Seasonal and Diel Flight Periodicities of Rice Field Hydrophilidae[1]

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ABSTRACT

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Seasonal flight patterns and diel flight periodicities of *Berosus styliferus* Horn, *Cercyon praetextatus* (Say), *Enochrus cuspidatus* (LeConte), *E. hamiltoni* (Horn), *E. pygmaeus pectoralis* (LeConte), *Hydrophilus triangularis* Say, *Tropisternus columbianus* Brown, and *T. lateralis humeralis* Mots. were monitored using a rotary net machine and a blacklight trap, in conjunction with measurements of temperature, wind speed, and time of sunrise and sunset. Seasonal variations in date of initiation of flight, relative abundance of individuals, and time of peak flight activity existed among the species.

Peak flight typically occurred the hour following sunset, with a second, smaller peak at sunrise. Temperatures ranging from 11° to 34° C and wind speeds to 20 kph were extreme conditions under which flight occurred, although most flights were recorded during periods with a more narrow temperature range (20° – 22° C) and on calm nights. *B. styliferus* preferred the lower temperatures and later evening flight which is characteristic of an early season colonizer. *H. triangularis* demonstrated both a thermal dependence in relation to flight and a broader time of flight activity, possibly due to its size and range.

Since California rice is grown in water, fields must be continuously flooded for most of the production season, late April to late September. The paddies become a temporary habitat for many organisms normally associated with natural aquatic habitats of the Central Valley. Temporary waters may be colonized by aquatic insects seasonally, and flight is the foremost requirement to reach such habitats. Fernendo and Galbraith (1973) found considerable variance in mobility both within and between different families of insects, and they consider the Hydrophilidae and Corixidae the most mobile. Fernando (1961) believes such flights to be an integral part of the normal colonization cycle of these insects, and that regular trapping is a useful method for recording their seasonal movements.

The diel periodicity of flight by aquatic insects is variously dependent upon precipitation, temperature, wind speed (Landin and Stark 1973), and light intensity (Lewis and Taylor 1965). Landin (1968) found the morning and evening flight peaks of the hydrophilid *Helophorus brevipalpis* Bedel correspond to a temperature threshold. Yamamoto (1951) noted that the flight of water beetles to a light trap was greatest within one h after darkness.

Our study characterizes the seasonal and diel flight periodicities of the water scavenger beetle community in rice fields of the Sacramento Valley of California.

Methods

During the rice production seasons of 1977 and 1978, we collected 8 species of Hydrophilidae in a black light trap located on a levee at the California Cooperative Rice Research Foundation Experiment Station near Biggs, Butte Co., CA. Those species were *Berosus styliferus* Horn, *Cercyon praetextatus* (Say), *Enochrus cuspidatus* (LeConte), *Enochrus hamiltoni* (Horn), *Enochrus pygmaeus pectoralis* (LeConte), *Hydrophilus triangularis* Say, *Tropisternus columbianus* Brown, and *Tropisternus lateralis humeralis* Motschulsky. The trap was run continuously from mid-March through late September of both years. The trap counts from individual sampling periods were combined weekly. Temperature data was obtained from a battery operated Foxboro recorder near the trap, and the U. S. Weather Bureau Station at Chico. Flooding dates of fields in the area for both years were approximately April 26, and May 18, respectively. Draining of the fields was initiated September 12, and September 16.

Diel activity was monitored biweekly in 1977 (7×), and weekly in 1978 (18×). In 1977, a rotary net machine was operated for 15 min each hour during the 24 h sampling period. The machine (Strong et al. 1963) was equipped with 2 wire-screen funnels mounted on each end of a 3.5-m boom, 1.8 m above the ground. There was a 46 cm vertical separation between the upper and lower net. The boom revolved 52×/minute. A black light trap, monitored hourly in conjunction with the rotary net machine, was placed in a distant field so light would not bias the machine catch. Temperature was taken at each sampling interval with a maximum-minimum thermometer at the collection site. The average wind speed during each sampling period was estimated from the range observed during 30 seconds by a hand-held wind meter. Times of sunrise and sunset were recorded by the U. S. Weather Bureau Station at Chico (34 km N of Biggs). In 1978, collections were limited to the black light trap.

