

Studies on Subterranean Drift of Stygobiont Crustaceans (*Niphargus*, *Crangonyx*, *Graeteriella*)

by

Siegfried HUSMANN*

I. INTRODUCTION

Drift of benthic animals in running waters has been investigated extensively (lit. see Meijering 1972). Most publications, however, are concerned with drift in surface waters; we know much less about the corresponding phenomenon in subterranean biotopes. Müller et al. (1963) and Kureck (1967) found *Niphargus schellenbergi* (Karaman) drifting out of springs in fluctuating numbers, possibly reflecting a diurnal periodicity. Drift of *Niphargus* was not regarded to be an uncontrolled passive process, but probably dependent on locomotory activity (Kureck, 1967), which is timed by light-dark changes.

Kureck (1967) made his observations on *Niphargus* close to the vicinity of springs, but these locations are just a very small and random part of the entire *Niphargus* biotope in the subterranean water-body. So there remains some doubt whether drift of *Niphargus* from springs reflects actual drift movements of subterranean populations. In addition, since the genus *Niphargus* has been a member of the groundwater fauna for a long time in geological sense, it seems very unlikely that it retained diurnal activity rhythms throughout its phylogenetic development as a stygobiont animal. Ginet (1960) and Günzler (1964) accordingly could not find diurnal rhythms during their experimental work with this genus. Therefore, the purpose of the present study was to measure drift of *Niphargus* within the subterranean waterbody, where contact with the surface and the corresponding fluctuating environmental factors does not occur.

2. THE INVESTIGATED GROUNDWATER ECOSYSTEMS

The investigations were carried out in two drinking water installations at the Wiesbaden water works on the south slope of the Taunus Mountain (fig. 1).

* Limnologische Flußstation des Max-Planck-Institutes für Limnologie, D-6407 Schlitz.

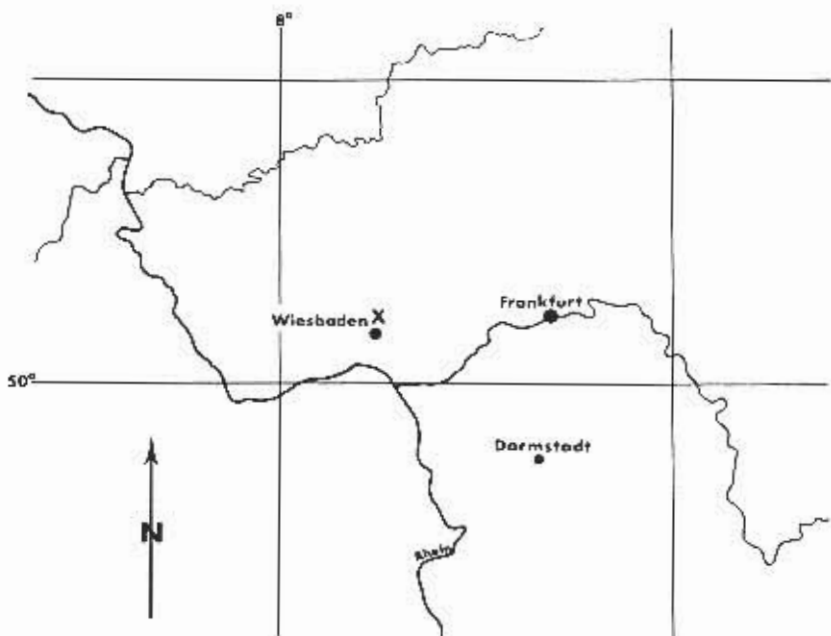


Fig. 1: The geographical location of the sample stations in West Germany.

In both cases groundwater canals run from subterranean waterbodies to groundwater reservoirs. Thin layers of sand within the canals offer temporary interstitial biotopes for drifting organisms (fig. 3); these systems represent an artificial ecosystem formed by both natural processes and technical methods of obtaining groundwater.

