

Florida (Capron, Haulover, Edgewater, Miami, Paradise Key), west to Iowa (Mt. Pleasant), Missouri (St. Louis) and Texas (Columbus), south through Central America to Colombia and Brazil. In the western United States, *S. geminata* was previously known to occur only in southern California (San Diego to Los Angeles), south of the Tehachapi Mountains.—JOHN W. ARMSTRONG, *Fresno, California*.

The Effects of Gregarines on the Metabolic Rate of *Tenebrio molitor* Larvae (Coleoptera: Tenebrionidae).—Most populations of *Tenebrio molitor* harbor large numbers of gregarine protozoans in the alimentary canal. Larvae may contain up to 6,000 gregarines completely blocking the alimentary canal. The respiration rate of infected and uninfected larvae were compared by use of a modified Wenneshind-Scholander single stage respirometer. Each larva was placed in a separate respirometer and readings were taken for a period of four hours, allowing half an hour for the larvae to adjust. Two trials were run, each consisting of 24 infected and uninfected larvae. The trials were performed at night between the hours of 9 p.m. and 2 a.m. The temperature ranged from 22.5 to 24.0 degrees centigrade. Upon the elapse of the four hours, the larvae were removed from the respirometers, weighed, mildly anesthetized with a few drops of 70% alcohol on the integument, and dissected. The alimentary canal was removed and teased to certify that infection or uninfection of the larvae. The results showed that there is a highly significant difference in the metabolic rate of the infected and uninfected larvae ($P \leq 0.01$), with the infected larvae respiring at a much higher rate.

To establish whether there is a correlation between the number of gregarines present and the metabolic rate of the larvae, the respiration rate of twenty infected larvae was studied. The concentration of gregarines was recorded as number of gregarines per larva. Regression analysis showed that there is a definite positive correlation between the number of gregarines and the larval metabolic rate ($P \leq 0.01$). The mean metabolic rate of uninfected larvae was determined to be 0.9275 ml O_2 /g. wet wt./hr., whereas the mean metabolic rate of infected larvae was 1.2173 ml O_2 /g. wet wt./hr. The increase in metabolic rate was calculated to be 0.00554 ml O_2 /g. wet wt./hr./gregarine.—GEORGE N. ZHOVREBOFF, *California State University, San Francisco*.

Dr. Zhovreboff also reported on the apparent absence of extra-cellular protozoan or helminth symbionts in the alimentary canal of the scorpion *Uroctonus mordax* (Vaejovidae), based on a detailed examination of 13 males and 7 females collected from Marin County, California.

The main speaker of the evening was Dr. C. B. Philip, California Academy of Sciences, who presented the following talk as the presidential address for 1974:

Horse-flies, too, Take Some Victims in Cold-blood, as on Galapagos Isles.

—It is not new that tabanid flies have been occasionally reported as attacking reptiles in various parts of the world, mostly subtropical. Such attacks, by host-seeking female flies to obtain ovigenous blood, relate to the availability of usually warm-blooded hosts, but recent evidence suggests occasional development of even preferential feeding on cold-blooded ones as well.

My interest in cold-blooded entomophagy was enhanced on coming to the California Academy of Sciences (CAS) in 1970, by finding a label, "biting turtle," cited later, on a pinned Galapagos horse fly. My speculative curiosity was aroused on how frequently horse flies might be attacking other reptiles on the Archipelago.

At one time, the islands, though of volcanic origin, were popularly believed to have had land connections to the mainland in the geologic past. Now, with the concept of continental drift widely accepted, the movement of the mostly submerged Pacific plate is considered to be slowly *toward* the continental plates some 600 miles to the east (Cox, 1966 *The Galapagos*, Univ. Calif. Press, pp. 78-86), not away from them. The obvious evolutionary derivation of the one Galapagos horse fly species from recent ancestors of a large group of mainland species indicates insular invasion by this horse fly in the relatively recent past. It is still a matter of opinion among taxonomists whether this is a specifically or only subspecifically distinct population, but reptile feeding would be an acquired secondary habit.

