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HIPPELATES EYE GNATS: A REVIEW AND BIBLIOGRAPHY

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December 1977

Interim Report for Period 1976-1977

USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
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NOTICES

This interim report was submitted by personnel of the Disease Surveillance Branch, Epidemiology Division, USAF School of Aerospace Medicine, AFSC, Brooks Air Force Base, Texas, under job order SUPTXXEP.

This report has been reviewed and is approved for publication.

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A review of the published work on Hippelates pusio taxonomy, life cycle, behavior, flight range, medical importance, and Hippelates control is presented. Following the literature review is a comprehensive bibliographic listing of Hippelates references. (cont on p. 7)

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Hippelates EYE GNATS: A REVIEW AND BIBLIOGRAPHY

INTRODUCTION

Hippelates are small flies, frequently called "eye gnats" because of their persistent habit of hovering about the eyes and feeding on lachrymal secretions. In areas of the United States where *Hippelates* are abundant, severe eye-gnat annoyance can cause reduction of outdoor work and recreational activities (105).

At the request of the Director of Base Medical Services, Robins AFB, Georgia, an investigative eye-gnat study was initiated by the Entomology Section, Epidemiology Division, USAF School of Aerospace Medicine. This request resulted from a history of severe eye-gnat annoyance at Robins AFB and no effective control techniques. The primary objective of the study, therefore, was to find a control measure that would reduce the eye-gnat annoyance problem to an acceptable level. A review of pertinent literature was the first step toward accomplishing this objective.

HIPPELATES PUSIO

Identification

Hippelates pusio is the dominant eye-gnat pest species in the Robins AFB area (167). These gnats are nonbiting Diptera in the family Chloropidae. Members of this family are characterized by a large frontal triangle, the sclerotized plate on which the ocelli are situated. Most *Hippelates* are very small (1.5 to 2.5 mm long). A distinct, curved, shiny black spine on the tibia distinguishes these adults from other Chloropidae (23). Several taxonomic references are available for speciating the adults of the genus *Hippelates* (11, 175, 177, 179). Immature stages of *H. pusio* can be identified with the aid of detailed drawings provided in papers by Herms and Burgess (21) and Hall (48).

Life Cycle

Most eye-gnat breeding occurs in light, moist, freshly disturbed soil with a 1%-27% content of organic matter (9, 21-24, 31, 34, 49). Adequate soil moisture appears to be one of the most important requirements of an oviposition site because *H. pusio* eggs desiccate rapidly when deposited on a dry medium. Hall (48) found that newly hatched *H. pusio* larvae immediately tunnel downward to feed and develop in moist areas of the soil and that pupation generally takes place in the interface region between moist and dry areas of the soil.

Duration of the H. pusio life cycle varies primarily with the amount of available food and moisture and the temperature of the soil. Under optimum laboratory conditions, the developmental period for each H. pusio stage is 2 days for eggs, 8-10 days for larvae, 7-9 days for pupae, and 4-6 days for adult maturation and oviposition (42). Although developing from egg to adult may take as little as 17 days in the laboratory, 28 days to 6 months may be required for one generation to develop in the field (9). Overwintering of H. pusio in the larval stage accounts for most of the longer developmental times. In the Robins AFB area, H. pusio adult populations annually peak from July through September (16).

Behavior

Eye gnats frequently come to the eyes, ears, nose, mouth, and wounds or sores of man and animals to feed on mucous and sebaceous secretions, pus, and blood (23, 29). They are extremely persistent pests. When searching for a feeding site they crawl over the skin or intermittently fly and alight on the skin, which adds to the annoyance of the host (23). After being brushed away, the gnats immediately and repeatedly return to feed.

According to studies made by Gerhardt and Axtell (61), the physical environmental threshold values that must exist before H. pusio is attracted to man are: temperatures above 17°C (62°F), vapor pressure deficit of 0.25 mm Hg or greater, light above 5.38 milliphots (5 ft-c), and wind below 4 km/hr (2.5 mi/hr). At temperatures above 34°C (93°F), flight activity of H. pusio decreases (62). During the high temperatures of midday, the activity is primarily in shaded areas; and in early morning and late evening, activity occurs more frequently in warmer sunny areas (62).

Flight Range

Eye gnats will fly with air moving at velocities up to 9.3 km/hr (6 mi/hr), and they are capable of flying against the wind at wind speeds of 3.1 km/hr (2 mi/hr) or less (60). In Georgia, Dow (1) reported catching 15 H. pusio gnats in less than 3.5 hours in traps located more than a mile (1.6 km) from the release box. Mulla and March (2) observed a flight range for H. collusor in California of up to 4.3 miles (6.9 km) downwind.

Importance

In localities where Hippelates eye gnats attain high population levels, these pests are considered to be a major public health problem (29). Their attraction to eyes, ears, nose, mouth, wounds, and sores of man make them a constant source of annoyance. After conducting extensive studies of this pest, Mulla (105) stated, "There is no doubt that Hippelates eye gnats are a deterrent to public welfare, hindrance to recreational pursuits, and are a cause of physical and mental discomfort...Eye gnats, in general, and in California in particular, are important not because of their potential role as disease vectors, but they are dreaded on account of their persistent attacks causing constant annoyance."

