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Gambusia holbrooki: A case study in India with special reference to Lake Nainital

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Abstract

Gambusia holbrooki (Girard), commonly called as mosquitofish, is a small, viviparous fish. This is a native to the eastern U.S.A. and has been extensively used for malaria control program in several countries. It was transported to India from Italy and was widely used biological control agent for mosquitoes. It was introduced in Lake Nainital, for the same reason by Malaria Control Department in nineteen nineties. This fish was supposed to be useful biological agent against mosquitoes in the past but recent studied have indicated its serious negative impacts on aquatic biodiversity. The present chapter which is the result of four years extensive study deals with various ecological and biological aspects of the fish. The present study is the comprehensive report on its introductory history and distribution, food and feeding habits, reproductive biology of fish, impact of *Gambusia* on planktonic community and nutrients excretion on lake ecology etc. Finally the discussion part is focused on its past and present status in global context and some suggestions control it.

Introductory History and Distribution of *Gambusia*

The renowned entomologist, Leland Ossian Howard (1901), was first to advocate the use of Poeciliids for the control of mosquito larvae (Krumholz, 1948). Smith (1904) stated that no fish native to New Jersey (U.S.A) could control mosquito larvae as efficiently as the mosquitofish. Nearly 10, 000 *Gambusia* and *Heterandria* were released in the vicinity of Camden in 1905 (Howard, 1910). This was the first attempt to introduce *Gambusia* into northern waters as a mosquito control measure.

The introduction of *Gambusia* into Europe was due to the efforts of Dr. Massimo Sella, who with the aid of the Red Cross, arranged to have shipments of *Gambusia affinis holbrooki* sent from Augusta, Georgia, to Spain and Italy in 1921 (Krumholz, 1948). Presently, both the subspecies of *Gambusia* have been widely distributed in Europe, Asia, and Africa and nearby islands. Because of the obscurity of some statements in the literature regarding the introduction of mosquitofish, it has been difficult to separate the introduction according to subspecies.
Due to its effectiveness against mosquito borne diseases, it was distributed worldwide as biological control agent for mosquitoes (Fig. 1.1).

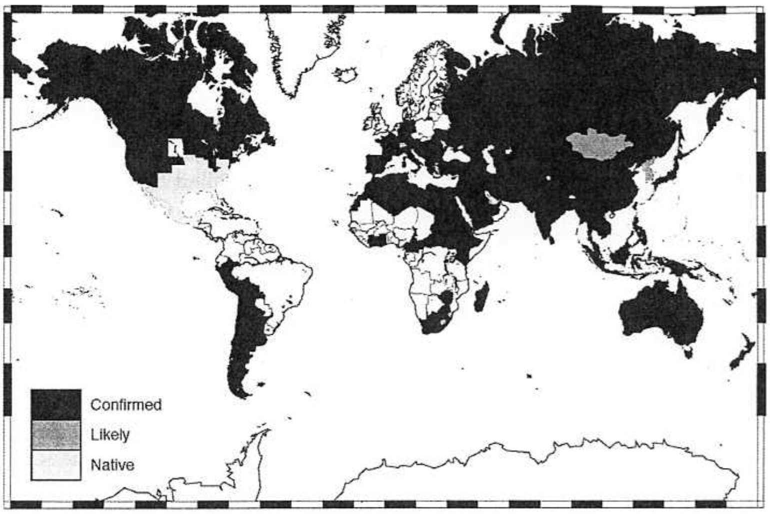

Fig.1 Worldwide distribution of *Gambusia* (Wessel and Smith, 1998).

Gambusia was brought to India by Dr. B. A. Rao from Italy in 1928 (Rao, 1984) and was introduced in Bangalore city first and later distributed to many parts of the country (Fig. 2).

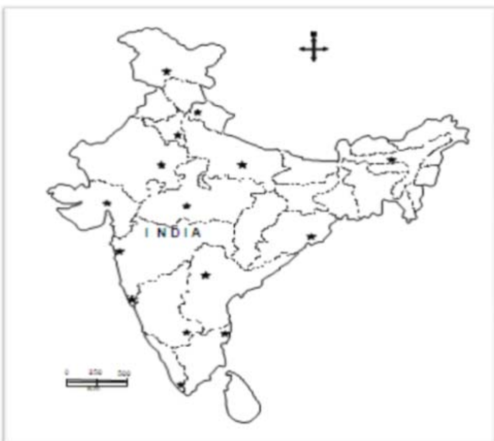

Fig.2. Map of India showing distribution of *Gambusia* (pers. com., Director, National Malaria Research Institute, New Delhi).