The hydrogeological conditions of these groundwater bodies, which are situated in the "Adamstal" and near the "Rabengrund" were investigated by the "Hessisches Landesamt für Bodenforschung", Wiesbaden. In their report* the following findings are described.

2.1 *The hydrogeological conditions around the percolating gallery "Adamstal"*

The groundwater of "Adamstal" (adams valley) (fig. 2) is developed by a percolation gallery in layers of rubble and in deposits of sand and gravel. The former layers are situated on the slopes, while the latter fill up the underground of the valley. These deposits are covered by strata that vary from 14 to 4 m in

* Gutachten betr. Einrichtung von Trinkwasserschutzgebieten für die Sicker-galerie Adamstal, den Münzbergstollen, die neue Gewinnungs-Anlage Platte, den Wilhelmsstollen, Wiesenstollen, Altwieherstollen und Bergstollen der Stadtwerke Wiesbaden AG 341-4378/60 Mi-Thc/Sch vom 13.2.1961.

thickness. Occasionally this cover is thinner. This is because the bed of a brook (Kesselbach) has eroded into the surface near the percolation gallery. The layers of rubble, mixed with loamy sediments and the deposits of sand and gravel are efficient filtration materials. The sporadically thinner covering, however, permits infiltrate contaminations to occur here and there. This was demonstrated by the appearance of *Escherichia coli* in the percolated groundwater.

2.2 The hydrogeological conditions in the percolating galleries to the east of "Rabengrund"

The percolation gallery "Rabengrund" (fig. 2) consists of a system of three galleries ("Wilhelmstollen", "Wiesenstollen", "Altweiher-Stollen"). They are

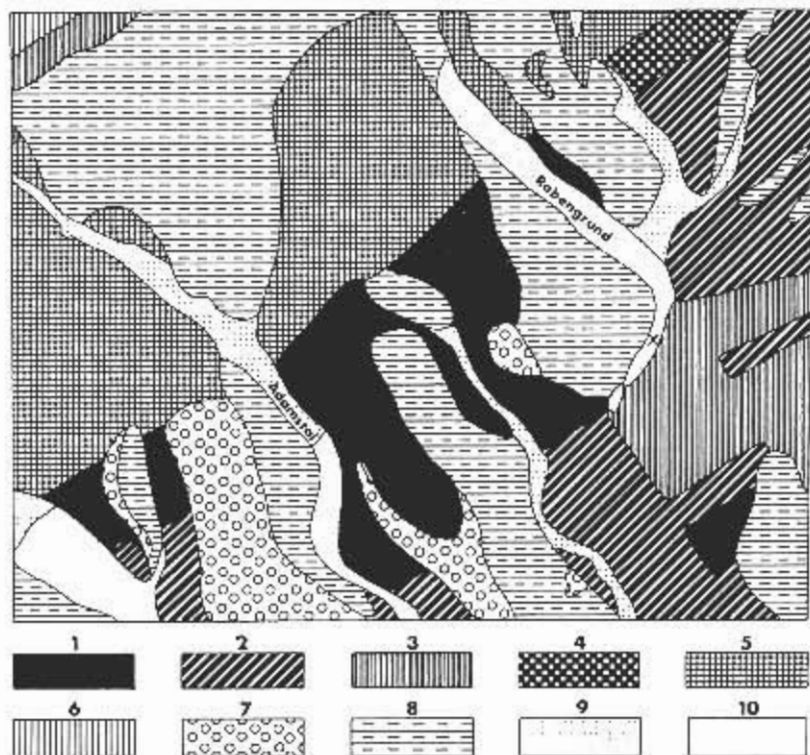


Fig. 2: The geological conditions of the surrounding area of the investigated percolation galleries. *Antedevonian*. 1: green-grey and green phyllite; 2: quartz keratophyre; 3: porphyritic soda keratophyre. *Lower devonian*. 4: blue-grey and grey-green shales; 5: violet and grey-green, often phyllitic, clay-shales; 6: grey to white quartzite with light clay-shales layers. *Diluvium*. 7: gravels from the Taunus; 8: scree. *Alluvium*. 9: drift gravels and pebbles; 10: lehm and sandy lehm.

all situated in deposits of rubble which are mixed with loamy sediments. These layers overlie sericite gneiss and are covered by strata 3-8 m thick. Similar to the conditions in the "Adamstal" groundwater contaminations from infiltration were discovered in different places.