The difference between the relative abundance of individuals captured each hour by the rotary net machine and the black light trap was determined for the total of all species and all sampling dates in 1977 by a Spearman rank correlation coefficient test where the greatest number of individuals of a species captured by each sampling method on a given sampling date was assigned a numerical rank of one. Sampling periods when hydrophilids were absent were not included in the test.

A Mann-Whitney rank-sum test was used to compare the times post-sunset, the temperatures, and the wind speeds at which flight occurred for each species with the weekly means of each of the variables for the other spe-

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cies. The mean weekly figure for each species was calculated as the fraction of total numbers captured at a recorded value of each variable thought to affect flight. The mean seasonal value of all 3 variables for each species was also determined. Hour "O" post-sunset represented the hour during which sunset had occurred.

A regression analysis was made for temperature in relation to the hourly percentage of the total catch for the entire sampling date.

Results

Seasonal Periodicity

When comparing the seasonal flight activity of the 8 species of beetles (Fig. 1), it is apparent that some specific differences exist in terms of the date of initiation of flight, relative abundance of individuals, and the date of peak flight activity. For most species, the patterns were similar in both years.

Initiation of flight appears to correspond with the maintenance of the mean weekly temperature above 18° C. However, *B. styliferus* and *H. triangularis* were regularly captured early in the season when mean weekly temperatures were low. *T. columbianus* was captured only during a brief period in July.

T. lateralis was the most abundant species with a maximum of over 250,000 specimens captured during one weekly sampling period. *E. cuspidatus, E. hamiltoni*, and *B. styliferus* were also common in relation to the other species, each exceeding 10,000 individuals taken at the seasonal peak.

To allow for variation among samples, the peak flight period was defined as the interval when the weekly capture exceeded 10% of the total seasonal capture of a species. On this basis, *B. styliferus* and *C. praetextatus* were early-season fliers, with peak flights occurring in the mid May through late June period.

Diel Periodicity

A rotary net machine presumably utilizes no attraction when sampling a volume of air for insects, therefore we believe it to be an unbiased method of determining rel-

