AN ANNOTATED BIBLIOGRAPHY OF PAPERS RELATING TO THE CONTROL OF MOSQUITOS BY THE USE OF FISH (REVISED AND ENLARGED TO 1965) ¹

by

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¹ The greater part of this revision of an earlier bibliography (Gerberich, 1946) was undertaken while the senior author was serving as a consultant to the World Health Organization (Environmental Biology, Division of Environmental Health) in August, 1965. It should be observed that a number of the references appearing herein were not seen in the original and have yet to be checked for accuracy of detail (see p. 7-8).

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Ce document ne constitue pas une publication. Il ne doit faire l’objet d’aucun compte rendu ou résumé ni d’aucune citation sans l’autorisation de l’Organisation Mondiale de la Santé. Les opinions exprimées dans les articles signés n’engagent que leurs auteurs.
SYNOPSIS

For almost half a century prior to the widespread and spectacularly successful adoption of vector control procedures based upon the persistent synthetic organic pesticides, a great deal of attention had been paid to the biological control potentialities of mosquito-eating fish. Very many pertinent observations from nature were published, together with the results of laboratory studies and practical field experience with indigenous and exotic larvivorous species. Reaching its peak in the decade 1921-1930, during which Gambusia affinis was exported from the United States of America to Spain and thence introduced into various parts of Europe and North Africa, interest in the subject then began to wane. After the advent of DDT it continued to decline, falling to its lowest point just as insecticide resistance began to assume prominence in the mid 1950's. Today, in answer to problems posed by both resistance and the non-selectivity of some widely used and long-lasting insecticidal compounds, there is a marked trend towards the concept of integrated control on the part of public health entomologists. This is causing biotic control factors to receive renewed consideration, as is evident from the fact that the volume of literature on larvivorous fish over the past five years almost equalled that for the preceding decade. Therefore, the most recent annotated bibliography on the subject having been published 20 years ago, and many overlooked earlier references having been noticed since then, it was felt timely to prepare this up-to-date version as a service to research.

* * *

INTRODUCTION

Relatively little was known concerning the biometrics of mosquitoes prior to 1880, the date of the first reference herein, and for all practical purposes the history of mosquito control only commences at the very end of the nineteenth century. Pertinent research received much impetus from such diverse factors as the elucidation of the mosquito transmission of malaria and yellow fever, and the need for effective vector control during the building of the Panama Canal and particularly during the two
World Wars; in both of which very large bodies of men brought into areas where vector-borne diseases were endemic, became exposed to infection for the first time. Progressively more rapid means of transportation, and the development of contacts between peoples in widely separated regions, also complicated control problems and posed new hazards in this period.

In reviewing the literature on the use of fish for the control of mosquitoes, steady growth in research and practice is evident until about 1930. Thus approximately 4.5 per cent. of the existing references appeared in 1901-1910, when notable landmarks were: the first purposeful use of larvivorous fish against container-utilizing mosquitoes, one of the results of the emphasis placed upon sanitational measures for *Aedes aegypti* control through the dramatic eradication of yellow fever from Havana at the turn of the century; and the first long-distance transplantation of the mosquito-fish, \(^1\) *Gambusia affinis* (Baird & Girard), from its native southern United States (specifically Seabrook, Texas, in this instance) to Hawaii, \(^2\) in 1905 (Van Dine, 1907). Also, in 1909, an unsuccessful effort was made to acclimatize the guppy, \(^3\) *Lebistes reticulatus* (Peters), in India (O'Donnell, 1930). In 1911-1920, when 18 per cent. of the existing literature on larvivorous fish was published, major stimuli to the development of effective mosquito control methods were provided by World War I and the construction of the Panama Canal. Initially unsuccessful attempts to establish *L. reticulatus* in new areas (e.g. South Africa - Gilchrist, 1913; Malaysia - Strickland, 1913, 1915) continued to take place, the results sometimes not becoming apparent until long afterwards (e.g. the discovery of thriving colonies of guppies in Singapore - Johnson & Soong, 1963; and Thailand - Sasa et al., 1964). More

\(^1\) To use the common name recommended by the Committee on Names of Fishes, American Fisheries Society, 1959 (A list of the common and scientific names of fishes from the United States and Canada, 2nd Ed., Amer. Fish. Soc. Spec. Publ. No. 2, Waverly, Baltimore, 102 pp - 1960). *G. affinis* and its subspecies are also widely referred to as "top-minnows", or simply as "Gambusia".

\(^2\) Whence it was introduced to various parts of the Pacific, including the Philippines (in 1913 - Seale, 1917) and many island groups where (as during World War II) the acclimatizations went unrecorded.

\(^3\) Often referred to as the "Barbados millions", "millions fish" or simply, "millions". Early references to *Giardinus poeciloides* relate to *L. reticulatus* too.
significantly, though, purposeful establishments of G. affinis were being made
(although to a large extent against container-utilizing mosquitos) in Mexico, Central
and South America (Anon., 1921a, 1921b, 1921c) in connexion with the widespread drive
against yellow fever instituted with the support of the Rockefeller Foundation.

At the opening of the following decade, which saw the appearance of some 30 per
cent. of all papers on larvivorous fish published between 1880 and 1965, perhaps
the most momentous event in the earlier history of biological control in public health
entomology took place. For in 1921, Gambusia affinis \(^1\) was successfully introduced
into Spain from the United States of America (Anon., 1926; De Buen & De Buen, 1922;
Lozano, 1942). This fish, soon to become the best-known of all larvivores, was
taken from Spain to Italy in the following year (Sella, 1927). The resultant
Italian stock was the source of similarly successful introductions into Yugoslavian
islands in the Adriatic in 1924 (Trausmiller, 1932), Transcaucasia \(^2\) in the same year
(Kalanadze & Mchelidze, 1930), Algeria (Sergent & Sergent, 1927) and Corsica (Brumpt,
1928) in 1926, and Greece in 1928 (Balfour, 1936). From Corsica, mosquitofish were
taken to Egypt and thence to Cyprus, Syria and the Sudan (Khalil, 1930). In the North
American continent, there were even successful acclimatizations as far north as
Chicago, Illinois, in 1923 and 1925 (Krumholz, 1948a) and (in thermal waters) Banff,
Alberta, Canada, in 1924 (Gibson, 1927; Hearle, 1928; Mail, 1954).

\(^1\) Interestingly enough, there was much confusion, to this day not fully resolved,
as to the subspecies (or species, according to the rankings then prevailing)
concerned. Although De Buen and De Buen (1922) referred uncompromisingly to
G. affinis, later authorities, although dealing with descendants of the same stock
of fishes, used other names. Thus Artom (1924) asserted that the mosquitofish
originally imported into Spain was G. holbrooki (today accorded only subgeneric
status as G. affinis holbrooki), while Boettger (1933) stated that G. patruelis was
the correct identification. AS CERTAINTY ON THIS POINT IS OBVIOUSLY MUCH TO BE
DESIRED, THE ENVIRONMENTAL BIOLOGY UNIT, WORLD HEALTH ORGANIZATION, GENEVA, WOULD
WELCOME CONSIGNMENTS OF GAMBUSIA (PRESERVED IN SEVEN PER CENT. FORMALIN) FROM ANYWHERE
IN THE EUROPEAN AND EASTERN MEDITERRANEAN REGIONS FOR ONWARD TRANSMISSION TO AN
APPROPRIATE ICHTHYOLOGIST.

The Secretariat

\(^2\) Thence subsequently to various other parts of the USSR (Rukhadze, 1934;
Sokolov, 1936, 1958).
As is evident from the following pages, some of these aclimatizations were well-conceived, against a background of sound ecological information. Others were not, examples of *G. affinis* simply being placed in mosquito larval habitats without any prior reference to the ecological parameters of the species in general or of the subspecies and strain involved in particular. Introductions of the latter sort either failed completely or at best gave indifferent results, differing radically from the achievements of carefully planned work in this field. Partly because of this, partly because many had naively expected *Gambusia* to eradicate anophelines rather than to simply add its weight to pre-existing natural population-limiting factors, and probably to some extent as a result of the disruption entailed by the worldwide depression, interest in the potentialities of larvivorous fish as practical mosquito control agents began to fall off. The trend was quite slight at first, and in fact during the 1930's great success attended the regional use of *Gambusia* on a sound ecological basis, in the USSR (Beklemishev & Raevskii, 1935; Danilov & Lappin, 1936; Gromov, 1940; Kulagin & Martzinovskii, 1936; Petriščeva, 1936; Sokolov, 1936; etc.). Work on cold-hardy strains of mosquito fish proceeded too, e.g. in the Central Ukraine (Shapkin, 1940), and in the same period brackish-water strains of the descendants of the original stock first introduced into Europe in 1921 became adapted to Black Sea coastal areas of the USSR (Prondel et al., 1932) and to strongly saline lagoons in Morocco (Sicault, 1934). Nevertheless, in 1931-1940, the percentage of the over-all literature published fell from the 30 per cent. of the preceding decade to 21.5 per cent.

This trend continued after the introduction of DDT during World War II and the momentous successes achieved with this and other persistent synthetic organic pesticides then and in the latter part of the 'forties. Thus while as recently as 1943 a consignment of the original European *G. affinis* stock was sent from Spain to the Canary Islands to help combat a malaria outbreak there - (Najera, 1944), the above figure fell to 14.5 per cent. for the years 1941-1950. In the 'fifties, when only six per cent. of the over-all literature on larvivorous fish appeared\(^1\) - the lowest

\(^1\) With further attention to cold-hardy strains of *G. affinis*, D. L. Smith (1960) demonstrated successful overwintering under outdoor conditions at Winnipeg, Manitoba, Canada.
10-year figure for half a century - the attention of the great majority of medical entomologists continued to be focused upon either control methodologies based on the synthetic insecticides, or (increasingly, as the decade progressed) the developing problems of insecticide resistance and non-selectivity. It was these problems that, in the late 'fifties, stimulated some investigators to begin to reconsider the place of biological control in public health entomology (Laird, 1959). WHO's long-term biological control research programme dates from this period, and there is now every indication that the research pendulum has begun to swing in the other direction; for in the first half of the 1960's, almost as many papers on larvivorous fish appeared as in the whole of the preceding decade. It is encouraging to note that several of these papers (Bay, 1965, 1966; Haas, 1965, 1966; Hildemann & Walford, 1963; Kovchazov & Kolarov, 1966) concern a hitherto overlooked group of predators of great potential significance. This group of South American and African cyprinodonts have desiccation-resistant eggs, rendering them highly suitable as candidates for introduction into temporary pools to which the viviparous Gambusia and Lebistes are quite un-adaptable, but which constitute anopheline larval habitats of major importance in, for example, Filanesia.

The present compilation consists of an annotated bibliography of papers in which observations, studies or trials relating to larvivorous fish are reported.¹ Data summarized in the respective entries often simply being repeated from contemporary abstracts,² it should be pointed out that many of the scientific names mentioned have long been outmoded. While appropriate emendations have been made in a few instances (e.g. as regards such well-known mosquitoes as Aedes aegypti and Culex pipiens fatigans), there is obvious need to bring the names of some Culicidae and numerous fish into line with modern usage - a task for which there was no time in this project.


²Biological Abstracts and the Review of Applied Entomology, Series B, were the sources of much of the information reproduced herein.
Besides containing much information of historical interest as well as practical significance, as already outlined in this Introduction, these papers serve to illustrate basic research trends of great importance to the future of public health entomology. Thus it is clear from the more recent of them not only that greater attention is now being given to such topics as the acclimatization and genetics of larvivorous fish, and their adaptability to specific types of habitats, but also that the investigators concerned are looking more and more into the feasibility of developing selective integrated control methodologies in which both pesticides and fish and other biotic agents have their own roles to play (Mulla, 1961, 1963a; Mulla & Isaak, 1961). More care is being given today to the selection of larvivores the habits of which correlate closely with those of the immature stages of the particular target mosquito concerned, and just as the potentialities of "annual" fish are today under critical evaluation through WHO-co-ordinated work in several parts of the world, there would seem to be no lack of other promising candidates for this kind of attention; for example, the South-east Asian Panchax panchax (Brahmachari, 1909; Chandhuri, 1911; Hora & Nair, 1938), also marsh-dwelling cyprinodonts from Nigeria (Graham, 1911; Mattingly, 1952) and electrids from Fiji (Laird, 1956, 1959). Also, there are lessons to be learnt from past experience, particularly from pre-war studies in Indonesia, on the potentialities of employing combinations of fish that occupy different niches in the same biotope and complement one another as mosquito control agents - e.g. fish that feed on algae and other aquatic vegetation facilitate the access of predaceous species to larvae (Schuster, 1942; Soesilo et al., 1933; Walch & Schuurman, 1929; Walch & Soesilo, 1937). This type of biotic activity can be termed "bio-synergistic", the combined effects of different biotic agents greatly exceeding the effect which either is able to produce alone.

REQUEST FOR NOTIFICATION OF OMISSIONS AND CORRECTIONS

The authors concede that many pertinent references are likely to have been overlooked, especially where information on larvivorous fish has been included in the body of a paper primarily devoted to a broader topic. Notifications of such omissions
would be greatly appreciated, as would corrections to incomplete or otherwise imperfect literature citations. Such information could be mailed to either of the authors at the addresses shown at the head of this contribution.

ACKNOWLEDGEMENTS

Appreciation is expressed for the helpfulness of the undermentioned during the preparation of this bibliography, in the course of which the senior author visited libraries in the United States of America, and London, England. In addition to the institutions mentioned in this list, reference was also made to the libraries of the London School of Hygiene and Tropical Medicine and Imperial College, London, and while the bibliography was being assembled at Geneva, World Health Organization files were consulted too.

Miss Delia Anderson, Reference Librarian, Wisconsin State University, Eau Claire, Wisconsin.

Miss Chant, Assistant Librarian, Commonwealth Institute of Entomology, London.

Capt. J. D. DeCoursey, U.S.N., Military Entomology Information Service, Forest Glen Section, Walter Reed Army Medical Center, Washington, D.C.

Dr Carlton M. Herman, Patuxent Wildlife Research Center, Laurel, Md.

Dr J. Mathewson, Department of Entomology, University of Rhode Island, R.I.

Dr P. F. Mattingly, Department of Entomology, British Museum of Natural History, London.

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RESUME

Pendant près d'un demi-siècle avant que ne se généralise avec un succès spectaculaire l'application de méthodes de lutte contre les vecteurs fondées sur l'emploi de pesticides organiques de synthèse à effet rémanent, on s'était beaucoup intéressé aux possibilités offertes dans ce domaine par la lutte biologique au moyen de poissons insectivores. On avait publié de très nombreuses observations effectuées en milieu naturel, ainsi que les résultats d'études en laboratoire et d'expériences pratiques portant sur diverses espèces larvivores trouvées sur place ou importées. Après avoir atteint son apogée au cours de la période 1921-1930, pendant laquelle Gambusia affinis a été exporté des États-Unis d'Amérique en Espagne et introduit ensuite dans diverses régions d'Europe et d'Afrique du Nord, l'intérêt porté à cette question a commencé à faiblir. Cet intérêt a continué à baisser après l'entrée en scène du DDT et est tombé à son point le plus bas au moment précis où la résistance aux insecticides a commencé, vers 1955, à susciter de sérieuses inquiétudes. Aujourd'hui, devant les problèmes posés tant par la résistance des vecteurs que par la non-sélectivité de certains des composés insecticides à action durable les plus utilisés, les entomologistes de la santé publique ont nettement tendance à concevoir la lutte contre les vecteurs sous une forme intégrée. C'est pourquoi les moyens de lutte biologique font l'objet d'un renouveau d'intérêt, comme le prouve l'abondance des documents qui ont été publiés depuis cinq ans sur les poissons larvivores et qui sont presque aussi nombreux que les documents publiés sur la même question pendant les dix années précédentes. Comme la bibliographie annotée la plus récente sur cette question avait paru il y a vingt ans et comme de nombreuses références antérieures avaient échappé à l'auteur et ont été retrouvées depuis lors, il a semblé opportun d'en mettre une nouvelle version revisée à la disposition des chercheurs.
BIBLIOGRAPHY


Aders, W. M. (1913) Entomology in relation to public health and medicine. Med. and Sanit. Report, Zanzibar, 76-82. During 1912, a consignment of fish, Haplochilus playfairii, arrived from the Seychelles. They proved to be voracious feeders on mosquito larvae and this was also the case with young mullet, Mugil sp. and sea perch, Ambassis commersonii.

Aders, W. M. (1917) Insects injurious to man and stock in Zanzibar. Bull. ent. Res., 7, 391-401. Fish imported from Seychelles were of some use in wells and tanks (e.g. against A. aegypti) but in the larger swamps their efficiency was uncertain.

Afanasev, S. F. (1944) Some facts on Gambusia viability and other phenomena observed during its dissemination in the reservoirs of the Checheno-Ingushetian Republic (In Russian) Med. Parasitol., 12, 71-73. Outlines experiments with the propagation of G. affinis in reservoirs fed by springs of warm water and not freezing over in winter, indicated the feasibility of extending the dissemination of these fish north of the fiftieth parallel. Other studies indicated that individual specimens will remain alive for four days in reservoirs which are almost dry, if the temperature does not rise above 18°C and the humidity does not fall below 85 per cent., and if there is absence of direct, full sunlight. Under these same conditions some Gambusia can live entirely out of the water for 6-1/2 hours.


Ahuja, S. K. (1964) Salinity tolerance of Gambusia affinis, - Indian J. Exper. Biol., 2, 9-11. Laboratory experiments, allowing for periods of acclimatization, provided for the exposure of G. affinis to gradually increasing salinities. At a salinity of five per cent. the mortality was 50-55 per cent. When the salinity stood at eight per cent., 95 per cent. or more of the fish died.

Aitken, E. H. (1901) Notes on Anopheles or malaria mosquito. Jour. Bombay Nat. Hist. Soc., 12, 695. The author advocated two species as particularly useful against anopheine larvae, one the indigenous "piku" fish (Panchax lineatus) and the other the exotic goldfish (Carassius auratus).

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1 This fish (= Lebias dispar, Aphanius dispar) occurs in Ethiopia, Israel and the Red Sea area in general. Thirty years ago Dr E. P. Hicks mentioned it as being established in a spring and brackish drain (273.9 parts NaCl:100 000 water) lacking mosquito larvae at Karachi Airport (Hicks & Diwan Chand, 1936; Prashad & Hora, 1936).
Alcock, A. (1902) *A Naturalist in Indian Seas*, p. 201 London. Alcock observed at Aucutta-Island (Laccadive Is.) that the wells and tanks "positively swarmed with a little species of carp (*Barbus*), and with two species of sea-fishes acclimatised to fresh water". As a result no mosquitoes were found on this island, while they were abundant on the adjacent island of Minnikoy where these fishes were almost absent from the wells and tanks.

Alcock, A. (1920) *Entomology for Medical Officers*. 2nd Edition, 70-72. London. Fishes were placed first among the natural enemies of mosquito larvae (particularly surface-feeding ones and especially Cyprinodontidae, which are widespread in low latitudes and have broad environmental tolerances).

Ambialet, R. (1937) Observations sur la campagne antipaludique de 1936 et sur les campagnes antérieures dans le département de Constantine. *Arch. Inst. Pasteur* Alger 15, 389-410. A discussion of the use of *Gambusia* in Algiers against anopheline larvae, with attention to some of the reasons why they did not give satisfactory results, and suggestions for means by which their rearing and distribution might be more satisfactorily carried out.


Anon. (1913a) *Directoria Geral Do Servico Sanitario*, Instruccoes sobre a prophylaxia do-impaludismo. *São Paulo, Diario oficial*, 9 pp. W. P. Seal of the US Bureau of Fisheries, suggested for use in this region a small insect-eating fish called the "anablis" 1 which is found in the fresh waters of South America. Also, the "guaracaru", a poecilid of southern Brazil, is said to have all the qualities that should make it useful except that it feeds on decaying organic matter as well as insects.


Anon. (1915c) Insect notes from the Seychelles. *Ann. Rept. on Agric. and Crown Lands for the Year 1912, Victoria, Seychelles*, p. 17. In connexion with the control of mosquito larvae (mostly Aedes of the subgenus Stegomyia) an experiment was conducted with a local small fish called "goujon" - (Haplochilus) = Pachypanchax playfairii - differing little in habits from the celebrated "millions" fish of Barbados (*Lebistes reticulatus*). In a small basin where mosquito larvae were teeming, 50 goujons were introduced one afternoon. The next morning not a single larva could be found and none was found afterwards. The fish, after two months, began to multiply considerably.

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1 The Andean catfish, *Astroblepus* sp? (see Myers, 1925)
Anon. (1913d) 12th Annual Report of the Philippine Islands Bureau of Science, Manila, p. 67


Anon. (1915) Fish as larvicides. Annual Medical and Sanitary Report of the Colony for 1915, Bathurst, Gambia, p. 15

Anon. (1916) 15th Annual Report of the Philippine Islands Bureau of Science, Manila, p. 27

Anon. (1917) Work in the botanic gardens and observations on plants. Rept. Agric. Dept. St Vincent for 1916-1917, Barbados, 1-3. Girardinus pocciloides\(^2\) ("millions" fish) flourished in a lily pond in the gardens, keeping down mosquito larvae. Fish from this pond introduced into swamps in two malarial districts became well established.


Anon. (1919b) Fish as a factor in mosquito control. J. Amer. med. Assoc., 73, 342

Anon. (1920) Les moustiques et les canards. Jour d'Agric. Pratique, 23, 364. An experiment is recorded in which two basins of equal size were made in a mosquito-infested stream, one being stocked with fish and the other with ducks. That containing fish continued to show mosquitos in all stages, but after two days that containing ducks was freed from mosquito larvae and pupae.

Anon (1921a) Fighting mosquitoes with fish. 7th Ann. Rept. 11th Bd., Rockefeller Foundation, 1920, New York, 20-23. Emphasizes the value of top-minnows (Gambusia affinis) as destroyers of Anopheles larvae. In 89 per cent. of the waters in Hinds County, Mississippi, in 1919 and in 85 per cent. in 1920, mosquito breeding was completely controlled thereby. When this paper went to press, the method was being practised against Aedes aegypti in Mexico, Central America and Peru.

Anon. (1921b) Top minnows as yellow fever eradicators. Science, 53, 423-433. In view of the success that has attended the use of Gambusia in eradicating anophelines in various parts of the United States, this method was adopted against Aedes aegypti at Tampico, Mexico, in preference to oilling.

\(^1\) = Panchax panchax (Buchanan-Hamilton).

\(^2\) = Lebistes reticulatus.
Anon. (1921c) U.S. Bur. Fisheries Bull. 71. Gambusia proved useful in Mexico and Central America as a means of controlling Aedes (Stegomyia) in barrels, tanks, and other receptacles used for catching and storing rain water for domestic purposes, in which crude oil could not be used.

Anon. (1921d) Prompt mosquito control by use of the top-minnow, Gambusia. Public Health Rept., U.S., 56, 2220-2221. A case is recorded in which the numbers of anopheline larvae were greatly checked by the introduction of Gambusia into a pond.

Anon. (1922a) Proceedings of the Hayling Island Mosquito Control Assn. from sept. 1920 to June 1922. Southsea, England, 12 pp. Antimosquito work at Hayling Island during 1922 included experiments with larvicial fish. In this connexion, Gobius microps, found in sea-filled ditches, gave promising results against Aedes (Ochlerotatus) detritus.


Anon. (1924) Use of fish for mosquito control. Internat. Hlth Bd. Rockefeller Foundation, New York, 120 pp. Summarizes the literature (217 titles) on fish as mosquito larvivores, and includes brief biological data and photographs of most of the species referred to. Mentions that it had been a household custom for generations in the United States of America to keep such fish as perch in shallow wells to reduce mosquito breeding and "purify the water". States (p. 96) that "it is evident that fish are of no use where mosquitoes breed in ... moist spots where water is not permanent".

Anon. (1926) Brit. med. J., 3442, 1237. Data furnished by the Malaria Commission of Spain indicated that Gambusia (introduced from the United States in 1921) had become well acclimatized and was proving useful.

Anon. (1927a) The use of American fish to fight Italian mosquitoes. Science, 66, Suppl. p. xii. Following the introduction of large numbers of Gambusia into Italy, the fish was flourishing in all the malarial regions of the latter country from Istria to Sicily. Small ponds, large lakes, and fresh or slightly salt water were all favoured habitats. Gambusia had been found able to resist high temperature and other unfavourable conditions.

Anon. (1927b) Principles and Methods of Antimalarial Measures in Europe. Second General Report of the Malarial Commission, League of Nations Health Organization, Genoa, 95 pp. In Spain, great success was being reported with respect to introductions of Gambusia into pools used by cattle.

Anon. (1933) Fish for control of mosquito in Shanghai. Chinese Med. J., 47

Anon. (1933) Report of the Health Division of the Rockefeller Foundation for 1933. Advocates use of as many as possible different naturalistic control measures, including the use of fish, in the same places pointing out that while individual biological aids are "fickic" when used alone, they may be made 100 per cent. effective in combination.


Anon. (1947) Malaria control on impounded water, USPHS & TVA, U.S. Govt. Printing Office, Washington, D.C. xiii + 422 pp. Some state health department impoundage regulations require that small reservoirs be stocked with Gambusia, Fundulus, etc., rates of 100 to 200 minnows per acre being recommended where top-feeding minnows are not already present in the stream feeding the lake. The fish may be obtained from nearby streams, ditches or ponds, or they can be supplied from state or federal fish hatcheries.

Anon. (1958) Fish culture in rice fields: a preliminary review and annotated bibliography. Indo-Pacific Fish Counc. Proc., FAO Fisheries Division, 7, 193-205. The history and widespread use of this practice is briefly reviewed, and species constituting the fish crop in rice fields in different countries are enumerated.


Armoult, J. (1959) Poissons des eaux douces. Faune Madagascar No. 10, 38-39. The cyprinodonts, Pachyrchanax homolopterus and P. playfairii, occur in Madagascar, into which Lobotites reticulatus and Xiphophorus hellerii have been introduced as larvivores.

¹,² See comment in Tamashiro. 1964.
Artom, C. (1924) La specie di Gambusia acclimatata in Italia (Gambusia holbrooki) in relazione alla stabilità del carattere del gonopodi. Atti R. Accad. Naz. Lincei, Rend. Classe sci. fis., mat. e nat., 32, 278-282. In the United States, representatives of the genus Gambusia are distributed as follows: G. holbrooki, in a zone between the States of Virginia and Alabama; G. patruelis from the State of Florida to the State of Texas; and G. affinis from Florida to Tampico, Mexico. The species imported into Spain and Italy, and subsequently established there, is G. holbrooki. The development of this species in Italy is more rapid than in the United States.

Ascoli, Vittoria (1915) The use of fish in mosquito control. (In Italian) In his La Malaria: parasitologia, patologia e clinica, pp. 838, 947-948, Torino

Asnes, S. M. (1939) Results of observations on the colonization by Gambusia of rice fields in the Azovris district of Mariopol, Stalino region, in 1938. (In Russian). Med. Parasitol., 2, 354-365. From experiments carried out in July 1938, 800 adult Gambusia were established in a 500 square yard rice field area densely populated by larvae of Anopheles maculipennis, the author concluding that to achieve satisfactory control the fish should be released in June at the rate of two to three per 10 square feet.