2.3 *The structure of the artificial ecosystem*

The considerable ancient percolating galleries (years of construction: 1873-1875) are built in stone (height: 1.20 m; width: 0.80 m; length: 1530 m/Adamstal, 550 m/gallery to the east of "Rabengrund"). The groundwater passing through these galleries enters a subterranean canal, also built in stone (diameter: 66 cm, length: about 500 m). At the end of this canal a small outflow pipe allows water to flow into a sedimentation pit (fig. 3).

3. METHODS

This sedimentation pit offered a simplified system for investigations on drift of subterranean organisms. Drift nets (diameter: 20 cm; length: 35 cm; mesh size: nr. 80) were installed below the outflow pipe in the pit (fig. 3). The pit was

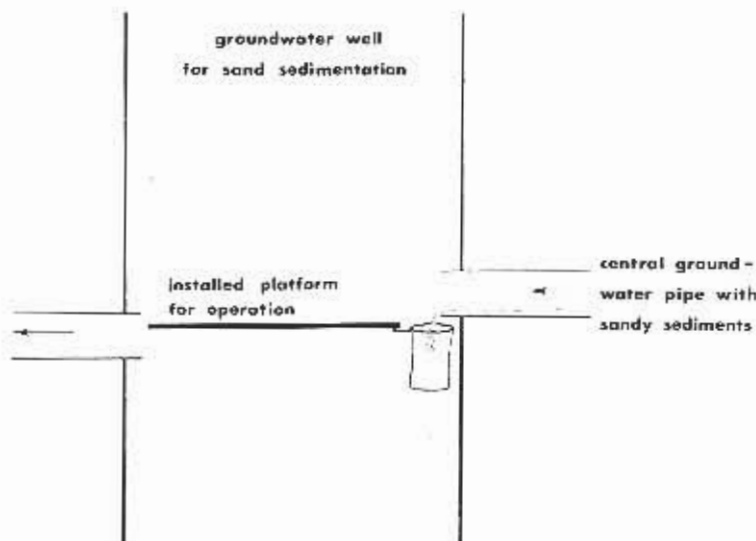


Fig. 3: The sedimentation well with an installed drift net.

large enough (depth: 3.60 m; length: 2 m; width: 1.50 m) so that nets could easily be placed there. In order to facilitate the sampling, however, a platform

was installed just above the level of the water in the pit (fig. 3). The nets were changed every 2 hours during periods of from 1 to 4 days in June, August, September and October, 1964. Samples were preserved in formaldehyde.

4. THE DRIFTING ORGANISMS, AND ECOLOGICAL CONCLUSIONS BASED ON THE FINDINGS

Besides groundwater organisms (Nematoda, Oligochaeta, Ostracoda, Harpacticoida, Syncarida, Halacarida), in the drift nets were caught terrestrial subterranean organisms which obviously are able to maintain an amphibious existence (Paupoda, Symphyla, Diplopoda, Campodeidae, Collembola, Japygidae) (see: Husmann, 1971).

The interstices in the aquifers (rubbles, gravels) thus offer biotopes for groundwater organisms, as well as for amphibious representatives of the subterranean fauna, which live primarily in interstices filled with moist air.