Although Hippelates are nonbiting, they possess mouthparts with minute spines capable of scarifying epithelial linings, and thus pathogenic organisms carried by the eye gnats can gain a foothold (151). Circumstantial evidence incriminates Hippelates gnats as vectors of conjunctivitis in the United States and other countries (146, 149-153, 159). In Jamaica, isolations of the yaws organism, *Treponema pertenue*, have been made from Hippelates, and this organism has been experimentally transmitted to rabbits by Hippelates (154-157). Blancho et al. (147) and Parra and Blancho (158) reported the transmission of mal del pinto organisms by Hippelates to human volunteers in Mexico. Eye gnats have been shown to transmit Naga sore in Assam (163). Hippelates probably contributed to the rapid spread of an outbreak of *Streptococcus pyogenes* skin infection in Trinidad (146). In addition to vectoring human disease, Hippelates have been proven experimentally to be vectors of bovine mastitis and incriminated as potential vectors of anaplasmosis in cattle in the United States (160-162, 164, 165).

HIPPELATES CONTROL

Attractants/Repellents

Of the numerous attractancy studies conducted with eye gnats, only Dow (68) and Snoddy (83) have worked extensively with *H. pusio*. Using a rotary bait station, Dow found that aged liver bait was more attractive to *H. pusio* than egg bait. In his studies of the attractancy of various milk components, Snoddy reported that the most promising carbonyl compound, 2,3-pentanedione, was not attractive to *H. pusio*. Most of the published eye-gnat studies have been accomplished with *H. collusor*, and have been performed by Hwang (69-73) and Mulla (74-82) and their associates. None of the work, however, has resulted in an effective or practical bait which can be mixed with a toxicant or chemosterilant for Hippelates control.

Mulla (74) tested 15 chemicals for their repellency activity against *H. collusor* and found that dimethyl carbate, ethyl hexanediol, and Triple Mix Repellent (64% dimethyl phthalate, 17% ethyl hexanediol, and 19% Indalone) performed best. His results also showed that a standard military-issue repellent, diethyltoluamide (deet), provided excellent protection for 30 minutes after application and good protection from 30 to 120 minutes. In a repellency screening test with 20 chemicals against *H. pusio*, Axtell (66) found that the most effective repellents were Triple Mix, MGK (McLaughlin Gormley King Co.) Formula 5780, MGK Repellent 11, butyl acetanilide, and butyl ethyl propanediol. He found only moderate repellency by deet against *H. pusio*. Further studies are needed, however, to develop a highly effective and acceptable repellent that will offer good protection against Hippelates eye-gnat annoyance.

Biological/Cultural Control

Biological control work with eye gnats has primarily involved collecting and identifying parasites found in Hippelates larvae and pupae. So far, very little work has been done with rearing and releasing parasites or predators to control Hippelates.

Two parasites taken from H. pusio are a flagellate, Herpetomonus muscarum, and an egg parasite, Ooencyrtus submetallus Howard (85, 86), most often found in eggs of the southern green stink bug. Three hymenopterous parasites of H. collusor have been successfully cultured in the laboratory: Phaenopria occidentalis Fouts, Spalangia drosophilae Ashmond, and Eupteromalus nidulans Thomson (89). Of the three, only S. drosophilae shows any promise in field release studies. In one test where Legner and Bay (93) exposed Hippelates eye gnats to natural field parasitism, only Trybliographa spp. and S. drosophilae parasites were recovered. Besides Hymenoptera, beetles of the subfamily Aleocharinae, belonging to a tribe of which very little is known, have been found parasitizing Hippelates in Coachella Valley, California (103).

Legner et al. (102) and Mulla (105, 143) have tested the effects of varying farming techniques on H. collusor populations. In Legner's study, naturally breeding field populations of H. collusor were reduced when urea fertilizer was applied to the soil. Control apparently was due in part to an increase in the abundance of Saprolegnia (fungi pathogenic to gnat larvae) in some soil cultures treated with urea. Mulla (105) reported that flexible cultural control would help control eye gnats. The measures he found detrimental to eye-gnat production in the soil were: (1) using recommended herbicides to control weeds in tree fruit crops, (2) using frequent tillage to control weeds before growth reached 2-3 in. (5-7.3 cm), and (3) not incorporating vegetative matter into the soil during the heavy breeding season of Hippelates eye gnats.

Chemical Control of Adults

Axtell and Edwards (107) tested the effectiveness of nine insecticides applied as thermal fogs to kill caged laboratory-reared H. pusio adults. They found that naled and propoxur were the most toxic. Mulla (111) observed that of the 15 (primarily experimental) insecticides he evaluated against H. pusio and H. collusor, malathion had the lowest toxicity. Other adult Hippelates chemical control studies have used a variety of ground and aerial control techniques, but none reported in the literature have yielded a practical and effective method of controlling Hippelates adults (108-110, 112, 114).

Chemical Control of Larvae

Excellent control of H. pusio has been obtained for short periods in Brooks County, Georgia, using soil applications of aldrin and chlordane

(114). The Environmental Protection Agency restrictions on many of the residual insecticides and the lack of long-term benefits, however, make chemical control of Hippelates larvae impractical. Additionally, in California where soil treatments with residual insecticides have been used, eye-gnat populations developed resistance to the insecticides (115).

Chemosterilants

The use of chemosterilants has been difficult to implement as a control measure due to both the limited effectiveness of the chemicals tested and the difficulty of exposing large numbers of eye gnats to the compounds (131-134).

