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Waters T F. Diurnal periodicity in the drift of stream invertebrates.

Ecology 43:316-20, 1962.

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Benthic stream invertebrates were observed to drift downstream in a distinct diel [24 hr.] periodicity. Drift was low during daylight hours, increased greatly at time of darkness, and returned to daytime low levels at dawn. Drift was highest in summer, lowest in winter. [The SC1® indicates that this paper has been cited in over 105 publications since 1962.]

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"The discovery of a diel periodicity in the drifting of aquatic stream invertebrates was, in the late 1950s, an event whose time had come. Circadian rhythms of many kinds had been commonly reported—why not for stream invertebrates? The reasons, I think, were that we stream ecologists had our own diel periodicities and were used to a regular night's sleep.

"When I moved from the Michigan Department of Conservation to the University of Minnesota in 1958, my main scientific interest lay in the ecology of stream productivity, as it does today. In the summer of 1959, my research assistant, Robert J. Knapp, and I were putting around with an enclosure device in Valley Creek, Minnesota, trying to develop a method to estimate the production rate of benthic stream invertebrates. (It didn't work.) Our method included measuring drift from the enclosure, and, for some reason I cannot now recall, we continued collecting from the enclosure into the night. About the time of full darkness, the number of organisms drifting out increased

greatly. We thought something had gone awry: the enclosure was leaking, muskrats must be chewing at it, etc. But we found nothing wrong.

"I was not totally unaware of the possibility of a diel periodicity, because a friend and colleague in the Michigan Department of Conservation, Gaylord Alexander, had been doing some drift work there and had told me he thought he had detected some peaks at dawn and dusk (corresponding to the best times for trout fishing!). So Knapp and I kept the enclosure going, and we found the same thing the next night. Then I was pretty sure that we had stumbled onto something new. Just to be sure that it was not unique to Valley Creek (muskrats, etc.), we collected 24-hour drift from other Minnesota streams in the summer of 1960. We found a diel periodicity in all streams (unpublished)—different species, different patterns, but apparently the same phenomenon.

"At the time, I thought it was a first—but it was not. Tanaka's¹ paper was brought to my attention, and after I had obtained a copy and had it translated from the original Japanese, it was clear to me that he had, indeed, made the first published observation of the diel phenomenon. I regret that I was not aware of it earlier. Müller^{2,3} soon made independent observations in the Federal Republic of Germany. The experience convinced me that you can't write a grant proposal for a scientific breakthrough.

"Stream invertebrate drift as a research subject became very popular, very quickly. The diel phenomenon occurs in virtually any stream, the methodology is easy, and the results are often striking. The reason why my paper is cited so frequently is simply that it was one of the first to report the phenomenon. Several recent reviews have been published.^{4,5} The full ecological significance of the phenomenon is still unknown—but still intriguing."

1. Tanaka H. On the daily change of the drifting of benthic animals in a stream, especially on the types of daily change observed in taxonomic groups of insects. *Bull. Freshwater Fish. Res. Lab.* 9:13-24, 1960.
2. Müller K. Tag-Nachrhythmus von Baetidenlarven in der "Organischen Drift." *Naturwissenschaften* 50:161, 1963.
3. -----, Diurnal rhythm in "organic drift" of *Gammarus pulex*. *Nature* 198:806-7, 1963.
4. Bournaud M & Thibault M. La dérive des organismes dans les eaux courantes. *Ann. Hydrobiol.* 4:11-49, 1973.
5. Müller K. Stream drift as a chronobiological phenomenon in running water ecosystems. *Annu. Rev. Ecol. Syst.* 5:309-23, 1974.