These amphibious living subterranean organisms as well as species of groundwater fauna can be carried out of their primary biotopes by streaming groundwater. In this way both ecological groups of subterranean fauna can be transported to the percolating galleries; and from there may be forwarded into the groundwater canals. In these artificial biotopes both groups of subterranean fauna can find secondary biotopes in layers of sandy sediments. In addition to these biotopes, amphibious living species can find ecological niches besides the floating groundwater, especially at the ancient moist walls of the percolating galleries; in seams and crevices of these old installations. Both ecological groups appeared in the subterranean drift which was caught in the drift nets (fig. 3). *Niphargus aquilex* Schiödte, *Crangonyx subterraneus* Bate und *Graeteriella unisetigera* (Graeter) were caught in greater numbers than other species. Therefore they were studied more closely.

5. THE DRIFT OF *NIPHARGUS AQUILEX*, *CRANGONYX* *SUBTERRANEUS* AND *GRAETERIELLA UNISETIGERA*

Marked fluctuations in drift intensity occur in our results for the amphipods *Niphargus aquilex* and *Crangonyx subterraneus* (fig. 4-6) as well as for the copepod *Graeteriella unisetigera* (fig. 7, 8). None of them, however, can be correlated to the day-night cycle; on the contrary, they prove to be irregular.

The total number of individuals obtained from drift catches taken during the day-time, that is from 6 a.m. to 6 p.m., and during the night from 6 p.m. to 6 a.m. was compiled for *Niphargus*, *Crangonyx* and *Graeteriella* (fig. 9). These data indicate that there is no difference between the amount of drifting organisms during day and night. In *Crangonyx* only there was a little more drift during the night time. Sums of drifting *Niphargus aquilex* taken in 6 subsequent 2 hr drift samples, calculated for various times of day (data of fig. 5 rearranged) demonstrate that this phenomenon applies in all considered periods of day time (fig. 10).

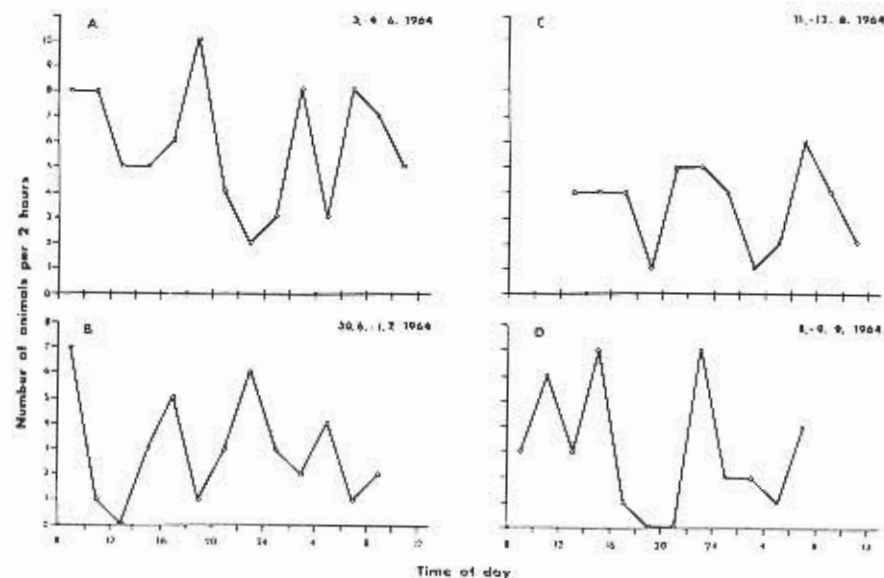


Fig. 4: Activity patterns of *Niphargus aquilex* (groundwater canal to the east of "Rabengrund", outlet "Platterstrasse"). Collections were made at 2-hr. intervals.