Traps and Other Potential Control Methods

Attempts to use traps to control eye gnats have been unsuccessful (135, 136). The primary emphasis on Hippelates trap studies has been with their development for eye-gnat surveillance (137-139). The only other potential control method of note is the use of radiation to sterilize Hippelates. Flint (140) studied the effects of gamma radiation on the fertility and longevity of H. pusio. He was able to sterilize both sexes by treating the late pupal stages with a dose of 4,500 R. The males, however, recovered some fertility 3 weeks after radiation, and the 4,500-R dose level did not increase eye-gnat mortality. Although Flint's study indicated that radiation sterilization shows potential as an eye-gnat control technique, no additional tests with eye-gnat radiation have been reported.

CONCLUSIONS

The primary emphasis in developing an eye-gnat control program at Robins AFB, Georgia, should be placed on controlling the adults. Currently, the control of immature stages would be impractical because of the Federal restrictions placed on the use of residual insecticides and the expense of treating large eye-gnat breeding areas. Of the adult control procedures available, insecticide treatments similar to those used for mosquito control would be the most promising approach because of the Air Force's inability to treat off-base areas, and the time and expense required to develop a control program using any of the other available control techniques.

HIPPELATES BIBLIOGRAPHY

Biology and Behavior

Flight Range

1. Dow, R. P. Dispersal of adult *Hippelates pusio*, the eye gnat. Ann Entomol Soc Am 52:372-381 (1959).

2. Mulla, M. S., and R. B. March. Flight range, dispersal patterns, and population density of the eye gnat *Hippelates collusor* (Townsend). Ann Entomol Soc Am 52:641-646 (1959).

3. Thomas, S. L. Tagging technique for use in flight range studies of the *Hippelates* eye gnat. Mosquito News 11:219 (1951).

General

4. Aldrich, J. M. Notes on synonym of Diptera, No. 3. Proc Entomol Soc Wash 31:32-36 (1929).

5. Axtell, R. C., and T. D. Edwards. Seasonal populations of *Hippelates* gnats (Diptera: Chloropidae) in North Carolina. Ann Entomol Soc Am 63:1049-1053 (1970).

6. Bigham, J. T. *Hippelates* (eye gnat) investigations in the Southeastern States. J Econ Entomol 34:439-444 (1941).

7. Borror, D. J., and D. M. DeLong. An introduction to the study of insects, p. 498. New York: Holt, Rinehart and Winston, 1964.

8. Burgess, R. W. The eye gnat in the Coachella Valley, California. U.S. Dept Agric, Bur Entomol & Plant Quar Bull E-335:1-6 (1935).

9. Burgess, R. W. The life history and breeding habits of the eye gnat, *Hippelates pusio* Loew, in the Coachella Valley, Riverside County, California. Am J Hyg 53:164-177 (1951).

10. Clausen, C. P. Entomophagous insects, p. 688. New York: McGraw-Hill Book Co., 1940.

11. Cole, F. R. The flies of western North America, pp. 416-417. Berkeley and Los Angeles: Univ. Calif. Press, 1969.

12. Colquillett, D. W. On the habits of the Oscinidae and Agromyzidae reared at the USDA. Bull. No. 10, N. Ser., U.S. Dept Agric, Div Entomol, pp. 70-79, 1898.

13. Comstock, J. H. An introduction to entomology, p. 1064. New York: Comstock Publishing Company, 1940.

14. Curran, C. H. The families and genera of North American Diptera, p. 512. New York: Henry Tripp, 1934.

15. Dow, R. P. Larval habitat of Hippelates dissidens (Diptera: Chloropidae). Ann Entomol Soc Am 63:897-898 (1970).

16. Dow, R. P., and G. A. Hutson. The measurement of adult populations of the eye gnat Hippelates pusio. Ann Entomol Soc Am 51:351-360 (1958).

17. Dow, R. P., et al. Sequel to "Hippelates (eye gnat) investigations in the Southeastern States" by John T. Bigham. Proc Entomol Soc Wash 53:263-271 (1951).

18. DuBose, W. P., and R. C. Axtell. Sensilla on the antennal flagella of Hippelates eye gnats. Ann Entomol Soc Am 61:1547-1561 (1968).

19. Herms, W. B. Hippelates flies and certain other pests of the Coachella Valley, California. J Econ Entomol 19:692-695 (1926).

20. Herms, W. B. The Coachella Valley (California) Hippelates fly project. J Econ Entomol 21:690-693 (1928).

21. Herms, W. B., and R. W. Burgess. A description of the immature stages of Hippelates pusio Loew and a brief account of its life history. J Econ Entomol 23:600-603 (1930).

22. Hummadi, M. K., and G. R. DeFoliart. Biology of Hippelates pallipes and H. bishoppi (Diptera: Chloropidae) in Wisconsin. J Med Entomol 4:66-70 (1967).

23. James, M. T., and R. F. Harwood. Herm's medical entomology, 6th ed., pp. 243-248. London: MacMillan Co., Collier-MacMillan Limited, 1970.

24. Jay, E. G., Jr. Laboratory and field studies on the ecology of Hippelates pusio Loew (Diptera: Chloropidae) and related species. M.S. Thesis. Univ. of Florida, Gainesville, 1961.

25. Jay, E. G., Jr. Species of Hippelates (Diptera: Chloropidae) gnats collected from mammals. J Econ Entomol 56:1011-1012 (1962).

26. Karandinos, M. G., and R. C. Axtell. Age-related changes in the fertility of Hippelates pusio, H. bishoppi, and H. pallipes (Diptera: Chloropidae). Ann Entomol Soc Am 65:1092-1099 (1972).