Balfour, A. (1925) Report on medical and sanitary matters in Bermuda, 1923, 91 pp. London, Crown Agents for the Colonies. Goldfish proved useful larvivores in tanks, barrels, etc., but failed to survive in exposed cisterns where summer temperatures could reach 100°F. In such habitats an indigenous fish, Fundulus bermudae, was used. The latter species readily devours mosquito larvae, but as it also feeds on vegetable matter, cisterns must be kept free from algae.
Balfour, A. (1928) Health lessons from Bermuda. *Brit. Med. J.*, 3506, 447-448. *Fundulus bermudae*, was reported to keep down the number of *Culex pipiens fatigans* and *Aedes* spp, a natural balance having been established. It is suggested that fish and predatory arthropod larvae may have been a factor in preventing the establishment of *Anopheles* on this malaria-free island, where there must have been frequent past opportunities for introductions; although the possible significance of adverse physico-chemical conditions in local surface waters must also be admitted.

Balfour, M. C. (1936) Some features of malaria in Greece and experience in its control. *Riv. Malariol.*, 15, 114-131. *Gambusia* was introduced into Greece from Italy in 1928, and a special field study of its action was conducted. It was doubted, however, whether the fish could control the larvae of *Anopheles superpictus* in torrents subjected to floods. No follow-up information was available on the effectiveness of the control measure.

Ballow, H. A. (1908) Millions and mosquitoes. Imperial Dept. of Agriculture for the West Indies, Barbados. Pamphlet ser. 55, 16 pp. Introduction of the "millions" fish into Panama did not result in its establishment.

Bana, F. D. (1943) A note on the adaptability of *Anopheles stephensi* to breed in salt water in Bombay, with some observations on larvivorous fish. (Abstract) *J. Malar. Inst., India*, 5, 123


Barber, M. A. (1928) Malaria survey in irrigated regions of the Rio Grande River, New Mexico. *Southern med. J.*, 21, 737-738. Two species of *Gambusia* were introduced against *Anopheles maculipennis* in 1927, and one had begun to multiply by the late summer.


Barber, M. A., Komp, W. H. W. & King, C. H. (1929) Malaria and the malaria danger in certain irrigated regions of south western United States. *Pub. Hith Rep.*, 44, 1300-1315. Great variability was observed in the effectiveness of *Gambusia* against anopheline larvae in drains, and there was some evidence that these fish are more effective against some species of *Anopheles* than others due to differing larval habitats. The widespread use of *Gambusia* is, however, recommended, at least in the warmer areas.
Barber, M. A. et al. (1915) Malaria in the Philippines. Phil. J. Sci., 10(B), 177-245. Fish mentioned among natural enemies of stream-breeding anophelines.

Barney, R. L. & Anson, B. J. (1920) Relation of certain aquatic plants to oxygen supply and to capacity of small ponds to support the top minnow, Gambusia affinis. Proc. Amer. Fish. Soc., 1, 268-278


Bay, E. C. (1965) Instant fish! - a new tool for mosquito control? Pest Control Magazine, 33, 14-16 and 58. A unique group of fishes from the highlands of Argentina and Brazil and others from parts of Africa show promise for mosquito control where breeding sources exist a few months out of the year. The adaptability of these fish, Aphyosemion, Nothobranchius from Africa; Cynolebias from Argentina and Brazil and Simpsonichthys from Brazil, to permanent mosquito larval habitats in the south-western U.S. is now under study by the Department of Biological Control at the University of California, Riverside.

Bay, E. C. (1966) Adaptation studies with the Argentine Pearl Fish, Cynolebias bellottii, for its introduction into California. WHO/EBL/66.68 (mimeographed)

Beklemishev, H. N. & Raevskii, G. E. (1935) On entomological research concerning malaria in provincial institutions. III. Methods of utilizing Gambusia under conditions of a given region/ (In Russian) Med. Parasitol., 4, 327-328. This deals with the utilization of Gambusia against anopheline larvae in permanent and temporary accumulations of water. Factors to be considered in determining the prospects are briefly discussed.

Bentley, C. A. (1910) The natural history of Bombay malaria. Journ. Bombay Nat. Hist. Soc., 20, 392-422. Panchax lineatus was found very useful as a larvicide when present in sufficient numbers and not "hampered by floating weeds or rubbish". It proved particularly effective for clearing wells of mosquito larvae; Anabas testudineus ("Kazari"), also a surface-feeder and well-adapted to life in large containers, was found to destroy both larvae and pupae of Anopheles. Polyacanthus cupanus (Macropodus cupanus), while larvivorous, was less so than A. testudineus. "Chilwai" (Chela argentea), were felt to be of less practical significance than any of the other three species.
Bernard, C. J. (1944) Une methode biologique pour lutter contre la malaria. *Acta Tropica* (Basel), 1, 285-288. Satisfactory anopheline control in Indonesia (then the Dutch East Indies) by the "bandeng" (*Chanoïa chanos*) and the "kapala tima" (a cyprinodont, *Panchax panchax*) is described.

Bhasker, R. R. & Ramoo, H. (1942a) Some notes on the practical aspects of mosquito control in wells and tanks by the use of larvivorous fish. *Jour. Malar. Inst. India*, 4, 341-347. Reviews various factors that might have contributed to the disappearance of *Gambusia affinis* and *Apolocheilus* (*Panchax*) *parvus* from wells into which they had been introduced for the control of anopheline larvae, in the light of observations made in Pattuk-kattae Taluk, Madras. In reservoirs, the native *A. parvus* seemed to survive without special measures, but *G. affinis* did so only if measures were taken to exclude larger predatory fish and to prevent this species from being washed away with the discharged water if the reservoir overflowed.

Bhasker, R. R. & Ramoo, H. (1942b) Observations on the relative utility of *Gambusia affinis* and *Panchax parvus* in the control of mosquito breeding in wells and tanks. *Jour. Malar. Inst. India*, 4, 633-634. Laboratory and field experiments indicated the usefulness of *Gambusia affinis* (which had been acclimatized in India for 12 years) for the control of mosquitoes breeding in wells and reservoirs in Pattuk-kattae, Madras. *G. affinis* is easier to rear in large numbers than the indigenous *Apolocheilus* (*Panchax*) *parvus*. It consumes more larvae, thrives better in wells, is more effective in the wells and is more adaptable to diverse environmental conditions than the latter species, which is not suited for use in confined waters.


Biriukov, V. I. (1944) *Acclimatization of Gambusia in the Kharkov district* (In Russian) *Med. Parasitol.*, 13, 91-92. Though it was formerly thought that *Gambusia affinis* could not be acclimatized in reservoirs in the northern Ukraine, an establishment in October 1938 in a reservoir near Kharkov survived the winter, the fish multiplying to great numbers the following summer.

Boettger, C. R. (1933) Ueber die Artzugehörigkeit des in Italian zur Malaria- bekämpfung eingeführten Zahnkarpflings. *Zool. Anz.*, 105, 9-14. An investigation of the morphology of the species of *Gambusia* acclimatized in Italy for the control of mosquito larvae, showed it to be not *G. holbrooki*, as had been generally believed, but *G. patruelsis*.


Bogoyavlenskii, N. A. (1936) Failure of Gambusia to destroy Anopheles larvae in nature. Arch. Schiffs.-u. Tropenyg., 40, 201-203. A close association of anopheline larvae (A. maculipennis, A. superpictus, A. pulcherrimus, A. claviger) and Gambusia was observed in various localities of the Lenkoran district, but the larvae were not destroyed because of a great profusion of water plants which afforded mechanical protection for the mosquitoes and abundant food for the fish.


Borthwick, T. (1923) An anti-mosquito campaign in delade. Health, 1, 259-265. Among numerous control measures applied, indigenous larvivorous fish (including Melanotaenia nigrans, Priopis olivaceus and Carassius galii) were reared in large numbers to stock the waters.

Bose, K. (1925) (extract from a report on mosquito control at Birnagar) Calcutta Med. Jour., 20, 202-209. Tanks fully stocked with small fish, such as Chela punctis and Anabas scandens, did not show any marked diminution of mosquito larvae.

Boto, R. (1932) Resultado das observacioes efectuados nos concelhos de Benaventi e Salvaterra de Magos sobre a distribucioas da Gambusia e a sua proavel procedencia. Arg. Inst. bact. Cam. Pest., 6, 151-243. Suitable larval habitats proved free from Anopheles maculipennis. This was attributable to Gambusia holbrooki, which had apparently come down the Tagus from Spain, where it had been introduced against mosquito larvae. The distribution of G. holbrookii in the Benaventi area is discussed.

Botsford, R. (1930) Mosquito control in Connecticut in 1929. Bull. Conn. Agric. Expt. Sta. No. 315, 608-613. Experiments were made in inland waters with the common killifish, Fundulus heteroclitus, which is effective in mosquito control in salt marshes, and Rhinichthys atratus (blacknose dace), but the results were inconclusive.


1 = Lebistes reticulatus (Peters).
Boyd, J. E. M. (1920) The value of small fish regarding the destruction of mosquito larvae. *Jour. R.A.I.C.*, 22, 406-409. Fish, especially surface feeders such as minnows and sticklebacks, destroy a considerable number of mosquito larvae, particularly where the latter are not protected by weeds. In the author's examinations of the intestinal contents of *Gasterosteus pungitius* as many as seven larvae (probable of *Anopheles maculipennis*) were found in one individual, the average number being two.


Boyd, M. F. & Aris, P. W. (1925) A malaria survey of the island of Jamaica, W.I. *Amer. Jour. trop. Med.*, 2, 309-399. In Jamaica, the most extensively used larvivore is the "millions" fish *Girardinus poecilolois*. Other suitable species found are *Gambusia graecilior* and *Gambusia dominicensis* (= *Limia dominicensis*).


Brahmachari, B. B. (1909) Campaign against malarial fevers at Cossipore-Chittur Municipality. *Calcutta Med. Jour.*, 3, 318. In this part of Bengal, it was found that in the absence of weeds, mosquito larvae were restricted to the edge of fresh-water tanks where "techoko" (*Panchax panchax*) preyed on them in very large numbers. Enthusiasm was expressed for the use of larvivorous fish against anophelines under such conditions.


\[1 = \text{Lebistes reticulatus (Peters).}\]
Britton, H. E. (1914) A remarkable outbreak of Culex pipiens. J. Econ. Ent., 7, 257-260. In spite of recent anti-mosquito measures at New Haven, Conn., Culex pipiens was found to have become more numerous than before. The unusual prevalence of larvae was thought to reflect the absence of larvivorous fish, which had been driven from the area concerned by extensive water pollution due to dye wastes discharged from a factory. Another unusually large outbreak of mosquitoes occurring at Greenwich, Conn., in 1913 was attributed to similar fish mortalities.

Brodier, L. (1920) La lutte contre le paludisme en Algérie. Paris medicale, la semaine du clinicien, 37, 293-302. An indigenous fish of Berbera, Cyprinodon iberus, had been tried in Algeria for the control of mosquitoes. This fish proved very voracious and an excellent larvivore.

Brumpt, E. (1928) Role du poisson vivipare américain, Gambusia holbrooki, dans la lutte contre le paludisme en Corse. C. R. Acad. Fr., 186, 909-911. The 1926 introduction of Gambusia holbrooki, under the direction of the author, from Italy into Corsica proved extremely successful. Very few larvae were collected in 1927 from places where in 1926 an average of 300 to 500 per square yard were taken.

Brumpt, E. (1942) Notes parasitologiques concernant l'aménagement agricole de la Crau. Ann. Parasitol. Hum. et comp., 19, 74-84. The use of Gambusia is recommended against both Anopheles and Aedes, on the basis of successful trials in the Camargue and Crau regions, where an establishment was effected despite the presence of larger predatory fish. However, although Gambusia can resist water of considerable salinity, even 52 g per litre, it does not reproduce when the salinity exceeds 20-25 g per litre.


Buddle, R. (1928) Entomological notes on the Canton Delta. J. Roy. Nav. Med. Serv., 14, 190-200. The natural enemies of mosquito larvae observed include goldfish (which will eat larvae but are lethargic and poor hunters) and a small anabantid fish (which is very active and voracious). The latter feeds on the surface as well as below, and it is also very hardy and thrives in the muddiest water.
Burton, C. J. (1960) Studies on the bionomics of mosquito vectors which transmit filariasis in India. IV. Observations on larvivorous activities of various fishes in filarial areas of Kerala State, South India. *Indian J. Malarial.*, 14, 93-118. Observations were made on the larvivorous habits of 14 species of fish taken from tanks or ponds containing *Pistia stratiotes* and *Eichornia speciosa* and from (freshwater) stagnant ditches along the Malabar coast, from Cochin to Chertallay. The three most effective were *Macropodus cupanus*, the introduced *Tilapia mossambica* and *Ophioccephalus gachua*, all of which readily ate larvae and pupae of *Mansonella uniformis*, *M. annulifera* and *Culex pipiens* fatigans and would live in dirty stagnant water. *O. gachua* would be less desirable than the two first-named species for use in mosquito control, because it eats smaller larvivorous fish. It was submitted that the indigenous *Macropodus cupanus* would be the best all-round larvivore for use in the stocking of ponds and ditches were a biological control programme to be undertaken against filariasis vectors in Kerala.


Caldwell, B. W. (1921) Use of small fish in the campaign against yellow fever in the Vera Cruz. *Dept. of Public Health, Mexico City*. Satisfactory results followed the use of fish.


Carneiro, H. (1926) Medidas complementares anti-larverias na prophylacia da malaria. *A Folha Médica*, 7, 158-159. A brief description of the various methods (oiling, Paris green applications, and stocking with larva-destroying fish then used against anopheline larvae as auxiliaries to such permanent work as land reclamation and drainage.

Carter, H. R., LePrince, J. A. A. & Griffiths, T. H. D. (1916) Impounded water - surveys in Alabama and South Carolina during 1915 to determine its effects on prevalence of malaria. Public Hlth. Bull. No. 79, 34 pp. During a June survey on the Coosa River, Alabama, anopheline larvae were found in holes made by digging for angleworms. For certain localities the authors recommended the introduction of larvivorous cyprinodonts such as Fundulus notatus and Gambusia affinis, especially the former.

Carter, H. F., Rustomjee, K. J. & Saravanamuttu, E. T. (1927) Report on malaria and anopheline mosquitos in Ceylon. Ceylon Sessional Paper 7, 84 pp. Several potentially valuable larvivorous fish belonging chiefly to the genera Haplochilus, Barbus, Danio and Rasbora have been found in Ceylon, only Haplochilus lineatus having been tested in the field. These fish seemed definitely more abundant in the south-west, presumably on account of the prevalence of permanent swamps and pools there. Little was to be hoped for from the introduction of fish into the large areas of natural water in the dry zone without aiding their action by cleaning the weeds, etc. It was therefore considered that their use should be limited to confined or temporary collections of water, such as wells, shallow flood areas, etc., since these situations are not only very numerous during the rainy season but are frequently prolific sources of anophelines including the dangerous species, A. culicifacies and A. listoni. The imported Lebias reticulatus had been established in several places, but attempts to establish H. lineatus had been less successful, perhaps because this indigenous fish has narrower environmental tolerances.


Cauvet (1925) Note sur les poissons susceptibles d’être utilisés dans la lutte contre le paludisme en devourant les larves de moustiques. Arch. Inst. Pasteur Alger., Ill, 146-154. A short description is given of the various fish that might be used in Algeria for the destruction of mosquito larvae. The species dealt with include Tella apoda, particularly adapted to life in small shallow pools, where it devours all the small aquatic animals it finds; Phoxinellus chaignoni and Cyprinodon iberus which are easy to maintain in aquaria and are able to withstand great variations in temperature; and G. fasciatus, which is widely distributed and occurs in more or less brackish waters.


Chacko, P. I. (1948a) Acclimatisation of the "millions" Lebistes reticulatus (Peters) in Madras. Curr. Sci., 17, 157-158. Lebistes reticulatus was widely believed incapable of withstanding the climatic conditions in the hotter tracts of India. It was found thriving in the tanks of the Rameswaram temple situated in Ramanad district in February 1946. It is possible that it had been introduced from Ceylon, where it had been established many years previously. In October 1946, a consignment of 1000 fish was taken to Madras and distributed to various areas where they soon became acclimatized not only to the freshwater habitats but also to brackish water ones; proving of moderate significance as a factor in the control of malaria vectors. Cannibalism was not observed in the "millions", which was found to live in harmony with Gambusia affinis, Oryzias melastigma and (Aplocheilus) = Panchax blochii. Its enemies in its native waters are the fishes, Crenicichla saxatilis and Rivulus barb; the common frog, Rana hexadactyla, was found to feed on it in Madras.

Chacko, P. I. (1948b) On the habits of the exotic mosquito-fish Gambusia affinis (Baird & Girard) in the waters of Madras. Curr. Sci., 17, 93. In 1929 the first consignment of 600 G. affinis was imported from Ceylon, and in 1930 a second consignment of 100 was brought to Madras City. G. affinis duly became locally established in the province, its habitats ranging from brackish water canals and creeks to freshwater situations, and from the coastal area up to an elevation of about 7000 ft. Under Madras conditions, the biology, ecology and life-cycle of G. affinis differ somewhat from the descriptions of earlier workers. Its voraciousness has caused a striking diminution of the population of the indigenous fish (Aplocheilus) = Panchax blochii.

Chacko, P. I. (1949a) Food and feeding habits of the fishes of the Gulf of Manaar. Proc. of the Ind. Acad. Sci., 39 (page reference not available). The food components and feeding habits of 59 species of fish occurring in the Gulf of Manaar were tabulated. The habit of eating fish eggs and larvae was found in Anodontostoma chaunua, Chanos choanos and Rastrelliger kanagurta.


Chacko, P. I. (1950) Progress Report 1 April 1948 - March 1950, Part I, "Observations of fishes". Indian Council of Agricultural Research, Madras, 1-64. An outline is presented of the biology, ecology, and life-cycle of the many fish studied during this period. Stomach contents revealed that Chela untralii and (Aplocheilus) = Panchax lineatus feed on dipterous larvae. Under aquarium conditions A. lineatus is found to consume young Gambusia, Lebistes and carp fry. It also thrives well on prawn shell meal, earthworms, and other artificial food. It is very active and agile, and has been observed to jump over a garden pond wall two feet high.

3 Ref. e.g. Hildebrand, S. F. (1917) and Seale, A. (1917).
Chacko, P. I. & Ganapati, S. V. (1949) On spawning conditions and larvicidal propensities of Carassius auratus. *Curr. Sci.*, **18**, 257-258. Goldfish are predaceous, and have been observed to feed on young *Beroe sauretensis*, *Barbus stigma* and *B. ticto* and on their own young. Goldfish culture in farneries and ornamental ponds provides an effective check on mosquito breeding, individual fish consuming about 200 mosquito larvae in 24 hours. *C. auratus* can be transported over long distances without any casualty, provided that the water in the container is changed every six hours and the temperature is kept below 30°C.

Chacko, P. I. & Kurigan, G. K. (1948) On the food of nine species of *Barbus* of Madras. *Sci. and Culture*, **12**, 347. Gut-content assessments of 1320 specimens representing all nine species revealed that four are not in the habit of eating dipterous larvae, three do so rarely, and two regularly eat them as a minor part of the diet. The author's observation thus supports earlier views¹ that these indigenous fish are of little utility in the reduction of mosquito larval incidence. However, various other workers² have reported species of *Barbus*, especially *B. sophore* and *B. ticto*, to be effective and valuable larvivores.


Chacko, P. I., Venkataraman, R. S. & Ranganathan, V. (1946) On the bionomics of the silver fish, *Chela argentea*, Day. *Curr. Sci.*, **15**, 167. *Chela untrahi*, *C. argentea*, *C. phulo*, *C. hoopsis* and *C. olueoids* occur in the inland Waters of Madras Presidency. They are surface feeders, insects comprising approximately 40 per cent. of their diet. Other investigators have stressed the importance of these fish in the control of mosquito incidence.

Chamberlain, R. V. & Rees, D. M. (1935) Survey of mosquitoes and mosquito abatement work of Salt Lake City, 1934. (Mimeographed document) A detailed account is given of the seasonal prevalence of mosquitoes in Salt Lake City in 1934, and of the various antilarval measures adopted including drainage, oiling and the distribution of *Gambusia affinis*.


Chatterjee, G. C. (1929) Role which fish play in the control of malaria. 
Ind. Med. Rec. (reference incomplete)

Chatterjee, G. C. (1934a) Relation of fisheries to the malaria problem of Bengal. 
(Reprinted from) Sonar Bangla, Calcutta, 2, 14 pp.

Chatterjee, G. C. (1934b) Biological control of malaria in rural areas of lower Bengal. 
Central Co-op. Anti-Malaria Soc. Ltd., Calcutta, 1-28


Jour. and Proc. Asiat. Soc. Bengal, 5, 36-37. An investigation of the larvivorous qualities of (Haplochilus) = Panchax spp. revealed that these "tiny surface-swimming fishes possess ravacious appetite for living and moving larvae in water, and that they eat the wriggling larvae of mosquitoes with great avidity" under both laboratory and natural conditions.

Chaudhuri, B. L. (1911) Fish and mosquito larvae. Calcutta Med. Jour., 6, 457-470. The author strongly condemned the use of chemical larvicides for mosquito control in waters containing fish and other animals. He recommended improving the drainage in such localities, to eliminate some larval habitats and render the remaining ones more accessible to fish. In an account of his own relevant studies he outlined the necessary characteristics of fishes to be selected for such work; with slight modifications his recommendations were duly adopted by the Malaria Survey of India as a standard. The species which he found particularly useful as larvivores were first and foremost (Haplochilus) = Panchax panchax, then: Balis badis, Ambassis nama, Trichogaster fasciatus (= Colisa fasciata), Anabas scandens (= L. testudineus), Barbus putinio, Muria danrica (Eoemus danricus), Notopterus kapirot (N. notopterus) and Rasbora daniconius. He also considered Pterilampus atpar (= Laubuca atpar) and P. laubuca (= Laubuca laubuca) as being of some practical utility. This paper contains a very useful review of the whole subject, while the information regarding the local names and habits of the different species of indigenous larvivorous fish makes it especially valuable for reference.


Chevey, P. (1936) Description zoologique des principales espèces de poissons d'Indochine utilisables dans la lutte antipaludique. Arch. Inst. Pasteur d'Indochine, 6, 476-484

Chidester, F. E. (1917) A biological study of the more important of the fish enemies of the salt-marsh mosquitoes. N.J. Agric. Expt. Sta. Bull. 300, 16 pp. The following fishes were instanced as enemies of mosquitoes: Fundulus heteroclitus, F. majalis, F. diaphanus, Gambusia affinis, Cyprinodon variegatus, C. calaritanus, Heterandria sp., Brachycephalus chryssoleucus, Carassius auratus, Lepomis gibbosus, Mollies, latipinnis, Lebistes reticulatus (= Girardinus pescioloides), Girardinus caudimaculatus and (Haplochilus) = Panchax sp. Of these, the author viewed Fundulus heteroclitus as by far the most important. It is a most voracious enemy of mosquitoes at all stages of its development (and also eats the larvae of Dytiscus and Notonecta, though the number of these mosquito enemies destroyed by it is relatively small). The importance of H. heteroclitus lies in the facts that it migrates from the ocean to inshore waters (and even into almost freshwater) in vast shoals, and also that it may be artificially fertilized. As the fry are remarkably vigorous and hardy, it is simple to stock pools and streams with this species.


Christopher, S. R. & Shortt, H. E. (1921) Malaria in Mesopotamia. Indian J. med. Res., 8, 508-552. In lower Mesopotamia, fish (Cyprinodontidae) are an important factor in the natural regulation of numbers in anopheline populations.


Clare, H. L. (1915) Report of the Surgeon General for the year 1914-1915. Trinidad and Tobago Council Paper No. 154 of 1915, Port of Spain, 153 pp. The Dry River showed a scarcity of larvae owing to the presence of larvivorous fish and the swiftness of the current in certain parts.


Clarke, J. L. (1943) Minnows as a means of mosquito control extended to northern waters through the discovery of a sport. Mosquito News, 3, 68-69. Ordinarily, Gambusia affinis does not survive northern winters. However, a strain found in a pool at the Whitman estate, Winnetka, Illinois, had survived nine winters when transplanted to other locations.


Connor, M. E. (1920a) Yellow fever control in Ecuador: Preliminary report. Jour. Amer. Med. Assoc., 74, 650-651. An indigenous perch was found to be a voracious destroyer of Aedes aegypti larvae but its habits of jumping three or four feet out of the water in order to escape led to its replacement by two other native fish, which yielded good results.


Connor, M. E. (1921) Fish as mosquito destroyers. An account of the part they played in the control of yellow fever at Guayaquil, Ecuador. Nat. Hist., 21, 279-281. Various fish were experimented with against mosquito larvae. Gambusia was not found sufficiently hardy, and eventually, of several native fish tried, one known as the "chalaco" was selected as being the most useful in this connexion. Arrangements were therefore made for its continued distribution to all water containers in Guayaquil. More than 30,000 water receptacles were freed in this manner from mosquito larvae.


Connor, M. E. (1922b) Final report on the control of yellow fever in Merida, Yucatan, Mexico. Amer. J. trop. Med., 2, 487-496. When the anti-larval campaign began in February 1921, the A. aegypti index was nearly 50 per cent.; by the end of October it had been reduced to 8.5 per cent. and later dropped to 1.75 per cent. The antilarval measures employed included the stocking of containers with bottom-feeding perch (voracious consumers of mosquito larvae).

Connor, M. E. (1922c) Notes on the use of freshwater fish as consumers of mosquito larvae in containers used in the house, based upon experience in Guayaquil, Ecuador, and Merida, Yucatan, Mexico. Amer. Jour. Public Health, 12, 193-194. This is a condensed account of the author's experience with larvicidal fish in many campaigns against yellow fever. Points that make the use of fish effective are enumerated. Top-feeders are best for open-air fountains and collections of water of a similar nature, while bottom-feeders are best for tubs, barrels, etc., in the house. Apparently no fish will live in metal tanks; for these, tight-fitting lids must be provided.


Cooling, L. E. (1923) Mosquito-larvivorous fishes in relation to mosquito reduction work in Australia. Health, 1, 94-98. Permanent fresh waters of Australia that have been untouched by man harbour larvivorous fish. Marshes with fairly well-defined edges generally do not breed mosquitoes because of the fish with which they abound. Melanotaenia nigra is one of the most widely distributed larvicidal fish in eastern Australia. Others are Priois olivaceus and Carassius (astrogobio) galli. Pseudomugil signifer occurs in both salt marshes and fresh waters, and though it displays marked predatory habits in fresh water aquaria, its presence in a salt marsh is not always indicative of the absence of larvae of Aedes vigilax, A. alternans and Culex sitiens. It is possible that in these cases it finds a greater variety of food organisms (e.g. marine forms such as the smaller Crustaceae). The only importance that can be attached to fish such as Carassius compressus is that they are valuable indicators of pollution and self-purification in field studies of mosquitoes. When streams become polluted, as by sewers discharging into them, the water is deoxygenized; this has no inhibitory effect on certain mosquito larvae (e.g. Culex pipiens fatigans) but fish cannot survive.

Cooling, L. E. (1923) Report on mosquito survey of the Brisbane Metropolitan Area. Aust. Dept. Health., typewritten document, 43 pp. When the activities of indigenous larvicidal fish in marshes and streamlets are impaired by aquatic vegetation, a few anopheline larvae (A. annulipes) can generally be found, also certain culicines. It is during periods of protracted drought, when natural waters are covered with aquatic vegetation, and particularly with water hyacinth that the maximum amount of anopheline development is observed. If streamlets become polluted by sewage so that the fish are killed, domestic species of mosquitoes (e.g. Culex pipiens fatigans) are able to breed in them.