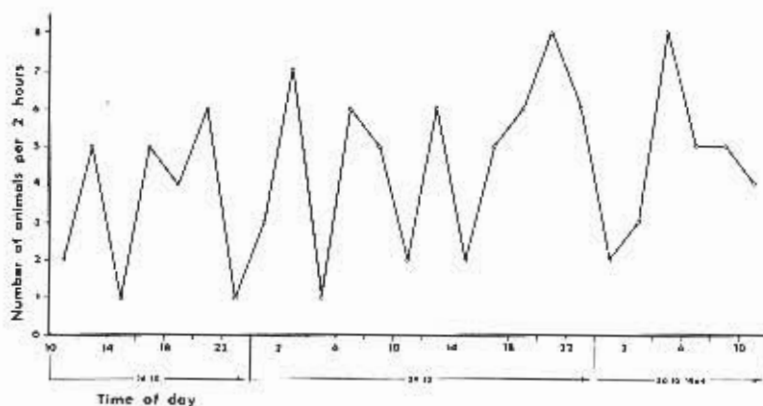


Fig. 5: Activity pattern of *Niphargus aquilex* (groundwater canal to the east of "Rabengrund", outlet "Schacht 2"; Ra/S2). Collections were made at 2-hr. intervals from 28.-30. Oktober, 1964.

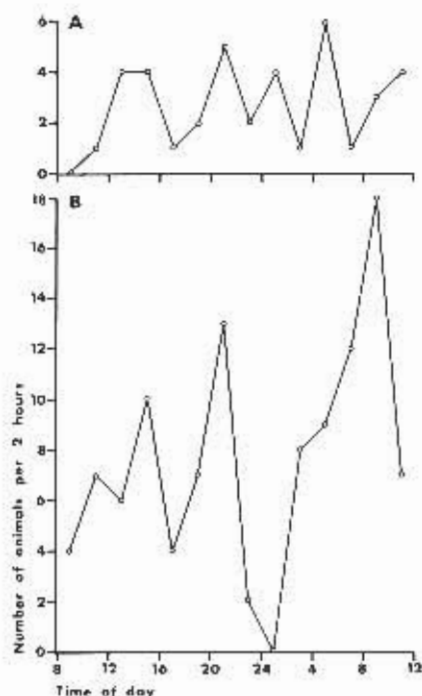


Fig. 6: Activity patterns of *Crangonyx subterraneus* (groundwater canal to the east of "Raben-grund").

A: outlet "Platterstrasse" (collections were made at 2-hr. intervals from 13.-14. August 1964);

B: outlet "Schacht 2" (collections were made at 2-hr. intervals from 30. September-1. October 1965).

6. DISCUSSION

Considering our present results we can stress the fact that no diurnal periodicity could be proved, but that drift activity followed a scheme characterized by continuous fluctuations. If we now examine more closely the curves published by Kureck (1967), it is obvious that these curves exhibit irregular fluctuations. The only fact we can conclude from these figures is that drift at night is more intensive. However, the animals involved must be regarded as a small part of the *Niphargus* population living in the subterranean waterbody. The animals moving in and out of spring No. 8 (Kureck, 1967) are those that just happen to be near that spring vicinity. During the night they migrate from the spring to the brook as long as darkness permits and no other environmental factors limit their distribution downstream in the brook. This drifting out of the spring, however, is obviously