It was most extensively used in the country for the control of mosquito breeding in towns under the Urban Malaria Scheme (UMS) of the National Malaria Eradication Programme (NMEP) (Sitaraman et al, 1975). As a result several hatcheries and stock ponds have been established in different states of India for mass production of the fish.

Taxonomic Status of the fish

Due to obscurity of data in the past, there is some confusion regarding the introduction *Gambusia holbrooki* and *Gambusia affinis* in different parts of the world. Singh and Gupta (2007) has confirmed on the basis of detailed investigation of gonopodium of male *Gambusia* (Fig 3 and 4, Lloyd and Tomasov 1985) that the species present in Lake Nainital is only *Gambusia holbrooki* which was previously identified as *Gambusia affinis*. From the history of introduction (Krumholz, 1948) it is presumed that the *Gambusia* found all over India must be *Gambusia holbrooki*. The National Institute of Malaria Research, New Delhi (India) informed the authors (Pers. Comm.) that it was *G. affinis* that was introduced to India for malaria control and now is being extensively used for this purpose throughout India. However, it is doubtful whether the *Gambusia*, distributed throughout India, was *G. affinis* or *G. holbrooki.*

Fig. 3. Photograph of a gonopodium (30 X) showing structural details of *G. holbrooki* from Lake Nainital. Rays 3 and 4p are indicated (Singh and Gupta, 2007).

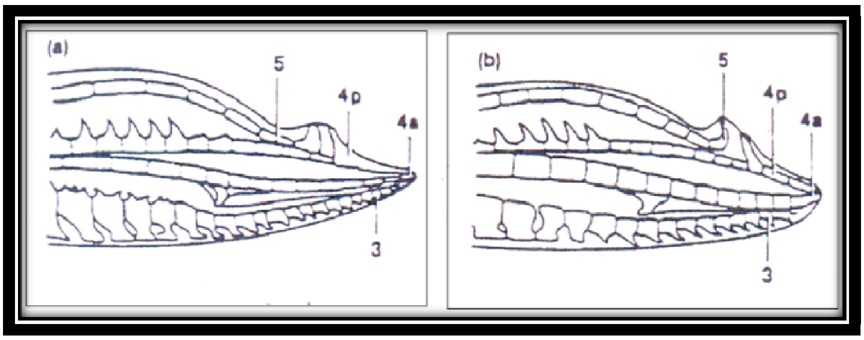

Fig.4. Gonopodium structure of *Gambusia holbrooki* (a) *and Gambusia affinis* (b). Rays 3, 4a, 4p, and 5 are indicated. Reprinted from Lloyd and Tomasov (1985) with kind permission of Australian Journal of Marine and Freshwater Research.

Names Assigned to *Gambusia*

A variety of common names have been used for *Gambusia*, reflecting their appearance, behaviour taxonomic status and impacts on other organisms. The initial common name of Top Minnow for *Gambusia*, reflected its minnow like appearance and its habit of swimming near the surface (Hildebrand, 1919). After 1905, when both *Gambusia affinis* and *Gambusia holbrooki* began to be introduced into waters for control of mosquito larvae, they (collectively) became increasingly known as the 'mosquito fish' (Seale, 1917), though the names Top Minnow and *Gambusia* have continued to be used (Grant, 1978). Because of concern regarding deleterious impacts of these fish on other organisms including other fish, frogs and aquatic invertebrates, some people have recently begun to use the name Plague Minnow (Pyke and white, 2000). With the elevation of these two fish to species level from the sub-species level in 1998, the names Eastern and Western *Gambusia* have been adopted by some authors (Meffe, 1989).

