in the afternoon) the emergence synchronism for the bulk of the population seems to be related to the habitat occupied by the larvae. These, although present under river stones, were more abundant in the shallow muddy standing waters situated upstream to the sampling point. We believe that this could be the reason of the more definite daily pattern.

The interpretation of the daily patterns of pupal exuviae of chironomids from figures 4-7 is more complicated, especially because great differences exist in exuvial and pupal patterns of some abundant species (fig. 7), as in *M. atrofasciata, P. quadriguttatum, T. calvescens.* Are these exuvial patterns showing real emergence patterns? We do not believe that is the case.

The pupal skins of emerged individuals could be retained between the river vegetation or close to the river banks. Changes in river flow or other disturbances could wash the exuviae out of this places downstream. Thus a large amount of pupal exuviae would be present in drift during these disturbance events, and accounted for as an increase in drift rate. We believe that our morning peak of exuviae between 6 and 8 a.m. of August 6 could have been produced by some flow disturbance and does not reflect a real emergence as would seem to be because of the differences in pupae and pupal exuviae drifting rates (figs. 2, 3 and 7). Although no direct evidence of flow changes can be presented we believe that it is the reason of the big peak in pupal exuviae in nearly all the collected species (figs. 4 to 7).

Finally, in the general drift rate (fig. 2), as well as in the adult chironomid drift (fig. 3) and the exuvial pattern of many species (figs. 4 to 7) a slight increase can be observed at 1 a.m. As it was a full-moon night, the depressive effect of the moon should also be considered. So the disappearance of the moon behind mountains or clouds would increase the drift although controversial opinions exist as to evaluation of the true effect of monlight on emergence (ANDERSON, 1966; CHASTON, 1969; KROGER, 1974).

In summary the high temperature and river productivity of this reach of the Llobregat river together with some disturbance effects seem to explain the differences in number of drifting organisms at each hour. However care must be taken in interpreting patterns of drifting exuviae as result of emergence, because in many cases the differences with the number of pupae in drift are very high. On the other hand the most abundant species in the river bed, *Rheotanytarsus chalybeatus* and *Micropsectra atrofasciata*, had a nearly constant drift rate (specially if pupae are considered) a pattern which could be suspected from a productive and high temperature river. In Mediterranean rivers this situation is frequent during some months of the year. Our opinion is that in these cases pioneer species, like chironomids, do not follow a clear pattern of diel emergence. We believe that the application of the hypothesis of diel periodicity in Mediterranean rivers is, therefore, of limited value and more flexible and dynamic models are needed to understand these rivers as ecological units.

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RESUMEN

Ritmos diarios de deriva de los quironómidos en el río Llobregat (NE, España). Desde las 10 a.m. del día 5 hasta las 9 a.m. del día 6 de agosto de 1982; en el tramo medio del río Llobregat, se tomaron muestras de deriva con periodicidad de una hora. En las 21 horas de muestreo se recogieron 25.719 individuos, de los cuales el 65 % fueron quironómidos, y de éstos, 13.900 (el 54 % de la deriva total) fueron exuviales pupales. Se identificaron 62 especies de quironómidos, de las que 19 son nuevas citas para la fauna española. El 41 % fueron Orthocladiinae, el 40,7 % Chironominii y el 15,3 % Tanytarsinii.

Las frecuencias de deriva, hora a hora, de las exuvias pupales de los quironómidos de diferentes especies parecen mostrar cuatro ritmos (o modelos) de deriva distintos. Unas especies presentan máximos de deriva de exuvias al atardecer, otras al amanecer, otras en ambos momentos y finalmente aparecen especies con un ritmo constante de deriva.

Al comparar las abundancias de pupas en la deriva para cada período de tiempo (1 hora) con las frecuencias de las exuvias pupales de las 5 especies más abundantes (fig. 7) se observa que los máximos de deriva de exuvias al amanecer no concuerdan en el tiempo con los incrementos de deriva de adultos y pupas. Por ello la deriva en las primeras horas de la mañana no parece estar exclusivamente relacionada con la emergencia de adultos, sino con algún factor «catastrófico», como por ejemplo sería un cambio en el caudal del río.

En el río Llobregat el patrón de deriva de los quironómidos no parece venir definido únicamente por un ritmo acoplado a los cambios de luz, como es norma en muchos estudios de este tipo. Aunque la emergencia es importante en estos momentos, los máximos de deriva situados en otras horas del día o la presencia de pupas a lo largo de todo el día, parecen indicar un modelo más completo, difícil de dilucidar con un solo ciclo diario. La temperatura y productividad biológica elevadas, la heterogeneidad del sustrato y las perturbaciones que sufre el medio por cambios en el flujo o intervenciones humanas, parecen generar un patrón en el que es difícil reconocer cuál es la importancia de cada uno de ellos.

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