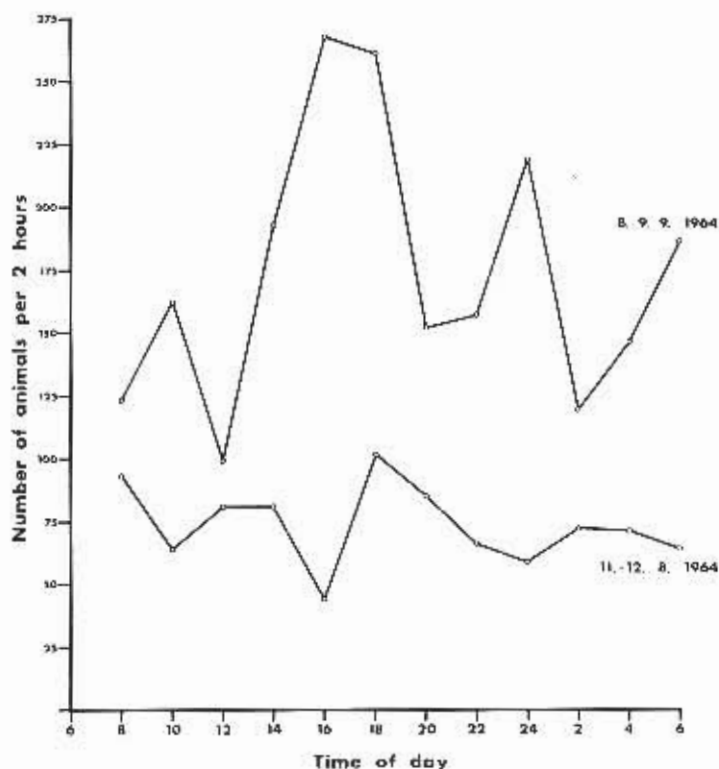


Fig 7: Activity patterns of *Graeteriella unisetigera* (groundwater canal "Adamstal", outlet "Platterstrasse").

suppressed by daylight, and Kureck (1967) indeed found the animals in some cases migrating back into the spring. It seems clear that these negatively photophobic organisms try to hide under leaf litter, stones and if necessary in crevices during daylight. By means of this behaviour the animals also may move back into the spring region. We cannot agree with Kureck's assumption that his curves reflect some sort of "Aktivitätsperiodik" since this term signifies an endogenous rhythm controlled by L/D-changes like a "Zeitgeber" as described by "Aschoff (1954)".

Our results concerning *Crangonyx subterraneus* and *Graeteriella unisetigera* confirm that the lack of diurnal rhythms is not restricted to *Niphargus* but characterises other stygobiont crustaceans as well. In a former paper (Husmann, 1971) other stygobiont organisms as well as the subterranean

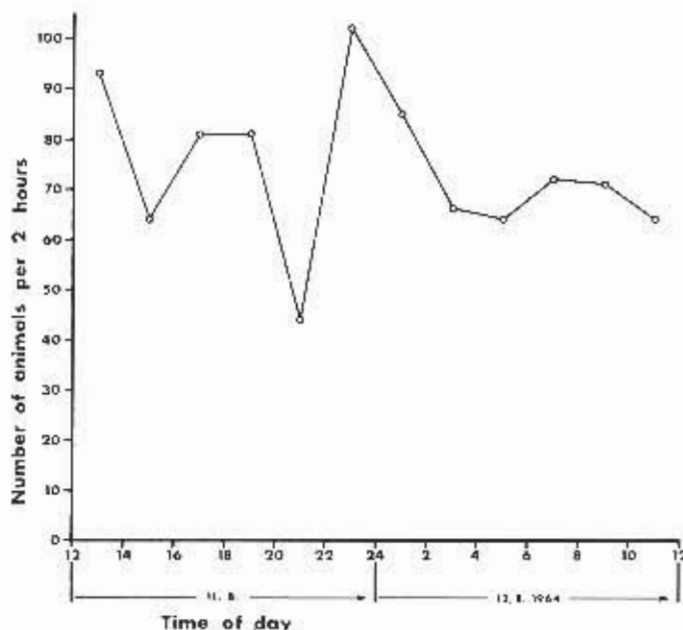


Fig. 8: Activity pattern of *Graciliella unisetigera* (groundwater canal "Adamstal", outlet "Platterstrasse").

amphibious animals were found to behave in a similar way. So we must regard the lack of diurnal periodicity as a widely distributed character of stygobiont and trogllobiont animals. The present results from the subterranean biotope coincide with those found under experimental conditions in the laboratory by Ginot (1960) and Günzler (1962) especially with regard to *Niphargus*.