Historical. Interest in feeding of biting flies on reptiles was accelerated by discovery of natural and experimental feeding of *Culex* mosquitoes on hibernating and caged garter snakes, and impingement on a potential overwintering mechanism of western equine encephalitis virus (see Thomas and Eklund, 1962, *Proc. Soc. Expt. Biol. Med.*, 109: 421-424). The recent first discovery by DeGiusti and colleagues at Wayne State University, of biological transmission of a blood protozoan *Haemoproteus*, among Michigan turtles by *Chrysops callidus* Osten Sacken, added interest to this subject. *C. callidus* is a well-known deer fly pest of man and animals, sometimes locally numerous from British Columbia to Maine and south from Arizona to Florida; it is likely that other species of tabanids with suitable habits can also carry the turtle blood-parasite.

Tabanid association with reptiles has been noted sporadically in the past. The original series in the British Museum of the rare *Tabanus crocodilinus* Austen from Nyassaland was labelled "on crocodile." Though actual attack on these reptiles was questioned later in 1954 by Oldroyd (*The Horse-flies of the Ethiopian Region*, Vol. II.), credibility is strengthened by observations, specimens and photographs from Professor Federico Medem of Instituto "Roberto Franco," Villavicencio, Colombia, during unpublished conservation studies of caimans in upper tributaries of the Amazon River. He observed 4 species in 3 tabanine genera to feed exclusively or preferentially on indigenous crocodilian hosts: *Phaeotabanus fervens* (Linn.), *P. obscuripilis* (Krb.) (= *nigri flavus* Krb.), *Stenotabanus incipiens* (Walk.), and *Tabanus dorsiger* ssp. *modestus* Wied. He also forwarded for identification another 6 species in 4 genera which he took occasionally on these reptilian hosts, namely, *Diachlorus curvipes* (Fabr.), *Catachlorops* (*Psarochlorops*) *testaceus* (Macq.), *P. cajennensis* (Fabr.), *P. innotescens* (Walk.), *P. ?prasiniventris* (Krb.), and *T. cicur* Fehld. (= ?*dorsiger* ssp. *stenocephalus* Hine.). One of these, *P. fervens*, has also been reported biting South American boas. A boa is also listed as bitten in Old Panama Zoo by *Fidena isthmiae* (= *flavipennis* Krb.). Austen (cited by Oldroyd) also notes that "*Tabanus*" (= *Neavella*) *albipectus* Bigot, which is precinctive in the Malagasy Archipelago, was observed biting sea turtles on Aldabra Is., and apparently also at sea, probably an old-established feeding habit there. Aldabra Is., he it noted, is the only place outside the Galapagos where giant tortoises have barely survived extinction by man.

Bequaert (1940, *Rev. Entomol.*, 11: 253-269) comments on "the poverty of the tabanid fauna" in the Antilles as well as of the usual mammalian hosts with no native ungulates there, the preferred source of blood elsewhere. He further states "it is quite possible that some of the horse flies which we now observe biting man and domestic animals, occasionally fed on cold-blooded vertebrates," since certain

species have elsewhere been observed "feeding on reptiles (crocodiles, monitors, and turtles)." The reference to monitors is probably the one reviewed by Leclercq (cited by Oldroyd) of *T. guyonae* Surc. on a large, sun-basking, *Varanus* monitor in the Algerian desert country. Inquiries of biologists studying the Komodo dragon in the East Indies have not revealed tabanid attacks.

Observations on Galapagos Horse Flies. A long series, *Tabanus vittiger* Thomson in CAS from various Galapagos islands, includes a female collected by F. X. Williams, Entomologist on a 1906 Academy expedition, with his pencilled label "biting turtle." A published photo (see Slevin, 1911, Calif. Acad. Occas. Pap. 17: 1-162) shows him in a lagoon in a row-boat with overturned sea turtles; since an objective of the expedition was land tortoises, his label would have so indicated had a tortoise been the host. On recent inquiry of first-hand observers, I have confirmed that this, the only species of tabanid on Darwin's "Enchanted Isles," has been seen biting not only bathers and sea turtles, basking in the lagoons, but also land tortoises in pens at the Darwin Research Station, Santa Cruz Island. I suspect that in suitable locations land iguanas could have been also sources of blood. Since their numbers have become so depleted and isolated locally, they are not now the important hosts that I hypothesize various reptilians once were on the Archipelago before man introduced now-common goats, pigs, dogs, and other warm-blooded animals.