Cooling, L. E. (1927) Australian fish as mosquito larvae destroyers. Health, 6, 11-12. Reference is made to a German attempt prior to World War I to introduce Australian larvicidal fish into New Guinea. After two failures, a successful result was achieved in 1914, when four species of fish were imported from Sydney into the Bismarck Archipelago. In addition to the fish previously noticed in Australia, the family Centropomidae and the genus Ambass are stated to include effective larvivores.

Colun, G. (1928) Biologie du Gamba was holbrooki. Prophylaxie du paludisme, Blanc et Gauthier, Rabat.

1 = Lebistes reticulatus
Coulon, G. & Sautet, J. (1931) Gambusia holbrooki et paludisme en Corse. Resultats de six années de lutte antilarvaire au moyen des poissons culicophages. Ann. Parasit. Hum. comp., 2, 532-545. An account is given of the results obtained from the distribution and maintenance of Gambusia holbrooki, in all important anophele breeding-places, carried out in Corsica over a six-year period. Beneficial results were obtained for comparatively little expenditure. In the coastal regions and low-lying valleys conditions are very favourable for the growth and multiplication of this fish, and the climate, with mild winters and warm summers, is very suitable. Moreover, there are no really formidable natural enemies. The fish can adapt itself to salt waters and tolerates a higher degree of salinity than the anophele larvae present. The best results are obtained in permanent collections of water, such as garden wells, marshes with or without drainage canals, and pools formed by flooding and not in communication with the rivers at other times. G. holbrooki is most effective in summer and autumn; in spring its work should be supplemented by such measures as clearing of vegetation and application of chemical larvicides. Supplies of fish should be kept to re-stock mosquito larval habitats that dry up during the summer, and where possible fish-ponds should be dug at the lowest point of marshes to ensure abundant re-stocking following rainy spells.


Covell, G. (1935) Anti-mosquito measures with special reference to India. Malaria Bureau No. 3, Health Bulletin, 11, 1-60, Calcutta. Species of Haplochilus (= Panchax, = Aplocheilus), Barilius, Chela and Varbus were felt to be the most promising indigenous larvivores of India.


Danilova, M. I. & Lappin, G. I. (1936) On the transport of Gambusia (In Russian) Med. Parasitol., 5, 579-583. Experiments to find the optimum conditions for transporting Gambusia were carried out in Sukhumi in 1935. It was found that for a journey of up to eight days the fish may be kept at the rate of 20 per litre of water (50 per gallon) in open receptacles, allowing free access of air, at a water temperature not exceeding 13-16°C (55-60°F). Covered receptacles stocked with fish at the same rate should be only half filled with water, and the water in them should be kept cool since mortality among the fish is low at 6-8°C, whereas almost all die at 14-20°C. In the basis of these experiments, about 180 000 fish were transported in large wooden barrels, by steamers from Sukhumi.
to Rostov-on-Don, and from there to a number of districts. They multiplied in various collections of water in the course of the summer and migrated under the ice in December. When under transportation, dead fish should be removed as often as possible. Other conditions being equal, the best receptacles are those that expose the largest area of water surface to the air. Gambusia can withstand starvation for considerable periods. Appropriate experiments showed that they are not affected by the presence in water of iron oxide from rusty containers. They thrived in water with a salinity of up to 1.5 per cent, provided that there was suitable aquatic vegetation; in the absence of the latter, they began to die at a salinity of 1 per cent.

Davis, N. C., Lobo, M. M. & Cabarrow, F. G. (1927) Lucha antialudica en Medinas. Relación preliminar después de un año de trabajo. Sem. med., Buenos Aires, 24, 467-485. Of a number of larvivorous fish occurring in this region, the most effective against Anopheles pseudopunctipennis appeared to be Fitzroya lineata.


De Buen, E. (1929a) Estudio experimental de algunas substancias larvicidas antianofelicas. Med. Paises Calidos, 2, 401-430, 508-540. An account of field and laboratory experiments with various oils and other larvicides and with Gambusia for the control of Anopheles maculipennis, in the Spanish province of Caceres. It was concluded that the best results were obtained by using Gambusia and supplementing its action by means of Paris green. All collections of water, however small, were stocked with the fish and then dusted every 10 days, the presence or absence of Gambusia being followed closely so that the supply could be renewed if necessary. The cost of the combined method was very little higher than that of dusting alone. It was found that ponds containing Gambusia only had to be dusted once in June and did not need dusting in July, August or September, whereas other ponds required dusting from March to October.

De Buen, E. (1929b) La invasion de nuestras aguas dulces por las Gambusias (Gambusia holbrooki Gnd.) Rev. Biol. forest. Limnol., Madrid, 1, (A) 49-53


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1 See comment in Tamashiro, 1964.
De Buen, E. (1930b) Notas sobre la fauna ictiológica de nuestras aguas dulces. *Notas y Tesoreros Minist. Fom.* (Spain) Ser. 2(46), 62 pp. These notes deal briefly with the fish found in channels, rice-fields, and slow-moving streams in Spain in which anophelines breed. The species discussed include *Gasterosteus aculeatus*, which feeds voraciously on insect larvae but also destroys other fish, and *Gambusia holbrooki*, which became established since its introduction for the control of anopheline larvae.

De Buen, E. & De Buen, S. (1922) Note sull' acclimatizzazione della "Gambusia affinis" Ann. d'Igiene, Rome, 32, 281-285. A consignment of *Gambusia affinis*, supplied by the US Bureau of Fisheries, was kept for four months in an aquarium of the Spanish Institute of Oceanography. Dried cod-roe proved a suitable food but life in captivity hindered reproduction to a considerable extent. When placed in outdoor ponds, the reproduction rate increased. By the time the article was written the stock had passed through three generations.

De Burca, B. (1939) Note on anti-malaria measures in Quetta Cantonment during 1938. *J. Malar. Inst. India*, 2, 121-130. Since no anopheline larvae were found in stretches of water to which certain fish had access, experiments were undertaken to investigate possible value of the latter in control work. One, *Nemachilus kessleri*, controlled anopheline breeding in a reservoir near the city during August and September; the other, *Discognathothys rossicus* var. nudiventris, was found to be at least as efficient as *Gambusia* which had been successfully used in various reservoirs.

De Carvalho, F. A. (1940a) Larvivorous fish in malaria control work. *Serv. Profil. Malar.*, Sao Paulo, 18 pp. Fish were used in Brazil to control *Aedes aegypti* but were of less use against anophelines. The larval habitats of the latter provide both ample food for various forms of life and shelter from attack; the artificial larval habitats of *A. aegypti* do not. Candidate larvivores should be small, strong and prolific, and be surface feeders with mosquito larvae as their preferred food. Cyprinodonts and *Rivulus santensis* lend themselves to use in water of restricted area and depth, while tetragonopterids are more suited to large collections of water. Methods of stocking and rearing are discussed.

De Carvalho, F. A. (1940b) *O Rivulus santensis como elemento de combati as larvas anofelinas nas vaclus dos bananais da baixada litoranca.* Arch. Hig. Saude publ., 5, 125-127 (Rev. Appl. Ent., 24, 31)


Derwald, W. F. (1919) New Jersey's work in mosquito control. *Jour. Amer. Med. Ass.,* 72, 737-741. Laboratory and field studies of *Fundulus majalis, Fundulus diaphanus* and *Cyprinodon variegatus* were undertaken by the New Jersey Agricultural Experiment Station in relation to mosquito control.


Donald, C. W. (1923) List of larvicidal fish found in the Punjab, with their vernacular names. Office of Health, Delhi.


Dulzetto, F. (1928) Osservazioni sulla vita sessuale della "Gambusia holbrooki" (Gord.) Atti. R. Accad. Naz Lincei, Rend. Cl. Sci. fis. mat. e nat., 37, 96-101. This paper describes observations made in Sicily on the reproductive capacity of females of the imported Gambusia holbrooki. There is only one male to 8-10 females, and a fertilized female can produce several generations of young in the course of a summer without further pairing. Such females kept without males through the winter in a tank out of doors at Catania again produced young in the following spring. During the winter they remained in the mud at the bottom of the tank. Hitherto it had been assumed that the females could not retain reproductive power through the winter.

Dunn, L. H. (1926) Mosquito control at Barranquilla, Colombia, as a prophylaxis against yellow fever. Amer. J. Hyg., 6, Suppl., 1-18. Dormitor maculatus, a small species of freshwater fish, obtained in numbers from the Magdalena River, was frequently introduced into water containers against Aedes aegypti and Culex pipiens fatigans.


Dzhaparidze, P. 3. (1937) Dynamics of malaria in Abkhaz during recent years and the methods to follow for its eradication (In Russian) Med. Parasitol., 6, 782-793. Introduction of Gambusia proved to be of great value. Once firmly established, the fish greatly reduced the numbers of mosquito larvae.
Earle, W. C. (1930) Malaria in Puerto Rico. Amer. J. Trop. Med., 10, 207-230. Small fish, especially Poecilia vivipara and Dormitator maculatus, were very abundant in some districts; but although they fed on anopheline larvae in captivity, they did not seem to control them in nature.


Eggert, E. G. (1920) Gambusia affinis. Texas Health Mag., 1, 7-10. Employment of Gambusia advocated for such waters as stock ponds, watering troughs and surface reservoirs, where oiling and draining are impractical.

Eigenmann, C. H. (1923) Yellow fever and fishes, Amer. Nat., 57, 443-448. Besides L. reticulatus the most useful South American larvivores are Pygidium piuare, Lebiasina bimagulata and "chalacon".

Eigenmann, C. H. (1924) Yellow fever and fishes in Colombia. Proc. Amer. Phil. Soc., 63, 236-238. In Peru the most effective larvivorous fish is Pygidium piuare, which is active at night. A smaller species, P. striatum, was utilized in Colombia, as well as the widespread Piabucina panamensis. Dormitator latifrons was utilized on the Pacific slope of Colombia, an allied species in Barranquilla and along the Atlantic slope being D. maculatus. The former had proved very effective, and there was every reason to believe that the latter would be equally so, if present in sufficient abundance. Other fish being tried out in Colombia were Geophagus steindachneri and two species of catfish, Pimelodella charragrensis and Rhamdia sebae. Mollenisia caucana, a poecilid abundant in the swamps of the lower Magdalena basin, is a minute fish felt to merit trial as a larvivore too. Other representatives of the genus Mollenisia are widely distributed in Colombia; and along the coasts of the Guianas this genus is rich in species and numerically abundant.

Emerick, A. M. (1942) Mosquito fish. Proc. 12th Mtg. Calif. Mosq. Contr. Ass., 128-129. A report is given of the establishment of Gambusia against mosquito larvae in all the ponds of the Calistoga sewage farm, California. The fish were first introduced into the lowest and cleanest pond in 1533, and as they became acclimated, they were moved up every six months, until they were established in all the ponds and even in the septic tanks. They proved very effective. The edges of the ponds were kept clear of grass by a small flock of sheep. While admitting that fish cannot effectively be used where algae are abundant, the author stated that algal control can be effected by the use of copper sulfate.
Enikolopov, S. K. (1935) Observations on the biology of Gambusia that have been acclimatized in Dagestan (In Russian) Med. Parasitol., 4, 408-413. Following its introduction for the control of mosquito larvae in Dagestan in 1928, Gambusia became well established and widely distributed in the plain. Eight permanent breeding ponds had been established for overwintering purposes and for use as stockponds. Observations in concrete tanks at Makhachkala on the Caspian Sea, showed that a female may produce up to six broods comprising a total of over 920 young between mid-June and the beginning of September, the intervals between broods being 21-25 days during the first three months. In the course of the summer, the fish of the first and second broods also produce offspring. The maximum production of young occurred at the beginning of June at a mean temperature of 15°C (59°F). Two or three broods could be produced after one fertilization, which is of importance, since males may not occur among the few fish liberated in individual small pools in the country, (even though the sex ratio was found to be 1:1). Sexual dimorphism became apparent 36 days after birth, and young fertilized females produced young 17 days later. The development of the fish chiefly depends on the supply of food and to a lesser extent on the temperature. Fish in which the sexual characters had just become apparent readily swallowed mosquito larvae of the first three instars, but not those of the fourth instar, or pupae. No cases of cannibalism occurred in reservoirs with an abundance of food, whereas if food was scarce and the water devoid of vegetation, all the young fish were eaten by the parents in less than 24 hours. In the course of a night an adult female was able to eat 94 pupae of Aedes, or 109 fourth instar larvae of Aedes, Culex and Anopheles. Fish one month old destroyed 20 fourth instar larvae of Aedes in 24 hours. Young fish survived following their dissection from females that had just died.


Permi, C. (1919) La lotta contro la malaria mediante la grande e piccola bonifica e la disinfestazione idro-aerea antianofelica, Rome, 62 pp. In numerous experiments, goldfish, chub, and sticklebacks proved useful as larvivores. In the districts around Rome, Brunelli found Cyprinodon calaritonus and Gasterosteus aculeatus satisfactory. The former (termed "Nonni") are apparently excellent larvivores because they can live in shallow and somewhat warm collections of water.

Permi, C. (1926) Note di anofelinologia. Riv. Malariol., 5, 113-131. Although members of the genus Gambusia do not devour insects of comparatively large size with a hard integument (such as medium-sized Coleoptera, larvae of dragonflies, dytiscid beetles or notonectid bugs), they feed on the larvae of mosquitoes and other Diptera, such as chironomids and Dixa. Where a surface carpet of
emergent vegetation protects anopheleline larvae from fish, raising the water level and submerging the plants will temporarily increase the usefulness of the fish. To prevent the escape of Gambusia from irrigation tanks when the slices are opened, the author developed a device (based on the assumption that most surface water fish dislike swimming in dark passages or tubes) consisting of a long pipe fitting the outlet and extending across the tank close to the opposite wall.

Fermi, C. (1933) Diserbo biologico delle acque. (The biological clearing of aquatic vegetation) Riv. Malariol., 12, 523-531. A sheet of water in Sardinia, which covered about 150 acres and in which mosquitoes bred prolifically was so full of aquatic vegetation that in some parts even Gambusia holbrooki was unable to penetrate. As a result of stocking with carp, the plants were completely cleared away and thereafter no mosquito larvae could be found (their absence was attributed primarily to the free movement of the water and not to the presence of Gambusia).


Figueira, L. & Landeiro, F. (1923) Relatorio do primeiro ano de luta antisezonatica. Arq. Inst. bact. Cam. Pest., 6, 191-243. Some apparently suitable mosquito larval habitats were free from these insects, probably due to Gambusia holbrooki having come down the Tagus from Spain, where it had been introduced against mosquito larvae.

Fisher, H. C. (1924) Report of the Health Department Panama Canal for 1923, 95 pp. In the Panama Canal Zone the minnow Poecilia sphenops is quite abundant and is an effective larvivore.

Floch, H. & Abonnene, E. (1946) Poissons larvivores de La Guyane francaise. Publ. Inst. Pasteur Guyane No. 132, 6 pp. A collection of nearly 2000 small fish from ponds, streams, wells etc., in the neighbourhood of Cayenne, was found to comprise 11 species. The number of each and their place of capture are shown in a table. Brief notes are given on the distinguishing characters of most species, and on the habits and larvivorous potentialities of those taken in sufficient numbers. The most numerous were Hemigrammus rodwayi, Poecilia vivipara and H. unilivertus. P. vivipara is considered the most useful species for local domestic mosquito control, because of the ease with which it adapts itself to waters of different types and to small containers.

Flu, P. C. (1912) Rapport over het wetenschappelijk onderzoek naar het voorkomen der kolonie Suriname an de bestruwing van dis ziekte. s'Gravenhaag, Algemeene Landdrukkerij, 124 pp. In inspections of Lelydorp, Surinam, mosquito larvae were never found in rice-fields in the presence of Lebistes reticulatus (= Girardinus guppy).


Fowler, J. (1964b) Gambusia fish for rice-field mosquito control in California. Proc. 17th Ann. Mtg. Utah Mosquito Abatement Assn. Reported that over the preceding year, approximately 35 per cent. of Californian rice-fields had been planted with an estimated total of 1 257 300 Gambusia. The cost was much less than that of repeated chemical treatments, and better control was achieved - "less mosquito production than is realized by present practices using chemical control". In 1963, of 83 rice-fields planted with Gambusia, only five averaged as much as 0.5 larvae per dip during the long rice-growing season.


Fratazi, L. (1939) Étude épidemiologique du paludisme a Beni Abbes (Sahara oranais). Ann. 1937. Arch. Inst. Pasteur Alger., 17, 429-437. Gambusia was introduced. The fry of a local fish, Barbus figuiensis, were found to destroy mosquito larvae. No larvae were found in the pools in which they were present, and although they were less active than Gambusia, they were well-adapted to local conditions.

Fry, A. E. (1912) Indigenous fish and mosquito larvae. Paludism, 5, 71-74. Lists common larvivorous fishes of Bengal fresh waters as: (Haplochilus) = Pachax panchax, H. melastigma, Ambassoides nama, A. ranga, Barbus ticota, and several species of Trichogaster. It was observed that permanent waters with any of these larvicidal forms present "if free of weed and with clean cut sides without grass or bush and with no shelving mud flats" lacked larvae. Culex and Anopheles larvae were found in abundance in the presence of excessive and thickly-matted weeds, only anopheline larvae being found where weeds were not very excessive and the edges are shelved. Indigenous fish were felt to be sufficiently numerous to keep down mosquito larval incidence, and the importation of exotic species was considered unnecessary. It was emphasized that to avoid needless destruction of fish and other wildlife, chemical larvicides should be used with discretion.


Galliard, H. (1928) Contribution à l'étude des culicidés d'Espagne. Ann. Parasit. hum. Comp., 6, 206-210. The larvae of Culex theileri were controlled by Gambusia almost as completely as were those of Anopheles maculipennis.

Galli-Valerio, B. (1923) Beobachtungen über Culiciden, nebst Bemerkungen über Tabaniden und Simuliden. Centralbl. Bakt. (Abt. 1 Orig.), 90, 38-40. Many larvae of Anopheles maculipennis were found developing in the presence of Elodea canadensis and Hydrodictyon reticulatum along the banks of an ornamental lake containing goldfish; and in 1919 numerous larvae of A. maculipennis and A. bifurcatus were found in a tank with many trout. However, the author noted that Leuciscus rutilus (roach) eats many larvae and pupae.

Galli-Valerio, B. (1932) Observations sur les Culicidés, les Tabanides et les Simulidés. Centralbl. Bakt. (Abt 1 orig.) 123, 485-490. Gasterosteus aculeatus (three-spined stickleback) was found to feed actively on anopheline larvae and pupae in Switzerland, but it would be inadvisable to introduce it into lakes and rivers owing to the danger to other fish.

Galli-Valerio, B. & Rochaz-de Jongh, J. (1903) Studi e ricerche sui culicide dei generi Culex e Anopheles. Atti. Soc. studi d. malaria, 4, 3-48. These writers confirmed earlier observations to the effect that goldfish (Carassius auratus) are useful larvivores in tubs, casks and small ponds. They stated that Phoxinus laevis (minnow) and Telestes muticus are both excellent larvivores. Their observations upon them seem to have been restricted to container habitats. By some experiments made both in tubs and in two small pools, they concluded that Cyprinus praemus and Cobitis barbatula (stone loach) are valuable in the destruction of larvae.


Geiger, J. C. & Purdy, W. C. (1919) Experimental mosquito control in rice-fields. Jour. Amer. Med. Assoc., 72, 774-779. Top-minnows are usually found near the embankments and water outlets of rice-field, rarely in mid-field. As a result of their experiments the authors concluded that intermittent flooding as a remedial measure is probably not feasible. The preference of top-minnows for deeper water was held to limit their value, although it was acknowledged that their presence means a considerable reduction in mosquito larvae.
Geiger, J. C. & Purdy, W. C. (1920) The malaria problem of the rice-fields of the United States. **Southern Med. Jour.**, 13, 577-582. The tremendous area of rice-fields and the abundance of obstacles diminish the usefulness of small fish, although in drainage ditches they may be entirely satisfactory.

Gerberich, J. B. (1946) An annotated bibliography of papers relating to the control of mosquitoes by the use of fish. **Amer. Mid. Nat.**, 36, 87-131. A review of available literature, listing 298 relevant articles published up to 1942. A summary of data indicated that 216 species of fish had been used in the control of 35 species of mosquitoes in 41 countries.


Germer, W. G. & Behrens, H. (1942) Ein Beitrag zur Stechmuckenfrage von Gran Canaria. **Z. Parasitenk.,** 12, 645-658. Goldfish and Lebistes reticulatus were placed in tanks that were suitable.


Gilchrist, J. D. P. (1913) The introduction of "millions" in Cape of Good Hope. **Marine Biol. Rept., Union of South Africa, Prov. of the Cape of Good Hope,** 1, 67-70. It was considered doubtful whether Lebistes reticulatus could become established in South Africa, although individuals had survived there for some months under experimental conditions. Other fish held to be potentially useful as larvivores under South African conditions were species of Tilapia from Pretoria; species of Fundulus from East Africa and Seychelles; species of Haplochilus from Nyasa and Albert Nyanza; and species of Galaxias from the south-west of the Cape Province.

Gilroy, A. B. (1948) Malaria control by swamp drainage. **Ross Institute, London.** Refers to the importance of Electria lebretori in keeping un-oiled drains free from mosquito larvae in Nigeria.


Gioseffi, M. (1919) Per la lotta contro la malaria in Istria: contributo alla conoscenza delle condizioni igienico-sociali dell' Istria. **Reforma medica,** 25, 671-675. Gioseffi failed to attain any success from experiments in which sticklebacks (Gasterosteus enneaculeatus) were introduced into a lake.
Gioseffi, M. (1922) La malaria in Istria nel 1920. *Tl Poli clinico, Sez. prat.*, 27, 920-924. No larvae were found in a pool where fish had been placed in the previous year.

Gioseffi, M. (1926) Le "Gambusie" nella lotta antimalarica in Istria. *Riv. Malari ol.*, 5, 469-475. Gambusia affinis is effective against anopheline larvae in Istria where after becoming acclimatized it survived the hot summers and winter frosts of 1925-1926. It was held to have practically caused the disappearance of larvae in collections of water, and to have reduced the incidence of endemic malaria.

Gioseffi, M. (1935) Malaria and anti-malarial work in Istria from 1 November 1932 - 31 October 1933 (In Italian) *Riv. Malariol.*, 13, 734-806. In the district of Arsa all waters in the bed of an almost empty lake were stocked with Gambusia.


Gogol, V. A. (1945) *Causes of the low effectiveness of Gambusia in some reservoirs in the Province of Samarkand* (In Russian) *Med. Parasitol.*, 14, 74-77. Observations in 1944 showed that the effectiveness of Gambusia in destroying anopheline larvae in ditches in Uzbekistan was increased by freeing the water from surface vegetation, which hindered the movements of the fish and forced them to hunt at lower levels where their diet consisted chiefly of micro-organisms. They successfully controlled larvae over some 32 acres of swampland when the surface vegetation was raked away.


Gorgas, W. C. (1915) Vegetation and fish control. In his "Sanitation in Panama", New York, 159-160. If the water was accessible and clear of grass, the native fish significantly reduced larval incidence.


Graham, W. M. (1911) A fish that preys on mosquito larvae in Southern Nigeria. *Bull. Ent. Res.*, 2, 137-139. An indigencus cyprinodont, Epilatys (Haplochilus) grahmi, was found to eat mosquito larvae but refused pupae of any species. These fish were found to keep a distance of one to two feet, which gave them a great capacity for spreading themselves over flooded land by leaping from pool to pool. This same ability offered the fish protection from adverse aquatic environmental factors. They themselves appear to be very vulnerable to predation, and were found only in pools free from other fish.


Grainger, W. E. (1947) The experimental control of mosquito breeding in rice-fields in Nyanza Province, Kenya, by intermittent irrigation and other methods. E. Afr. med. J., 24, 16-22. Gambusia introduced into an experimental plot in a rice-field had little or no effect on mosquito production, possibly because the vegetation was thick, although its numbers increased from 97 to over 1200 in four months.

Grassi, B. (1923a) Pesci nostrali antimalarici. Atti R. Accad. Naz. Lincei, Rend Classe sci. fis. mat. e nat., 32, 511-512. The conclusion reached in this review of the various attempts made in Italy to use indigenous fishes against mosquitoes is that little can be expected from these species. However, two exotic species, Lebias reticulatus and Gambusia affinis, were considered worthy of tests on a large scale.

Grassi, B. (1923b) Acclimazione delle Gambusie in Italia. Atti R. Accad. Naz. Lincei, Rend. Classe sci. fis. mat. e nat., 32, 544-548. Experience with Gambusia affinis, brought to Rome from Spain in July 1922, indicates the potentialities of this fish in destroying mosquitoes in Italy. However, it was noted that it is unable to penetrate dense aquatic vegetation, and that frogs prey on it.


Gromov, A. S. (1940) On a previously unknown property of the fish, Gambusia (in Russian) Med. Parasitol., 2, 645. Laboratory studies in eastern Turkmenistan showed that Gambusia holbrooki can survive out of water for considerable periods and so can be transported over short distances. At room temperature the fish lived up to 12 hours on damp filter paper and up to 15-20 hours on a damp cloth if covered with a piece of muslin. They succumbed more quickly to crowded conditions in a small quantity of water, than when handled in the preceding fashion. If wrapped in muslin, they died in 10 to 12 hours even if there was sufficient moisture, probably because the muslin stuck to the gills and interfered with respiration.

Gray, H. F. (1947) Mosquito control problems in Japan. Mosquito News, 7. Consideration of the introduction of larvicidal fish (e.g. Gambusia affinis) into rice-fields was advocated. Fish already present in Japanese rice-fields were species of food significance.
Green, H. W. (1921) Preliminary report on Anopheles mosquito reduction and its relation to malaria control in Aquirre, Puerto Rico; with notes on methods used and results observed in 1921. ( Mimeographed document) 175 pp.


Guiteras, J. (1916) Insect-borne diseases in Pan-America. *Havana Department of Health Sanidad y beneficencia Boletin oficial*, 15, 93-132. Indigenous fishes were compared with exotic ones as regards their effectiveness in controlling mosquito larvae.

Guppy, P. L. (1934) Observations on Trinidad larvicidal fishes. *Trop. Agric.*, 11, 117-122. After briefly reviewing the literature on the fish of Trinidad, the author describes the situations in which larvivorous fish have been found, suggesting measures that might be taken to insure their conservation and dispersal. In an appendix, notes are given on the morphology and bionomics of the more important species, together with a list showing their distribution.

Gutzevich, A. V. (1937) *Anopheles hyrcanus* Pall. and its importance in the transmission of malaria in the Far East. (In Russian) *Trav. Acad. Milit. Med. Kiroff Armée Rouge*, 8, 127-149. Since *Gambusia* cannot survive very severe winters, the use of a local small fish, *Pseudorasbora parva*, was suggested. This fish occurs throughout the Amur basin. It feeds close to the surface of the water, and experiments in northern China showed it to destroy anopheline larvae readily.


