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Predatory impact of the mosquitofish (*Gambusia holbrooki* Girard) on zooplanktonic populations in a pond at Tenuta di Castelporziano (Rome, Central Italy)

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ABSTRACT

A study of a permanent pond located in a nature reserve in Central Italy was carried out over two periods (1985-87; 1995-98) to determine the structure and dynamics of planktonic biocoenosis. The composition of the zooplankton community was quite different in the two periods of study: in the first period, rotifers, small-bodied cladocerans and larval copepods were the dominant groups; in the second there was a shift from rotifers and microcrustaceans to dominance by large-bodied Daphnidae and adult copepods. The possibility is stressed that Gambusia holbrooki*, present in 1985 and absent in 1995, may be responsible for the changes in the planktonic community.*

Key words: zooplankton, fish predation, Gambusia holbrooki*, pond*

1. INTRODUCTION

The natural reserve of Castelporziano (Latium, Italy), a rare residue of the original Mediterranean maquis along the Latium coast, contains more than a hundred ponds, both temporary and permanent. We have had the opportunity to sample the former since 1964, and the second since 1985, and have found significant differences in the population dynamics and composition of both biotopes. In 1963 *Gambusia holbrooki* Girard was introduced (Valenti 1964) to some permanent pools in order to eliminate the risk of paludism brought by *Anopheles* larvae of the *maculipennis* complex. This small, ovoviviparous fish is native to the southern coastal United States but now has a virtually worldwide distribution, thanks to man's recognition of its appetite for mosquitoes. Moreover, in most habitats, *Gambusia* feeds selectively on conspicuous zooplankton, selecting large and actively moving individuals (Zaret 1980) and consequently influences the structure and dynamics of aquatic communities (Margaritora 1990). In pools freed by *Gambusia* of the grazing pressure of zooplankton, blue-green algae can develop into a persistent high density algal bloom. The related effects are very green water, greatly reduced light penetration and increased afternoon water temperature. These consequences have been verified in natural and artificial pools (Hurlbert *et al*. 1972) and particularly in temporary ponds in the Castelporziano Reserve (Stella *et al*. 1984). In the tested pond (Piscina della Luce) the mosquitofish was present during the first period of study (1985-87), but in 1988 the scarce rainfall strongly reduced the water volume, causing the disappearance of the fish. The present paper examines the changes in zooplankton assemblages, and pays particular attention to the impact of *Gambusia*'s presence/absence on zooplanktonic structure and dynamics, in order to analyze the biocoenosis' response to exposure to fish predation in natural ponds.

2. MATERIAL AND METHODS

From January 1985 to December 1987 and from May 1995 to July 1998 horizontal zooplankton hauls (15-20 m) were performed using a plankton net (90 µm, mouth diameter 25 cm), and vertical hauls from bottom to surface were carried out to determine percentage density values for each taxon. Counts of zooplankton forms were effected on subsamples of 1/2 to 1/8 of the entire sample; nauplii of calanoids and cyclopoids were counted as one single group. Body length of each individual was measured and the results arranged into four size classes, as reported in table 2. The minimal size of a mature individual was arbitrarily taken as the length of the smallest egg-bearing female found in each sample.

3. RESULTS

Table 1 shows the comparison between biocoenosis composition in the two investigation periods, and reveals considerable differences. While rotifers and copepods taxa were substantially unchanged, cladocerans increased from 5 to 11 taxa, mostly large Daphnidae. Particularly *Daphnia obtusa*, which stood out among all cladocerans (12-88%), was found in May 1995 for the first time, as well as *Scapholeberis rammneri* and *Moina micrura*. *Simocephalus vetulus*, the only large taxon sporadically present in 1985-86, also increased (Fig. 1). Of the Chidoridae, the total density of *Chydorus sphaericus* did not differ in the two study periods,

Tab. 1. Zooplankton taxa found in a temporary pond of Castelporziano reserve during the two periods of study.