However, subsequent, admittedly rather sketchy information, makes me revise my earlier theory that land reptiles on the Galapagos could have supplied the past major source of ovigenous blood for the indigenous horse flies. An analysis of casual horse-fly collection records points to habitats near sea-level lagoons and beaches, with none of these flies among insects collected from the rainy cloud-moistened uplands.

While blood-seeking female *Tabanus* are strong fliers, circumstantial evidence in general indicates reluctance to stray far from semi-aquatic (here probably brackish water) breeding places, depending on availability of hosts. It is likely also that non-bloodsucking males would not wander very far from such breeding sites. Surprisingly, only 1 male *vittiger* has been reported. It was described by me in 1965 (Ann. Entomol. Soc. Amer., 58: 876-880) from Post Office Bay, Floreana, taken in April with 22 females by a Munich Museum expedition.

Data which I have compiled from various collections and reports on 250 females additional to 2 other locations (locs.) on Floreana (or in some early ship's logs, Charles) for April and July, are also from coastal areas, probably in vicinity of mangrove thickets: SANTA CRUZ (INDEFATIGABLE)—5 locs., Febr., Mar., Apr., May, July, and Nov.; SAN CRISTOBAL (CHATHAM)—2 locs., Apr., Oct.; ISABELLA (ALBERMARLE)—Apr.; FERNANDINA (MARBOROUGH)—June; BALTRA (SEYMOUR)—Mar.; SAN SALVADOR (JAMES)—Febr.; and SAN BARTOLOME—2 locs., Febr.

These casual samples by various collectors since 1906 suggest not only that the species has been established in the Archipelago long enough to invade most, if not all, the major islands, but that breeding may be less seasonal in these equatorial situations near sea level, than the breeding of mainland relatives. The above sporadic records include all months except December, and tabanids have been taken on occasion in considerable numbers together in one place. Word from actual collectors of several series, located the prolific sites as on beaches near mangrove thickets. The only record that appears to be at a distance from the

beaches, is Finca Castro at "200 m. alt.," which is an hacienda in the hills a short distance above Academy Bay on Santa Cruz.

Such coastal breeding habitats are also substantiated by Dr. Peter Cramer, former Director of the Darwin Research Station, Santa Cruz (*in litt.*, May 1971) who observed horse fly prevalence along the coasts, especially during the "hot season" (Jan. to Apr.) when often several flies at a time fed on penned tortoises at the Station, biting between the horn plates.

During questioning of Tui De Roy, who spent 18 years of her youth on the islands, I learned that she and her brother had stirred up submerged, torpedo-shaped "maggots which surfaced swimming" in rain pools above a lagoon; these might have been tabanid larvae. The biting adults with prominently-lined abdomens, were quite familiar to the De Roys, especially while bathing, and they also confirmed biting of sun-basking sea turtles. In her most recent letter, she confirms also seeing flies at least attempting to bite young sea lion pups at play on a mangrove-bordered beach. The pups seemed to pay no attention to the flies, but were too active to determine at a distance if any flies actually obtained blood. It seems not improbable that flies ranging from such habitats, might also invade marine iguana rookeries on not too distant rocky points, though wind would likely be more of a deterrent on such exposures.

The present wide inter-island horse fly distribution can hardly have resulted either from the advent of man's introduced animals or from some unknown migrant mammal that has disappeared. On the other hand, the here-postulated considerable, primitive resort of this horse fly to reptiles as a source of blood would be a secondary development by the flies after early "invasion" from the mainland. This tabanid has been isolated on the Archipelago long enough to develop its own biological identity, but is still considered only a recent offshoot from a vigorous, modern, highly specialized group of mainland *Tabanus* the females of which are primarily dependent on warm-blooded vertebrates for their ovigenous blood-meals.