Since *Niphargus* descended from ancestors which, according to Schellenberg (1933) lived in the darkness of the sandy and gravel layers of sea-shores and from where they penetrated into limnic groundwater bodies, they have been adapted for a long time to the dark interstitial environment. This adaption not only affected their morphology but their physiology. With regard to the long course of their phylogeny in marine, brackish and limnic subterranean waterbodies, it may be thinkable on paper that they conserved a tidal rhythm. However, it is not likely they retained endogenous diurnal rhythms, which are characteristic of surface animals.

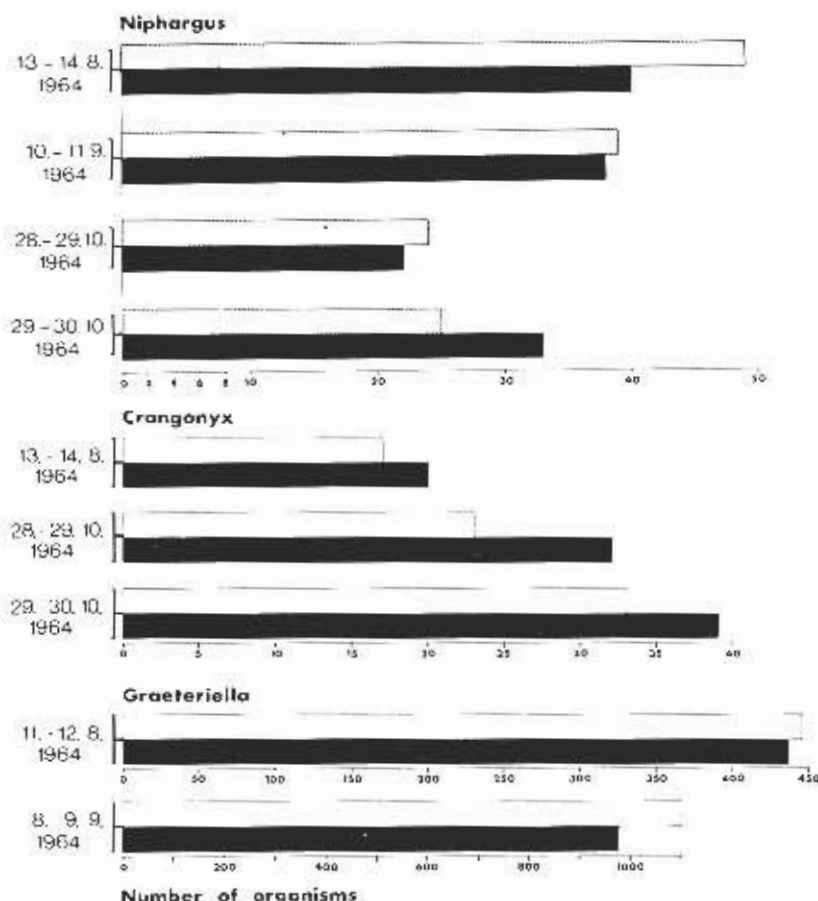


Fig. 9: Diurnal patterns of *Niphargus aquilex* from groundwater canal to the east of "Rabengrund", outlet "Platterstrasse" (13.-14.8.1964), and from outlet "Schacht 2" (10.-11.9.1964, 28.-29.10.1964, 29.-30.10.1964);

Crangonyx subterraneus from groundwater canal "Rabengrund", outlet "Schacht 2";

Graeteriella unisetigera from groundwater canal "Adamstal", outlet "Platterstrasse". Black bars, night time, stippled bars, day time.