	1985-87	1995-98		1985-87	1995-98
Gastrotricha			*Asplanchna girodi* De Guerne		+
Chaetonotus sp.	+		*Dicranophorus forcipatus* (O.F.M.)	+	
Chaetonotus heidery Brehm	+		*Testudinella patina* (Hermann)	+	+
Polymerurus nodifurca (Marcolongo)	+	+	*Filinia terminalis* (Plate)	+	+
Rotatoria			*Hexarthra mira* (Hudson)		+
Bdelloidea indet.	+	+	*Sinantherina socialis* (L.)		+
Epiphanes brachionus var. spinosus (Rousselet)		+	*Ptygura peduncolata* Edmondson		+
Brachionus patulus (O.F.M.)		+	**Tardigrada**		
Brachionus quadridentatus Hermann	+	+	*Dactylobiotus* sp.	+	+
Keratella quadrata (O.F. M.)	+	+	**Cladocera**		
Beauchampiella eudactylota (Gosse)	+		*Ceriodaphnia reticulata* (Jurine)	+	+
Euchlanis dilatata Ehrbg.	+		*Scapholeberis rammneri* (Dumont & Pensaert)		+
Mytilina ventralis var. brevispina Ehrbg.	+	+	*Simocephalus vetulus* (O.F. M.)	+	+
Lophocharis salpina (Ehrbg)		+	*Daphnia obtusa* Kurz		+
Colurella obtusa (Gosse)		+	*Moina micrura* Kurz		+
Colurella uncinata O.F.M.	+		*Macrothrix hirsuticornis* Norman & Brady		+
Lepadella patella (O.F.M.)	+		*Alonella excisa* (Fischer)	+	
Lepadella ovalis (O.F.M.)	+		*Dunhevedia crassa* King		+
Squatinella mutica (Ehrgb)	+		*Chydorus sphaericus* (O.F. M.)	+	+
Lecane tenuiseta Harring	+		*Alona rectangula* G.O.Sars	+	+
Lecane luna (O.F. M.)	+		*Alona guttata* G.O.Sars	+	+
Lecane bulla (O.F. M.)	+	+	*Alona nuragica* Margaritora		+
Lecane ohioensis (Herrick)	+	+	**Ostracoda**		
Lecane lunaris Pejler	+		*Ilyocypris gibba* (Ramdohr)	+	
Lecane closterocerca (Schmarda)	+	+	*Candona lactea* Baird	+	+
Cephalodella catellina (O.F.M.)	+		*Cypridopsis hartwigi* G.W.M.	+	+
Cephalodella gibba Koste	+		*Cypridopsis vidua* (O.F. M.)	+	
Cephalodella gr. *tenuiseta* Koste	+		*Cypricercus affinis* (Fischer)	+	+
Scaridium longicaudum (O.F.M.)	+		**Copepoda**		
Notommata sp.	+		*Eudiaptomus padanus etruscus* (Losito)	+	+
Trichocerca ruttneri (Donner)	+		*Cyclops abyssorum* G.O.Sars	+	+
Trichocerca musculus Hauer	+	+	*Megacyclops viridis* (Jurine)	+	+
Trichocerca bicristata (Gosse)	+		**Hydracarina**		
Trichocerca rattus (O.F.M.)	+		*Arrenhurus* sp.		+
Synchaeta pectinata Ehrbg	+	+	**Diptera**		
Poliarthra gr. *vulgaris-dolichoptera* (Carlin)	+	+	*Chaoborus flavicans* Parma		+
Asplanchnopus multiceps (Schramk)	+				

while the numbers of *Alona rectangula* decreased and *Alonella excisa* was not found during the last period (1995-98). *Dunhevedia crassa* was present over the same period with a good density, while a species typical of temporary pools, *Alona nuragica*, was occasionally found.

Qualitative copepod composition did not differ in the two study periods, but in the second set of samples the taxon was represented almost exclusively by *Eudiaptomus padanus etruscus* (Fig. 2). This population increase was due mainly to nauplii and copepodites, as much as in the first period of study when the reproductive cycles were irregular. Conversely, during the 1995-98 seasons the *Eudiaptomus* lifecycle followed a similar trend in permanent pools containing no mosquitofish (Margaritora 1990) and in temporary basins of the reserve (Margaritora & Roberti 1995).

The composition and annual mean densities of total zooplankton were very different from the first to the second study periods (Fig. 3). Before the disappearance of the mosquitofish the zooplankton communities were usually dominated by rotifers, which accounted for 47% of the total zooplankton. On the whole, copepods accounted for 31% of the total zooplankton, with nauplii and copepodites being particularly abundant. A few cladocerans (6%) were represented in particular by small-bodied species (*C. sphaericus*, *A. rectangula*, *A. guttata*), the remaining population being made up of some species of ostracods (9.6%), a small number of microturbellarians, tardigrades and gastrotrichs (*Alia*, 6.4%). After the disappearance of planktivores, *Alia* (2.8%) were represented by *Chaoborus* larvae, microturbellarians and water mites; ostracods suffered a strong drop (0.6%), while total population was dominated by copepods (52.4%), mostly represented by calanoids. Cladocerans increased in density (24.3%) and shifted from small-sized to large-sized species; conversely, rotifers decreased in numbers (20%) and in species richness (from 36 to 20 taxa).