27. Kumm, H. W. The digestive mechanism of one of the West Indian "eye gnats," Hippelates pallipes Loew. Ann Trop Med Parasitol 29:282-302 (1935).

28. Magy, H. I., and A. A. Lee. Occurrence of Hippelates eye gnats in a coastal habitat in California. J Econ Entomol 54:206-207 (1961).

29. Mulla, M. S. Recent developments in the biology and control of Hippelates eye gnats. Proc & Papers Annu Conf Calif Mosquito Control Assoc 26:78-82 (1958).

30. Mulla, M. S. Some important aspects of Hippelates gnats with a brief presentation of current research findings. Proc & Papers Annu Conf Calif Mosquito Control Assoc 27:48-52 (1959).

31. Mulla, M. S. The breeding niches of Hippelates gnats. Ann Entomol Soc Am 55:389-393 (1962).

32. Mulla, M. S. Biology and control of Hippelates eye gnats. Proc & Papers Annu Conf Calif Mosquito Control Assoc 33:26-28 (1965).

33. Mulla, M. S. Oviposition and emergence period of the eye gnat Hippelates collusor. J Econ Entomol 59:93-96 (1966).

34. Mulla, M. S., and H. Axelrod. Organic wastes and soil additives as producers of Hippelates eye gnats (Diptera-Chloropidae). Environ Entomol 2:409-413 (1973).

35. Parman, D. C., and R. W. Burgess. Some of the more significant results of recent work on eye gnats (Hippelates) and suggestions for control of these gnats and of flies in Coachella Valley, California. U.S. Dept Agric, Bur Entomol and Plant Quar Bull E-288:1-3 (1931).

36. Peterson, A. Larvae of insects, p. 416. Ann Arbor, Michigan: Edwards Brothers, Inc., 1951.

37. Schwartz, E. A. Notes on Hippelates pusio in the Southern States. Entomol Soc Wash 3:178-180 (1894).

38. Schwartz, E. A. The Hippelates plague in Florida. Insect Life 7:374-379 (1895).

39. Taylor, M. L., and L. D. Olinger. An egg survey of Hippelates gnats in the vicinity of Orlando, Florida. J Econ Entomol 51:557 (1958).

40. The California eye gnat. Science 69:1783 (1929).

41. Tinkham, E. R. First annual report on eye gnat research and control. Rep. Coachella Valley Mosq. Abatement District, Indio, Calif., 26 pp., mimeographed, 1948-1949.

42. Turner, E. R. Certain aspects of the biology and control of the eye gnat Hippelates pusio Loew. M.S. Thesis, Univ. of Florida, Gainesville, 1960.

43. Womeldorf, D. J., and E. W. Mortenson. Occurrence of eye gnats (Hippelates spp.) in the central San Joaquin Valley, California. J Econ Entomol 55:457-459 (1962).

44. Womeldorf, D. J., and E. W. Mortenson. The occurrence of Hippelates gnats in the Mojave Desert, Kern County, California. Calif Vector Views 10:25 (1963).

45. Womeldorf, D. J., and E. W. Mortenson. Hippelates gnats in central California. Calif Vector Views 10:57-60 (1963).

Rearing

46. Axtell, R. C. Laboratory rearing of Hippelates pusio and H. bishoppi (Diptera: Chloropidae). J Elisha Mitchell Sci Soc 80:163-164 (1964).

47. Eskafi, F. M. Increased efficiency in the mass production of Hippelates collusor (Diptera: Chloropidae). J Med Entomol 12:575-576 (1975).

48. Hall, D. G. Some studies on the breeding media, development, and stages of the eye gnat Hippelates pusio Loew (Diptera: Chloropidae). Am J Hyg 16:854-864 (1932).

49. Jay, E. G., Jr. Effect of organic content in the larval medium on the production of two species of Hippelates. J Econ Entomol 56:127-129 (1963).

50. Karandinos, M. G., and R. C. Axtell. Population density effects on fecundity of Hippelates pusio Loew (Diptera: Chloropidae). Oecologia 9:341-348 (1972).

51. Mulla, M. S. Control of mites in laboratory cultures of the eye gnat Hippelates collusor (Townsend). J Econ Entomol 51:461-462 (1958).

52. Mulla, M. S. Mass rearing of three species of Hippelates eye gnats (Diptera: Chloropidae). Ann Entomol Soc Am 55:253-258 (1962).

53. Mulla, M. S., and M. M. Barnes. On laboratory colonization of the eye gnat Hippelates collusor Townsend. J Econ Entomol 50:813-816 (1957).

54. Scherer, L. E. Ecological studies of the eclusions and development of the eye gnat Hippelates pusio Loew (Diptera: Chloropidae). M.S. Thesis, Univ. of Florida, Gainesville, 1963.

55. Schwartz, P. H. Aspirator for rapid sexing and transfer of eye gnats Hippelates pusio. J Econ Entomol 57:784-786 (1964).

56. Schwartz, P. H. Reproductive system of the eye gnat Hippelates pusio (Diptera: Chloropidae). Ann Entomol Soc Am 58:293-303 (1965).

57. Schwartz, P. H. Some observations of the reproduction of the eye gnat Hippelates pusio. J Med Entomol 2:141-144 (1965).

58. Schwartz, P. H., and R. B. Turner. A dietary study of the adult eye gnat Hippelates pusio (Diptera: Chloropidae). Ann Entomol Soc Am 59:277-280 (1966).