Hardy Nature of *Gambusia*

Gambusia are eurythermal but generally prefer warm water temperatures (>25 ^{0}C) (Clarke et al, 2000; Lloyd, 1984). Populations are able to withstand wide temperature ranges from just above freezing point of 0.5 ^{0}C to a critical thermal maximum of 38 ^{0}C (Lloyd, 1984). Populations, which are warm adapted, have been known to survive short periods of time in water temperature as high as 44 ^{0}C (Lloyd, 1984). *Gambusia* is tolerant of a wide range of salinities, from very low salinity fresh water to fully marine conditions (Arthington and Lloyd, 1989). All these observations show the hardy nature of this fish and its ability to survive in diverse habitats. Due to its hardy nature and efficiency for consuming mosquito larvae, it was introduced all over the world as mosquito control agent. But soon its negative impacts on indigenous fauna were noticed.

Food and Feeding Habits of the Fish

The basic functions of the organisms like its growth, development, reproduction etc., all take place at the expense of the energy, which enters their body in the form of food. Fishes have adapted to wide range of feeding habits. Some fishes are herbivorous, some are carnivorous and a large number are omnivorous also. The fishes, which depend for their nutrition mainly on zooplankton and phytoplankton, are known as planktivorous. The present study deals with food and feeding habits of the *Gambusia* in Lake Nainital with two main objectives: (I) to identify the main prey items of the fish; (II) to determine the relationship between diet composition and fish length.

The striking feature of the diet of *Gambusia holbrooki* is the diversity of prey consumed and the variability of the diet under different circumstances. It feeds on zooplankton (Cladocera, Copepoda and Rotifera etc.), snails, larval chironomids, floating terrestrial insects, certain benthic insects and a variety of zoobethos in pond ecosystems (Hurlbert et al, 1972; Hurlbert and Mulla, 1981). In rice field ecosystems, rotifers, mollusca, crusustacean, insecta, and algae (Chlorophyceae and Desmidaceae) form its dietary components (Sokolav and Chavaliova, 1936). Hayes and Rutledge (1991) reported that in New Zealand lakes, terrestrial invertebrates, particularly dipterans and spiders were important food items in the diet of mosquitofish. Some studies have also reported the high proportions of plant materials in the diet composition of *Gambusia* (Speczier, 2004). Some experimental works have shown that *Gambusia* can survive on restricted diet, e.g. *Tubifix tubifix* (Shakuntala and Reddy, 1977), *Daphnia* (Bence and Murdoch, 1986), various species of mosquitoes (Reddy and Pandian, 1972), frog eggs (Grubb, 1972) and even on fish (by cannibalism; Dionne, 1985). Most of the studies have reported this fish as zooplanktivorous. Singh and Gupta (2010) reported from Lake Nainital that *G. holbrooki* fed mostly on zooplankton, aerial insects and zoobenthos. Further in their study they reported that mosquito, mosquito larvae and pupae formed the negligible proportion of its diet and cladocerans were the main prey. This observation supports the idea that this fish is not suitable for mosquito control. Similar to other studies (Stober et al, 1998) benthic animals also formed a good proportion of diet of *Gambusia* in their investigation. In *Gambusia sp.* cannibalism is often detected in dense laboratory stocks (Benoit et al, 2000), but less important in wild. No cannibalism was found in the study conducted on Lake Nainital (Singh and Gupta, 2010).

Authors have also investigated that in Lake Nainital there was no qualitative difference in diet composition though, quantitatively female fed more intensively than male. Juveniles differed in diet quality from males and females and preferred nauplius of *Cyclops*. It appears that in Nainital lake, differences in diet quality was due to differences in habitats of adult and juvenile fish.

Various size classes of the fish also differed in food composition. Small females and males prefer smaller prey items (Singh and Gupta, 2010). This result was similar to other studies (Arthington, 1989; Garcia-Berthou, 1999), which reported size specific predation. Size specific predation could be due to anatomical attributes or ecological factors as reported by Mansfield and McArdle (1998).

Reproductive biology of the fish

Development is a process consisting of irreversible changes extending from the moment the ovum is laid down in the mother's body to the death of the individual. An organism exists by taking elements from its environment and by discharging its products to the latter. Reproduction is the process in the life cycle of a fish, which, in connection with other links, ensures the continuation of the species. The present study was carried out for a period of two years from 2005 to 2007 and deals with the life history characteristics and reproductive properties of *Gambusia holbrooki* in Lake Nainital.