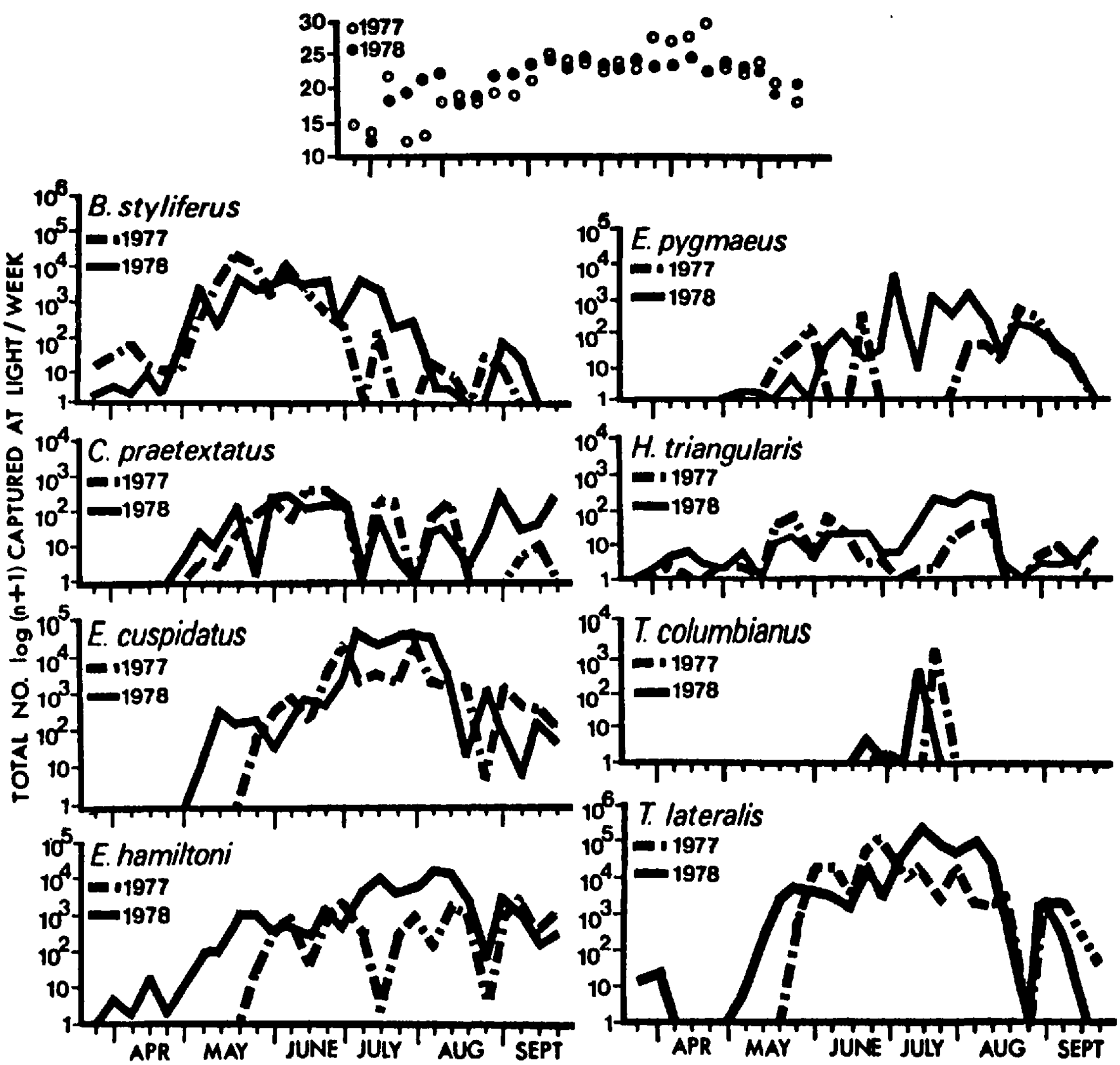

FIG. 1.—Seasonal flight data expressed as total number log (n + 1) per week captured at light.