Weather Influences

59. Dorner, R. W., and M. S. Mulla. Response of the eye gnat Hippelates collusor to light of different wave lengths. Ann Entomol Soc Am 54:69-72 (1961).

60. Dorner, R. W., and M. S. Mulla. Laboratory study of wind velocity and temperature preference of Hippelates eye gnats. Ann Entomol Soc Am 55:36-39 (1962).

61. Gerhardt, R. R., and R. C. Axtell. Flight of the eye gnat Hippelates pusio (Diptera: Chloropidae): effects of temperature, light, moisture, and wind velocity. J Med Entomol 9:425-428 (1972).

62. Gerhardt, R. R., and R. C. Axtell. Flight of the eye gnat Hippelates pallipes (Diptera: Chloropidae): correlation with temperature, light, moisture, and wind velocity. J Med Entomol 10:290-294 (1973).

63. Karandinos, M. G., and R. C. Axtell. Temperature effects on the immature stages of Hippelates pusio, H. bishoppi, and H. pallipes (Diptera: Chloropidae). Ann Entomol Soc Am 60:1055-1062 (1967).

64. Karandinos, M. G., and R. C. Axtell. Effect of temperature on the longevity, fecundity, and activity of adult Hippelates pusio, H. bishoppi, and H. pallipes (Diptera: Chloropidae). Ann Entomol Soc Am 60:1252-1255 (1967).

65. Spielman, A. The influence of rainfall upon the abundance of Cuban Hippelates (Diptera: Chloropidae). Ann Entomol Soc Am 55:39-42 (1962).

Control

Attractants/Repellents

66. Axtell, R. C. Evaluations of repellents for Hippelates eye gnats. J Econ Entomol 60:176-180 (1967).

67. Dorner, R. W., and M. S. Mulla. Nature of eye gnat attractant chemical contained in ground-up eye gnats, Hippelates collusor. Ann Entomol Soc Am 55:33-35 (1962).

68. Dow, R. P. A method of testing insect traps and attractants, and its application to studies of Hippelates pusio and Culex tarsalis. J Econ Entomol 52:496-503 (1959).

69. Hwang, Y. S., and M. S. Mulla. Hippelates eye gnat attractant. 1. Isolation and identification of ether-soluble coattractants produced by fermentation of whole-egg solids. Ann Entomol Soc Am 64:1086-1091 (1971).

70. Hwang, Y. S., and M. S. Mulla. Attractants for synanthropic flies. 1. Some physico-chemical factors as related to the potency of Hippelates eye gnat attractants. J Econ Entomol 66:1055-1058 (1973).

71. Hwang, Y. S., and M. S. Mulla. Attractants for synanthropic flies. 5. Isolation and attractancy of Hippelates eye gnat attractants. J Econ Entomol 66:1339-1340 (1973).

72. Hwang, Y. S., et al. Attractants for synanthropic flies: evaluation of chemical attractants and coattractants against the eye gnat Hippelates collusor (Diptera-Chloropidae). Environ Entomol 4:769-773 (1975).

73. Hwang, Y. S., et al. Effects of structural modifications on the activity of Hippelates eye gnat attractants and coattractants. Environ Entomol 5:65-67 (1976).

74. Mulla, M. S. Chemical repellents for Hippelates eye gnats: A method and procedure for evaluation. J Econ Entomol 56:753-757 (1963).

75. Mulla, M. S. New attractants and baits for controlling gnats and flies. Calif Agric 27:3-6 (1973).

76. Mulla, M. S., and H. Axelrod. Attractants for synanthropic flies: attractant-toxicant formulations, their potency against a Hippelates eye gnat. J Econ Entomol 67:13-16 (1974).

77. Mulla, M. S., and H. Axelrod. Attractants for synanthropic flies: longevity of attractant and toxicant formulations evaluated against Hippelates collusor. J Econ Entomol 67:641-643 (1974).

78. Mulla, M. S., and H. Axelrod. Attractancy of putrefied animal and plant proteins to the eye gnat Hippelates collusor (Diptera: Chloropidae). J Med Entomol 13:497-500 (1977).

79. Mulla, M. S., et al. Olfactometer and procedure for testing baits and chemical attractants against Hippelates eye gnats. Ann Entomol Soc Am 53:529-537 (1960).

80. Mulla, M. S., et al. Effects of aging and concentration of the attractancy of proteinaceous materials to Hippelates gnats. Ann Entomol Soc Am 53:835-841 (1960).

81. Mulla, M. S., et al. Attractants for synanthropic flies. 3. Evaluation, development, and formulation of attractive baits against Hippelates collusor. J Econ Entomol 66:1089-1094 (1973).

82. Mulla, M. S., et al. Attractants for synanthropic flies: area-wide control of Hippelates collusor with attractive baits. J Econ Entomol 67:631-638 (1974).

83. Snoddy, E. L. 2,3-Pentanedione as an attractant for Hippelates (Diptera: Chloropidae). Mosquito News 28:320-322 (1968).

Biological/Cultural Control

84. Bailey, C. H., and W. M. Brooks. Transmission of the flagellate Herpetomonas muscarum in laboratory cultures of the eye gnat Hippelates pusio (Diptera: Chloropidae). Proc 4th Int Colloq Insect Pathol, Soc Invertebr Pathol, pp. 60-65, 1971.

85. Bailey, C. H., and W. M. Brooks. Histological observations on larvae of the eye gnat Hippelates pusio (Diptera: Chloropidae), infected with the flagellate Herpetomonas muscarum. J Invertebr Pathol 19:342-353 (1972).