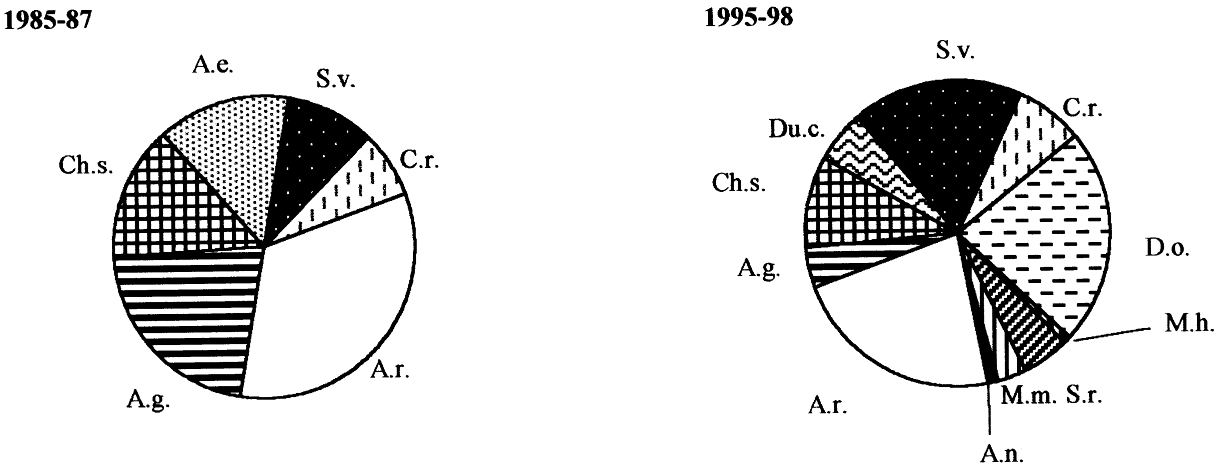

Fig.1. Percentage values of cladocerans during the two periods of study. **A.e.**: *Alonella excisa*, **A.g.**: *Alona guttata*, **A.n.**: *Alona nuragica*, **A.r.**: *Alona rectangula*, **C.r.**: *Ceriodaphnia reticulata* **Ch.s.**: *Chydorus sphaericus*, **D.o.**: *Daphnia obtusa*, **Du.c.**: *Dunhevedia crassa*, **M.h.**: *Macrothrix hirsuticornis*, **M.m.**: *Moina micrura*, **S.r.**: *Scapholeberis rammneri*, **S.v.**: *Simocephalus vetulus*.