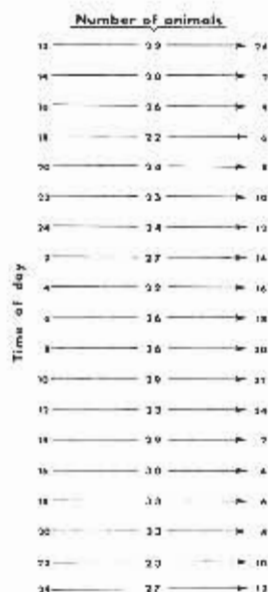


Fig. 10: Sums of drifting *Niphargus aquilex* taken in 6 subsequent 2 hr drift samples, calculated for various times of day (data of fig. 5 rearranged).

ACKNOWLEDGEMENTS

I am indebted to the water work "Stadtwerke Wiesbaden A.G." for the opportunity for realization of my investigation plans. Especially I am thankful for technical help and for assistance in changing the drift nets. Furthermore I want to express my gratitude to the "Hessisches Landesamt für Bodenforschung", especially to Prof. Dr. Noering, Wiesbaden, for information about the hydrogeological conditions in the investigated areas. Dr. R. Hall, University of Wisconsin, U.S.A., is thanked for important advice concerning interpretation of the results and, together with M. Hall, for correcting the manuscript. The figures were drawn, after sketches of the author, by Gabriele Hartwig (1) and Gisela Stüber (2-10), Limnologische Flusstation, Schlitz.

SUMMARY

In two groundwater canals of a water work in West Germany the drift of stygobiont groundwater organisms was investigated. The collections were made at two-hour intervals. *Niphargus aquilex* Schiödte, *Crangonyx subterraneus* Bate and *Graeteriella unisetigera* (Graeter) were considered more closely, because they were caught in greater numbers than other organisms. These stygobionts show no sign of diel periodicity.

ZUSAMMENFASSUNG

In zwei unterirdischen Kanälen, die Grundwasser aus Sicker galleries zu einem Wasserwerk in Wiesbaden leiten, wurde die Drift von stygobionten Grundwassertieren untersucht. Die Entnahme von Proben wurde in 2-Stunden-Intervallen ausgeführt. *Niphargus aquilex* Schiödte, *Crangonyx subterraneus* Bate und *Graeteriella unisetigera* (Graeter) fanden besondere Berücksichtigung. Bei diesen 3 stygobionten Grundwassertieren waren keine Anzeichen eines tagesperiodischen Verhaltens zu erkennen.

REFERENCES

- Aschoff, J. 1954: Aktivitätsmuster der Tagesperiodik. *Naturwissenschaften* 41: 49-56.
 Ginet, R. 1960: Ecologie, éthologie et biologie de *Niphargus* (Amphipodes Gammaridés hypogés). *Ann. Spéléol. Fr.* 15: 1-254.
 Günzler, E. 1964: Über den Verlust der endogenen Tagesrhythmik bei dem Höhlenkrebs *Niphargus puteanus puteanus* (Koch). *Biol. Zbl.* 83: 677-694.
 Husmann, S. 1971: Die gegenseitige Ergänzung theoretischer und angewandter Grundwasserlimnologie; mit Ergebnissen aus Wasserwerken Wiesbadens. *Wissenschaftliche Berichte über Untersuchungen und Planungen der ESW: Stadtwerke Wiesbaden AG*, 1: 79-90.
 Kureck, A. 1967: Über die tagesperiodische Ausdrift von *Niphargus aquilex schellenbergi* Karaman aus Quellen. *Z. Morph. Ökol. Tiere* 58: 247-262.
 Meijering, M. P. D. 1972: Experimentelle Untersuchungen zur Drift und Aufwanderung von Gammariden in Fließgewässern. *Arch. Hydrobiol.* 70: 133-205.
 Müller, K., Kureck, A. & Müller-Haeckel 1963: Zur Tagesperiodik von *Niphargus aquilex schellenbergi* Karaman (Gammaridae, Amphipoda). *Naturwissenschaften* 50: 579-580.
 Schellenberg, A. 1933: *Niphargus*. Probleme. *Mitt. Zool. Mus. Berlin* 19: 406-429.