86. Bailey, C. H., and W. M. Brooks. Effects of Herpetomonas muscarum on development and longevity of the eye gnat Hippelates pusio. J Invertebr Pathol 20:31-36 (1972).

87. Bay, E. C., and E. F. Legner. Quality control in the production of Hippelates collusor (Townsend) for use in the search and rearing of their natural enemies. Proc NJ Mosquito Exterm Comm 19:403-410 (1963).

88. Bay, E. C., and E. F. Legner. The prospect for the biological control of Hippelates collusor (Townsend) in southern California. Proc & Papers Annu Conf Calif Mosquito Control Assoc 31:76-79 (1963).

89. Bay, E. C., et al. Hippelates collusor (Diptera: Chloropidae) as a host for four species of parasitic Hymenoptera in southern California. Ann Entomol Soc Am 57:582-584 (1964).

90. Gaydon, D. M., and T. R. Adkins, Jr. Effect of cultivation on emergence of eye gnats (Hippelates spp.) in South Carolina. J Econ Entomol 62:312-314 (1969).

91. Legner, E. F. Competition among larvae of Hippelates collusor (Diptera: Chloropidae) as a natural control factor. J Econ Entomol 59:1315-1321 (1966).

92. Legner, E. F. Parasite activity related to oviposition responses in Hippelates collusor. J Econ Entomol 61:1160-1163 (1968).

93. Legner, E. F., and E. C. Bay. Natural exposure of Hippelates eye gnats to field parasitization and the discovery of one pupal and two larval parasites. Ann Entomol Soc Am 57:767-769 (1964).

94. Legner, E. F., and E. C. Bay. La primera exploracion para buscar enemigos naturales de Hippelates en Puerto Rico (Insecta: Chloropidae). Caribbean J Sci 4:467-471 (1964).

95. Legner, E. F., and E. C. Bay. Culture of Hippelates pusio (Diptera: Chloropidae) in the West Indies for natural enemy exploration and some notes on behavior and distribution. Ann Entomol Soc Am 58:436-440 (1965).

96. Legner, E. F., and E. C. Bay. Ooencyrtus submetallicus Howard in an extraordinary host-relationship with Hippelates pusio Loew. Can Entomol 97:556-557 (1965).

97. Legner, E. F., and E. C. Bay. Predatory and parasitic agents attacking the Hippelates pusio complex in Puerto Rico. J Agric Univ Puerto Rico 49:377-385 (1965).

98. Legner, E. F., et al. Parasitic and predacious agents affecting the Hippelates pusio complex in Jamaica and Trinidad. Can Entomol 98:28-33 (1966).

99. Legner, E. F., et al. Influence of physical factors on the developmental stages of Hippelates collusor in relation to the activities of its natural parasites. Ann Entomol Soc Am 59:851-861 (1966).

100. Legner, E. F., et al. Behavior of three native pupal parasites of Hippelates collusor in controlled systems. Ann Entomol Soc Am 59:977-984 (1966).

101. Legner, E. F., and G. S. Olton. Migrations of Hippelates collusor larvae from moisture and trophic stimuli and their encounter by Trybliographa parasites. Ann Entomol Soc Am 62:136-141 (1969).

102. Legner, E. F., et al. Effects of low biuret urea on natural populations of Hippelates collusor (Townsend) and Leptoconops kertezi (Kieffer). Mosquito News 30:633-640 (1970).

103. Moore, L. D. A coleopterous parasite of Hippelates eye gnats of the family Staphinidae. Proc & Papers Annu Conf Calif Mosquito Control Assoc 33:61-62 (1965).

104. Mulla, M. S. Recovery of a cynipoid parasite from Hippelates pupae. Mosquito News 22:301-302 (1962).

105. Mulla, M. S. Hippelates eye gnats: control by source reduction. Pest Control 31:9, 11-12, 14 (1963).

106. Thompson, W. R. On natural control. Parasitology 21:269-281 (1929).

Chemical Control of Adults

107. Axtell, R. C., and T. D. Edwards. Susceptibility of adult Hippelates pusio to insecticidal fogs. J Econ Entomol 63:1184-1185 (1970).

108. Axtell, R. C., and T. D. Edwards. Susceptibility of adult Hippelates eye gnats to insecticide deposits. J Econ Entomol 63:1186-1187 (1970).

109. Georghiou, G. P., and M. S. Mulla. A method and results of screening insecticides against adult Hippelates eye gnats. J Econ Entomol 54:264-267 (1961).

110. Jones, R. W., and H. E. Magy. Mosquito control technique for control of Hippelates spp. (Diptera: Chloropidae). Mosquito News 11:102-107 (1951).

111. Mulla, M. S. Activity of new insecticides against adults of Hippelates collusor and H. pusio. J Econ Entomol 56:47-50 (1963).

112. Mulla, M. S., and T. S. Adams. New insecticides against adults of two species of Hippelates eye gnats. J Econ Entomol 57:505-509 (1964).

113. Rees, B. E. The Hippelates fly or eye gnat in Fresno, California, and the feasibility of its control by present mosquito abatement method. Proc & Papers Annu Conf Calif Mosquito Control Assoc 20:85-87 (1952).

Chemical Control of Larvae

114. Dow, R. P., and M. J. Willis. Evaluation of insecticides for the control of Hippelates pusio in soil. J Econ Entomol 52:68-71 (1959).