Sex ratio of any population may differ from situation to situation. At the time of birth the ratio may remain 1:1 but may change thereafter due to selective mortality or different habitat preference of males or females (Fernandez-Delgado and Rossomanno, 1997). In our observation in Lake Nainital, females dominated over males (Singh and Gupta, 2014). The males' mortality could be attributed to their shorter life span and (or) increased competition with juveniles for food.

Singh and Gupta (2014) reported that breeding period of *Gambusia holbrooki* varied from April to October during both the years in Lake Nainital. It released its first brood in the lake in the month of June. The Young of the Year (YOY) female and male born early in the breeding season (2005-06), grew at a very fast rate and attained maturity within two months at smaller sizes to take part in reproduction. The YOY female and male born late in the breeding season did not take part in reproduction and grew very slowly and survived as small overwintered females and males. They attained maturity by April and constituted the major portion of parent stock of the next breeding season (2006-07). Haynes and Cashner (1995) also found similar results in their study.

Gambusia females may have multiple broods over a single breeding season, with older and larger females having more broods during the breeding season than younger females (Pyke, 2005). However, it is not clear how many broods a single female can have during her lifetime. The number of broods produced in a season depends on female status (Haynes and Cashner, 1995). Six consecutive broods during one breeding season have been observed on a number of occasions (Milton and Arthington, 1983), and the maximum observed number of broods per female per season has been nine (Milton and Arthington, 1983). Variation in gestation period of *Gambusia* was also observed in literature. Krumholz (1948) reported the gestation period of *Gambusia* ranging from 21-28 days while Turner (1937) had reported 28-30 days. In the present study, gestation period ranged from 24 to 28 days. Considering the gestation period of 24-28 days and examining, the pattern of change in the developmental stages suggested that in Lake Nainital a maximum of 6-7 broods were produced by parent female. The YOY female produced 2-3 broods while the large OW females (which had bred already in the previous breeding season) produced 2-3 additional broods and then died early in the breeding season. Thus, the large OW females produced 8-10 (6 to 7 + 2 to 3) broods in their life span. The decrease in brood size of overwintered females was observed in the present study. This could be due to physiological changes in the mother with aging (Krumholz, 1948). In the present investigation, clutch size ranged from 3-120 with an average of 40 and 35 young, being produced during breeding season in the first and the second year, respectively. In the present study the minimum S.L. at first reproduction of OW female was 24 mm and that of YOY was 17 mm which are exactly similar to Barney and Anson (1921).

A search in literature reveals that temperature and photoperiod period play important role in breeding of *Gambusia*. For example, Medlen (1951) found that reproduction could be stimulated in *Gambusia* at temperatures above 15.5 ^{0}C. In the present investigation, temperature remained above 15.5 ^{0}C during the breeding season (April to October) (Singh and Gupta, 2014). The fish ceased reproduction in winter when water temperature fell below 15.5 ^{0}C. Some authors are of the view that the timing of the reproductive cycle in mosquito fishes is governed by photoperiod (Milton and Arthington, 1983; Haynes and Cashner 1995). Similar to these observations the reproductive cycle in *G. holbrooki* in Lake Nainital occurred when day length exceeded 11-13 hours (Singh and Gupta, 2014).

In the light of these data, we can say that 2 different generations of mosquitofish propagate in one reproduction period. However, because not all of the new generations matures and takes part in reproduction, the mosquitofish is considered to be a partly bivoltine species (Fernandez-Delgado, 1989; Fernandez-Delgado and Rossomanno 1997). Our results are consistent with other studies (Krumholz, 1948; Fernandez-Delgado, 1989) who reported that mosquitofish populations contain two age groups; after first reproduction, and the parental generations disappear and are replaced by their young ones.

Impact of *Gambusia holbrooki* on Planktonic community

A major challenge in aquatic ecology is to determine the degree to which primary producers are controlled by consumers (“top-down” forces) or resources (“bottom up” forces) and under what conditions either control mechanism is likely to operate. As it is revealed earlier that *Gambusia holbrooki* is a highly zooplanktivorous fish. It is presumed that the fish should have the controlling effect on the phytoplankton community structure, indirectly by affecting the structure and size composition of zooplankton. In the present study experiments were performed to assess the impact of grazing pressure of *G. holbrooki* on planktonic community structure and composition.