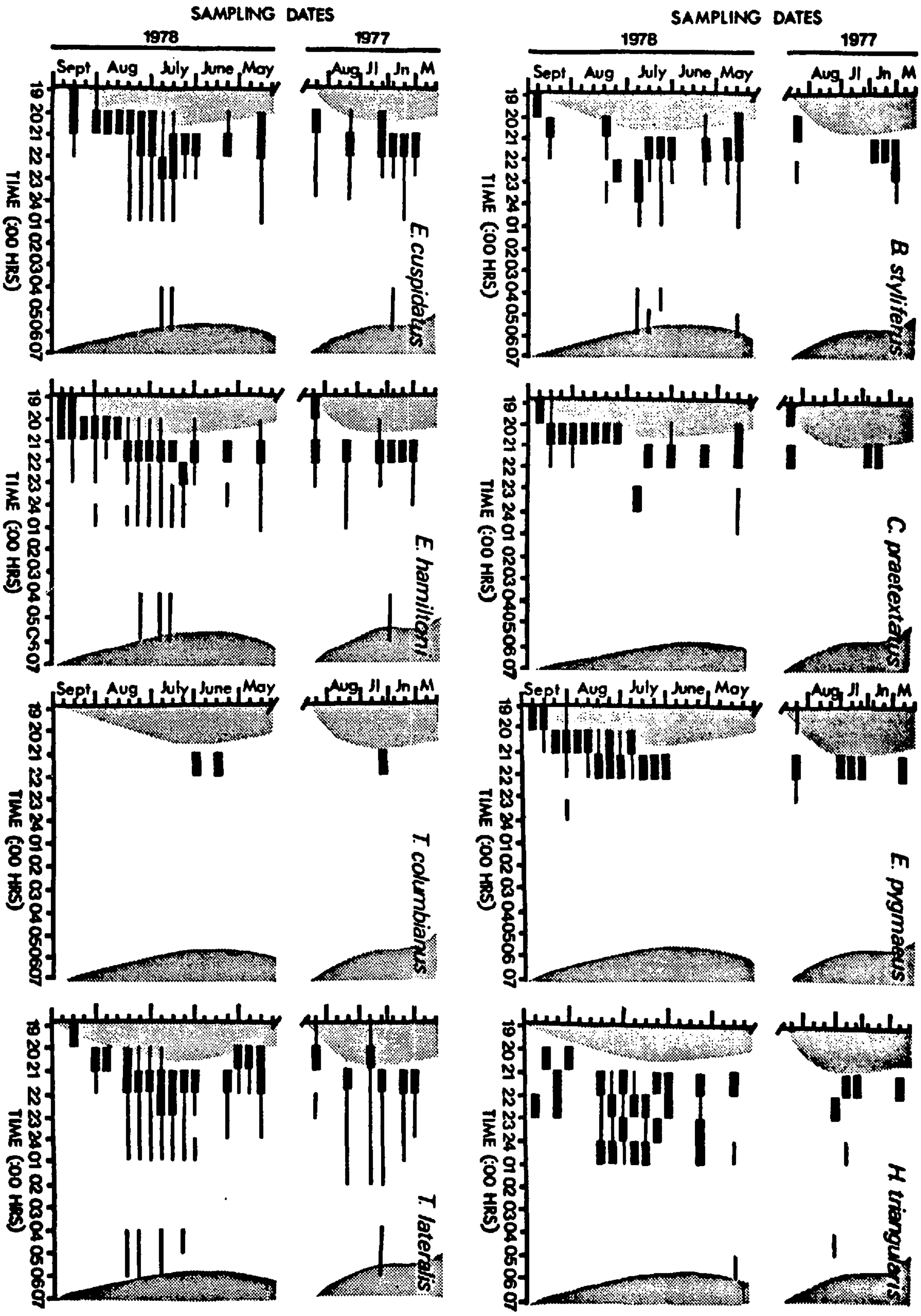

FIG. 2.—Diel flight periodicities of Hydrophilidae. Bold lines indicate periods when total numbers captured exceeds 25% of total captures for the date. Thin lines indicate other periods when hydrophilids were captured. Shaded areas represent daylight periods.

ative numbers of a species flying at a given time. When we compared the relative hourly catch of hydrophilids from the rotary net machine to that from a black light trap using a Spearman rank correlation coefficient test, we found no significant difference between the two collection methods ($P<0.025$; $r=0.2169$; $n=93$). As no water beetles were captured during daylight hours with the rotary net, we considered the black light trap to reflect the relative number of individuals flying at a given hour during the night. Further, the black light trap yielded a great number of specimens, allowing a more sensitive determination of flight parameters.

Light intensity.—A relationship exists between the time of flight and time of sunset and sunrise for the season (Fig. 2). For most species, peak flight (the period we define as when the total number captured exceeds 25% of total captures for that date) occurred during the hour immediately following sunset. The exception was *H. triangularis* which exhibited its peak flight for an extended period during the night.

While the time of peak flight each night appeared limited, most species were captured during a prolonged period in the evening (Fig. 3). Smaller, morning flights were also recorded. Again, the instances of capture were most common the hour following sunset. The mean flight time post-sunset for *C. praetextatus* ($\bar{x}=0.77\pm0.66$; $n=9$) was significantly less than that of the other species ($P<0.05$; $W=24$). *E. pygmaeus* ($\bar{x}=0.91\pm0.77$; $n=12$) also exhibited significantly earlier flight times ($P<0.05$; $W=56$). Conversely, the mean flight time post-sunset for *H. triangularis* ($\bar{x}=2.26\pm0.61$; $n=8$) was significantly later than that of other species ($P<0.0005$; $W=54$).

Temperature.—The maximum number of hourly periods during which most hydrophilid species were captured occurred when the recorded air temperature was