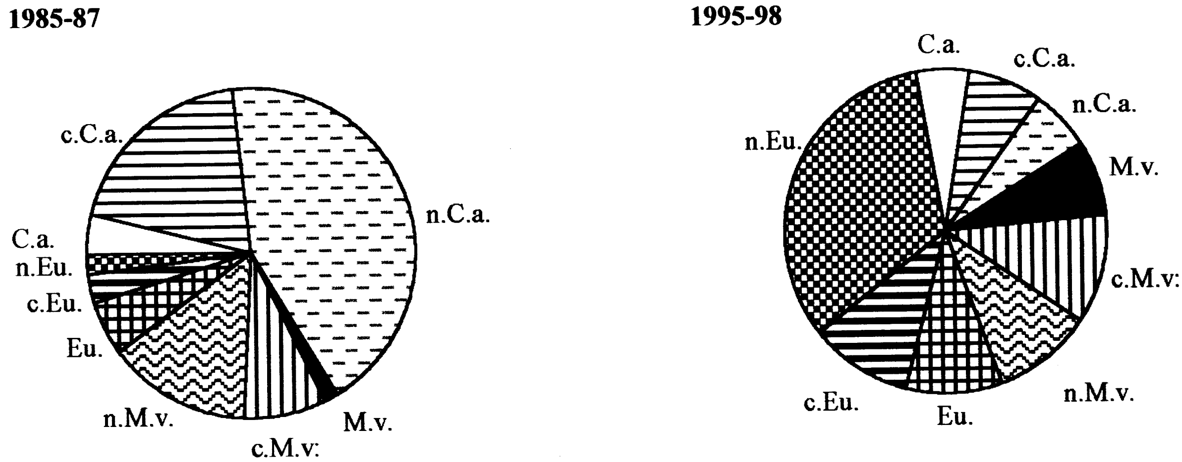

Fig. 2. Percentage values of copepods during the two periods of study. **C.a.**: *Cyclops abyssorum*, **M.v.**: *Megacyclops viridis*, **Eu.**: *Eudiaptomus padanus etruscus*, **n.**: nauplii, **c.**: copepodites.

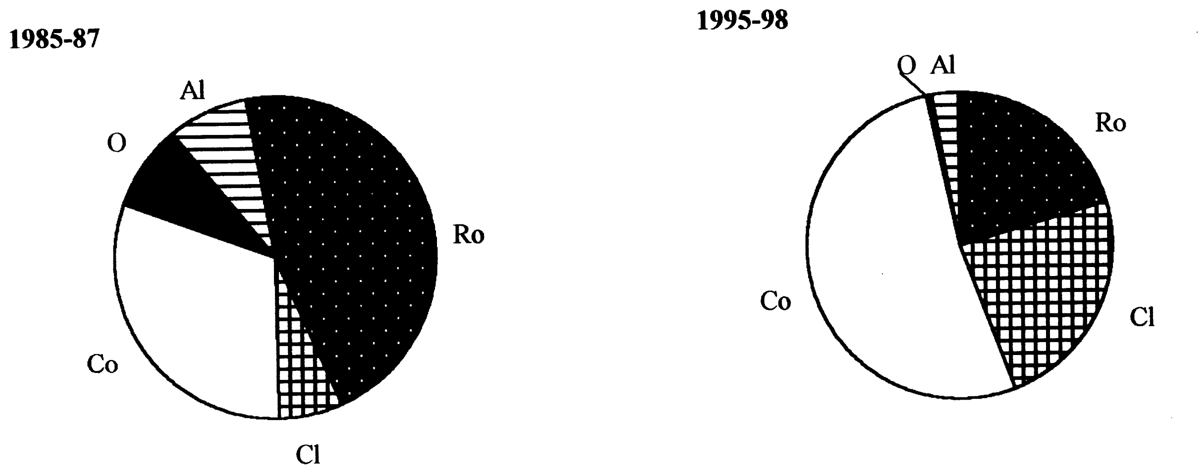

Fig. 3. Percentage values of zooplanctonic biocoenoses during the two periods of study. **Al**: *Alia*, **Ro**: Rotatoria, **Cl**: Cladocera, **Co**: Copepoda, **O**: Ostracoda.

The size classes of all individuals are reported in table 2. Size structure of the total community differed between ponds with fish (1985-87) and without fish (1995-98) (Fig. 4). In the presence of *Gambusia* the zooplankton communities of the pond were dominated by small-sized species (<0.3 mm, I class); in the absence of the fish we observed a larger number of large-bodied (>1 mm, IV class) and a smaller number of small-sized individuals.

Tab. 2. Distribution into size classes of taxa found in "Piscina della Luce" during the two study periods.

1 (<0.3 mm)	2 (0.3 - 0.5 mm)	3 (0.5 - 1 mm)	4 (>1 mm)
Rotatoria	nauplii	copepodites	Calanoids
	Chydorids	*Cypridopsis*	Cyclopoids
	Bosmina	*Ceriodaphnia*	Ostracods
		Scapholeberis	*Macrothrix*
		Moina	*Daphnia*