Singh (2013) reported that *G. holbrooki* has high grazing pressure on zooplankton community structure which leads to excessive growth of phytoplankton. A significant reduction in zooplankton number in ponds with fish suggested that this fish had cascading effect on zooplankton community structure and abundance. However, in control pond (without fish) significant ($p<0.01$) increase (60 %) in zooplankton number was observed. Earlier studies both in laboratory and field by Hurlbert et al. 1972; Hurlbert and Mulla 1981; Nagdali and Gupta 2002; Gkenos et al. 2012 suggested that *G. holbrooki* had top-down control on zooplankton community structure which in turn had cascading effect on phytoplankton density.

The interesting results obtained in experiments with different categories of fish (female, male and juvenile) suggested that the feeding by fish is size-specific, i.e. large fish fed on large sized zooplankton while the smaller one on small sized zooplankton. Size specific predation by *Gambusia* was demonstrated by Bence and Murdoch 1986; Arthington 1989 and Mansfield and McArdle 1998 in their respective studies.

The decrease in zooplankton number in the experimental pond with female *G. holbrooki* was maximum while minimum with juvenile and remained moderate in experiment with male. Interestingly, maximum growth of phytoplankton was noticed in experiments with female fish while least with juveniles and moderate with male, which is exactly in reverse order with the reduction of zooplankton in these experiments. Predation of *Gambusia* on herbivorous zooplanktons (*Daphnia* sp. and *Ceriodaphnia* sp.) in experimental ponds seems to be the one reasonable explanation for the increase phytoplankton community. Many investigations indicated that *Daphnia* is the most powerful grazer within the group of filter feeding-feeding zooplankton in lakes (e.g. Kasprzak et al. 1999). In the present study the maximum phytoplankton growth was observed in experiment with female fish and least in experiment with juvenile fish because large sized zooplankton are more effective in controlling the phytoplankton growth than small sized zooplanktons (Lynch and Shapiro 1981).

A significant (p<001) decline (74 %) in phytoplankton density in control pond was due to grazing of zooplanktons while increase in phytoplankton density in experimental ponds may be due to direct grazing of fish on zooplankton as well as due to indirect effects such as nutrient inputs from fish excretion (unpublished data) .

The present study clearly reveals that all the three categories of *G. holbrooki* (viz. female, male and juvenile) have suppressed zooplankton community structure and abundance in general. The selective predation pressure of *G. holbrooki*, lead to the change in food web structure, resulting in ecosystem alteration. Study also suggested that there was a strong controlling effect of zooplankton on phytoplankton and thinning of zooplankton by *G. holbrooki* increases the phytoplankton density.

Nutrients excretion by the fish

Nutrient recycling occurs when nutrients are released into the environment by animals or microbial consumers. Fish mediated nutrient recycling is an important source of nutrients for primary producers in many aquatic ecosystems, sometimes even exceeding external loading rates (Attayde and Hanson, 2001). Most studies on recycling have focused on nitrogen and phosphorus because these elements often limit primary production (Vanni, 2002). The present study deals with the experiments performed under laboratory condition to assess the rates of nitrogen and phoshorus excretion by male and female *Gambusia holbrooki*. The effects of feeding and time since feeding on N and P excretion rates and N: P ratio excreted was also examined.

In the present investigation, feeding significantly increased the amount of N and P excreted by both the sexes in comparison to unfed fishes (Singh, 2008; unpublished data). However, male *Gambusia* excreted more N and P than female *Gambusia* on a mass specific basis, due to the smaller size of males (Lamarra, 1975; Brabrand, et al., 1990; Schindler et al., 1993). In this study, the pattern of excretion also changed with time. N and P excretion rates for both sexes were highest immediately following feeding (0-4 hr, 4-8 hr) and declined over time (8-24 hr) (Singh, 2008; unpublished data). Similar results were found by Mather, et al., (1995). The P excretion rate decreased more rapidly through time than the N excretion rate, resulting in an excreted N: P ratio that increased with time since feeding. The N: P ratios observed for both male and female *Gambusia holbrooki* are generally lower as reported for some other species. The low N: P ratio released indicates the potential for this species to shift phytoplankton community structure towards one dominated by blue greens because low N : P ratio was favoured by blue green algae (Smith, 1983).