"Invasion from the mainland" is a glib way of avoiding speculation on how this one horse fly species could have reached the islands. Flying heavy-bodied insects are not believed to have made the long, overseas journey by wing. Conversely, at least some, like cerambycid beetles, most likely were carried by the prevailing currents, though seasonal, in floating material, which seems the most likely pathway for *T. vittiger* in the larval stage to have reached the islands. To become established, however, there would be the further extraordinary circumstance of both incipient sexes of these probably cannibalistic tabanid larvae surviving successfully cross at or about the same time! They obviously arrived long before the advent of man as discussed above. No other explanation for their insular occurrence at present seems plausible, but it is not unlikely the progenitors were also brackish water, sea-level breeders. This may even provide an ecological clue for seeking a close, modern relative on the west coasts of the mainland from which the Humboldt current takes its well-known swing westward to envelop on occasion the Galapagos Archipelago.

The closest presently recognized relative, based on adult structural similarities in both sexes, *T. guatemalanus* Hine, is not known southwest of Panama. Fairchild (1942, Ann. Entomol. Soc. Amer., 35: 153-183) makes the pertinent statement that *guatemalanus* (as subspecies of *vittiger*) in Panama occurs uncommonly "where it seems to be confined to the drier areas of the Pacific Coast." I have

seen specimens from the Mexican west coasts of Nayarit, Sinaloa, and Sonora (including a confirmatory male from "nr. San Jose beach, 40 mi. SW Obregon, 16-23.V.64, Howden & Martin" with females in the Canadian National Coll.). The species is more common from around the eastern Mexican Gulf Coast, southern Florida, and some Caribbean islands, to Surinam; the breeding habitats, when known, could also include brackish water situations. Recent capture in April, 1974 by J. T. Doyen of 4 *guatemalanus* females in a Malaise trap set in a sea-level mangrove swamp on Isla San Jose in the Gulf of California, strengthens the postulated similarity in breeding sites to the Galapagos relative. Of possible further related zoogeographic significance is that certain other components of the Galapagos insect fauna and flora are known to have some early Caribbean relationships. It is interesting that another of the "lined horse fly" group, *T. dorsiger* var. *modestus* Wied., widespread in northern South America, is one of the species reported by Dr. Medem to preferentially attack crocodilian hosts in the Colombian Amazon Basin.

The speculative question naturally arises, could the progenitors of modern, bloodsucking Tabanidae ever have fed on dinosaurs when those large reptiles were a dominant form of terrestrial life. Though the paleontologic evidence is meager, the answer appears to be "yes."

Mackerras (1954, I. Aust. J. Zool., 2: 431-454) summarizes the evolution of the Tabanidae as a specialized derivation of the Diptera which Tillyard believed originated in the Permian just before the Mesozoic era, often referred to as the "Age of Reptiles." Generalized, non-bloodsucking ancestral tabanids were suggested to have originated about the beginnings of the Mesozoic; they probably fed on "juices of plants," but an "adaptation to blood-sucking" was considered by Mackerras to be one of the early trends in their evolution. Certain groups of tabanids with the popular "Gondwanaland distribution must have evolved not later than the middle of the Mesozoic"; this would have been when reptiles were flourishing, and would furnish probably the most available source of blood for those specializing tabanid ancestors that had "developed the habit."

No need to carry this speculation further than to contrast it with the present-day situation when, as Bequaert (referred to above) states in discussing food habits of the adults: "The females of most species suck vertebrate blood, but they often prefer to bite certain types of animals. Mammals, and particularly ungulates, are the preferred hosts of the majority of species."

It is also speculative to decide which, if any, present-day species attacking cold-blooded vertebrates, are exhibiting atavistic, "cold-blood-feeding" tendencies, or simply the pursuit of vertebrate blood from the most available local hosts. At least in the early restricted Galapagos ecosystem, any habitual feeding on reptiles must have developed secondarily.

Finally, an amusing bit of speculation relates to the oft-cited inclusion of "dinosaur juices" in the fossil fuel with which we propel our cars—if ancient tabanids occurred in pest numbers, I've been intrigued by the possibility I might be burning fossil tabanids in my auto travels as well.

THREE HUNDRED AND SIXTY-FOURTH MEETING

The 364th meeting was held Friday, 21 March, 1975, in the Morrison Auditorium of the California Academy of Sciences, Golden Gate Park, San Francisco, President Daly presiding, with 16 members and 14 visitors present.



Philip, Cornelius B. 1976. "Horse-flies, too, take some victims in cold-blood, as on Galapagos Isles." *The Pan-Pacific entomologist* 52(1), 84–88.

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