Haas, R. (1965) Preliminary report on experimental introductions of *Nothobranchius guentheri* (Pfeffer), an annual cyprinodont fish, as a potential mosquito larvivore. *WHO/EBL/59.65* (mimeogr.), 9 pp. A laboratory population of the fish was established in India, and a small-scale field introduction was attempted on Guadalcanal (British Solomon Islands Protectorate).

Hacker, H. P. (1923) Malaria Bureau Annual Report, 1922. *Suppl. to F.M.S. Govt. Gaz.*, Kuala Lumpur, 16-22. Experiments with fish showed that while *Cyclocheilichthys apogon* would eat mosquito larvae only in the absence of preferred food (mioro-organisms, algae, etc.), *Betta pugnax* was a promising larvivore.

Hackett, L. W. (1931) Recent developments in the control of malaria in Italy. *Jour. S. Med. Assoc.*, 24, 426-430. Introduction of Gambusia from the United States of America led to unexpected results. No horizontal vegetation, however thick, could protect anopheline larvae from the fish, large and small, constantly patrolling every square inch of water surface. On an area of about eight square miles under observation for five years in Istria, the spleen index in a scattered rural population went down from 98 per cent. in 1924 to about 10 per cent. in 1930. Nothing but Gambusia distribution had been done in this area.


Hamid Khan (1944) On the relative value of certain larvivorous fishes from the Punjab, with notes on their habits and habitats. *Indian J. Vet. Sci.*, 13, 315-325. When introduced into a reservoir *Colisa lalia* and *Ambassis bacularis* fed on the mosquito larvae present. Their normal food consists of crustaceans, rotifers and larval aquatic insects. *Barbus saphore* in ponds mostly feeds on mud, decayed vegetation, algae and aquatic weeds and thereby reduces the food supply of mosquito larvae.

Hamlyn-Harris, R. (1929) The relative value of larval destructors and the part they play in mosquito control in Queensland. *Proc. R. Soc. Queensland*, 41, 23-28. Particular reference is made to larvivorous fish, several species being discussed of which some of the most valuable are: *Craterocephalus fluviatilis* and *Melanotaenia migrans* in fresh water and *Pseudomugil signifer* in brackish water and salt water.


Hancock, G. L. R. (1930) Some records of Uganda mosquitoes and the ecological association of their larvae. *Bull. Soc. roy. ent. Egypte*, 38-56. A species of *Haplochromis* appeared only to attack the larvae in the absence of other food. *Haplochilus* sp. seemed likely to be of more value; it consumed large numbers of larvae under laboratory conditions as did a species of *Barbus* which was not, however, a surface-feeder.

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1 See preceding entry.
Handley, H. (1917) Report on malaria in the Punjab during the year 1916, together with an account of the Punjab Malaria Bureau. Lahore, Supt. Govt. Printing, 13 + xxxiv pp. At Kasas, in the sacred tank, larvae were found to abound side by side with innumerable fish (Cirrhina latia and Barbus terio) which, especially when young, are destroyers of mosquito larvae. Similar observations were made at the Shalamer Gardens, Lahore, where larvivorous fish had been specially introduced.

Hanson, H. (1925) General report on the yellow fever campaign in Colombia, May 1923 to December 31, 1924. Amer. Jour. Trop. Med., 5, 353-409. In the course of the campaign 908 655 houses were visited, in 69 690 of which A. aegypti was found, chiefly in containers; and 364,926 larvivorous fish were distributed. Geophagus steindachneri did not prove of much value, but Piabucina panamensis was effective; Pimelodella chagresi, Dormitar sp. and other fish were also employed. The use of fish in Colombia was not so successful as in Peru, less hardy species being available.

Hanson, H. & Dunn, L. H. (1925) The use of fish in the control of yellow fever in Peru. Milit. Surgeon, 57, 232-241. In 1921 and 1922 trials of larvivorous fish were undertaken against Aedes aegypti. A local species (Pygidium piurae) which fed voraciously on larvae and pupae, survived crowding in the pails and cans used for transport purposes, and rapidly adapted itself to life in containers. More than 80 per cent. of some 857,000 fish distributed belonged to this species.


Harrington, R. W., Jr (1959) Delayed hatching in stranded eggs of marsh killifish. Fundulus confluentus. Ecology, 29, 430-437. Viable eggs of marsh killifish, Fundulus confluentus, which hatched within 15 to 30 minutes after immersion in water, were obtained in pods out of water for two to three months. Stranded eggs survived the severest Florida winter. They hatched in fresh water, but did so more readily in brackish water.

Harrington, R. W., Jr & Harrington, E. S. (1961) Food selection among fishes invading a high sub-tropical salt marsh: from onset of flooding through the progress of a mosquito brood. *Ecology*, 42 (4), 646-666. During a severe drought this Florida swamp went dry, losing its fishes and accumulating dense deposits of eggs of mosquitoes - notably *Aedes taeniorhynchus*, ready to hatch at the annual autumn flooding. An abrupt tidal-fluvial flooding then gave fishes sudden access to the whole marsh in concurrence with a massive, synchronized mosquito hatch. The best larvivores were: *Fundulus confluentus*, *Gambusia*, *Lucania*, *Cyprinodon*, *Mollinesia*, *Fundulus grandis*. During their superabundance, mosquitoes contributed to total food volumes as follows: *F. grandis*, 94.8 per cent.; *F. confluentis*, 85.5 per cent.; *Gambusia*, 78.7 per cent.; *Lucania*, 72.8 per cent.; *Cyprinodon*, 57.3 per cent.; *Mollinesia*, 52.3 per cent. There was good correlation between the size of the fish and that of larvae eaten by them - the smaller the fish the greater the proportion of first-third instars eaten. Preference for pupae seemed to reflect choice on the part of the fish species, and was not correlated with fish size.

Harrington, R. W., Jr & Rivas, L. R. (1958) The discovery in Florida of the cyprinodont fish, *Rivulus marmoratus*, with a redescriptions and ecological notes. *Copeia*, 2, 125-130. Dissection of one 19.6 mm female fish revealed among the stomach contents one adult female and five larvae of *Aedes taeniorhynchus* and three pupal heads of *Aedes* sp. (probably also *A. taeniorhynchus*).

Haslam, J. F. C. (1925) Observations on the experimental use of fish indigenous to British Guiana for the control of mosquitoes breeding in vats, tanks, barrels and other water containers. *Jour. Trop. Med. Hyg.*, 28, 284-288. In British Guiana, the fairly common practice of keeping one or more fish (nearly always *Hoplosternum littorale*) in water receptacles, led to a study of the various indigenous fish that might be of value in mosquito control. The mosquitoes found breeding in the water receptacles were *Aedes aegypti* and *Culex pipiens f. stagnanum* with occasionally, *Anopheles tarsimaculatus*. The trials with the various fish are described and their results tabulated. Silverbait (species of *Tetragonopterus*, *Charax*, *Hemigrammus*), *Hoplosternum littorale*, and *Cichlasoma bimaculatum* appeared promising in this respect. For the smaller domestic water-containers silverbait are particularly useful, especially as they are able to live in water without the presence of mosquito larvae; for large vats or tanks the other species are more suitable. The advantages and disadvantages of each are briefly discussed.

Haslam, J. F. C. (1926) Report on experimental use of fish indigenous to British Guiana for the control of mosquitoes breeding in vats, tanks, barrels, and other water containers. *Br. Guiana, C.S.O.*, No. 3579/25, 8 pp., Georgetown. The following species are considered: *Hoplosternum littorale*, *Cichlasoma bimaculatum* and silverbait (*Tetragonopterus chaleus*, *Charax gibbosus*, *Hemigrammus rodwayi* and *H. unilineatus*). The silverbait are the most suitable for small domestic water-containers, being easily-obtained voracious feeders devouring all stages of larvae. Their use by villagers proved most satisfactory, particularly as it did away with the continual rescreening of vessels.

Bol. Inst. bras. Sci., 2, 262-265. Phalloceros caudomaculatus, a viviparous fish belonging to the same family as Gambusia affinis, is stated to be a very useful fish for destroying mosquito larvae, which it prefers to any other food. It frequents the edges of collections of water, thrives at temperatures between 10°C and 24°C (50°F - 75°F), and is very prolific.


Havens, L. C. & Dehler, S. A. (1923) The effect of Gambusia affinis on the Bacillus coli index of pollution of water. Amer. J. Hyg., 3, 298-299. In Alabama waters, the normal intestinal flora of G. affinis includes Bacillus pyocyaneus and an unidentified bacillus. Escherichia coli is not normally present in G. affinis, and experiments showed that the addition of fish to water polluted with E. coli causes the latter to disappear as a result of the inhibiting influence of B. pyocyaneus. The presence of G. affinis in large numbers may thus render the coli index an unreliable guide to pollution.


Heare, E. (1928) Mosquito control activities in western Canada. 58th Ann. Rept. Ent. Soc. Ontario 1927, 45-50. Gambusia affinis was thriving in warm sulfur pools in western Canada following its introduction, but at the time of publication no data were available as to whether the fish had acclimatized itself in the cold water.


Henn, A. W. (1921) The large-mouthed black bass in mosquito control. In his "notes on classification of fishes" accompanied by a letter to E. C. Meyer dated New York, May 23, 1921. The United States Bureau of Fisheries, because of the danger to native and useful species, sometimes declined to furnish bass and other fish that might do more harm than good.


Herald, E. S. (1942) Three new pipefishes from the Atlantic coast of North and South America, with a key to the Atlantic American species. Stanford Ichthyol Bull., 2, 125-134.

Herms, W. B. (1928) Limitations in the use of top minnows in Anopheles mosquito control in California and observations on anopheline flight activities. Southern Med. Jour., 21, 761-762. In a large percentage of anopheline breeding-places in California, it is difficult to maintain effective control by means of Gambusia on account of winter floods that carry away the minnows. The pools left by the receding streams are prolific sources of anophelines. Arrangements were being made in one locality to keep several thousand minnows in a concrete tank during the winter for restocking streams after the winter floods.

Herms, W. B. (1934) Mosquito control in California under the CWA. J. econ. Ent., 27, 102-1029. Gambusia was extensively employed in the major U.S. Civil Works Administration activities discussed.


Hess, A. D. & Tarzwell, C. M. (1942) The feeding habits of Gambusia affinis affinis, with special reference to the malaria mosquito, Anopheles quadrimaculatus. Amer. Jour. Hyg., 35, 142-151. As the effectiveness of a predator in reducing the numbers of a species depends mainly on its biotic potential and the preference that it shows for the prey, and the rapidity with which G. affinis became abundant in the newly impounded waters of the Tennessee Valley indicated a satisfactory biotic potential, studies were carried out from 12 June - 20 September 1940 to determine whether it showed a preference for Anopheles. Three different ecological situations in Wheeler Reservoir, Alabama, were included in the investigation, which involved the collection and examination of surface organisms from a sample totaling 255 sq. ft., and the stomach contents of 1018 Gambusia affinis. The forage ratio, obtained by dividing the percentage of a given organism in the
stomachs by the percentage of it in the environment, was used as a criterion of feeding preference. The data obtained indicate that the size of the forage ratio for any particular organism is affected by the species composition of the population of food organisms, the relative and absolute densities of the organisms, and their stage of development. Probably other factors, such as the amount of protection available for the prey, are also important. The size of the forage ratio for both anophelines and culicines was directly correlated with their population densities, but when they were present in equal numbers, the great preference was shown for culicines. As mosquito densities increased, the number of fish eating them and the number eaten per fish also increased. The forage ratio for anophelines was one when the larval density was about two per sq. ft of water surface; below this point it decreased and above it increased, reaching over 14 when the larval density was 17 per sq. ft. Male Gambusia ate only half as much food as females of the same size groups, but the organisms concerned exhibited similar species composition. The amount of food eaten by females increased with their size, and the largest fish took less plankton and more macroscopic foods than smaller stages. In the case of all Diptera, Gambusia showed a much greater preference for pupae than for larvae, and for the later larval instars than for the early ones. In general, the studies indicated that availability is more important than choice in determining the extent to which a particular kind of organism will be taken as food by Gambusia.


Hicks, E. P. & Diwan Chand (1926) A mosquito survey of Karachi airport. Rec. Mal. Surv. India, 6, 515-535. The absence of mosquito larvae from a spring was believed to be due to the introduction of a larvivorous fish, Lebias dispar. This species devours larvae eagerly and appears to be hardy; it was reported to have maintained itself in the habitat concerned and to have increased in numbers without the stock being replenished.


Hildebrand, S. F. (1919) Fishes in relation to mosquito control in ponds. U.S. Publ. Hith Repts., 34, 1113-1128. Wherever Gambusia affinis was introduced, mosquito larval populations were reduced in a very short time, unless sufficient protection was offered by submerged vegetation (e.g. aquatic grasses such as Hydrochloa caroliniensis, Myriophyllum and algae). During these experiments, details of which are given, it was noticed that certain mosquitos may develop in water so strongly acid that it is lethal for Gambusia. The number of fish required to effect mosquito control in a given pond varies with the conditions, being relatively small where the water is free from aquatic vegetation and other hiding places for the larvae. Although top-minnows are very prolific and multiply rapidly,
to ensure their use in mosquito control they must be protected from predaceous enemies such as the large-mouth black bass. For this purpose shallow hiding places must be provided near the water's edge. Other fish that might prove useful in mosquito control were held to include Fundulus notti, several species of sunfishes (CENTRARCHIDAE), and goldfish (Carassius auratus), the last-named being chiefly suitable for small and artificial waters.

Hildebrand, S. F. (1921a) Suggestions for a broader application of Gambusia for the purpose of mosquito control in the South. Publ. Hlth Reps, 36, 1460-1461. The value of Gambusia in mosquito control is discussed, and its widespread distribution to all possible standing and sluggish waters is advocated. Ponds that are easily accessible and adapted to the propagation of the fish should be used to breed them for general distribution. Every effort should be made to educate the public as to the importance of this fish and where a supply of it may be obtained free.

Hildebrand, S. F. (1921b) Prompt mosquito control by use of the top-minnow Gambusia. Publ. Hlth Reps, 36, 2220-2221

Hildebrand, S. F. (1921a) Top-minnows in relation to malaria contrl., with notes on their habits and distribution. Pub. Hlth Bull., 114, 34. (Spanish translation in Bull. Pan American Union, Spec. Ed. Nov. 1922; Portuguese translation in Portuguese Ed., Dec. 1922) The fish dealt with are Gambusia affinis, Heterandria formosa, Fundulus notti, F. notatus, and Mollienesia latipinna. With the exception of the last-named, all of these had proved of some value in controlling mosquito larvae and pupae in the southern United States (but owing to the limited observations made on H. formosa no definite information had been obtained regarding its practical value as a larvicide). The use of Gambusia affinis during antimalaria campaigns in 1920 reduced the cost and added greatly to the permanent nature of the work. An account is given of the distribution and habits of this fish. In the case of G. affinis, new broods consisting of any number up to 200 are produced at intervals of three to six weeks throughout the breeding season, which varies according to the duration of the warm weather. The two species of Fundulus were thought to be probably of very limited importance. Nowhere found abundantly, they seemed difficult to propagate in large numbers, so that it was felt extremely doubtful that they would prove of practicable significance except under very restricted conditions.

Hildebrand, S. F. (1922a) Fishes as guardians of health. Outlook, 130, Mar. 22.

Hildebrand, S. F. (1922b) Fishes in relation to mosquito control. Jour. Elisha Mitchell Sci. Soc., 37, 161-166. Experiments and observations on Mollienesia latipinna, a minnow often found with G. affinis in great abundance in potential mosquito breeding areas, had led to the conclusions that the food of the former species consists wholly of plants and that it is worthless as a larvicide. Gambusia affinis is compared with Heterandria formosa and Fundulus sp. as regards its biology and its effectiveness against mosquitoes.
Hildebrand, S. F. (1925a) A study of the top-minnow, Gambusia holbrooki i.: its relation to mosquito control. Publ. Hith Bull., 153, 136 pp. Investigations were conducted in Georgia during the summer of 1921 to 1924 with a view to obtaining accurate information on the actual value against mosquito larvae, under the widest range of conditions available, of Gambusia holbrooki (the species of Gambusia in the Atlantic Slope Region). They showed that an average total reduction of mosquito incidence of some 50 per cent. in the case of anophelines and 80 per cent. in that of culicines may be brought about by the establishment of the fish in ponds or swamps. The most successful control by Gambusia followed its introduction into an artificial pond that had previously contained no top-minnows and had a bottom growth of Myriophyllum, which was later superseded by Utricularia. Here the average reduction compared with 1921 over the three succeeding years was 97 per cent. for culicines and 75 per cent. for anophelines, the heaviest decrease occurring among pupae and large larvae. Similar treatment of various temporary swamps was less successful owing to the protection afforded to the larvae by vegetation, though a considerable reduction took place. Although complete control was not secured by introducing additional minnows into ponds already stocked with the fish, the reduction effected was large enough to be significant. It appeared from the experiments that culicine breeding decreases more rapidly in cool weather and towards autumn than anopheline breeding, and that culicines in general are less successful than anophelines in escaping from this predator. A series of experiments was carried out to determine the degree of protection afforded by Gambusia afforded by various types of vegetation. Hydrochloa carolinensis is the most important plant of a protective type. Scattered growths of this grass were observed to harbour more larvae and pupae than dense ones, so that better control by Gambusia is secured by leaving them undisturbed. The minnows were found to be effective in controlling culicines and anophelines in ponds where pine needle floatage had been deposited. The latter provided inadequate protection for mosquito larvae owing to the short time it remained afloat. In a ditch polluted by sewage water that had been treated with a commercial disinfectant as a larvicide, mosquito breeding continued but the fish died, although when oil was used instead of the disinfectant, the fish survived and controlled the mosquito larvae. An increase in the water level brought about by heavy rains sufficient to submerge all vegetation, resulted in almost complete elimination of mosquito breeding until readjustment took place. Where the vegetation was only partly submerged by rain, concentration round the remaining water plants occurred, though it is probable that the total number of larvae and pupae actually present was smaller, particularly as the minnows proved exceptionally active after rain. A constant water-level is thus conducive to maximum mosquito breeding both in fishless areas and in those stocked with Gambusia.

Hildebrand, S. F. (1925b) Installation of ponds for propagating Gambusia at impounded water projects. Publ. Hith Bull., 156, 98-103

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1 Now generally recognized as a subspecies of Gambusia affinis.
Hildebrand, S. F. (1931) *Gambusia* in foreign lands. *Science*, 74, 655-656. In Spain *Gambusia* became established rather quickly. *Gambusia* was then distributed, from the population originally established in Spain, to most countries of Europe from Germany and Austria southward. The antimoquito results claimed for the fish in southern Europe, and especially in Italy, far exceed those secured in United States. *Gambusia* was introduced, not only into southern Europe, but also into Palestine (where it failed), the Philippine Islands (from whence it is reported to have been taken on to China and Japan), Hawaii, the West Indies and Argentina.

Hildemann, W. H. & Walford, R. L. (1963) Annual fishes: promising species as biological control agents. WHO/EBL/7 (mimeogr.), 6 pp.; and *Jour. trop. Med. Hyg.*, 66, 163-166. The special merit of these fishes lies in their capacity to survive and multiply in impermanent water where other species would perish, thanks to their desiccation-resistant eggs which may remain viable for several months in the dried mud of intermittent ponds. Annual fishes occupy a wide range of temperate and tropical habitats of impermanent nature, and are native to certain parts of South America and Africa. The eggs may be concentrated, transported and dispersed in slightly damp peat. The voracious young are hardy and mature rapidly, the adults exhibiting high fertility.

Hindle, E. & Feng Lan Chow (1929) Experiments with malaria and mosquitoes in Shantung, China: with a note on the value of local species of fish for the destruction of mosquito larvae. *Trans. roy. Soc. Trop. Med. Hyg.*, 23, 71-80. Indigenous larvivorous fish are discussed, with respect to a lake from which these predators moved into temporary streams where they brought about a substantial measure of mosquito control. It is also noted that the common goldfish, so frequently kept in ornamental pools in gardens, serves to prevent the occurrence of mosquitoes in what would otherwise be very favourable breeding places.

Hixson, H. (1943) Data and observations on the natural reduction of *Anopheles* mosquito larvae in certain environments. *Florida Ent.*, 26, 17-24. *Gambusia affinis* was the most important predator upon anopheline larvae in a small lake near Gainesville, Florida, larvae of water scavenger beetles (*Tropisternus* spp.) assuming first importance in situations in which the minnows did not occur.


Hofstede, A. E. (1953) The development of *Anopheles* larvae on rice-fields during a combined cultivation of rice and fish. *In: Fish Culture in Indonesia; Indo-Pacific Fisheries Council Special Publications, No. 2*, pp. 103-111. Discusses the necessity of an ecologically sound approach to pisciculture in order to minimize the chances of anopheline production from fish ponds.
Hollands, E. A. (1953) An experiment in the control of malaria in New Ireland by distribution of Gambusia affinis. Trans. roy. Soc. Trop. Med. Hyg., 26, 529-538. At Kavieng, about 100 individuals of Gambusia affinis were introduced from Rabaul. Multiplication took place immediately in the drains, and the number of anophelines was diminished in a few weeks. Ponds, however, had to be repeatedly restocked from the drains.

Hollins, F. R. (1957) The atoll of Ontong Java, its depopulation and malaria control. J. trop. Med. Hyg., 60, 231-237. In 1954, as part of an antimalaria campaign, pits were made and stocked with Gambusia, which was already well established in some parts of the atoll. Six months later, the digging of more pits for Gambusia was advised. After a further six months, two anopheline larvae were collected near the village of Leuniau; but neither larvae nor any adults could be found elsewhere.


Hora, S. L. & Mukherji, D. D. (1953) Table for the identification of Indian freshwater fishes, with descriptions of certain families and observations on the relative utility of the probable larvivorous fishes of India. Hlth Bull., 12, 1-45
Horai, S. L. & Nair, K. K. (1938) Observations on the nutrition of Panchax panchax (Hamilton). Proc. Nat. Inst. Sci. IndiA., 4, 245-251. It is pointed out that practically no mosquito larvae were found in the habitats of Panchax panchax. From experiments carried out in the field by introducing the fish into mosquito larval habitats, it was evident that Panchax prefers to feed on mosquito larvae; and only when their supply is exhausted does it begin to feed on other organisms mostly insects and especially ants. These results were confirmed by laboratory experiments, in which the fish were given a mixed diet of mosquito larvae and other arthropods including chironomid larvae, corixid bugs, mayfly nymphs, water-mites, beetles, etc. Under these circumstances the fish showed a definite preference for mosquito larvae. It was also observed that, when kept with algae, the fish starved rather than feed on vegetable matter. The voracity of feeding and the intensity of digestion of P. panchax are also dealt with, and it is pointed out that this fish is not valued as human food. It is thus a very effective larvivore, and its practical use is strongly recommended. It is concluded that under Indian conditions this species has more to offer than Gambusia or Lebistes.

Horing, F. O. (1939) Yellow fever control in Brazil. Arch. Schiffs. u. Tropenhyg., 43, 352-368. Small collections of water were oiled, large ones being stocked with fish that destroy Aedes aegypti larvae.

Horn, A. E. (1916) Colony of the Gambia: Annual Medical and Sanitary Report for the year 1915. Bathurst, 23 pp. Fish taken in local drains were emptied into a large brackish lagoon to control Culex thalassius. The supply had to be constantly replenished, however, because predatory birds ate many of the larvivorous fish.

Houdemer, E. (1932) Observations sur quelques poissons dulcaquicoles culiciphages du Tonkin. Bull. Soc. med.-chir. Indochine, 10, 740-746. Freshwater fish native to Tonkin were found to devour mosquito larvae and pupae in an aquarium. The species experimented with, in order of efficiency, were: Anabas scandens, Macropodus verdiauratus, Carassius auratus (goldfish), Rasborinus lineatus, Toxabramis houdemerii, Culter breviceuda, and Barbus hainanii. Further investigations would be required to ascertain their value under natural conditions, in the presence of a rich plankton.

Houle, E. C. (1922) Yellow fever, fifth zone, northwest coast of Mexico, 1919-1922, 13 pp. (Mimeographed). The indigenous fish, Rabalo plateado, was employed as a mosquito larvivore.


Howard, H. H. (1920b) Use of top-minnow (Gambusia affinis) as an agent in mosquito control. International Health Board Rept. No. 746, June 1920, 89 pp., New York (mimeographed)
Howard, L. O. (1901) Mosquitoes, how they live, how they carry disease, how they are classified, and how they may be destroyed. New York, McClure, Phillips, 241 pp. Outlines experiments on indigenous fish of North America, and advocates the use of perch in open, shallow wells to keep down mosquito populations and assist self-purification processes in the water.


Howard, L. O. (1923) Recent results of anti-mosquito work of the Bureau of Entomology, United States Department of Agriculture. Proc. N. J. Mosq. Exterm. Ass., 2, 68-78. A survey for Gambusia affinis in anopheles larval habitats showed that this fish finds no difficulty in establishing itself in relatively deep and open water. In open impounded water, however, there is no mosquito breeding, and larger fish present there in numbers are an indirect aid to mosquito control; their attacks on Gambusia tending to drive the latter into the shallow water along the margins, utilized as mosquito larval habitats.


Howlett, F. M. (1914) Report of the Imperial Pathological Entomologist. Rept. Agric. Res. Inst. and Coll., Pusa, 1912-1913. Calcutta, pp. 80-83. The introduction of the West Indian "millions" fish proved useful under semi-domestic conditions, but otherwise a failure. The fish were placed in large tanks in which they were apparently destroyed by large dytiscid beetles which attacked both the young fry and the adult fish. It is probable that indigenous Haplochilus spp. are equally effective as larvives.


Hubbs, C. L. (1915) The stickleback: a fish eminently fitted by nature as a mosquito destroyer. Calif. Fish and Game, 5, 21-24. Gasterosteus aculeatus feeds upon developing mosquitoes, even in the presence of an abundance of other foods. The fish feeds at all levels of the water and is relatively unmolested by larger fishes. It is widely distributed, living from brackish bays to small mountain streams and pools. Summer temperatures seem not to affect G. aculeatus, which withstands transportation from its native streams to artificial ponds, in open buckets or in cans, such as those used to transport fish fry for planting in streams distant from hatcheries.
Hubbs, C. L. (1927) *Gambusia manni*, a new species from the Bahamas. *Copeia*, 164, 61-66. On the basis of habits and mouth structure it is suggested that this fish may prove valuable in mosquito control.


Hubbs, C. L. (1940) Fishes from the Big Bend region of Texas. *Trans. Texas Acad. Sci.*, 23, 3-12. *Gambusia gaigei*, Hubbs is confined to "a marshy cattail slough fed by springs, located close to the Rio Grande at Boquilles, Brewster County, Texas, opposite the Mexican village of the same name". Introduced bass and sunfish may have decimated or even annihilated the small, native larvivorous fishes of the Big Bend region, thus contributing towards an increase in anopheline incidence evident at this time.


Thering, R. von (1928) Os "guaras" on "barrigudinhos". Brasileiros na luta contra as larvas de Culicideos. *Sci. Med.*, 6, 8 pp. (reprint pagination)


Jackson, L. E. (1929) Memorandum on trials with *Gambusia* in Hudson County. *Proc. N. J. Mosq. Exterm. Assoc.*, 14, 84-86. Tests with *Gambusia patruelis* and *G. affinis*, each of which gave practically the same results, showed that both fish have a decided preference for mosquito larvae. They thrive equally well in salt and fresh water and are not disturbed by a rather high degree of pollution. Optimal environmental conditions include a temperature of 73°F, and the presence in the habitat of some vegetation. Their preference for shallow water leads them to seek the inland ends of ditches, where mosquito larval incidence is heaviest, and prevents them from passing from the ditches into deep water from which they are not likely to return. Although these fish are viviparous and are said to reproduce very rapidly where a high temperature is maintained, the breeding period in New Jersey is likely to be short. In consequence, no great increase in the number of
Fish imported is to be expected there even if the species can survive the winter. Mosquito larvae remain absolutely still when aware of the approach of fish, which rarely take one unless it is moving. The larvae shelter beneath vegetation or in the corners of a tank to escape detection.