Feeding habits of fishes and their movement patterns can affect transport of nutrients between benthic to littoral zone and fish feeding on benthic prey but excreting nutrients into open waters may represent a substantial vector for nutrient transport into epilimnetic waters (Lamarra, 1975, Vanni, 1995). The importance of P release by fish for the P budget of a lake depends on the consumed diet. For e.g. Kasprzak et al., 2003 reported that when the P released is derived from zooplankton, fish only recycle P already present in the water column. However, when the consumed diet contains food from littoral and bottom areas (i.e. plants, benthic animals or sediment), the released P is a net addition to the water column. Singh & Gupta (2010) reported that zooplankton form the major portion of gut contents of *Gambusia*, whereas benthic animals like chironomids form the insignificant proportion of its diet. So, on the basis of above discussion *Gambusia* might be able to release new source of P in the water column. It is presumed that *Gambusia* might be able to affect phytoplankton density in many different ways: (1) by excreting nutrients in the available form (PO_4 and NH_3) like other fishes (Brabrand et al., 1990), (2) by excreting low N: P, (3) by altering the nutrient recycling rates (Hurlbert et al., 1972) and (4) by releasing new source of P in the epilimnion through consumed diet. Because it is often difficult to balance nutrient budgets in lakes (e.g., Caraco et al., 1992), transport of nutrients by fish should be considered as one of the key factor to construct such budgets.

Discussion on Past and Present status of the fish

During the early 1900s, after it was discovered that mosquitoes transmit both malaria and the deadly yellow fever, public health officers and doctors worldwide began to show an interest in reducing or eradicating those diseases by attacking mosquito larvae (Boulton and Brock 1999). Many attempts have been made to reduce the problems caused by mosquitoes, with many mosquito control options suggested, including physical and chemical methods. The search for a natural control method for mosquitoes led to the concept of biological control (Lloyd 1990).

Gambusia spp. was first used in 1905 as control agents when specimen from Texas was liberated in Hawaii (Krumholz 1948; Wilson 1960). Public health authorities were delighted by the hardness of the so-called “mosquitofish” and the ease with which it spread (Boulton and Brock 1999).

Its efficiency in mosquito control has been studied by many workers in abroad and in India. Due to its plus points this fish gained much publicity within a short time and was recommended for introduced worldwide as biological control agents for the aquatic life stages of mosquitoes (Dawes 1991). In India, *Gambusia* has been extensively used in mosquito control programmes and distributed almost throughout India for the same reason.

Very soon after its introduction, its negative impact on other aquatic biota and eco-functioning of the lakes and ponds was seen. *Gambusia* have been reported in the extinction of many small fishes (Arthington and Lloyd, 1989), exhibit aggressive behavior towards other fish and involved in chasing and fin nipping (Mckay, 1984), predation by this fish is major factor in regulating the distribution of amphibian fauna (Wilbur, 1984; Hayes and Jennings, 1986; Kats et al., 1988; Gillespie, 2001; Hamer et al., 2002). Now it is regarded as a significant aquatic pest and rewarded with various titles such as “Fish destroyer” “Damnbusia” and “Plague minnow” (Myers, 1965, McCullough, 1998; Pyke and White, 2000). Since 1982 the World Health Organization (WHO) has no longer recommended the use of *Gambusia* for malaria control programme.