115. Georghiou, G. P., and M. S. Mulla. Resistance of chlorinated hydrocarbon insectides in the eye gnat Hippelates collusor. J Econ Entomol 54:695-698 (1961).

116. Mulla, M. S. Effectiveness of granular insecticides against eye gnats and mosquitoes as affected by toxicant concentration. Mosquito News 20:362-371 (1960).

117. Mulla, M. S. Chlorinated hydrocarbon insecticides as soil treatments against the eye gnat Hippelates collusor (Townsend) in the laboratory. J Econ Entomol 53:367-372 (1960).

118. Mulla, M. S. Loss of chlorinated hydrocarbon insecticides from soil surface in the field. J Econ Entomol 53:650-655 (1960).

119. Mulla, M. S. Loss of activity of chlorinated hydrocarbon insecticides in soil as measured against the eye gnat Hippelates collusor. J Econ Entomol 53:785-787 (1960).

120. Mulla, M. S. Organophosphorus and carbamate insecticides as soil treatments against the eye gnat Hippelates collusor in the laboratory. J Econ Entomol 53:1102-1107 (1960).

121. Mulla, M. S. Longevity of insecticides in soil as tested against the eye gnat Hippelates collusor. Mosquito News 20:376-379 (1960).

122. Mulla, M. S. Control of Hippelates gnats with soil treatments using organochlorine insecticides. J Econ Entomol 54:636-642 (1961).

123. Mulla, M. S. Resistance in the eye gnat Hippelates collusor to soil insecticides. J Econ Entomol 55:130-133 (1962).

124. Mulla, M. S. Effectiveness and residual activity of new compounds in soil against the eye gnat Hippelates collusor. J Econ Entomol 57:873-878 (1964).

125. Mulla, M. S. Field evaluations of organophosphate insecticides as soil treatments for the control of Hippelates gnats. J Econ Entomol 58:654-658 (1965).

126. Mulla, M. S., et al. Soil treatments with insecticides for control of the eye gnats Hippelates collusor and H. hermsi. J Econ Entomol 53:362-365 (1960).

127. Mulla, M. S., et al. Residual activity of organophosphorous insecticides in soil as tested against the eye gnat Hippelates collusor. J Econ Entomol 54:865-870 (1961).

128. Spielman, A. Susceptibility of an eye gnat Hippelates pusio to residual insecticides. J Econ Entomol 54:130-131 (1961).

129. Tinkham, E. R. The eye gnats of Coachella Valley with notes on the 1951 larviciding program. Proc & Papers Annu Conf Calif Mosquito Control Assoc 20:83-84 (1952).

130. Tinkham, E. R. Control of eye gnats by soil larvicides. Proc & Papers Annu Conf Calif Mosquito Control Assoc 21:67-68 (1953).

Chemosterilants

131. Mulla, M. S. Chemosterilants for control of reproduction in the eye gnat (Hippelates collusor) and of the mosquito (Culex quinquefasciatus). Hilgardia 39:297-324 (1968).

132. Schwartz, P. H. Reproduction and chemical sterilization of the eye gnat Hippelates pusio Loew. PhD Dissertation. Univ. of Florida, Gainesville, 1964.

133. Schwartz, P. H. Effects of apholate, metepa, and tepa on reproductive tissue of Hippelates pusio Loew. J Invertebr Pathol 7:148-151 (1965).

134. Williams, D. F., and L. C. Kuitert. Sterilization of Hippelates pusio with tepa and metepa. J Econ Entomol 64:448-450 (1971).

Traps

135. Parman, D. C. Construction of the box-type trap for eye gnats and blowflies. U.S. Dept Agric,Bur Entomol & Plant Quar Bull E-299 (mimeographed), 1931.

136. Parman, D. C. A box-type trap to aid in the control of eye gnats and blowflies. U.S. Dept Agric Circular 247:1-4 (1932).

137. Roberts, R. H. A steer-baited trap for sampling insects affecting cattle. Mosquito News 25:281-285 (1965).

138. Snoddy, E. L. Some aspects of trap color and design for *Hippelates pusio* (Diptera: Chloropidae). J Med Entomol 11:499-500 (1975).

139. Womeldorf, D. J., et al. A modified Tinkham *Hippelates* eye gnat trap. Calif Vector Views 10:63 (1963).

Other Control Procedures

140. Flint, H. M. The effects of gamma radiation on the fertility and longevity of *Hippelates pusio* Loew. J Econ Entomol 58:555-559 (1965).

141. Mulla, M. S. Eye gnat control. Univ. of Calif., Extension Service, One Sheet Answer No. 136, 2 pp., 1963.

142. Mulla, M. S. An ecological basis for the suppression of *Hippelates* eye gnats. J Econ Entomol 56:768-770 (1963).

143. Mulla, M. S., et al. Control of *Hippelates* eye gnats with herbicidal oils. J Econ Entomol 59:552-556 (1966).

144. Tinkham, E. R. Gnat control in the Coachella Valley. Proc & Papers Annu Conf Calif Mosquito Control Assoc 19:97-99 (1951).

Disease Association

145. Bassett, D. C. J. *Hippelates* flies and streptococcal skin infection in Trinidad. Trans R Soc Trop Med Hyg 64:138-147 (1970).

146. Bengtson, I. A. Seasonal acute conjunctivitis occurring in the Southern States. Public Health Rep 48:917-926 (1933).

147. Blancho, Y., et al. Nota sobre la transmission experimental mal del pinto medio de una mosco del genera *Hippelates*. Gac Med Mex 70:534-538 (1941).