Jepson, F. P. (1917) Insects injurious to man and animals. Dept. Agri. Fiji, Ann. Rept. for the year 1916, Suva, 23-25. Fish introduced from Honolulu in 1910 to feed upon mosquito larvae in shallow ponds and swamps were reported to be still breeding vigorously.


Job, T. J. (1941b) Food and feeding habits of the glassfishes (Ambassia Cuv & Val.) and their bearing on the biological control of guinea-worm and malaria. Indian J. Med. Res., 29, 531-562. Analysis of the gut contents of 268 specimens of Ambassia nama and 313 Ambassia ranga collected from malarious areas of Bengal in 1939 and 1940, showed that these "glass fish" feed at all levels in the water and subsist mainly on micro-crustaceans that are abundant in the subsurface plankton. To a small extent they indulge in "sight feeding" also, consuming mosquito larvae (mostly culicines) from the subsurface and worms from the bottom.

Job, T. J. (1941c) On the comparative efficacy and relative cost of biological and chemical methods of mosquito control in clean-weeded railway borrow-pits at Fuleshrwar, Bengal. Jour. Vetal. Inst. India, 4, 211-215. A railway borrow-pit was divided into three sections, each 20 ft by 12 ft, of which the first was dusted with 4 oz. of 2 per cent. Paris green mixture every fifth day according to the routine procedure in the neighbouring area, the second was stocked with 96 adults and 48 young individuals of Aplocheilus panchax, and the third was left as an untreated control. The Paris green only destroyed anopheline larvae in the late instars, other stages of anophelines and all culicines being unaffected. The fish destroyed first the older larvae and pupae of both anophelines and culicines and later the younger larvae; the section was free from larvae and pupae four days after the introduction of the fish and remained so. All aquatic stages of mosquitoes continued to thrive in the control section. Excluding expenditure on supervising staff, which is essential in chemical control, the cost of treatment with Paris green was more than 20 times that of introducing the fish.

Job, T. J. (1944) Public Health Fish Farming. Indian Farming, 5, 10-13

John, C. C. (1940) Observations on the utility of Aplocheilus lineatus (Cuv. and Val.) for mosquito control. J. Malar. Inst. India, 3, 67-80. The range of the larvivore (Aplocheilus) = Panchax panchax includes Bengal and Orissa. The fish does not extend to the peninsular part of India, where it is replaced by P. lineatus.


Jordan, D. S. (1927) The mosquito fish (Gambusia) and its relation to malaria. Rept. Smithsonian Instn., 1926, 361-368. Gambusia parvula and G. holbrooki devour mosquito eggs, larvae and adults in enormous numbers. They are prolific breeders, are easily transported, and are capable of withstanding a large range of temperature. They have been found to survive in a pond covered with 1-1/2 ft of ice in Illinois, and have been observed in water at 102°F. In establishing the fish in a new region, it is advisable to prepare a pond, not more than 4 ft deep with a lining of concrete. Copper sulfate, sometimes used to clear weeds from ponds, is fatal to Gambusia, and large water beetles (Dytiscus spp.) are very destructive to it.

Jordan, J. (1937) Mosquito larvicidal measures. Chin. Med. Jour., 51, 927-936. Larvivorous fish were held to be of limited value in Shanghái, Gambusia requiring feeding during the winter months as an alternative to repeated restocking of the ponds.


Observations were carried out in and near Batum on the biology of Gambusia affinis, which following its introduction into Abkhaz in 1924 greatly increased in numbers and came to play an important part in the control of mosquitoes. It was found that the fish could survive under very unfavourable conditions; they thrived in highly polluted water which was hardly deep enough to cover them, and developed normally in water rich in tannin. The presence of any iron oxide in the water, however, was fatal to them, and when placed in sea water they died within a week. The young fish could subsist entirely on the micro-organisms that occurred in water containing vegetation. Other small fish were readily attacked by Gambusia even when mosquito larvae were available. Each female produced 50-100 completely developed young at a time, but under artificial conditions these were invariably
devoured by the adult fish. In an experiment the young were dissected from
the female and released in a separate reservoir, where they developed normally.
This method is, therefore, recommended for breeding G. affinis under artificial
conditions. In nature the young fish avoid being eaten by hiding among dense
vegetation or by remaining in very shallow water. They feed on mosquito larvae
of the first and second instars, and on various micro-organisms. The adults
show a definite preference for larvae of Culex (especially in reservoirs with
abundant vegetation) and the eggs of Anopheles. One individual may devour 300
or more larvae in five minutes. At temperatures below 10°C (50°F) the fish
hibernate in the mud. Oiling was fatal to Gambusia only when applied in very
shallow water devoid of vegetation, but most of the fish were killed by the
routine application of Paris green.

Arch. Schiffs- u. Tropenhg., 36, 539-544. An experiment indicated that Gambusia
can develop normally in water containing iron oxide.

and on its enemies/ (In Russian) Med. Parasitol., 2, 356-339. Notes are given
on the history of the introduction of Gambusia into Europe and its establishment
in the USSR.

Kaman, M. (1928) Distribution and biology of Anopheles maculipennis in the malarious
region of the Mur and Drava (district of Prelog and Ludbreg) (In Serbian).
Glasnik hrv. prirodosl Dr., 39-40, 176-191. The feasibility of the introduction of
Gambusia, unsuccessfully attempted in 1926, is discussed.

Glasnik, (Bull. Min. Hyg.), Belgrade. Use might be made of the fish Rhodesus
amurus of Lake Dorian and Paraphoxinus minutus and P. epiroticus of Lake Frespa
and Lake Ohrida. All three species destroy mosquito larvae along the shores of
these lakes.

Kazantsev, B. N. (1943) Observations on the hibernation of Gambusia in the vicinity
of Stalnabad (In Russian) Med. Parasitol., 12, 74-77. Gambusia was shown to
hibernate well in natural water reservoirs in which the temperature at the bottom
does not fall below 11°C to 12°C. Concrete basins seemed unfavourable for
hibernation.

Dept., London, 20-21. Undetermined species of indigenous fish proved useful in
the control of mosquitoes in household wells, residents believing them of more
practical significance than well covers.

Khalil, M. (1930) Introduction du poisson *Gambusia affinis* en Egypte, dans le Soudan anglo-egyptien, à Chypre et en Syrie pour combattre le paludisme. *Ann. Parasit. hum. comp.*, 8, 553-557. The author describes the introduction of *Gambusia affinis* from Corsica into Egypt for the purpose of controlling anopheles. This fish is more valuable than *Tilapia nilotica*, which lives in fresh water, and *Cyprinodon* sp. from salt water. It had multiplied rapidly in Egypt, where it had been widely distributed, proving particularly useful as a larvivore in covered collections of water. From Egypt consignments of *G. affinis* were sent to Cyprus, the Sudan and Syria.


Khozatskii, L. L. (1944) The role of amphibians and reptiles as natural enemies of *Gambusia* (in Russian) *Med. Parasitol.*, 13, 67-71. Natural enemies of *G. affinis* in the USSR include snakes, terrapins, amphibians and water birds. Less important are predatory fishes (which are usually absent from the smaller ponds and reservoirs used as *Gambusia* establishment sites) and aquatic insects and their larvae. Among the birds, ducks and geese consume large numbers of mosquito fish. Snakes (Coluber karelini, *Natrix tesselata*, *N. natrix*), newts, frogs (*Rana ridibunda*, and *R. esculenta*) and terrapins (*Emys orbicularis*) feed extensively upon *Gambusia* as well as upon other insectivorous fishes (species of *Rutilus*, *Gobio*, *Varicorhins*, *Alburnoiles*, *Nemachilus*, etc.)

Kimball, J. H. (1965) Integration of sewage disposal and mosquito control in Orange County, California. *California Vector Views*, 12. For 20 years, mosquito control was a constant problem in an impoundment basin. The introduction of larvivorous fish was then undertaken, and proved highly effective over the six years prior to the publication of this account. Orange County Mosquito Abatement District, as part of its district-wide mosquito abatement programme, then furnished and delivered whatever quantity of mosquito fish were necessary for adequate control within suitable ponds and holding reservoirs, always providing that the sewage effluent was sufficiently stabilized to contain a sufficient level of dissolved oxygen.
King, A. (1913) Report of the Medical Officer of the Second Division for the year 1912-1913. Ann. Rept. on the Hospitals and Dispensaries, St. Lucia. In spells of dry weather, stocks of Lebistes reticulatus died out except in large collections of water. Smaller pools thus had to be restocked constantly.

Kligler, I. J. (1930) The epidemiology and control of malaria in Palestine. In Biological Methods, University of Chicago Press, pp. 152-154. Gambusia was brought from the United States and successfully acclimatized. This paper reports on experiments with indigenous species of Cyprinodon and Tilapia, the former feeding selectively upon mosquito larvae. They are not top feeders, and rarely hunt their food among surface plankton. When confined in small clean pools or aquaria, they will keep them free from both culicines and anophelines. In pools covered with algae or surface vegetation, however, they are practically useless. In moderately clean canals, or in pools having a limited food supply, Gambusia yields excellent results. Tilapia is an omnivorous feeder. Under confined conditions in the laboratory, it eats algae, vegetable matter, such as leaves and young shoots, larvae and young Cyprinodon or Gambusia with equal voraciousness.

Kligler, I. J. & Shapiro, J. M. (1925) Organization of areas for mosquito control in Palestine (In Yiddish) Harefuah, 1, 180-188. In reservoirs serving orange groves, Tilapia sp. had been used with great success as a mosquito larvivore.

Kirpichnikov, V. S. (1945) On the utilization of Percottus glehni Dyb. for the control of the larvae of bloodsucking mosquitoes (In Russian). Med. Parasitol., 14, 82-84. This predacious freshwater fish is common in ponds, lakes and swamps in the Russian Far East and under laboratory conditions will feed readily on larvae of Anopheles and other mosquitoes. It frequents marginal vegetation, feeds on insects, reaches sexual maturity in two years (females then contain about 1000 ripe eggs) and in winter can survive in ponds frozen almost to the bottom.


Kovchazov, G. & Kolarov, K. (1966) Laboratory and field studies of exotic larvivorous annual fish at Varna, Bulgaria. WHO/EBL/66.67 (mimeogr.)

Krieg, H. (1950) Experience in the control of anophelines in Upper Italy, (Adriatic Region). Anz. Schadlinzsk., 23, 177-181. Gambusia was employed together with chemical control measures, in the control measures implemented after the great rise in malaria incidence during World War II.
Krumholz, L. A. (1948a) Reproduction in the western mosquito fish, Gambusia affinis affinis (Baird & Girard), and its use in mosquito control. Ecol. Monogr., 18, 1-43. 30 095 specimens of G. a. affinis, a sexually dimorphic, viviparous fish, were sexed, measured and classified as mature or immature individuals. It was found that females generally attain a greater length than males, because they continue to grow until they die, whereas males stop growing when the gonopodium is completely formed. Length frequencies indicate that females, under natural conditions, give birth to one to five broods a summer, depending on their age at maturity, then die. Offspring of the first and possibly the second brood mature within six weeks after birth, give birth to one to three broods, then die. Later broods do not mature until the following spring, then give birth to three to five broods and die. The gestation period is 21-28 days, the average of 14 periods in the laboratory proving to be 23.9 days. Thus the reproductive period may extend over four to 15 weeks, depending on the age at maturity. The size of the mother is to a certain extent a limiting factor on the brood size, but the rate of increase in the brood size is not as rapid as that of the mother and is apparently controlled by some metabolic factor. The decrease in fecundity with increasing size of the mother holds for fish of all ages. The reproductive period is followed by a period of sterile senility. The sex ratio is 1:1 at birth but gradually shifts in favour of the females because of differential death rate between the sexes. Investigations during two summers showed that mosquito fishes were 90.9 and 94.8 per cent. effective in controlling anopheline production. When G. a. affinis was introduced into a fish-free pond at the height of the mosquito-breeding season, 80 per cent. control was affected.

Krumholz, L. A. (1948b) The mosquito fish, Gambusia, established in the Great Lakes Region. Copeia, 2, 144. The western mosquito fish, Gambusia affinis affinis, was first introduced into the region of Chicago, Illinois, in 1923 and again in 1925. From those plantings a hardy strain developed and thereafter maintained itself, under natural conditions, in various parts of Cook County, Illinois.


Kühlhorn, F. (1965) An investigation of the natural enemies of Anopheles larvae (Diptera: Culicidae) in different areas at varying altitudes in West Germany. WHO/EBL/57.65, mimeogr., 18 pp. Examination of the intestinal contents of free-living specimens of Gasterosteus aculeatus and Phoxinus leavis repeatedly revealed remains of anopheline larvae. Cyprinus carpio ate mosquito larvae under experimental conditions, and carp are held to be of distinct value as predators on Anopheles larvae in natural biotopes lacking floating vegetation.
Kulagin, S. M. & Martzinovskii, V. I. (1936) Attempt to establish Gambusia in the cooling ponds of an electrical power station (In Russian) Med. Parasitol., 5, 52-61. A section of 22 sq. yds was partitioned off in one of the ponds in question, in a place with abundant marginal and emergent vegetation. Several thousand Gambusia obtained from the Caucasus were liberated there in July and September 1934. The fish multiplied in large numbers until November, when they were carried away into an adjoining peat swamp owing to the accidental flooding of the ponds. A few were found in December in one of the connecting channels in which the water had a temperature of 24°C, and in the following March they appeared in one of the ponds, becoming abundant by the end of May. The presence in the water of potassium hydroxide (which was used ten times a year to wash condensers) did not affect Gambusia although some fish of other species living in the ponds died. In 1935, young were produced until the end of October, and probably each overwintered adult female gave rise to at least seven broods of 75-100 fish. In the course of the summer, females of the first and second broods also produced offspring. In Gambusia, high temperatures accelerate sexual activity, and the development of the young in gravid females. In aquaria, with a constant temperature of 24-26°C, the young were produced from March to November inclusive. In the autumn of 1935 fish from the breeding reservoir were sent to several antimalaria stations in the Moscow area and liberated in natural accumulations of water. Previous efforts to establish Gambusia there had shown that until the frost begins they thrive under natural conditions and are effective against anopheline larvae.


Lacan, 1 (1956) Les gites larvaires dans les étangs de pisciculture. 2nd Symposium on African Hydrobiology and Inland Fisheries, C.S.A., Comm. Tech. Co-op. Afr. South of the Sahara, Brazzaville, 259-261. At Mossendjo, Central Congo, nine species of Anopheles including the dangerous malaria vectors A. gambiae and A. funestus had been found in fish-ponds. Tilapia spp. raised for food are seldom larvivorous and in any case are not surface feeders; and should be accompanied in fish-ponds by effective larvivores such as Gambusia affinis.

Laird, M. (1954) The mosquitoes of Aitutaki, Southern Cook Islands. Bull. Ent. Res., 45, 423-427. Irrigation ditches in which larvae of C. annulirostris were found contained various predators and there was striking evidence of the effectiveness of Gambusia (which had been introduced some 20 years earlier) in controlling this mosquito. Note: on the basis of the identification of specimens collected, Laird (1956) emends this predator citation (which resulted from the statement in relevant Government reports that Gambusia was indeed the subject of the introduction in question) to Lebistes reticulatus (see Tamashiro, 1964, here-under).

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1 Initials not given in original publication.
Laird, M. (1956) Studies of mosquitoes and freshwater ecology in the South Pacific. Roy. Soc. N.Z. Bull., 6, 213 pp. The fishes occurring in freshwater habitats in the tropical islands of the South Pacific are, with the exception of introduced cyprinodonts, of recent marine origin. The families Gobiidae, Electrotridae and Ambassidae are all represented. Some 20 different fish studied from Queensland, the Solomon Islands, New Caledonia, the New Hebrides, Fiji, Samoa and the Cook Islands showed varying degrees of larvicidal activity. Lairdina hopletupus Fowler is of particular interest in this respect. Native to Viti Levu, Fiji, this electrid lives in marshes and readily flings itself across several inches of wet mud to invade marginal hoofprint pools, favourite culicine larval habitats in the locality concerned. Under laboratory conditions, L. hopletupus and also Ctenogobius nebulosus (Solomons, Fiji, etc.) thrive on an exclusive diet of mosquito larvae (Culex annulirostris). They destroy pupae as well, but exhibit a preference for larvae when both developmental stages are available.


Laveran, A. (1907) Traité du Paludisme (Deuxième Ed.) Masson, Paris, vii + 622 pp. Confirms an earlier observation of ponds of equal size being left after flooding, one with a few fish and the other without; the former remaining free from mosquito larvae, which, however, became numerous in the latter.


Legendre, F. (1934b) Note sur une tournée de prospection antipalustre à Ambatoindrazaka et dans la région du lac Alaotra. Bull. Soc. Path. exot., 27, 957-960. Reservoirs for the rearing of Gambusia were established in this Madagascar town and at the agricultural school, and additional ones were to be established round the lake, etc. A small larvivorous fish found in a river near Andreba, although less effective than Gambusia, might also be used in the High Plateaux region.


Legendre, J. (1913) Prophylaxie du paludisme in Italie. Bull. Soc. Path. exot., 6, 468-476. Terni examined the stomach contents of small tench (Cyprinus carpio) and in each found from 60 to 80 mosquito larvae.
Legendre, J. (1914a) Index endémique du paludisme et sa prophylaxie à Tananarive (Madagascar). Ann. Hyg. Med. Colon., 17, 531-535. Those areas of water most removed from the irrigation canals were practically devoid of cyprinodonts, and there the mosquito larvae had practically no enemies; the incidence of malaria among children varied from 100 per cent. on the side where the water of the rice-fields was absolutely devoid of fish to 30 per cent. in another area where larvivorous fish were more or less abundant.


Legendre, J. (1916) Destruction des moustiques par les poissons. C. R. Acad. Sci. (Paris), 163, 377-378. A station was established at Tananarive, Madagascar, for the purpose of breeding two varieties of carp which feed on anopheline larvae and which were imported from France and the island of Reunion respectively. Observations on the introduced goldfish, Carassius auratus, were made in rice-fields, and it was found that the high temperature, and abundant food supply occasioned by the presence of mosquito larvae, caused a rapid multiplication. In one instance 1300 fish increased to 18 000 in five months.


Legendre, J. (1920b) Régime alimentaire du cyprin dori à Madagascar. Compte-rendu Hebdomadaire des Séances de l'Académie des Sciences, No. 120.


Legendre, J. (1937) L'utilisation de Gambusia affinis et Girardinus guppy pour la lutte antimalarienne. Bull. econ. Indochine, 40, 328-330. The desirability of attempting to establish Gambusia affinis and Lebistes reticulatus (=Girardinus guppy) for the control of anopheline larvae in Indo-China is questioned. A number of examples of Gambusia introduced into ponds in Tonkin bred prolifically between March 1935 and March 1936, and then disappeared completely. Others introduced into a pond in Cochinchina, increased enormously in numbers between April 1936 and March 1937. If the disappearance of the fish in the first case was due to the unsuitability of biological or ecological conditions, then they would have to be specially reared and the expenses incurred would be great. On the other hand, although the climate in Cochin and Cambodia would appear to be favourable, it was feared that the introduced fish would destroy large numbers of the indigenous varieties that not only form one of the staple articles of food of the inhabitants but are also dried and exported in large quantities. These arguments apply equally well to both species. It is concluded that since the utilization of larvivorous fish is, at best, only a supplementary measure against malaria, it is undesirable to introduce the exotic species; particularly as there are several widely distributed native species that are not only equally larvivorous but are also of considerable food value.


Le Van, J. H. (1941a) Methods for controlling Aedes aegypti mosquito with Gambusia holbrooki minnows at Key West, Florida. Publ. Hith Repts., 56, 1217-1221. An account of the introduction of Gambusia holbrooki into cisterns and wells in Key West, Florida, for the control of Aedes aegypti. A careful inspection of 2376 containers in May and June 1940, rather more than a year after they had been stocked, revealed the presence of fish in 1105 of them, and mosquito larvae were found in only eight of these. Many of the cisterns from which fish were absent had been pumped dry and had not been restocked when refilled. Mosquito larvae were found in 392 of the 869 cisterns, 216 of the 332 wells, and 24 of the 70 barrels in which there were no fish.


Lewis, D. J. (1944) Observations of *Anopheles gambiae* and other mosquitoes at Wadi Halfa. Trans. roy. Soc. Trop. Med. Hyg., 38, 215-229. Small fish were too numerous in the shallow water at the river's edge for many larvae to reach Wadi Halfa by drifting, and cars and boats that could carry adult mosquitos were few. *Gambusia holbrooki* proved a great success in the Faras Canal as there were no predatory birds, and predatory fish did not have access.

Lewis, D. J. (1948) The mosquitoes of the Jebel Auliya Reservoir on the White Nile. *Bull. Ent. Res.*, 39, 133-157. Several predacious fish are mentioned but their rôle in the natural control of mosquitos was inadequately known. 25 000 *Gambusia* were released, and this colony increased but not to the density of the stock pond. A native minnow (*Aplocheilichthys loati*) may have limited the density and spread of *Gambusia*.


Lindberg, G. U. (1934) *Contributions to the knowledge of the genus Gambusia* (In Russian) *Med. Parasit.*, 4, 351-367. Detailed descriptions are presented of the morphology of the male gonopodium and of both sexes of *G. affinis affinis* and *G. affinis holbrooki*.

Lloyd, R. E. (1910) Mosquitoes and fish. *Jour. Bombay Nat. Hist. Soc.*, 20, 1165-1166. From his own observations in the Zoological Gardens at Alipore, Calcutta, the author concluded that *Panchax panchax* was less efficient as a larvivore than other workers had claimed.

Loftin, U. C. (1919) Mosquitoes found about Gainesville, Florida. Mosquitoes and disease. *Florida Buggist*, 3, 37-43; 48-50. The most active enemies of mosquitos in Florida were held to be *Gambusia affinis* and the centrarchid *Chaenobryttus gulosus*.

Lowry, R. P. (1929) Mosquitoes of New Hampshire. A preliminary report. New Hampshire Agric. Expt. Sta., 243, 23 pp. The most important natural enemy of Aedes taenierhynchus in New Hampshire was claimed to be a killifish, Fundulus heteroclitus, which was extremely abundant, following the incoming tide anywhere on a marsh where there was sufficient water. However, only isolated pools that are not reached by ordinary tides are suitable as larval habitats for this salt marsh mosquito.

Lozano, A. (1942) Brief accounts of Gambusia holbrooki and its present distribution in Spain. (In Spanish) Rev. Sanidad e Hig. Publ., 17, 186. G. holbrooki was imported from the United States of America in 1921. It became widespread in Extremadura, Province of Salamanca, and occurred less commonly in the Provinces of Zaragoza, Avila, Valladolid, Madrid, Toledo, Cordoba, Barcelona, Tarragona, Castellon, Valencia, and Alicante. Earthenware tanks were used to transport the Gambusia during the establishment phase, and it proved that they were able to survive two days of travelling under summer conditions.

McCormick, E. M. (1940) The relation between the amount of arsenic a fish gets from mosquito-control dusting and the lethal dose. Jour. Tennessee Acad. Sci., 15, 342-351. There was no evidence that Gambusia or catfish were killed as a result of anti-anophelene dusting with Paris green in the neighbourhood of Reelfoot Lake, Tennessee. Fish caught in nature showed the presence of arsenic on the body but not in the alimentary tract. Some of those exposed to Paris green in the laboratory died, but probably not from arsenical poisoning. Although a very small amount of arsenic was found in one batch of two alimentary tracts, and death in this case might possibly have been due to poisoning, no arsenic was found in the other fish that died, and the positive result may have been caused by the accidental inclusion of a part of the skin in the test material. Moreover, other fish survived in water treated with much larger quantities of Paris green.

MacDonagh, E. J. (1946) Piscicultura del pejerrey. Rev. Fisca Agron., La Plata, 26, 33-50. Mackerel destroy mosquito larvae and other insects, and play a similar rôle to the carp grown under parallel conditions in Italy and elsewhere.

MacDonald, W. R. (1914) A short note on the use of larvicidal fish in combating malaria fever. Proc. Third All-India Sanitary Conf., 4, 75-77. The commonest larvivorous fish of Madras City were reported to be (Haplochilus) = Panchax panchax, P. melastigma, P. lineolatus, Chela sp., Rasboro danicouius and Therapon jarbua (in brackish water). (Haplochilus) = Panchax was claimed to be very voracious and Chela and Rasboro also killing many larvae. Therapon jarbua, though very efficient, was less widely distributed. A large number of wells and tanks were stocked with fish, but these at first made no headway against the larvae. Several tanks close to the Tamil Mission Orphanage, in which all the inmates were suffering from malaria, were found to contain quantities of fish, and at the same time to be swarming with larvae due to the protection afforded by a mass of algae. The weeds were then removed and the margins trimmed and made smooth so as to destroy all pools and footprints. The water was covered with petroleum, which did not in any way interfere with the fish, and by the end of March, the mosquitoes had diminished and the health of the occupants improved.

MacGregor, M. E. (1924) Report on the anophelines of Mauritius, and on certain aspects of malaria in the Colony, with recommendations for a new antimalaria campaign. London, 48 pp. Though larvivorous fish were very abundant and widely distributed, they were not felt to be of any great value under natural conditions. In artificial waters, though, their use had proved very successful.


McDonald, W. M. (1916) Suggestions for the institution of rural anti-mosquito measures in Antigua. Jour. trop. Med. Hyg., 19, 261-262. While small fish occurred in great numbers in the open waters of certain ponds, mosquito larvae were also very numerous among the grass and vegetation round the edges. The latter must be kept clear if larvivorous fish are to be of use.

McHardy, J. W. (1927) Report by the entomologist, Medical and Sanitary Services, Tanganyika Territory. Rep. Med. Lab. Dar-es-Salaam, 1926, 57-74. Small fish abundant in the drains were apparently reducing the number of anopheline larvae in those parts where they had free access to them.


Mail, G. A. (1954) The mosquito fish Gambusia affinis (Baird & Girard) in Alberta. Mosquito News, 14, 120. Gambusia affinis was introduced into Banff in 1924, approximately 200 fish being imported from California and held for some months in a cold woodland pool near a field laboratory. About 25 were planted in the warm waters overflowing from the Cave and Basin Swimming Pool at Banff. These waters flooded an extensive area of swampland, where mosquito larvae were plentiful, below the pool. The swamps were checked by the Park Warden Service almost 30 years afterwards (summer of 1953) and the presence of numerous schools of top-minnows was confirmed. This was believed to be the most northerly area where the successful establishment of G. affinis had been achieved.


Matthes, H. C. (1935) A study of the seasonal distribution of Anopheles in Houston, Texas. Amer. J. Hyg., 21, 233-248. Of the natural enemies of Anopheles quadrimaculatus found, Gambusia affinis was the only one that could be considered of practical importance.