Lake Nainital is one of the National Lake’s of India situated at about 1937 m above sea level in Kumaun Himalaya. The lake plays important role in socio-economic development of the region. The lake has undergone eutrophication in last many years due to external loading of nutrients and now it is categorized as hyper-eutrophic lake. In addition to this problem, an exotic fish popularly known as mosquitofish invaded the lake during nineteen nineties, which aggravated the problem of eutrophication. It has been introduced in the Lake Nainital with the same motive for mosquito control, although there is no threat of malaria in this region. Due to hardy nature and being prolific breeder it has successfully invaded and established in the Lake Nainital and form the mono-specific population in the entire littoral zone of the lake. Many studies have reported the potential of this fish to alter the ecosystem health (Hurlbert et al., 1972; Hurlbert and Mulla 1981; Nagdali and Gupta, 2002). The study conducted by Singh (2013) clearly reveals that *Gambusia holbrooki* have suppressed zooplankton community structure and abundance in general. The selective predation pressure of *Gambusia holbrooki*, lead to the change in food web structure, resulting in ecosystem alteration. The study also suggested that there was a strong controlling effect of zooplankton on phytoplankton and reduction of zooplankton by *G. holbrooki* increases the phytoplankton density (Singh, 2013). Top-down effect shown by *Gambusia* on phytoplankton community is well documented in literature (e.g. Hurlbert et al., 1972; Hurlbert & Mulla, 1981; Nagdali & Gupta, 2002). However, I emphasize that alteration in nutrient recycling caused by fish is one of key mechanisms by which it can affect phytoplankton growth. High values of N and P excretion rates and low value N: P ratio excreted by *Gambusia holbrooki* in Lake Nainital (Singh 2008, unpublished data), suggested that *Gambusia* may control phytoplankton density by “bottom-up effect” also. The present study confirms the findings from many investigations around the world that significant effects on lake water quality can be obtained by adequate fish removal (Carpenter and others, 1985; Jeppenson and others, 1990). On the basis of above discussion *Gambusia* could be considered as a good candidate for “Biomanipulation”. Singh (2013) strongly recommends the removal of *Gambusia holbrooki* from Lake Nainital under Biomanipulation for the conservation and management of the Lake Nainital.

Recommendations and Suggestions to control it

Very few documented control programmes specifically targeted at *Gambusia* are recorded to date, due mainly to the absence of control methods, which are both effective and specific for *Gambusia*. As a consequence, the only effective control methods available to date suffer from some problems, i.e., the total stock of fish species (and often other taxa) at the control site must be sacrificed to ensure the complete removal of *Gambusia*. However, this is impossible in case of Lake Nainital. Following suggestions can help in controlling the population of this fish in Lake Nainital and its further distribution in other lakes, where it has not established as yet.

- There is no doubt that manual removal of *Gambusia* from the lake is useful method but it can be made more effective using electrofisher. In the present study the breeding season of the fish varied from April to October (Singh and Gupta, 2014). During this time almost all the females were pregnant and looked sluggish. The juveniles born could easily be seen near the shore. At this time feeble electric current through electrofisher can be passed in water. The equipment itself can control the distance upto which electric current should travel. By the electric current passed, *Gambusia* can be paralysed and removed. However, there are some side effects of electrofishing: i.e. other organisms such as plankton will be killed within the range of the electric current. But, if *Gambusia* is controlled to large extent by this method then loss of other aquatic organisms may be considered as negligible, because plankton and other organisms from limnetic zone can migrate to littoral zone and thus can compensate the loss. Like electrofishing, the possibility for use of well known fish poison i.e. “retonnone” for controlling *Gambusia* population cannot be ruled out but this require lot of indebt planning and research.

- Singh and Gupta (2010) as well as studies carried out elsewhere have indicated that *Gambusia* is an ineffective mosquito predator, with mosquitoes only making up a small part of the diet. *Gambusia holbrooki* in Australia (NSW, 2002) and *Gambusia affinis* in New Zealand (Rowe, 2001) has already been reported as pest species. WHO (1982) has no longer supported the use of this fish in malaria control programme. Presently, *Gambusia* is considered among the 100 worst invasive species worldwide (Lowe et al., 2000). On the basis of above points, I propose this fish to be declared as noxious species in India because this declaration will prohibit the sale, possession and introduction of *Gambusia* into other waterbodies unless permitted by the authority. It is worthwhile to be noted here that it is extremely difficult to eradicate this fish once it has established well in the new environments.
- People should be made aware about the demerits of this fish so that in future there is no accidental introduction of this fish into new water bodies of ecologically importance. Media coverage and other awareness programme may be launched to give it a wide publicity.
- In the last, but not the least, it is also suggested that the name ‘mosquitofish’ should not be used for *Gambusia*, so that the myth that this fish controls the mosquitoes can be dispelled.

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