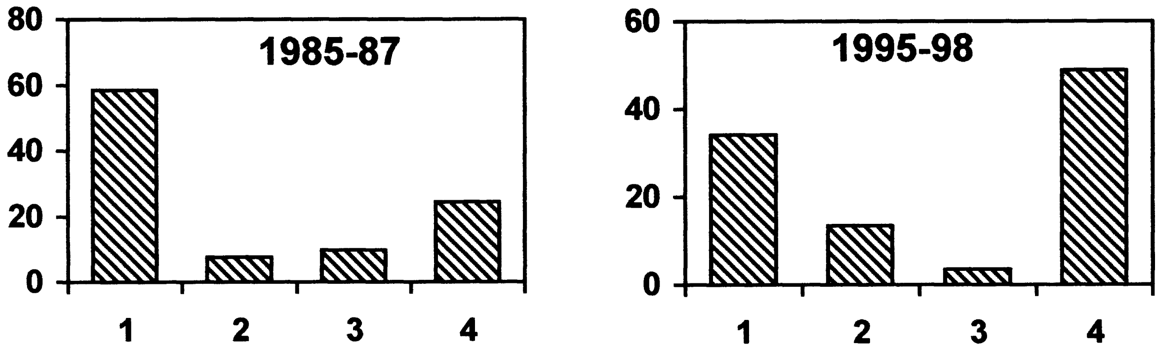

Fig. 4. Percentage values of dimensional classes during the two period of study. The classes 1-4 are riportated in table 2.

onstrate some prey size selectivity (Miura *et al.* 1979; Farley 1980; Garcia-Berthou 1999). In most habitats, mosquitofish diet consists of zooplankton, namely ostracods and copepods (Soto & Hurlbert 1991), with a preference for cladocerans in many biotopes, such as seminatural ponds (Miura *et al.* 1979), rice fields (Blaustein & Karban 1990), and drainage channels (Crivelli & Boy 1987).

In 1995-98, because of the elimination of fish predation, there was a marked increase in large-bodied species, e.g. Daphnidae and adult calanoids, and a corresponding decrease in the population density of the smaller organisms. The larger species, more efficient in collecting small organic particles and capable of collecting larger particles as well, succeeded in competitively excluding the smaller ones. The elimination of fish predation thus shows that *Gambusia* can influence the zooplankton community both directly, by killing the larger individuals and indirectly, by altering competitive forces within the herbivorous zooplankters. The observed patterns of species decline and replacement were consistent with previously reported changes in zooplankton communities responding to the presence/absence of predation by fish (Lyche 1989; Carpenter & Kitchell 1993; He *et al.* 1994; Post *et al.* 1997) and particularly by *Gambusia*. Similar findings emerged from research by Parenzan (1929) in some ponds of Carso (Italy), by Stephanides in some ponds of Corfù (Greece), by Hurlbert *et al.* (1972) in artificial pools of

4. DISCUSSION

The size-efficiency hypothesis stated by Brooks & Dodson (1965) and later by Hall *et al.* (1976) is widely accepted as an important aspect of food-chain ecology. According to this hypothesis, large-bodied organisms (i.e. Daphnidae), are the most efficient grazers in the zooplankton community, and competitively superior to most other herbivorous zooplankters. However, they are also among the most vulnerable species and are strongly preferred by planktivorous fish, which consequently affect the structure and dynamics of the zooplankton community (Langeland 1982; Gophen *et al.* 1988).

In 1985-87, no zooplankters longer than 1 millimeter were found in the pond studied. The dominance of small zooplankters, especially rotifers and larval copepods, is probably related to the presence of *Gambusia* and its selective predation of the large-bodied species. In fact, although mosquitofish are generalist feeders, they dem-

San Diego State College (USA), and by Margaritora (1990) in two pools in the nature reserve of Castelporziano (Italy).

At present the significant predation impact of Gambusia on natural populations of large-bodied zooplankton prompts several considerations. From epidemiological studies (see review by Fantini 1994) the paradox emerged of an "anophelism without malaria", due to the existence of both cattle-feeding and human-feeding mosquitoes in the *Anopheles maculipennis* complex. Since in Castelporziano only zoophilic *A. maculipennis* subspecies were collected which (unlike *Culex* and *Aedes* species) do not bite human beings (Valenti & Coluzzi 1962; Stella *et al*. 1984), it is evident that the introduction of such an exotic species (even if distributed worldwide) as *G. holbrooki* turns into an alteration of the biocoenoses equilibria in biotopes of high scientific and naturalistic interest that deserve protection rather than perturbation.

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REFERENCES

Blaustein, L. & R. Karban. 1990. Indirect effects of the mosquitofish *Gambusia affinis* on the mosquito *Culex tarsalis*. *Limnol. Oceanogr*., 35: 767-771.

Brooks, J.L,. & S.I Dodson. 1965. Predation, body size, and composition of plankton. *Science*, 150: 28-35.