Mattingly, P. F. (1952) In: Hopkins, G. H. E., Mosquitoes of the Ethiopian Region. I. London, Brit. Mus. (Nat. Hist.), p. 8. Under laboratory conditions at Lagos, Nigeria, small fish believed to be Epilatys (Haplochilus) grahami jumped up to three inches out of the water to take adult mosquitoes held by forceps. This species is abundant in the swamps near Lagos, and devours mosquito larvae voraciously. Dr Mattingly, in a personal communication (1965) mentioned that the individual fish recorded as jumping to the height mentioned above, were themselves much less than three inches long.


de Menezes, R. S. (1947) Um peixe da família do Cavalo Marinho em água doce, no Ceará. Seu provável papel como peixe larvicida no controle da Malária. *Historia Natural "Caca e Pesca",* São Paulo, 6, 32-33


Molloy, D. M. (1924) Some personal experiences with fish as an anti-mosquito agency in the tropics. *Amer. Jour. Trop. Med.*, 4, 175-194. The use of fish against mosquito larvae is reviewed, and the author's personal experience in Nicaragua is described. *Poecilia sphenops*, a fish of great value in Nicaragua, is found throughout Central America both in tidal waters and mountain streams. It is hardy and withstands transportation well. During the yellow fever campaign in 1919 all wells and other artificial water containers were restocked with this and other fish, and the disease, which was already on the wane, disappeared. The malaria rate was incidentally greatly reduced. Among the chief factors to be considered in using fish for mosquito control are the number of fish present in a given area and amount of available food-supply. In the case of limited food-supply the fish will surmount almost any barrier such as vegetation to get at the most remote breeding place. Examples of this type of natural control existing in Nicaragua are described. By applying supplementary measures (cleaning the edges of ponds and streams) mosquito control could be made almost absolute so far as both artificial ponds and streams are concerned.

Monchadski, A. S. (1946) Activity in attacking man and day rhythm of *Mansonella richiardii* Flt. (In Russian) *Bull. Acad. Sci. URSS Ser. biol.*, No. 2-3, 299-323. The relative scarcity of other mosquitoes on the Vakhsh was apparently due to the destruction of their larvae by *Gambusia affinis holbrooki*. However, this fish, which had been introduced several years before, did not destroy the larvae and pupae of *M. richiardii* which live submerged and attached to the stems of aquatic plants.
Monroe, W. M. (1923) Notes on the limit of the usefulness of fish in larvae (Aedes calopus) control. Amer. Jour. Trop. Med., 3, 21-26. For the control of A. aegypti (= calopus) the use of fish in fresh water containers proved most valuable. A number of experiments were carried out to test the efficiency in this respect of the bottom feeder, Dormitator maculatus, and the top feeder, Gambusia nicaraguensis. The results showed that the average consumption of mosquito larvae for these fish is generally about 150 a day, bottom-feeding fish being rather more efficient for their weight than top feeders. When mosquito breeding occurs in barrels where fish are present, it is due to the fact that the number of larvae is beyond the limit of the feeding capacity of the fish.

Moore, J. P. (1922) Use of fishes for control of mosquitoes in northern fresh waters of the United States. Appendix IV to the report of the United States Commissioner of Fisheries for 1922. U.S. Dept. Commerce, Bur. Fisheries, Document No. 923, 60 pp. No fish of which mosquitoes are more than an incidental item of diet are indigenous to the fresh waters of the north eastern United States, but several species of small fish and the young of some larger ones native to these waters proved to eat eggs, larvae and pupae of mosquitoes more or less habitually. Of these the most important were found to be a centrarchid, Lepomis gibbosus (= Eupomotis gibbosus), the most useful species in ponds and lakes; Umbra pygmaea, in shallow or swampy areas; and Fundulus heteroclitus, in fresh and brackish tidal marshes. Gambusia affinis had not survived the northern winters, but was shown to multiply so rapidly that it could be used effectively against both culicines and anophelines in small ponds and water gardens by restocking each spring. Small goldfish were claimed to be useful in fountain basins and small ponds with clean sides, being preferable to the top-minnow for use in rainwater tanks.


Morin, H. G. S. & Martin, P. (1936) Utilisation des poissons contre les moustiques. Arch. Inst. Pasteur. Indochine, 6, 443-505. In the first paper of this collection, Morin & Martin briefly reviewed the history of the use of fish against anopheline larvae, giving lists of the species that had been employed for this purpose in various countries, discussing the advantages and disadvantages of using indigenous species, quoting examples of the practical application of the method in Java, and giving notes on precautions to be taken to ensure survival during transportation and rearing. The next two papers, by Morin (pp. 462-464) and Morin & Martin (pp. 465-469), dealt with experiments towards the establishment in Indo-China of Lebistes reticulatus (= Girardinus guppyi) and Gambusia affinis, respectively. The fourth (pp. 470-471) listed the fish

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1 Which was also issued separately with the original pagination.
collected in Indo-China by the Anti-Malaria Service of the Pasteur Institutes, indicating the species that fed on mosquito larvae in the laboratory. The fifth (pp. 472-476), comprised a key by P. Chevey to the freshwater fish of Indo-China, the same author in the sixth (pp. 476-484), describing four felt to be potentially valuable as larvivores. In the last paper (pp. 485-495) Morin & Moreau summarized the research that had been carried out by Pasteur Institutes in Indo-China on the utilization of indigenous and exotic mosquito-eating fish; recommending large-scale field trials on the basis of their promising initial experiments.

Mufel, P. P. & Guterman, E. M. (1937) /Campaign against anopheline larvae in fish ponds/ (In Russian) Med. Parasitol., 6, 239-242. In view of the fact that fish had been found to die in water oiled for the control of anopheline larvae, experiments to study the effect on them of arsenical dust larvicides were carried out in the summer of 1936 in the Province of Voronezh. For this purpose, three large artificial water reservoirs containing dense aquatic vegetation and harbouring anopheline larvae were stocked with very young and one-year-old carp; the plants rising above the surface of the water were cut, and the water was repeatedly treated with dust shaken from a muslin net. In one dusted with Paris green mixed with oleugembrin in the proportion of 1:20, the film that formed on the surface remained intact for several days, and the number of larvae was reduced from 4.7 to 0-0.004 per sq. metre. The second reservoir was dusted with a mixture of calcium arsenite, Paris green and oleugembrin (which gave less than 50 per cent. control) and the third with calcium arsenite mixed with road dust (1:10), which reduced the number of larvae per sq. metre from 12.7 to 2.3. Analysis of the water before and after the treatments showed that there was no appreciable change in its composition, and no change occurred in the plankton and benthos. The condition of the fish was not affected in any way. This was confirmed in laboratory experiments in which young fish were placed in glass jars and the water was dusted with mixtures of oleugembrin and calcium arsenite or Paris green. The films remained on the surface of the water for five, six and 24 hours respectively, and the fish continued to be very active and in perfect condition. In another experiment, young fish and anopheline larvae were kept in a wooden box in one of the artificial reservoirs so that it was half full of water. The fish were dissected two to three days after dusting and their digestive tracts analysed for the presence of arsenic. The results were invariably negative. The fish were very active all the time, and the larvae were quickly destroyed by them.


Mulla, M. S. (1963b) Toxicity of organochlorine insecticides to the mosquito fish Gambusia affinis and the bull frog, Rana catesbeiana. Mosquito News, 23, 299


Mulligan, H. W. & Majid, S. A. (1936) Some notes on the care, transportaition, and use of Gambusia affinis under Indian conditions. Rec. Malaria Surv. India, 6, 537-547. In 1929, a stock of Gambusia affinis was established at Karnal. Demands for supplies for use in anophele control work increased to an enormous extent, requests being continually received for information on the care and use of the fish. This paper answers some of the commoner questions regarding their rearing, maintenance and transport under Indian conditions, and the types of mosquito larval habitats in which they had proved most effective.

Murphy, W.O'S. (1914) Larvae-eating fish in Sind (M.S.) (Reference incomplete, title and abstract secured from Prashad and Hora, 1936 q.v.) Murphy during his extensive tours in Nawabshah, Hyderabad and parts of the Karachi district investigated various indigenous fishes to evaluate their larvivorous propensities. He found that the smaller fish of the species, Cirrhina mrigala, Ambassas ranga, Perilampus atpar (= Leubuca atpar), Nuria danirea (= Escomus danricus), Barbus terio and Gobius giuris (= Glossogobius giuris) were all useful as larvivores. Some unidentified species were also found to have larvivorous propensities. According to Murphy, no mosquito larvae were found in any pool in which any of the five species listed above were present; and a decided preference was shown by the fishes for larvae over pupae.

Myers, G. S. (1925) Fishes and human disease. Fish culturist, 5, 27-29. The value of fish in mosquito control is briefly reviewed, with particular reference to Guayaquil, Ecuador, where it was claimed that Aedes aegypti was finally eradicated by the use of Lebiasina bimaculata, Dormitator latifrons and Lebistes reticulatus in domestic water-containers. Species of Gambusia and Panchax (Haploclilus) panchax were very largely used wherever conditions were favourable, and apparently always with success. The bottom-feeding catfish, Astroblepus sp. of the Andes, a ravenous larvivore of nocturnal habits, was much used in Peru. It was remarked that practical use had yet to be made of indigenous cyprinodonts of the genus Rivulus, which being able to travel overland1 can thus enter even small permanent larval habitats (e.g. hoof prints) in the jungle. These fish also readily enter leaves of floating aquatic plants utilized by certain mosquitoes as larval habitats.

1 See also Laird, 1956.

Myers, G. S. (1928) The species of *Piabacina* inhabiting Colombia. *Copeia*, No. 166, 4-5. The fish previously recorded as an enemy of mosquitoes in Colombia under the name *Piabacina panamensis* is not that species but *P. festae*, which is common in the Atrato and San Juan basins of the Pacific Slope.

Myers, G. S. (1965) *Gambusia*, the fish destroyer. *Tropical Fish Hobbyist*, January 1965, 31-32 & 53-54. Warns that *Gambusia*, when introduced into places where it does not occur naturally, may cause havoc to populations of indigenous fish including food and game species much larger than itself. In connexion with its attacks on the young of much larger fish, original observations are reported from California showing that when 11 goldfish and approximately 250 *Gambusia* were kept together in a garden pond the two populations remained comparatively stable in size over a five-year period, the biomass of goldfish in the pond at all times exceeding that of the top-minnows by some two to one. However, on removal of the *Gambusia*, the goldfish population increased to the point where, at the end of the seventh year of observation, the biomass of the latter in the pond was approximately three times as great as when *Gambusia* was present, and was still increasing. Furthermore, it is stated that when introduced into places where it does not occur naturally, "almost everywhere" where "Gambusia has been introduced, it has gradually wiped out most or all of the smaller native mosquito-destroying species". Thus its establishment in Bangkok has caused the indigenous larvivore (*Aplocheilus = Panchax panchax*) to become rare, in the lower Nile it has replaced the native *Micropanchax schoelleni*, and in the creeks of Laguna de Bay, Philippines, it has replaced *Gulaphonus*. It is pointed out that guppies (*Lebistes reticulatus*) are less harmful in these respects, and the need for fuller data on the over-all ecological consequences of past *Gambusia* introductions is stressed.


Neghme, A., Gutierrez, J. & Alee, R. (1956) Attempt to eradicate Anopheles in the malaria zone of Chile. Amer. J. trop. Med. Hyg., 4, 1114-1118. "Weekly application of petroleum to breeding places, marsh drainage and filling, repair of irrigation canals and control of springs, together with naturalistic measures and distribution of Gambusia affinis were the principal methods used until July 1944 when house spraying with DDT against the adults became the chief measure ..."


O'Donnell, S. P. (1930) Reports on the suitability of "millions" as destroyers of mosquito larvae in India. Rec. Malar. Surv. India, 1, 137-139 /Reprint of a paper first published separately in 1912/ Outlines the first unsuccessful importation of Lebistes reticulatus (150 examples were brought in via the Colonial Office, London, in 1909). The fish proved unable to withstand temperatures of 29.5°C (85°F). This paper also discusses other more promising experiments at Pusa, where Mr. F. M. Howlett of the Imperial Research Institute concluded that "millions" and climbing perch (Anabas testudineus) were better larvivores than the widespread indigenous Chela argentea.


Olenev, N. O. (1940) /Mosquitoes of the Lower Volga and their control/ (In Russian) Saratov, 88 pp. Mosquito control measures outlined include the use of Gambusia together with chemical procedures.

Osborn, H. L. (1907) Destruction of mosquitoes and their larvae by fish and lime. Jour. Bombay Nat. Hist. Soc., 17, 332-333. "Chilwa" fish (Chela argentea) were claimed to be very valuable larvivores. The species is a surface-feeder, found in most parts of India. The author conducted some experiments in a cistern about eight to nine feet long by five feet broad and five feet deep, finding that 50 to 60 "chilwa" were able to clear the habitat of mosquito larvae within a week or so.

Oxner, -- (1930) Trois années d’expériences d’acclimatization des Gambusia sur la Côte d’Azur. Mesures anti-larvaires dans la lutte générale contre les moustiques et instructions techniques sur l’emploi des poissons larvivores. Soc. Med. Litt. Mediterr., Nice, 20 pp. The history of the importation of Gambusia into Europe is reviewed, with notes on the conditions favourable to the life, transport and reproduction of these minnows; and an account is given of the results of rearing and acclimatizing them in the South of France, over a three-year period.

Paladino-Blandini, A. (1933) Ordinamento e primi risultati della lotta anti-anofelica generale in Calabria. Riv. Malariol., 12, 118-195. Liberations of Gambusia holbrooki were effected from 1928 to 1931. This paper does not report the results of the introduction.


Patterson, R. S. & von Windeghuth, D. L. (1964) The effects of Baytex on some aquatic organisms. Mosquito News, 24, 46-49. Baytex in a granular formulation at the rate of 0.2 pounds per acre over a three foot depth of water, exhibited no overt toxic effects on freshwater copepods, ostracods, Hydra, annelid worms, snails, clams, or the mosquitofish, Gambusia affinis. This situation remained unchanged over a period of four months.

Peach, J. H. (1923) Experiments made with larvivorous fish in British Honduras. Jour. R. Sanit. Inst., 43, 335-336. The species of larvivorous fish in British Honduras are Tetragonopterus teneus, Cichlasoma actofasciatum and Mollienesia sphenops. All of these fresh-water species are able to live in rain water with little light and no artificial feeding.

1 According to Prakash & Hora (q.v.), the name "chilwa" is applied to about a dozen species of Chela - all of which are eaten "by the poorer classes", a fact that obviously counts against their success as larvivores.
Pecori, G. & Escalar, G. (1930) Relazione sulla campagna antimalarica dell'anno 1929. Riv. Malariol., 2, 479-549. In spite of distributing over 116,000 Gambusia, this fish could not be established in waters rich in carbonic acid. Trout proved to be of some value in the destruction of mosquito larvae.

Pecori, G. & Escalar, G. (1934) Relazione sulla campagna antimalarica nell'Agro Romano durante l'anno 1933. Riv. Malariol., 13, 623-668. 78,500 Gambusia were placed in waters where this fish was rare or absent. The breeding of trout was continued on a property where their efficiency was held to be proved by the absence of malaria since 1932.


Perry, E. L. (1914) Endemic malaria of the Jeypore Hill Tracts of Madras Presidency. Ind. Jour. Med. Res., 2, 456-461. A small fish, Danio rerio, about an inch long, proved common throughout the Jeypore district, living in shoals in the streams and rice-fields. Where it occurred no mosquito larvae were ever found, although no actual proof that it is larvivorous was obtained.

Perryassy, A. (1919) Biologia dos anofelinos brasileiros. Saude, Rio de Janeiro, 11, 145-158. Among the natural enemies of Brazilian anophelines are a number of fish such as Girardinus caudimaculatus, Pocelia vopora, Glaicidodon januarius and Jenynsia lineata.

Perryassy, A. (1930) O emprego de peixes na destruição das larvas de mosquitos. A Folha medica, 11, 160-162. In this popular article on the use of fish against mosquito larvae, it is stated that Astyanax rutilus is very abundant around Rio de Janeiro, and is of considerable value in this connexion.

Peterson, E. & Walker, F. D. (1923) Mosquito control in St Thomas. U.S. Nav. Med. Bull 18, 291-303. In rural areas Anopheles larvae were kept down by fish, particularly Lobistes reticulatus, introduced many years previously but again specially imported (from St Kitts) in 1919.
Petragnani, G. & Castelli, A. (1927) Le Gambusie nella lotta antilarvale in provincia di Cagliari (con particolare reguardo alla biologia). Riv. Malarol., 6, 709-727. Gambusia holbrooki became established in Sardinia following its introduction as a larvivore. It can live in water with a salt-content of 20-25 parts per thousand as well as in fresh water, and tolerates waters too rich in decomposing organic matter for other fish, a fact that renders it useful against certain culicines. It is extremely prolific, but where other suitable food is lacking the young fish are eaten by the adults. At temperatures of 20-30°C (68-86°F) the fish lived without food for over three weeks. It was found advisable to stock the salt-water pools communicating with canals and ditches, even if their salinity precluded the occurrence of mosquito larvae; for in the dry season, when the canals and ditches dried up the pools themselves remained as a nursery for the fish, which could regain the canals when they were again filled. Individual fish kept a water surface of 11 sq. ft free from larvae.

Petriščeva, P. A. (1936) The rôle of Gambusia and some indigenous insectivorous fish in the control of malaria in Turkmenistan (In Russian) In Pavlovskij, E.N., pp. 111-138. Harmful animals, Moscow. A brief account of the use of different species of fish against mosquito larvae in the USSR since 1911, together with details of work in Turkmenistan in 1929. The latter activities involved the introduction of Gambusia, which greatly increased in numbers and spread in a system of ponds and ditches that become connected at the time of spring floods. The suitability of various types of habitats is discussed. The methods used for transporting Gambusia to different districts in Turkmenistan are described. Laboratory observations on the fecundity of the female showed that six to seven broods of 60-80 young fish may be produced from April to the end of October. Of the indigenous larvivorous fish, Alburnoides bipunctatus eichwaldi, Varicorhinus heratensis and Nemachilus malaperturus were found to be the most important; notes are given on their habits and the types of water in which they thrive. In the laboratory Alburnoides destroyed more mosquito larvae in a given time than the others, but not so many as Gambusia; Varicorhinus destroyed more than Nemachilus.

Phillips, W. J. (1930) Use of fishes for control of mosquitoes. N.Z. Jour. Sci. Tech. 12, 19-20. Gambusia was imported into New Zealand against indigenous culicines and to provide an ecological barrier against the possible accidental importation of anophelines. At least five species of fish indigenous to New Zealand were thought to be probable enemies of mosquitoes, though the only one in which mosquito larvae have actually been found is the smelt, Retropinna retropinna.

Piedallu, - (1930) Comment j'ai installé l'élevege des gambusias dans les grands bassins du jardin d'essai d'Algour. 2e Congrès international du Paludisme, Alger.

Piramov, Kh. N. (1942) A pond for Gambusia (In Russian) Med. Parasitol., 11, 123-124. This paper describes a suitable reservoir for the maintenance of a stock of Gambusia, its bottom being formed by terraces, each covered with water plants.


Pomeroy, A. W. J. (1920) The prophylaxis of malaria in Dar-es-Salaam, East Africa. Jour. R. Army Med. Corps, 35, 44-63. Dr Spurrier tried imported fish from the Seychelles, but common local species proved just as effective. The fish used in the campaign were all indigenous, consisting of Tilapia nilotica, T. ovata, T. natalensis, T. mossambica, Ambassies commersonii, Fundulus guentheri, Mugil macrolepis, Gobius giures and Eleotris fusca.

Prashad, B. (1915) The importance of insects to fisheries. Proc. 3rd Ent. Mtg., Pusa. pp. 908 & 909. Drew attention to the need for more critical studies of the potentialities of indigenous Indian fish as larvivores. Such studies should, it was urged, include careful observations of what these fish actually eat in nature.

Prashad, B. & Hora, S. L. (1936) A general review of the probable larvivorous fishes of India. Rec. Malaria Surv. India, 6, 631-648. An excellent survey (of which much use has been made in the preparation of the present bibliography) of the use of fish in controlling mosquito larvae in India. "We would like, however, to make it clear that in advocating a more extensive use in India of biological control - in this instance by larvivorous fishes - for anti-malarial measures we do not mean to decry entirely the use of chemical larvicides. Such chemical larvicides are, for example, specially valuable in waters of a temporary nature, where biological control with fish or other animals would be impossible. All the same, their use in tanks, bhees and other such large areas of water which support valuable fisheries and often are the sources of water-supply of the local population cannot be recommended."


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1 If the "Fundulus" referred to is in fact the fish today known as Nothobranchius guentheri, the record would be the earliest yet brought to light of the use of an "annual fish" for mosquito control (ref. Bay, 1965; Haas, 1965, 1966; Hildemann & Walford, 1963; Kovchakov & Kolarov, 1966; Vanderplank, 1941)

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under the climatic conditions of southern Ukraine. It was found that the fish could survive the winter (in a pond in which the water was covered with ice for 3 1/2 months), and multiply in large numbers during the summer and autumn without being given artificial food. They lived for several months in water, the salinity of which was gradually increased from 0.3 to 1.5 per cent, but died in a few days in water containing 2 per cent NaCl. They also lived in natural brackish water in drainage ditches, in which the salt content did not exceed 0.6 per cent. This power of adaptation to brackish water is of special importance on the north-western coast of the Black Sea, where larval habitats often become brackish in summer.

Prince, J. A. 1e & Orenstein, A. J. (1916) Mosquito Control in Panama, with an introduction by L. O. Howard. US Bureau of Entomology, Putnam's, New York. pp. xvi + 335. In a chapter on natural enemies, the value of small fish and the limitations of their actions are discussed at length. It is noted that in situations where rank vegetation and algae are produced rapidly, the larvivorous potentialities of top-feeding fish are much reduced.


Radcliff, L. (1915) Fishes destructive to the eggs and larvae of mosquitoes. Dept. Commerce, Bur. Fish., Economic Circular, 17, 19 pp. In considering candidate larvivorous fish, the habits of the target species of mosquito and its usual breeding places must be carefully considered if success is to be attained. In the United States, suitable freshwater fish include: Fundulus diaphanus, Fundulus dispar, F. notatus, F. chrysotus, F. notti, Notemogonites crysoleucas, Carassius auratus, Gambusia affinis, Heterandria formosa, Enneacanthus chaetodon (= Mesogonistus chaetodon), Centrarchus macropterus, Lebiasistes siculus, Elasmomma zonatum, E. evergladei and Helleniessa latipinnis. Those suitable for brackish or salt water use are Fundulus majalis, F. heteroclitus, F. grandis, F. similis, Lucania parva (L. venusta) (= Notropis venustus?) and Cyprinodon variegatus. When fish are sent by train, the journey should be as short as possible, and the water kept at an even temperature and well aerated.

Raina, B. L. (1945) Larvicultural fish of Kangra Valley. *Schizothorax progastus*. *Ind. Med. Gaz.*, 80, 273-274. In its early stages of development, *S. progastus* is a valuable larvivore, preferring mosquito larvae to other types of food available in its natural surroundings. The young ones, especially, are actively larvivorous. However, the older fish have the disadvantages (from the standpoint of mosquito control) of being relatively large in size and good for eating.


Raj, B. S. (1930) The value of fish as natural enemies of mosquitoes in combating malaria. Pamphlet, Madras Fisheries Dept. Deals with the most useful larvivores of South India, and includes practical advice on their mass rearing, transportation, and field release.


Ranganathan, V. & Ganapati, S. V. (1949) Collection, acclimatization and transport of the fry and fingerlings of the milk-fish, *Chanos chanos* (Forskal). *Indian Farming*, 10, 368-374


Rapson, A. M. (1957) Coastal and highland freshwater fishery problems in Papua and New Guinea. *Indo-Pacific Fishery Council, 7th Session, Bandung, May 1957* (Mimeogr.) Considered that the widespread use of Gambusia in New Guinea had not made any real impression on mosquito populations, and noted that World War II bomb craters sometimes contained the local fish *Gobiomorphus guirus* as well as mosquito larvae and Gambusia, the latter fish being attacked by *G. guirus* which was not observed to be larvivorous. Claimed that fish ponds well-stocked with *Tilapia mossambica* seldom contain mosquito larvae.

Rebrin, M. (1938) On the acclimatization of a new larvicidal fish in Uzbekistan. *Social Sci. Tech.*, 6, 106-107. In view of the successful results obtained in Dakar and Indo-China from the establishment of Lebistes reticulatus for the control of mosquito larvae, preliminary small-scale observations were carried out in Tashkent in 1937 by N. P. Sokolov. It was found first that though *L. reticulatus* produces young more often than *Gambusia*, the number in each batch is smaller, although on the whole, the fecundity of the two species is practically equal. Fertility depends on the size, weight and age of the female. Summer temperatures in Uzbekistan appeared to be suitable for acclimatizing *L. reticulatus*, but its reactions to winter conditions were still unknown.


Rees, D. M. (1945a) Supplemental notes on mosquito fish in Utah, *Gambusia affinis* (Baird & Girard). *Copeia*, 4, p. 263. From observations in the field and under laboratory conditions in Utah there was no evidence that *Gambusia* pass the winter hibernating in the mud at the bottom of ponds and streams. The immediate source of the water, with subsequent environmental effects was held to be the most important factor in determining the winter survival of *Gambusia* in Utah, since it had been determined that, except for a few explainable exceptions, they survived the winter only in water near its emergence from springs or artesian wells. In water from this source temperatures remain relatively constant, the water being well aerated and remaining open and comparatively free from ice; conditions favourable to the top-feeding and breathing habits of these fish and conducive to the production of food, which thus provide the essential requirements for winter survival.

Rees, D. M. (1945b) The utilization of fish by a mosquito abatement district; their effectiveness and limitations. *New Jersey Mosq. Exterm. Assn.*, 32nd Annual Meeting, p. 211. In Salt Lake City, two indigenous species of chub, *Gila atraria* (Girard) and *Iotichthys phlegothontis* (Cope), were found useful as predators on mosquito larvae in streams and gun club marshes. However, they had proved unsatisfactory for stocking smaller, more temporary pools and streams for mosquito control purposes. Both species have a restricted seasonal reproductive period and do not reproduce rapidly enough to provide the fish necessary for stocking purposes; and while they feed voraciously on mosquito larvae during the spring, they seem to ignore them as food later in the season. Goldfish (*Carassius auratus*) were frequently used to stock small ornamental pools, but fully half of the pools containing goldfish in the Salt Lake City district were also stocked with *Gambusia*, which did not permit the former to increase.

Reijntjes, E. J. (1922) Vischvijvers en malaria bestryding. Teysmannia, 33, 261-263.
In their investigations on the relationship of fish ponds to malaria in Java, van Breemen and Sunier concluded that the particular ponds examined by them favoured the breeding of Anopheles ludlowi and consequently increased the malaria hazard. It had been assumed elsewhere that all fish-ponds must necessarily encourage malaria, but this is not the case. In fact, conditions definitely unfavourable to A. ludlowi prevailed in such ponds when they were properly managed with a view to obtaining a large yield of fish.

Reyne, A. (1925) Eenige proeven met vischjes en chemicalien tot het dooden van muskietenlarven. Dept. Landbouw, Nijverheid en Handel in Suriname, Paramaribo, Bull. 47, 54 pp. The drainage ditches in the city proper did not breed mosquitos, owing to the presence of numerous fish of which Acantophacelus reticulatus was the most effective. Experiments with this and other fish are described.