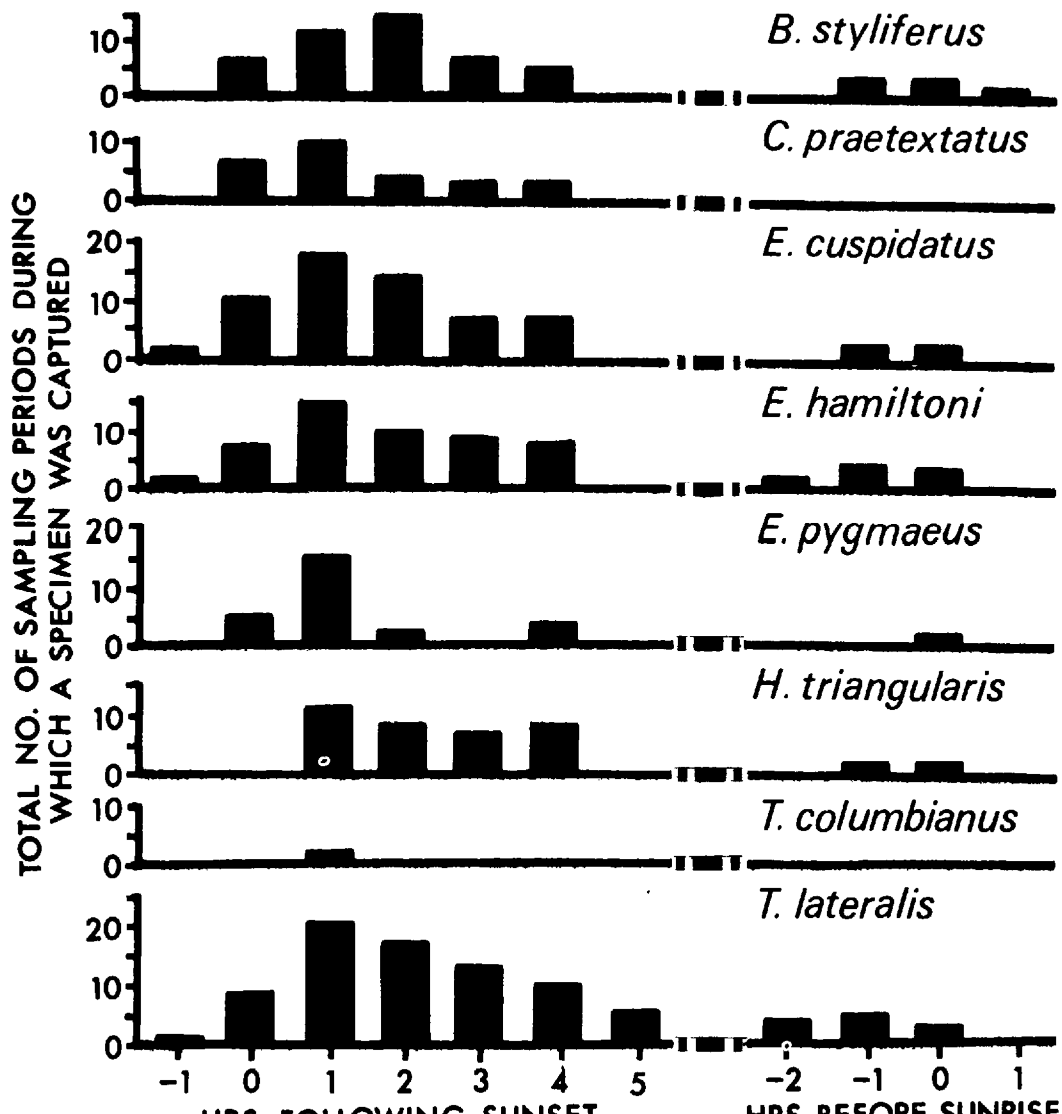

FIG. 3.—Number of sampling periods during which a hydrophilid was captured in relation to sunset and sunrise.

between 20° and 22° C (Fig. 4), however the mean temperature for the capture of all hydrophilids was 23.9°±3.3°C (n=87). *B. styliferus* were most often recorded in samples at a somewhat lower temperature range (17° – 19° C). The mean temperature at which *B. styliferus* flew to the trap was also significantly less (21.2°±3.3°C; P<0.05; W=43; n=9) than that of the other hydrophilid species. Both the minimum and maximum temperatures at which flight was recorded for *B. styliferus* were much lower than the corresponding temperatures for the other species (11° and 27° C respectively). No hydrophilids were captrued during periods when the air temperature exceeded 34°, or fell below 11°C.

A significant linear correlation between the relative number of individuals flying per hour on each sampling date and the corresponding temperatures was shown for *H. triangularis* (Y = −40.2800+3.0564x; r = 0.4864; n = 22; $P<0.05$). No correlation ($P<0.05$) between the factors was demonstrated for the other species.