Carpenter, S.R., & J.F. Kitchell. 1993. *The trophic cascade in lakes*. Cambridge Univ. Press.

Crivelli, A.J. & V. Boy. 1987. The diet of mosquitofish *Gambusia affinis* (Baird & Girard) (Poeciliidae) in Mediterranean France. *Rev. Ecol*., 42: 421-435.

Cryer, M. 1988 Predatory impact of New Zealand smelt on natural populations of zooplankton. *Verh. int. Ver. Limnol*., 23: 1778-1783.

Fantini,B. 1994. Anophelism without malaria: an ecological and epidemiological puzzle. *Parassitologia*, 36: 83-106.

Hall, D.J., S.T Threlkeld, C.W Burns. & P.H. Crowley. 1976. The size efficiency hypothesis and the structure of zooplankton communities. *Ann. Rev. Ecol. System.*, 7: 177-208

He, X., D. Scheurell, P.A. Soranno & R.A. Wright. 1994. Recurrent response patterns of a zooplankton community to whole-lake fish manipulations. *Freshwat. Biol*., 32: 61-72.

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Hurlbert, S.H., J. Zedler & D. Fairbanks. 1972. Ecosystem alteration by mosquitofish (*Gambusia affinis*) predation. *Science*, 175: 639-641.

Garcìa-Berthou, E. 1999. Food of introduced mosquitofish: ontogenetic diet shift and prey selection. *J. Fish Biol*., 55: 135-147.

Gophen, M., B. Azoulay & M.N. Bruton. 1988. Selective predation of Lake Kinneret zooplankton by fingerlings of *Clarias gariepinus*. *Verh. int. Ver. Limnol*., 23: 1763-1765.

Langeland, A. 1982. Interactions between zooplankton and fish in a fertilized lake. *Holarct. Ecol*., 5: 273-310.

Lyche, A. 1989. Plankton community response to reduction of planktivorous fish populations. A review of 11 case studies. *Aqua fennica*, 19: 59-66.

Margaritora, F.G. 1990. Influenza di *Gambusia affinis* sulla struttura e dinamica dei popolamenti zooplanctonici degli stagni di Castel Porziano (Lazio). *Riv. Idrobiol*., 29: 747-762.

Margaritora, F.G. & M.C. Roberti.1995. Analisi e struttura dei popolamenti di due bacini astatici della Tenuta di Castelporziano (Lazio) con particolare riferimento alla successione dello zooplancton. *Riv. Idrobiol*., 34: 1-14.

Miura, T., R.M. Takahashi & R.J. Stewart. 1979. Habitat and food selection by the mosquitofish *Gambusia affinis*. *Proceeding of the California Mosquito Vector Control Association*, 47: 46-50.

Parenzan, P. 1929. Saturazione delle acque per parte delle Gambusie e danni che ne derivano. *Boll. Pesca Piscic. Idrobiol*., 5: 1040-1047.

Post, D.M., S.R. Carpenter, D.L. Christensen, K.L. Cottingham, J.F. Kitchell, D.E. Schindler & J.R. Hodgson. 1997. Seasonal effects of variable recruitment of a dominant pescivore on pelagic food web structure. *Limnol. Oceanogr*., 42: 722-729.

Soto, D. & S.H. Hurlbert. 1991. Long-term experiments on calanoid-cyclopoid interaction. *Ecol. Monogr*., 61: 245-265.

Stella, E., I. Di Girolamo, G. Dell'Uomo & L. Rivosecchi. 1984. Osservazioni sulla distribuzione di *Gambusia affinis* (Baird and Girard, 1854) negli ambienti umidi naturali di Castelporziano a 20 anni dalla loro immissione. *Riv. Idrobiol*., 23: 173-186.

Stephanides, T. 1964. The influence of the antimosquitofish, *Gambusia affinis*, on the natural fauna of a Corfù Lakelet. *Prakt. Hell. Hydrobiol. Inst.*, 9: 4-8.

Valenti, M. 1964. Impiego delle gambusie per il controllo dell'anofelismo residuo a Castel Porziano (Roma). *Riv. Malariol.*, 43: 50-62.

Valenti M. & M. Coluzzi. 1962. Anofelismo residuo nel Comune di Roma a dieci anni dalla scomparsa dell'endemia malarica. *Riv. Malariol*., 41: 69-73.

Zaret, T. 1980. *Predation and freshwater communities*. Yale University Press, New Haven, London: 187 pp.