Reynier, C. (1954) Tiout (Sudoranesis) Etude historique, géographique et médicale. Arch. Pasteur Alger, 32, 107-141. Gambusia holbrooki, first introduced in 1935, was abundant in the smaller channels of a well drained area associated with a large water course, being regarded as making a significant contribution to malaria control.

Rice, L. A. (1941) Gambusia affinis in relation to food habits from Reelfoot Lake, 1940, with special emphasis on malaria control. Jour. Tenn. Acad. Sci., 16, 77-87. An account of the results of an examination of the stomach contents of 316 specimens of Gambusia affinis collected from 10 stations in the littoral zone of Reelfoot Lake, Tennessee, in 1939. Plant material, mostly Wolffia, was found to constitute 24.7 per cent. by volume of the food, and animal material 35.6 per cent., the remainder being digested matter or debris. Insects formed 22.4 per cent. of the whole, but larvae of Anopheles and Culex comprised only 0.4 and 0.5 per cent., and were found in only two and eight stomachs respectively. The food of the young fish was practically confined to plankton. Experiments showed that anopheline larvae can usually be identified as such and sometimes specifically identified during their passage through the stomach and intestine, and that the fish devour the larvae readily, but only when the latter are in motion. It was concluded that the dense aquatic vegetation of Reelfoot Lake and small pieces of debris afforded so much protection that the fish were of very little practical value there. No mosquito larvae were found in the stomachs of Gambusia collected between 9 and 16 July, 1940, although dips from the zone with heavy vegetation showed an abundance of larvae of Anopheles, Culex, and Uranotaenia. However, only the larger fish were examined, and it was found that these were not plentiful in this zone but congregated in the shallow water under willows; whereas the smaller fish entered vegetation and were seen to search for Anopheles.
larvae among the Ceratophyllum and to take them if they moved. In an examination
of the stomach contents of a total of 465 Gambusia taken between 9 July and
14 August from the same stations as those examined in 1939, 20 per cent. of the
food was vegetable and 80 per cent. animal, the latter including 23.5 per cent.
insects, 13 per cent. mosquito larvae, and 5 per cent. larvae of Anopheles.
Mosquito larvae represented 10 to 25 per cent. of the food of 154 Gambusia from
an area of heavy vegetation, but were not found in 125 from open water and areas
almost free of vegetation. The percentages of stomachs found to contain various
forms of food in earlier surveys are compared, the figures for anophelines being
0.6 and 13.1. The reason for the difference is not known, but various
explanations are suggested. The stomach contents of 46 specimens of Fundulus
dispars, which is present in Reelfoot Lake at the ratio of 1 Gambusia to 40
Gambusia where vegetation is heavy and 1:100 where it is light, bore considerable
resemblance to those of Gambusia, but 31.11 per cent. of the stomachs contained
anopheline larvae, which formed 10 per cent. by volume of the total food. From
these data, it appears that both fish are of value in the control of mosquito
larvae when they can gain access to the latter.

by the use of fish". Doc. 556, App. VII, R.V.S.C.F., 1925, 16-17

Rich, W. H. (1925) Progress in biological inquiries, "mosquito control". Doc. 990,
App. II, R.V.S.C.F., 37-64

Rimbaut, G. & Mathis, M. (1935) Utilisation des "poissons millions" pour la lutte
biologique contre les larves d'Anopheles à Dakar. Bull. Soc. Path. exot., 28,
575-577. An account is given of the successful establishment of Lebistes
reticulatus in a pond. At the time of introducing the fish (eight females and
two males) more than 1500 mosquito larvae were recorded in 10 dips; the numbers
of the larvae diminished rapidly as the fish increased, until 47 days later no
larvae were found and there were over 500 fish.

China Med. J., 26, 347-360

Pest., 6, 123-127 and 7, 363-374. Preparations were being made for the use of
Gambusia in 1938.

Rode, P. (1926) Un poisson grand destructor des larves des moustiques. Riviera Scient.,
Nice, 13, 17-18. A species of Tilapia which is an effective destroyer of
mosquito larvae, was claimed to have brought about drastic reduction of anopheline
and malaria incidence at Siwa, Egypt.

4, 449-455. Practically all the permanent and semi-permanent bodies of water are
densely populated by Gambusia, and the abundance of anopheline larvae seems to
depend on the amount of shelter provided by aquatic vegetation.

The production of guppies was found to vary inversely with the concentration of adults, and the number of young eaten increases with density of the adult population. The author suggests that as has been established for certain other aquatic organisms, rather specific water-borne body products of guppies may act to limit the population.

Ross, Sir R. (1911) Fish as a natural enemy of mosquitoes. In his "Prevention of Malaria", London (pp. 267-269) Between 1889 and 1890 Ross investigated the use of larvivorous fish and found minnows in India that could each devour in a few seconds a dozen or more larvae. Large fish, however, ignored such prey. He noticed also that fish and larvae lived together in ditches and in rice-fields. The freedom of Barbados from malaria he thought might be due to the fish locally known as "millions" (*Lebistes reticulatus*).


Roule, S. (1934) *Rôle des poissons larvivores dans la prophylaxie du paludisme*. (Thése Med.) Le François, Paris, 61 pp. The fish in question are classified according to whether they feed on the bottom or surface of shallow water, or in deep water, and the morphological and biological characters promoting larvivorous habits in different families of fish are discussed. These characters are most marked among the poecilids (including *Gambusia* spp.), which are the most hardy and voracious of larvivorous fish, and adaptable to a wide range of geographical and physical conditions. In habitats in which mosquito larvae are protected by aquatic plants it is not possible to destroy them by *Gambusia* alone, but where these fish can move about freely in the water, anopheline populations have sometimes been so reduced that malaria has disappeared as a result. The great advantages of the use of *Gambusia* are that it is easily introduced and the cost is low. The best results are obtained when it is combined with the use of chemical larvicides, which are required at the beginning of the season and become progressively less necessary as the population of larvivores increases.

Roy, D. N. (1938) On the control of malaria-mosquitoes in Bengal by the use of predacious fish and on the habits of two of them. *Jour. Malar. Inst. India*, 1, 405-416. Outlines field and laboratory observations on the behaviour of *Panchax panchax* and *Barbus phutum*. The two most important vectors of malaria in Bengal were said to be *Anopheles philippinensis* Ld., and *A. varuna* Iyen., breeding respectively in neglected reservoirs and in weedy and partly shaded reservoirs. The presence of a surface cover of duckweeds (Lema and Azolla) was in itself sufficient to interfere with the action of fish on anopheline larvae, so that unless it is possible to remove such vegetation or prevent its growth, the utilization of these larvivores in the control of malaria is impracticable. It was concluded that, although fish may aid in checking the multiplication of mosquitoes in general, the practical benefits likely to be derived from their extensive use for the control of malaria in rural areas in Bengal would be too slight to make it a measure of economic value.
Rukhanskij, S. V. & Levit, Y. S. (1934) /Fish-breeding as a method of controlling malaria in the Ukraine/ (In Russian) Rev. Microbiol., 13, 151-159. In the Ukraine, the endemic centres of malaria occurred in districts with vast expanses of water resulting from river floods. Neglected mill-ponds also offered favourable breeding places for mosquitoes, of which Anopheles maculipennis Mg., was the chief vector of the disease. As it was planned to use large accumulations of water for breeding fish, investigations were carried out in 1932 on the possibility of rendering the fish-ponds unsuitable for mosquito larvae or using the fish against them. For this purpose, over 50 carp-ponds were examined near Kiev. Measures suggested to prevent the breeding of anophelines included the removal of vegetation from the water, thus depriving the larvae of shelter from the fish; the improvement of the channels by which the ponds were filled or drained and in which anopheline larvae were often numerous; dusting with Paris green, which, unlike oil, does not affect the fish; and stocking the ponds with young carp, which feed readily on the larvae. The value of other fish in this respect was discussed, the introduction of Gambusia being particularly advocated - experiments having shown that it could be established in the Ukraine.

Rukhadze, N. P. (1934) /Gambusia in Abkhaz/ (In Russian) Med. Parasitol., 3, 60-68. Since the introduction of Gambusia into Abkhaz (Transcaucasia) from Italy seven years earlier, this fish had also been liberated in Russian Central Asia, North Caucasus and Odessa. In Abkhaz, numerous breeding ponds had been established, and nearly all reservoirs that were likely to harbour anopheline larvae were now stocked with this fish. In the Sukhumi district, Gambusia was very effective in 1932 in 78 per cent. of the total area of water infested, incidentally destroying anopheline eggs and pupae, which are scarcely affected by oil or Paris green, and in four years the amount of material used for oiling had been reduced by almost 50 per cent. The fish were found to disperse widely by entering streams, rivers and swamps after heavy rains. Some were carried by water during spring floods and remained in pools left after these receded, a prolific source of anophelines. The efficiency of Gambusia was also demonstrated in ponds and lakes formed by mountain springs, but as the water in these proved too cold for the fish to breed, they had to be artificially stocked. Artificial, temporary water reservoirs were stocked with Gambusia at the rate of one fish to 10 sq. ft of water surface if there was no vegetation, the number being increased in proportion to the density of the vegetation. Usually, most of the fish present in temporary accumulations of water died after these had dried up; in order to avoid the labour of restocking, deep pits should be dug at the bottom of such pools, ditches or ravines, as some of the water and a few fish will remain there till the next heavy rain or flood. The presence of iron oxide or even traces of it, in the water was shown to be fatal to the fish, which died in the laboratory when kept in water supplied by recently-installed iron pipes. Wild and domestic ducks, and snakes, proved the chief enemies of Gambusia in Abkhaz. In one locality the fish were protected from the snakes by spraying kerosene on the surface of the water, or strewing sulfur on the soil around the reservoirs. Also, administrative measures had to be taken to stop the local people from using Gambusia for feeding their ducks, geese and even pigs.
Russell, P. F. & Jacob, V. P. (1939) Some experiments in the use of fish to control Anopheles breeding in casuarina-pits. *Jour. Malar. Inst. India*, 2, 273-291. Experiments with larvivorous fish indicated that in sandy casuarina pits, in which vegetation is scanty, good control of the larvae might be obtained by using Gambusia affinis. It would, however, be necessary to have a suitable nursery to provide a constant supply of fish to replace those lost in various ways, and to employ a "fish patrol" to see that all pits were adequately stocked and to remove occasional patches of vegetation. The cost of such a method is discussed, and it is again concluded that although anopheline breeding is not completely precluded, the method is sufficiently cheap and effective to be applied as a routine measure. Experiments were also carried out with two local species of fish, but neither was as effective as Gambusia and it seemed unlikely that they could be rendered more efficient by artificial means.


Sasa, M. et al. (1964) Observations on a mosquito-eating fish (Lebias reticulatus) breeding in polluted waters in Bangkok. *WHO/EBL/26.64, WHO/Vector Control/59.64*, mimeographed, 24 pp. Field observations and experiments indicated that a pollution-tolerant strain of the introduced Lebias reticulatus is of considerable use against Culex pipiens fatigans. Furthermore, this mosquito is susceptible to sumithion applied at 0.1 ppm, a dosage which does not harm the Lebias colonies. Integrated control involving the joint use of this guppy strain and appropriate chemical procedures is therefore advocated for future use against C.p. fatigans in sewage-fed waters. In an addendum, the senior author mentions having since discovered an apparently cold-resistant strain of L. reticulatus in Japan.

Savitskij, V. I. & Ermolëenko, A. G. (1944) Experimental acclimatization of Gambusia in waters of Kiev and vicinity (in Russian) *Med. Parasitol.*, 13, 83-89. In this area, it was found best to undertake the planting of G. affinis in the spring, as fish established in natural reservoirs generally died (possibly from lack of food?) before the end of February.

Scharff, J. W. (1947) Report on a mosquito and sanitary survey of Labuan, with notes upon anti-mosquito measures proposed. *Malayan Med. J.*, 2, 88-95. Larvae of Anopheles ludowi Theo. were abundant wherever the salinity of the water was adequate, except in small pools in which the fish, Panchax panchax occurred and where mosquito larvae were unprotected by the presence of coarse grass or the green algae, *Enteromorpha intestinalis*. 

Schuster, W. M. (1942) *Fish-culture in Brackish Water Ponds of Java*. Indo-Pacific Fisheries Research Council, Special Pubs. No. 1. English Ed., Diocesan Press, Madras, xii + 1-143. If Puntius javanicus and/or Tilapia mossambica are reared together with *Chanos* *chamos*, the larvivorous activities of the latter are greatly increased. *P. javanicus* and *T. mossambica* are plant feeders, which benefit *C. chamos* with incompletely digested plant food materials, and they help to control aquatic vegetation. *C. chamos* apparently does not bother either of the other plant feeders. The establishment of *Myxophyceae* in the pools as a source of plant food for the herbivorous fish, has also been observed to inhibit anopheline breeding.

Seal, W. P. (1906) Report upon an experiment having for its object the introduction of Gambusia affinis and Heterandria formosa to the waters of New Jersey as destroyers of Anopheles larvae. *New Jersey Agric. Exper. Sta., Annual Rept.*, 27, 653-657


Seale, A. (1917) The mosquito fish, Gambusia affinis (Baird & Girard), in the Philippine Islands. *Phil. Jour. Sci.*, Sec. D, 12, 177-187. In 1905 mosquito larval habitats in Hawaii were stocked with Gambusia affinis from Texas. These fish multiplied rapidly, several hundred thousand being bred and distributed from the few hundred introduced. They destroyed not only mosquito larvae but also culicine egg rafts on the surface. In 1913, 24% of these fish were brought from Honolulu to the Philippine Islands; from this nucleus more than 7600 were soon produced and dispersed among streams and swamps of the Philippines. They proved capable of maintaining themselves in ponds already stocked with Micropterus salmoides (black bass) and such native fish as Ophioccephalus striatus and Therapon argenteus, multiplying in the presence of these voracious species.

Sebastian, V. (1942) On the rôle of Euproplus suratensis (Bloch) and Euproplus maculatus Bloch in the control of mosquitoes. *Jour. Bombay Nat. Hist. Soc.*, 43, 271-273. Having observed in Cochin that Euproplus suratensis would snap at any object thrown into the water in its vicinity and concluded that it would similarly attack mosquito larvae even though it might not swallow them, the author experimented with *E. maculatus*, and found that when larvae were thrown into the water the fish became very active and began to prey on them, often snapping at one and rejecting it several times before actually swallowing it. Some larvae were killed and not swallowed. He concluded that a study of stomach contents alone is not sufficient to show the larvicidal value of fish, and that their feeding habits also should be taken into consideration.
Sella, M. (1920) 'Fishes and malaria control' (In Italian) In his Seconda relazione della lotta antimalaria a Fiumicino (Roma) diretta dal Prof. B. Grassi. Rome, pp. 96-97


Sella, M. (1926) A new means of combating Anopheles in Italy: an account of the acclimatization and progress of Gambusia. C.R. Congr. Int. Paludisme (reprint only seen, 16 pp.) Asserting that indigenous fish are of little or no value against mosquito larvae in Italy, the author discussed the success obtained by the introduction of Gambusia. Complete destruction of larvae by this fish is possible, provided that plant harbourage is controlled. Horizontal vegetation impedes the activities of the predator, whereas vertical vegetation does not.

Sella, M. (1927) I pesci larvifagi e l’esperimento di campagna antimalaria con le Gambusie a Rovigno d’Istria. Riv. Malaricol., 6, 881-909. After a short account of the use of fish against mosquito larvae in various parts of the world, it is stated that the excellent results achieved by Vallet and Sepulcri were obtained with Alburnus lucidus and not Leuciscus erythroptalmus. Larvicidal fish (Gambusia) introduced into Italy from Spain in 1922, thrived and proved harmless to the native species. An antimalaria campaign, based exclusively on the use of Gambusia, was conducted in 1926-1927 in a district in Istria abounding in anophelean breeding-places, usually artificial watering pools. It was found sufficient to place only a few fish in a pool since they increased rapidly. Thus waters that dried up in summer could be readily restocked yearly, the fish being introduced in autumn and not at the end of winter, to allow time for their increase. Gambusia can resist severe frost if able to shelter in mud, and the lack of mud was held to be the reason why it failed to survive the winter in some parts of Venezia. The predator was found capable of surviving in water too salty for Anopheles claviger and A. sacharovi: it rarely lived as long as two years. The cost of using Gambusia was one-third of that of dusting with Paris green (which was sometimes employed as a supplementary measure).

Sella, M. (1929) Gambusie e verde di Parigi nella lotta antimalaria a Rovigno (Relazione per il 1928) e cenni sulla lotta in Istria. Riv. Malaricol., 8, 357-392. Gambusia was used alone in some districts, but in one Paris green was employed too. The efficiency of the fish for anophelean control was clearly demonstrated.

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1 Ref. p. 101 of this bibliography.
Sen, P. (1937) On the food-factors of the so-called mosquito-destroying fishes of Bengal, Panchax panchax, Barbus stigma, Esoxus danicus and Trichogaster fasciatus. Curr. Sci., 5, 357-361. Only about 10 per cent. of the field-collected P. panchax examined were found to have fed on Anopheles larvae. This fish seems to lack feeding selectivity, and as such cannot be relied upon as a larvivore. Field observations indicated that Panchax is simply attracted to small moving objects, whatever their nature. The author emphasizes the need for careful preliminary feeding studies of candidate larvivorous fish, before proceeding to actual field trials.

Senior White, R. (1929) Progress towards the realisation of biological control of mosquito breeding. Trans. Far Eastern Assoc. Trop. Med., VII Congr. 1927, 2, 718. Deplores the fact that biological control of mosquitoes has been regarded as almost synonymous with control by larvicidal fish, noting the latter's unreliability (like that of predatory aquatic insects) except in small habitats such as wells, etc.

Senior White, R. (1930) Malaria at Delhi: its incidence and causation...Rec. Mal. Surv. Ind., 1, 291. Advocates investigation directed to establishing fish in wells from which larvivorous species are apparently absent.

Sepulcri, P. (1926) La scardola comune (varieta piccola) nella lotta antimalarica. Riv. Malarol., 5, 663-675. As a result of his experiments the author confirmed the value against mosquito larvae of Leuciscus erythrophthalmus, a fish that occurs naturally in North Italy and indeed throughout Europe. In a number of tests it destroyed much larger numbers of larvae than Gambusia affinis, and demonstrated its ability to withstand low winter temperatures.

Sergent, Ed. (1932) Essai de peuplement d'une rivière d'Algérie (La Reghaia) par les gambouses. Arch. Inst. Pasteur Alger., 10, 348-355. Details an experiment carried out in Algeria from 1929 to 1931 on the establishment of Gambusia holbrooki in a stream, for the control of anopheline larvae. Batches of fish were released at frequent intervals. In parts of the streams where the bed was narrow and the current during the winter floods swift, it proved necessary to restock with Gambusia each spring; but in the wider parts the winter floods did not prevent the fish from breeding, and it could spread for considerable distances from the point of release. The presence of large fish of other species did not appear to check the multiplication of Gambusia, and where it was sufficiently numerous, it entirely prevented the breeding of anophelines, in spite of the presence of filamentous green algae, which in some places formed a thick mat.

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1 Ref. Sella (1927), p. 89 of this bibliography.
Sergent, Ed. (1939) Du cannibalisme des gambouses et d'un moyen d'y remedier. Arch. Inst. Pasteur Alger., 17, 139-142. Gambusia are very voracious and if placed in an insufficient volume of water, they devour their own young. To obviate this, a cage was designed to contain the gravid females. This cage was made of wire netting with a mesh sufficiently large to allow the escape of the fry and of males. It was kept on the bottom and marked by a floating cork attached to a string. In experiments, the number of fish present at the end of a month in two cement basins of equal size was always greater in the one in which the females were caged.

Sergent, Ed. et al. (1939) Experience de destruction des anophèles au moyen des gambouses dans un barrage-reservoir algerien. Arch. Inst. Pasteur Alger., 10, 153-156. Outlines an experiment carried out in Algeria on the establishment of Gambusia holbrooki in a reservoir for the control of anopheline larvae. The reservoir was filled during the third week of April. Several hundreds of fish were released at once, and 200-300 during the succeeding weeks until July. Culicine larvae and pupae which were first observed about 4 May were abundant by 21 May, and on 26 May the first anopheline larvae appeared. At first the fish were not sufficiently numerous to be effective, and on 27 May part of the edge was oiled to check the mosquito breeding. By 30 May all anopheline larvae had disappeared, but culicine larvae were still present, and the banks that had been oiled were, therefore, cleared of vegetation. Gambusia became more numerous and by 18 June all mosquito larvae had disappeared.


Sergent, Ed. & Sergent, Et. (1947) Histoire d'un marais algérien. Inst. Pasteur Alg., 293 pp. The best anti-larval results in the marsh of Ouled Mendil were achieved not with chemical larvicides, but with biological control by fish. After initial trials with indigenous fish had yielded only very indifferent control, Gambusia holbrooki Ord. was introduced into Algeria in 1926. The Italian zoologist Dr Maximo Sella, of the Rovigno Laboratory, Istria, sent these fish by cargo vessel, in buckets of fresh water (he has derived his own stock from the Spanish oceanographer, Dr E. De Buen, who in his turn had obtained them directly from the United States of America). Since its introduction, Gambusia had flourished in Algeria, from the coast to the cases of the Sahara. However, it was noted that these fish did not tolerate cold well. The first sent to the Algerian Sahara (for introduction into Lake El Golea) died of cold because the aircraft in which they were dispatched had to climb to an altitude of several thousand metres to escape a sandstorm (but a later attempt in calm weather succeeded). On the high plateaus of Algeria, where the climate is severe, the Gambusia populations were killed by cold almost every winter. The habitats there had to be restocked in the spring with fish brought from holding-ponds and rearing-tanks on the coast. In a discussion of natural enemies of Gambusia, snakes and various piscivorous birds are mentioned.


Sergiev, P. G. & Kovtun, A. S. (1937) Organization of the campaign against malaria in the USSR towards the twentieth anniversary of the October Revolution. Med. Parasitol., 6, 723-755. Survey of work carried out in the USSR since 1921 for control of malaria, including measures employed against anophelines. The introduction of Gambusia into the Caucasus, Central Asia and the southern Ukraine had given good results.

Service, M. W. (1960) The effect of Freetown emulsion and Tilapia sp. on mosquito larvae in borrow pits. J. Trop. Med. Hyg., 63, 287-290. In borrow pits of Kano, Northern Nigeria, that contained mosquitoes, including Anopheles gambiae, "there was no appreciable difference between mortalities in pits with and without Pistia, and there was no preferential control of any particular mosquito species in either case. The reduction in larvae caused by spraying and by fish, even in the presence of Pistia, were all statistically significant."


Severn, A. C. M. (1926) The mosquitoes of Hongkong. Caduceus, Jour. Hongkong Univ., 5, 5-9. Two or three indigenous species of small larvical fish occurred in ponds and streams, but were less common than formerly. Macropodus opercularis (Chinese Paradise Fish) feeds voraciously on mosquito larvae and even pupae.

Sewell, R. B. S. & Chaudhuri, B. L. (1912) Indian fish of proved utility as mosquito destroyers, Calcutta, 25 pp. (summarized in Trop. Dis. Bull., 2, 652-654, 1913) Under laboratory conditions, Barbus stigma devoured 100 mosquito larvae in 24 hours. However, (Haplochilus) = Panchax was considered of greater importance as a larvivore in nature, even in waters containing vegetation.

Sfarcio, A. (1927) Malaria in Dalmatien und ihre Bekämpfung. Abh. Gebiete Auslandsk. Hamburg Univ. Ser. d (Med.), 26, 532-538. The establishment of Gambusia affinis proved valuable, especially as there was a scarcity of impermanent waters in which mosquitoes could develop unchecked by this fish.
Shapiro, J. M. (1931) Report on the Malaria Research Unit. Ann. Rep. Dept. Hith., Palestine, 1930, 109-110. Although Gambusia affinis was found to feed voraciously on larvae in captivity, it was held less valuable under natural conditions.

Shapkin, L. A. (1940) Gambusia affinis and Leucaspius delineatus in the campaign against the larvae of Anopheles (In Russian) Med. Parasitol., 9, 511-514. Gambusia affinis holbrooki was introduced into the Province of Dniepropetrovsk (Central Ukraine) from Abkhas in 1934. It multiplied in the summer and survived the winter, but died in most of the waters in spring. A study was therefore made of the types of water in which it would thrive. The steppe rivers appeared to provide the most suitable conditions, being shallow, and having a slow current, sloping banks, a muddy bed and abundant aquatic vegetation. It was shown that artificial reservoirs should be at least 40 in deep and protected from wind, and should have sloping banks, submerged aquatic plants, a rich zooplankton, and a muddy bottom free from hydrogen sulfide. The presence of springs was considered desirable. Analysis of the stomach contents of these fish showed their preference for animal over vegetable food. Nevertheless, they could survive on algae as well as protozooa for an indefinite period. They were destroyed by pike and perch, but not by carp. Other natural enemies in the Province included ducks, and the predacious bug, Notonecta glauca, which was present in numbers wherever Gambusia was abundant. Since gravid females were common at water temperatures of 11-12°C (51.8-53.6°F), it was suggested that waters harbouring anopheline larvae should be stocked with Gambusia in April so that the first brood would be produced in May. Superfluous aquatic vegetation along the banks should be removed as it affords shelter to the mosquito larvae. As a result of breeding Gambusia under suitable conditions, the predator became available in large numbers in 1938, when over 600 acres of water were stocked with it. Leucaspius delineatus was the most effective of the indigenous fish feeding on anopheline larvae. Owing to the position of its mouth, this species feeds on objects occurring at or near the surface of the water. It remains near the banks, where mosquito larvae occur, and is very active and voracious. It spawns from April to the end of June, and unlike Gambusia, overwinters in any fresh water that does not freeze to the bottom. Some 25 acres of water were stocked with this fish in 1938. It was found that the most effective rates of release were five per 10 sq. ft for Gambusia and seven to eight for Leucaspius.


Sicault, G. (1934) Note sur l'adaptation du Gambusia holbrooki aux eaux salées. Bull. Soc. Path. exot., 27, 485-488. In view of the fact that in Morocco anophelines breed in brackish water in certain lagoons, experiments were undertaken to determine whether or not Gambusia holbrooki could be used for their control. It was found that these fish could be transferred from fresh water containing at least 11 g NaCl per litre without causing their death or diminishing their capacity for feeding on mosquito larvae. By progressively increasing the quantity of NaCl, it was possible to accustom them to a concentration of 33 g per litre, but at 18 g they did not feed so readily, at 26 g feeding ceased and there was an appreciable mortality, and at 35 g all the fish died.


Sicault, G. & Roule, S. (1935) Note sur la biologie du Gambusia holbrooki au Maroc. Bull. Soc. Path. exot., 28, 134-141. Gambusia holbrooki had multiplied and spread rapidly in marshes on the coast of Morocco. It effectively controlled anopheline larvae during the hot season of August to October when its numbers were sufficient—about 17 per square yard. In the spring and autumn, prevailing air temperatures then being below 5°C (41°F), it apparently left the shallows for deeper water of more stable temperature. Larval Anopheles maculipennis developing in water at lower temperatures, were prevalent in shallow water at these very seasons.