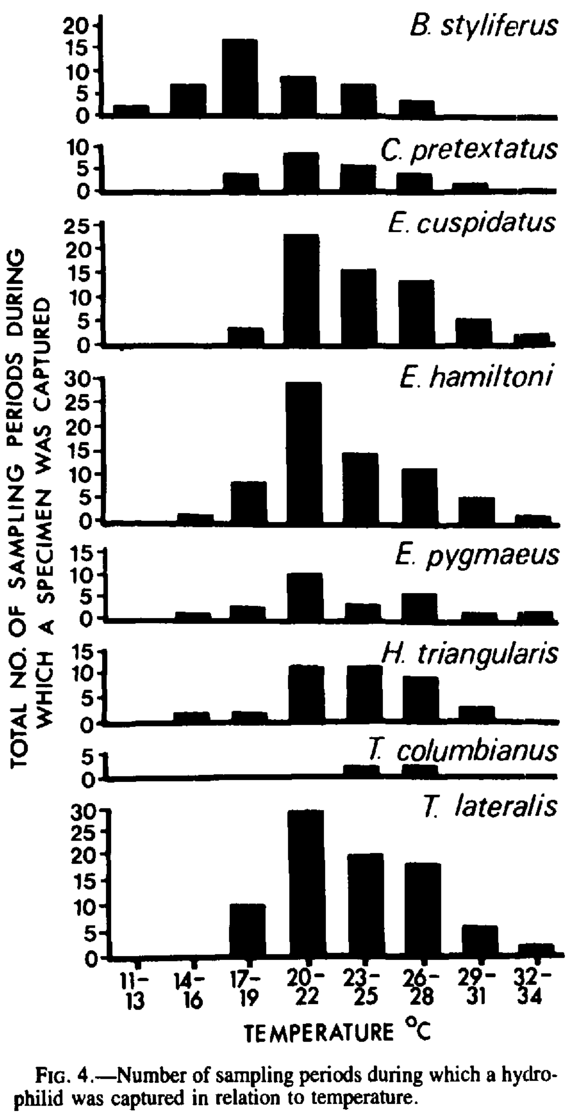

FIG. 4.—Number of sampling periods during which a hydrophilid was captured in relation to temperature.

Wind Velocity.—Patterns for flight with respect to wind speed were similar in all 8 species observed. In each case, more hydrophilids were captured during calm sampling periods. Fewer specimens were captured as the wind velocity increased, although there was no significant ($P<0.05$) difference between the total hydrophilids captured and the mean wind speed. The maximum wind speed at which *C. praetextatus*, *E. pygmaeus*, and *T. columbianus* were taken was 13.4 kph. *B. styliferus*, *E. cuspidatus*, *E. hamiltoni* and *H. triangularis* were never captured above 16.7 kph. Five *T. lateralis* were taken during a single period when the wind velocity was 20.0 kph.

Discussion

The concept of seasonal flight in relation to impermanence of habitat was developed by Southwood (1962) to apply to all groups of arthropods. Such temporary habitats can be expanded to include rice padddies which offer immigrants (including hydrophilids) both a potentially rich food source, and a suitable oviposition site. In addition to seasonal flight peaks, our data shows that pronounced diel flight periodicity also exists in the Hydrophilidae associated with California rice paddies.

The typical species studied has a flight peak occurring in late June through mid-August as is the case for *H. breviceps* (Landin 1976). The diel flight peak occurs during the hour following sunset, and as Landin (1968) reported for *H. breviceps*, a second, smaller peak occurs during the morning. Most flights occur during periods when the air temperature is 20° to 22°C, though a much wider range is tolerated. The mean weekly temperature at which all hydrophilids were captured was somewhat higher (23.9°C), due to the warmer temperatures recorded during peak seasonal flights. Wind velocity appears to be limiting only at a maximum threshold of 16.7 to 20.0 kph which would clearly not prevent most migrations, and might aid in dispersal.

B. styliferus is consistently different from most other rice field hydrophilids with respect to our recorded flight variables. Seasonally, it is captured in peak abundance throughout May and June. Further, it is the only hydrophilid we most frequently captured during sampling periods later in the evening (hour 2 post-sunset), and at a significantly lower mean temperature (21.2°C). Therefore, *B. styliferus* can be considered the initial hydrophilid colonizer, requiring lesser light intensity and lower temperatures for flight than other hydrophilids of the area.

H. triangularis also exhibits flight parameters unique among members of this guild. The mean flight time post-sunset (2.26 h) was significantly later than that of the other species (1.09 h). We have also found a significant correlation between temperature and individuals captured. This temperature relationship would be especially important in large Coleoptera such as *H. triangularis*. Hans and Thorsteinson (1961) have demonstrated inhibition of flight accompanying lower thoracic temperature in large beetles. The range of *H. triangularis* is reported to be all of North America (Leech and Chandler 1956), and might explain in part the relatively broader time of diurnal activity of the species.

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