148. Castellani, A. Experimental investigations of *Frambaesia tropica* (yaws). J Hyg 7:558-559 (1907).

149. Davis, D. L., and M. Pittman. Acute conjunctivitis caused by *Hemophilus*. Am J Dis Child 79:211-222 (1950).

150. Dawson, C. R. Epidemic Koch-Weeks conjunctivitis and trachoma in the Coachella Valley of California. Am J Ophthalmol 49:801-808 (1960).

151. Dow, R. P., and V. D. Hines. Conjunctivitis in southwest Georgia. Public Health Rep 72:441-448 (1957).

152. Graham-Smith, G. S. The Oscinidae (Diptera) as vectors of conjunctivitis, and the anatomy of their mouth parts. Parasitology 22:457-467 (1930).

153. Howard, L. O. Hippelates flies and sore eyes. Bull. No. 7, N. Ser., U.S. Dept Agric, Div Entomol, pp. 1-86, 1897.

154. Kumm, H. W. The natural infection of Hippelates pallipes Loew with spirochaetes of yaws. Trans R Soc Trop Med Hyg 29:265-272 (1935).

155. Kumm, H. W. Annual report: Entomological studies made for the Jamaica Yaws Commission during 1934. Rep Jamaica Yaws Commission for 1934, pp. 19-30, 1935.

156. Kumm, H. W., and T. B. Turner. The transmission of yaws from man to rabbits by an insect vector, Hippelates pallipes Loew. Am J Trop Med 16:245-262 (1936).

157. Kumm, H. W., et al. The duration of motility of the spirochaetes of yaws in a small West Indian fly, Hippelates pallipes Loew. Am J Trop Med 15:209-223 (1935).

158. Parra, Y. G. S., and Y. F. L. Blancho. Las moscus del genero Hippelates como posibles vectores del mal del pinto 12 a communicacion. Ciencia 4:299-300 (1943).

159. Payne, W. J., Jr., et al. The eye gnat Hippelates pusio as a vector of bacterial conjunctivitis, using rabbits as an animal model. J Med Entomol 13:599-603 (1977).

160. Roberts, R. H. A feeding association between Hippelates (Diptera: Chloropidae) and Tabanidae on cattle: its possible role in transmission of anaplasmosis. Mosquito News 28:236-237 (1968).

161. Roberts, R. H., and J. N. Love. The potential of Hippelates pusio Loew (Diptera: Chloropidae) as a vector of anaplasmosis. Proc 6th Natl Anaplasmosis Conf, Las Vegas, Nev., pp. 121-122, Mar 1973.

162. Roberts, R. H., et al. Culicidae and Tabanidae as potential vectors of anaplasmosis in Mississippi. Ann Entomol Soc Am 62:863-868 (1969).

163. Roy, D. N. Report on investigation into etiology and prevention of Naga sore in Assam. Indian Med Gaz 63:673-687 (1928).

164. Sanders, D. A. Hippelates flies as vectors of bovine mastitis (preliminary report). J Am Vet Med Assoc 97:306-308 (1940).

165. Sanders, D. A. Musca domestica and Hippelates flies — vectors of bovine mastitis. Science 92:286 (1940).

166. Schneider, A. An introductory report on pseudotrachoma endemic in the Salton Sea Region of California. Med Sentinel 35:154-161 (1927).

167. Snoddy, E. L., et al. Studies on the bacterial flora of Hippelates pusio (Diptera: Chloropidae). J Med Entomol 11:226 (1974).

168. Taplin, E., et al. Infection by Hippelates flies. Lancet 2: 472 (1967).

169. Taplin, D., et al. Skin infections in a military population, ch. 1, pp. 3-12. In: Developments in Industrial Microbiology, vol. 8. Washington D.C.: Am Inst Biol Sci, 1967.

170. Vargas, L. Nota sobre el papel que se atribuye a los Chloropidae en la transmission de enformedades. Medicina 21:306-310 (1941).

171. Wilson, P. W., and M. S. Mathis. Epidemiology and pathology of yaws. JAMA 94:1289 (1930).

Taxonomy

172. Aldrich, J. M. Notes on Hippelates (Diptera: Chloropidae) with a new Brazilian species. Proc Entomol Soc Wash 33:69-72 (1931).

173. Kumm, H. W. The Jamaican species of Hippelates and Oscinella (Diptera: Chloropidae). Bull Entomol Res 27:307-329 (1936).

174. Mallock, J. R. The genera of flies in the subfamily Botanabunae with hind tibial spur. Proc US Natl Mus 46:239-266 (1913).

175. Sabrosky, C. W. The Hippelates flies, or eye gnats: preliminary notes. Can Entomol 73:23-27 (1941).

176. Sabrosky, C. W. On the distribution and correct name of Oscinis pallipes, the swarming gnat of the Sudan. Bull Entomol Res 40:61-62 (1949).

177. Sabrosky, C. W. Nomenclature of eye gnats (Hippelates spp.) Am J Trop Med 31:257-258 (1951).

178. Se'quq. Insectes dipterous dugonere Hippelates Loew recuellis en Colombie et aw Venezuella liste et characteres des especes. Ann Parasitol Hum Comp 18:233-244 (1941).

179. Stiner, F. M., et al. Differentiation of Hippelates pusio, H. bishoppi, and H. pallipes (Diptera: Chloropidae) by electrophoresis. J Med Entomol 8:213-216 (1971).