Smith, D. L. (1960) The ability of top-minnow, Gambusia affinis (Baird & Girard) to reproduce and overwinter in an outdoor pond at Winnipeg, Manitoba, Canada. Mosquito News, 20, 55-56. Experiments demonstrated that the top-minnow G. affinis is able to reproduce and overwinter outdoors in Manitoba, this being claimed as the first record of G. affinis being successfully established in a climate as severe as that prevailing there.


Soesilo, R. et al. (1953) Malariabestrijding (Jaarverslag der Geneeskundig Laboratorium over 1932) Meded Dienst Volksgezondh. Ned. - Ind., 22, 99-120. In one district of Sumatra Anopheles kyoanuus sinensis was an important malaria vector, breeding in rice-fields, channels and fish-ponds. The larvae were protected from Neplochilus panae (which had been imported from Java) by aquatic plants, but it was found that these could be cleared by another fish, Puntius javanicus. The latter were best protected from the hot sun by raising the height of the dyke round the pond and digging a channel along the edge of it, P. javanicus being introduced almost a month after H. panae.


Sokolov, N. P. (1936) L'acclimatisation du Gambusia patruelis en Asie centrale. Riv. Malaria, 15, 325-344. An account of the introduction of Gambusia into Turkestan in 1935 for the control of anopheline larvae in rice-fields; and of observations of the species made from May to September of that year. The temperature of the water in the fields was very high during the day. Both the temperature and the oxygen content varied considerably at different hours, but the pH changed only slightly, the reaction being almost neutral. The fertility of Gambusia was found to depend on the age of the fish; females two to three years old and 45-50 mm long, being the most productive. The young proved to reach maturity in the very short period of 36-40 days, so that four to five generations could occur during one season from the sowing to the ripening of the rice.

Analysis of the stomach contents showed that calicines represented 20 per cent. of the food of the adults and anophelines 32.8 per cent. In the young fish the only mosquito larvae found were anophelines; they represented 64.8 per cent. of the food. The numbers of anopheline larvae in rice-fields containing Gambusia were reduced by about 90 per cent., as compared with fields not stocked with the fish, which were introduced at the rate of two or three per square yard.


Southwell, T. (1920) Fish and mosquito larvae in Bengal, Bihar and Orissa, India. *Ann. Trop. Med. Parasitol.*, 14, 181-186. Lists the following fish as larvivores: *Haplochilus panchax* (= *Panchax panchax*), *H. melastigma* (= *Apolocheilus melastigma*) and *H. lineolatus* (= *Panchax lineatus*) *Ambassis nama*, *A. range*, *Trichogaster fasciatus* (= *Colisa fasciata*), *Sardis badis*, *Barbus phuthunio*, *Anabas scandens* (= *Anabas testudineus*), *Wallago attu*, *Perilampus sp.* (*Laubuca sp.*), *Danio rerio* (= *Brachydanio rerio*), *Barilius sp.* and *Rasbora daniconius*. Of these, the three species of *Haplochilus* were considered much the most important.

Sowerly, A. de C. (1927) Fighting mosquitoes with fish. *China Med. Jour.*, 7, 104. *Polyacanthis opercularis* (Paradise Fish) (found in the rivers and creeks around Shanghai) readily devours mosquito larvae; but not being a rapid breeder, it was thought unlikely to be of great value in mosquito control. *Gambusia affinis* had proved extremely useful, and it was proposed to start a hatchery for the breeding of this fish where they could be protected from the cold (which destroyed most of those imported from Manila).


Stead, D. J. (1907) Fishes as mosquito destroyers in New South Wales. *Agric. Gaz.*, N.S.W., 18, 762-764.


Stephen, A. & Hornby, A. V. (1962) Mosquito control by biological methods. *Publ. Hlth*, Johannesburg, 26, 20-22, 25-26, 29. When chemicals failed to control *Culex pipiens fatigans* near Durban, biological methods were used. Control was effected in swamps, a mere and sewage ponds at moderate cost by using *Gambusia* or *Tilapia* in accordance with the ecological requirements of the species selected.

Steven, W. S. R. (1913) Report on an investigation in regard to the prevalence of malaria amongst the troops stationed at Karachi. J. roy Army med. Corps, 24, 251-261. The presence of a small fish (Lebias dispar) was considered responsible for the absence of anophele larvae from various streams, etc. which otherwise appeared to be excellent breeding-places. L. dispar inhabits both fresh and brackish waters.


Strangeways-Dixon, D. (1940) Gambusia affinis holbrooki; imported anti-malaria fish in East Africa. E. Afr. med. Jour., 16, 450-455. After discussing the use of Gambusia against anophele larvae and briefly describing their life-history and habits, the author gives an account of their first successful introduction into East Africa, in 1937, together with recommendations for their rearing and distribution. In June 1939, distribution centres were established in most provinces in Kenya, and were in the course of establishment in Uganda.

Strickland, C. (1915) The colonization of "millions" in the Malay Peninsula, Federated Malay States. Report by the travelling medical entomologists, Kuala Lumpur, 4 pp. Lebistes reticulatus had been found useful for stocking tanks and other receptacles to reduce the incidence of the Aedes (Stegomyia) spp. and culicines so common in the Malay Peninsula.

Strickland, C. (1915) An attempt to colonize "millions" in the Malay Peninsula for antimalarial purposes. J. trop. Med., 18, 88-89. Two reservoirs, a shallow pool, an old mining hole and a reedy permanent marsh were seeded with Lebistes reticulatus. However, in all these habitats the fish became rare or disappeared entirely. It was concluded that the acclimatization of imported fish is a difficult problem scarcely warranting the effort, as actively larvivorous fish occur naturally in every country.

Sundara, R. B. (1930) The value of fish as natural enemies of mosquitoes in combating malaria. Madras Fisheries Dept. Pamphlet

Sunder, L. H. (1927) The use of fishes for the control of mosquitoes. Indian Med. Gaz., 62, 187-188. (Aplocheilus) = Panchax melanostigma, P. parvus and P. striatus were generally kept in stock by the Fisheries Department, Madras. The utility of these species for destroying mosquito larvae had been proved, and they had been used extensively in antimalarial work. Inspection of tanks containing large carp, such as Catla catla, Labeo rohita and Cirrhina mrigala as well as small fish of the typical genera of larvivores such as (Aplocheilus) = Panchax, Ambassias, Chela and Barbus (Puntius) failed to reveal a single mosquito larva. Mosquitos were eliminated from one tank by the introduction of individuals of Panchax (= Haplochilus) panchax.
Supino, F. (1906) Il cosi detti pesci antimalarici. Atti della Soc. ital. sci. nat., Milano, **47**, 117-120. Experiments were tried with tench, Gobiidae, small eels, and other fish, all of which ate various insect larvae. The eels and tench were especially voracious. It was noted that Gambusia and tench ate mosquito eggs, while the indigenous eel did not.


Sweet, W. C. & Rao, B. A. (1934) Notes on malaria in Mysore State. Part V. The control of anopheline breeding in Bangalore City and its cost in Mysore State. **Rec. Malar. Surv. India**, **4**, 95-110. Wells were at first treated by stocking half of them with Gambusia affinis (introduced from Italy in 1928) and applying Paris green to the remainder. The latter method was more efficient, but as the use of Gambusia produced satisfactory results, and was cheaper, it was adopted throughout the city.


Symes, C. B. (1936) Anopheles funestus (Giles) as a "domestic breeder". **Ann. Trop. Med. Parasitol.**, **30**, 361-362. Tilapia mossambica was used to reduce anopheline populations in wells and tanks.

Tamashiro, M. (1964) Observations on the larval ecology of Aedes (Stegomyia) polynesiensis Marks on Aitutaki, Southern Cook Islands. WHO/EBL/22, mimeographed, 29 pp. Local larvivorous fish were not present in some ditches where conditions appeared suitable for them. In an addendum it is pointed out that there is still uncertainty as to whether Gambusia affinis is established at Aitutaki as well as Lebistes reticulatus; and it is emphasized that there is still, in fact, much uncertainty as to the present range of these two species throughout the tropics, many introductions (as during World War II) having been inadequately documented if not altogether unrecorded.


Tiedeman, W. V. C. (1927) Malaria in the Philippines. J. Prev. Med., Baltimore, 1, 205-254. The only fish that seemed promising was a halfbeak (Hemirhamphidae), Dermogenys viviparas, but it never occurred in large enough numbers to control mosquitoes effectively, probably because of the action of natural enemies. Gambusia affinis was introduced but was apparently killed off by the native fish.

Tischler, W. (1950) Malariaalage und Muckenbekampfung in Montenegro. Anz. Schadlingsk., 23, 65-69. The larvivorous fish, Gambusia patruelsis, gave very successful control in water that was not rich in vegetation, and steps were taken to increase its incidence and distribution.

Tisseuil, J. (1946) Au sujet des gites larvaires des moustiques au Sudan. Bull. Soc. Path. exot., 39, 289-290. In the Sudan, Anopheles gambiae preferred recent, very muddy collections of water. When such temporary puddles became clear they appeared less attractive to this mosquito. In larger bodies of water, even in those which contained neither fish1 nor amphibia, predatory insects such as notonectids, water beetles and dragon-fly nymphs markedly reduced mosquito larval populations.

Toumanoff, C. (1933) Sur un premier essai d'acclimation au Tonkin de Girardinus guppyi. Remarques sur le facteur thermique de l'activité larvicide de ce poisson. Bull. Soc. Path. exot., 26, 632-638. Details are given of the laboratory rearing in Tonkin of (Girardinus guppyi) = Lebistes reticulatus, which was brought from France with a view to its establishment for the destruction of anopheline larvae. It was found that both in the laboratory and in pools exposed to the open air this species multiplied well under local climatic conditions. Experiments to determine the effect of temperature on its activity showed that the average number of larvae consumed daily varied, according to the size of the fish, from three to 17 at 16-20°C and from 22 to 57 at 27-30°C. The results suggested seasonal variation in the activity of the fish, which were felt to be probably most useful during the summer months - these coincide with the rainy season, when the application of larvicidal chemicals is physically difficult and furthermore calls for frequent retreatment. In experiments with indigenous larvivorous fish captured in the course of surveys in Tonkin, (Haplochilus) - Panchax javanicus and Macropodus cupanus showed but slight activity during the cold weather in March, but small individuals of Rasborichthys helfrichi were more effective.

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1 A possible area for "annual fish" field trials? (Secretariat).
Trabut, L. (1928) Rôle des poissons dans la lutte contre le paludisme. Bull. Agric. Algérie-Tunisie-Maroc, 24, 61-63. Several small species of larvivorous fish able to live in ditches and pools containing small quantities of water, occur in Algeria. The most valuable in this respect are Tellia apoda, Cyprinodon fasciatus and C. iberus. The last-named (from Southern Oran) was considered to be the most promising for an introduction into the marshes of the Tell. The author cites an instance that came under his observation 30 years previously in which a garrison near a swamp where C. iberus was abundant remained in good health while in a neighbouring garrison near a swamp lacking this fish, malaria was severe. He also quotes the results of the introduction of Gambusia holbrooki then recently introduced into Algiers from Corsica.

Trausmiller, O. (1932) Ueber die Grenzen der Malaria-Bekämpfung mittels Gambusien. Arch. Schiffs- u. Tropenhyg., 36, 530-539. Gambusia holbrooki was successfully used to control anopheline larvae in two Yugoslavian islands in the Adriatic where the larvae chiefly occurred in rain-water ponds used for watering cattle. On one island, following the original importation of 200 specimens in August 1924, the fish became established everywhere, surviving the abnormally severe winter of 1929-30. As a result, anopheline larvae became rare, and the incidence of malaria was greatly decreased. At the beginning of the work, the ponds were kept clear of vegetation, but this was subsequently found to be unnecessary. The fish multiplied to such an extent that they penetrated even the densest vegetation in search of food. On the other island, in which malaria was rife in places, G. holbrooki was introduced in 1927, and by 1929 larvae were scarce in ponds, where no attempt to clear the vegetation had been made, and in a small coastal lake containing brackish water that had been a most prolific breeding-place. The adult mosquitoes disappeared from villages, and acute cases of malaria no longer occurred.

Trausmiller, O. (1935) Le paludisme dans les îles de l'Adriatique, Bull. Off. int. Hyg. publ., Paris, 27, 291-303. These three islands off the northern Adriatic coast of Yugoslavia, were dependant for water on natural or artificial reservoirs which bred mosquitoes. The latter were duly controlled by the introduction of Gambusia. Anopheline breeding in a marshy lake was also controlled successfully by Gambusia, showing that under favourable conditions these fish may be used with success even in extensive bodies of water.

Travis, J. (1947) Mosquito campaigning in Bermuda. Proc. Ann. Mtng. New Jersey Mosquito Extern. Assn., 34, 72-76. Mosquito control by antilarval measures was instituted during an outbreak of dengue in Bermuda in 1941, when 1401 cases occurred. The chief measures used were drainage, filling and the use of Gambusia. These were continued annually, and mosquito abundance was reported to have decreased each year.

Ustino, A. A. (1944) The role of Gambusia in mosquito larvae control in Abkhaz (In Russian) Med. Parasitol., 13, 58-67. Gambusia affinis, introduced into Abkhaz in 1925, had proved to be very effective in destroying mosquito larvae in permanent ponds in lowland marshes of the maritime regions. It was less effective in regions where numerous reservoirs and springs occurred.


Valle, V. (1928) Relazione della campagna anti-malarica 1926-1927. Riv. Malariol., 7, 104-140. Gambusia and Alburnus lucidus were distributed, destroying up to 20 percent of the larvae. Instead of prohibiting fishing in waters stocked with such predators, it would be preferable to specify the use of nets of large mesh which would capture the bigger predatory fish such as pike. In the province of Rovigo a cat-fish, Ailurus nebulosus (imported from Japan to check the pike), had cleared the waters of nearly all fish, rendering it impractical to use larvivores.

Valle, V. & Sepulcre, P. (1926) Sull'attivita larvifaga d'un peschiolino nostrano (scardola) nota preventiva. Riv. Malariol., 5, 306-309. In the Venetian region, imported Gambusia cannot withstand winter temperatures. Unless great expense is incurred in keeping breeding tanks heated in winter, it is thus necessary to renew the supply in spring. A native species, probably Leuciscus erythrophthalmus, was said to have given excellent results during the previous two years.

Van Breeman, M. L. (1920) Further particulars relating to the malaria problem at Weltevreden and Batavia. Meded. Burg. Geneesk. Dienst Nederl. Ind., 4, 63-115. Fish-ponds in well-drained littoral areas were rendered harmless as a source of malaria if (1) only sea water was allowed to enter the ponds, in order to keep the salt-content as high as possible; (2) a sufficient number of the fish Chanos chanos were kept in the ponds to ensure that all under-water and other vegetation is eaten; (3) care was taken that sufficient supplies of (Haplochilus = Panchax panchax were maintained. The drawback of such balanced fish-ponds proved to be that there was no excess of vegetation as food for C. chanos which was, therefore, of less market value. It was suggested that artificial feeding might solve this difficulty.

Vanderplank, F. L. (1941) Nothobranchius and Barbus species: indigenous anti-malarial fish in East Africa. E. Afr. med. Jour., 17, 431-436. It was submitted that Nothobranchius and Barbus are superior to Gambusia for control of mosquito larvae in East Africa in that they are indigenous and widely distributed, and the former at least is able to resist drought by deposing resistant eggs. Notes are given on their habits and the life-history of Nothobranchius. Pachypanchax playfairi, probably the most important of the other fish native to East Africa that prefer mosquito larvae to other food had not yet been studied by the author in natural habitats.
Van Dijk, W. J. O. M. (1960) Notes on the breeding of mosquitoes in fish-ponds in Netherlands New Guinea. Tech. Inf. Circ., South Pacific Commission, Noumea, No. 37, pp. 3-8. It having been suggested that fish-ponds might become highly favourable larval habitats for anophelines, a request was made for an evaluation of the risks attending their establishment on islands in the South Pacific lacking these mosquitoes and malaria. The necessary work was carried out in the Hollandia area during 1958-59. The author duly recorded Anopheles farauti and three other anophelines (all known vectors of malaria) in fish-ponds. However, he concluded that in well-managed ponds kept clear of submerged vegetation, floating-leaved plants and other floating matter, and stocked with Tilapia and Gambusia, the development of mosquito larvae was likely to be virtually precluded; although further observations were needed for definite conclusions.

Van Dine, D. L. (1907) The introduction of top-minnows (natural enemies of mosquitoes) into the Hawaiian Islands. Hawaiian Agr. Expt. Sta. Bull., 20, Honolulu, 10 pp. As the result of a widespread mosquito survey in 1902 and the suggestion in 1903 that top-minnows might well be introduced into Hawaii, a Citizens' Mosquito Control Committee was formed in 1904. In the following year this Committee succeeded in securing the appropriation of $1500 from the legislature to defray the expenses of such an introduction; and this fund duly financed the collection and shipment of three species of larvivorous fish (Gambusia affinis, Fundulus grandis and Mollinesia latipinna). Caught in Seabrook, Texas, these fish (approximately 75 examples in each of six specially prepared ten-gallon milk cans) were transported to Honolulu. During the twelve-day trip from Texas the approximately 450 fish were fed daily and the water frequently aerated and replaced. All but 27 were alive on arrival, when they were transferred to four ponds in which several hundred thousand were duly bred for distribution throughout the group.

Van Dine, D. L. (1915) The losses to rural industries through mosquitoes that convey malaria. Southern med. J., 8, 184-194. In open collections of water of a permanent character, having margins free from vegetation or rubbish, top-minnows and predacious aquatic insects were very effective in controlling anophelines and other mosquito larvae.

Van Dine, D. L. (1922) Impounding water in a bayou to control breeding of malaria mosquitoes. U.S. Dept. Agri. Bull., 1098, 22 pp. Gambusia affinis is generally prevalent in the Mississippi Valley region, but is often rendered non-effective by reason of the protection afforded to mosquito larvae by marginal vegetation and surface plant material. However, top-minnows were established in great numbers along the margins of an impounded area, and under the conditions of greater freedom from vegetation prevailing there they were an important factor in natural control.

Vasiliev, A. (1938) La lutte antilarvare, en Tunisie, doit-elle être saisonnière où continue? Arch. Inst. Pasteur, Tunis, 27, 31-34. The establishment of Gambusia in lakes and water courses proved a very effective measure of mosquito control provided that dense masses of algae, accumulations of dead reeds, etc., were removed periodically so that the predator had unimpeded access to the larvae.

Velichkevich, A. I. (1935) New data on the biology of Anopheles and on the epidemiology of malaria on the southern coast of the Crimea. Med. Parasitol., 4, 481-495. In the eastern part of this area, as a result of oiling, cleaning, or draining various accumulations of water, improving the method of irrigating tobacco, and introducing Gambusia, the percentage of potential breeding places actually harbouring anophelines dropped from 55 per cent. in 1929 to 36 per cent. in 1930 and 4.4 per cent. in 1934.


Vitoux, G. (1907) La lutte contre les moustiques. Presse medicale, 15, 614

Vittorio, V. (1926) Considerazioni su alcuni ausiliari alla lotta antimalarica. Ann. Med. nav. colon., 2, 273-292. Gambusia affinis, Carassius auratus, and Cyprinus carpio were all studied from the standpoint of their value as larvivores. The first is of undisputed value in this respect, but it was found necessary in Italy to keep tanks at a fairly fixed temperature to prevent Gambusia being killed by cold. Also, it proved to need protection from larger fish such as pike. Carassius auratus, feeding chiefly on vegetable matter, did not attack larvae if other food was present. Nevertheless, in water kept free from vegetation, goldfish were considered to have some value as a larvivore. The preference of Cyprinus carpio for deep water was given as a reason for its attacking surface-dwelling larvae only in the absence of other food.

Von Thering, R. (1933) Os peixes larvophagos utilizados no combate a febre amarela e a malaria. Riv. med.-cirurg., 41, 221-234. In northern Brazil, the Rockefeller Yellow Fever Service had made extensive and successful use of a number of species of fish for the control of Aedes aegypti, the most effective being Astyanax bimaculatus in large tanks and Hemigrammus unilineatus in small ones. It was submitted that the problem of controlling anophelines in natural larval habitats by means of fish, is complicated by the facts that they are not the only source of food (as are mosquito larvae in tanks) and that aquatic plants shelter the prey. It was suggested that attempts be made to find indigenous fish effective against anophelines in order to avoid the need for introducing Gambusia and so disturbing an existing fish fauna.

Walch, E. W. & Schuurman, C. J. (1929) Salt water fish-ponds and malaria. *Meded. Dienst. Volksgezondh. Ned.-Indie, Foreign edn.*, 18, 341-366. (See also: Zoutwatervischijvers en Malaria. *Geneesk. Tidjschr. Ned.-Indie*, 70, 209-234, 1930) Briefly reviews the literature dealing with fish-ponds in relation to the breeding of anophelines. Vegetation reaching the surface (consisting chiefly of green algae, forming a more or less stringy mass upon the water and other water plants) was stated to protect anopheline larvae from the predacious fish, *Haplochilus panchax*. However, where the latter occurred in open water in sufficient numbers, no anopheline larvae could be found.

Walch, E. W.; Van Breeama, M. L. & Reyntjes, E. J. (1930) The sanitation of the saltwater fishponds of Batavia. (A contribution towards the "hygienic" exploitation of the Bandong Ponds.) *Meded. Dienst. Volksgezondh. Ned.-Indie, Foreign edn.*, 19, 400-430. Saltwater fish-ponds were drained by a method that destroyed the algae but allowed the fish to gather in certain deeper portions. It was found that even with slight tides (of only about three feet) this method was successful and economical. Within two and a half weeks of the first general draining, anopheline larvae could no longer be found in the pools. Water free from floating green algae sometimes became utilized by anophelines unless the larvicidal fish, *Haplochilus panchax*, was present in sufficient numbers. A method was developed to prevent *H. panchax* from destroying the other fish for which the ponds were maintained.

Walch, E. W. & Soesilo, R. (1937a) Malaria control in the Netherlands Indies. *Trans. Ninth Congress Far East Assoc. Trop. Med.*, 2, 191-200. *Panchax panchax* was found efficient in pools where algae were scarce. *Chanos chanos* is herbivorous, but does not feed enough to keep fish-farm pools clear of algae. (Puntius) = *Barbus javanicus* had been introduced into the pools because of the large quantities of plant material it needs as food, and also because it had a very rapid rate of growth. *Barbus javanicus* may thus be used to clear vegetation, and *Panchax panchax* to eliminate the larvae of anophelines.


Wanson, M. (1936) Note sur un poisson culiciphage du Bas-Congo. *Ann. Soc. belge. Med. Trop.*, 16, 153-158. *Tilapia heudeloti* can devour large numbers of mosquito larvae, and proved a useful larvivore. It was found to withstand salinities of 0.50 to 72.07 g chlorides per litre, measures only 2 to 3 cm in length, is found in running water, and is indigenous to the mouth of the Congo. Individual fish destroyed 110-152 larvae daily, the optimal temperature being 28°C. Drawbacks encountered were that adults sometimes attacked their own fry, and that fish died during the dry season.

Watson, M. (1915) Fish control in the Barbados. In his Rural Sanitation in the Tropics. London, pp. 301-304. Quotes an observation to the effect that Culex larvae had been found in a swamp swarming with "millions".

Weed, A. C. (1924) Another factor in mosquito control. Ecology, 5, 110-111. Water covered with Eichhornia was found to teem with micro-crustaceans probably Ceriodaphnia sp. It was suspected that this animal might be an even more effective enemy of mosquitoes than Gambusia, or that at all events it would provide strong support to the larvivorous activities of this fish.

Weidner, H. (1950) The breeding sites of malaria mosquitoes in North Greece and their sanitation. Z. angew. Ent., 32, 86-133. Field tests of larvicides and biological control experiments were carried out in 1943-44. Gambusia was bred and liberated in pools that did not dry out during the summer, but the fish suffered high mortality when transported in bulk from the breeding tanks to the pools and few survived the winter.

Welch, S. W. (1923) Malaria control work in Alabama. New Orleans Med. and Surg. Jour., 76, 6-9. Anopheline control by the large-scale use of Gambusia was held likely to be more effective and economical than any other method, in spite of the many factors interfering with the successful employment of these fish.


Williamson, K. B. (1926) In: Annual Report of the Malaria Bureau, Institute for Medical Research, Federated Malay States, for the year 1925. Kuala Lumpur, reprint 10 pp. (See also Malayan Med. J., 1, 21-27, 1926) Small larvivorous fish (e.g. Panchax sp.) were abundant in rice-fields.


Willis, J. D. & Mulheren, T. D. (1962) Progress in controlling the mosquitoes in log ponds. Calif. Vector Views, March 1962. As the number of logs in ponds was reduced (when new methods of storing were introduced), the character of the water improved so that it would again support Gambusia which had since kept these ponds free from mosquito larvae. Some of the fish had apparently developed a considerable tolerance to the organic pollution occurring in some ponds, functioning effectively in ponds where they could not live when they were first introduced.


Wilson, H. C. (1914) A note on the treatment of swamps, stream-beds, ponds, wells and pools, with a view to destruction of mosquito larvae. Indian Jour. Med. Res., 1, 691-701 [reprinted (1917) in Madras Fisheries Bull., 11, 161-172] Cites the following genera of fish as natural enemies of mosquitoes, discusses the measures for their practical employment: Chela, Rasbora, Barilius, Hoplochilus (=Panchax, = Aplocheilus), and Barbus; in lily pools and small pools, Polycanthus (= Macropodus); and in salt water and brackish waters, Therapon and Polycanthus.

Wood, J. Y. (1915) Malaria in Koinadugu District, with special reference to Kaballa, the District Headquarters. Ann. Rept Med. Dept, Sierra Leone, for the year ending 31 December 1914. London, 37-41. Studies of three swamps of the Kaballa valley showed that anopheline breeding was not extensive there but was confined to certain areas, perhaps because of the presence of certain fish, of which a species of Barbus was the most active in destroying larvae. Another fish, Fundulus gardneri, was observed to feed on eggs, larvae and pupae of culicines.


Yang, Ching-Po (1931) Observations on the incidence of Anopheles in rural area outside Peiping and on the conditions of Anopheles breeding. Nat. Med. J. China, 17, 513-520. The fish Polycanthus opercularis (which is not a surface feeder) was liberated in ponds. However, because of the presence of aquatic vegetation, very little reduction in mosquito larval incidence was noted.

Zavattari, E. (1934) Acclimatazione della Gambusia e lotta anti-malaria nel Fazzan. Riv. Malariol., 13, 617-622. Gambusia holbrooki was imported from Tripoli to Fezzan in 1931 and was found well established there in 1933. Although the water in this region is usually very hard and sometimes very saline, no visible differences were observed in the fish. In the casis of Traghen and at Murzuch, this predator greatly reduced the numbers of Anopheles multicolor.

Shadin, V. I. & Gerd, S. V. (1961) Fauna and flora of the rivers, lakes and reservoirs of the USSR (In Russian) English translation, Israel Programme for Scientific Translations, Jerusalem 1963. The Smithsonian Institution, U.S.A. and the National Science Foundation, Washington, D.C., 626 pp. Mentions (p. 573 of English version) that after its initial importation into Italy from the Americas, Dr N. P. Rukhadze established a stock of Gambusia affinis in Abkhaz (Transcaucasia) where the climate is suitably warm. This was in the 1930's (see ref. Rukhadze, N. P., 1934, this bibliography), and today G. affinis is widespread in the Caucasus, the Crimea and Middle Asia, where it is highly effective against anophelines.
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