CAN TILAPIA REPLACE HERBICIDES

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Abstract. Aquatic weeds are an important component of any aquatic ecosystem, but when they are present in high densities and interfere with man's activities, they must be controlled. Chemical and mechanical techniques are usually costly and short-lived. Biological control techniques may be a satisfactory alternative. In southern California, Tilapia zillii are being used for the biological control of aquatic weeds in irrigation canals. T. zillii seems to meet most criteria established for evaluation of herbivorous fish for aquatic weed control. In laboratory tests, it showed a definite avoidance for one weed species, but in field tests, it controlled all weeds. Numbers of associated fish species increased in spite of a dense T. zillii population. T. zillii cannot survive winter water temperatures in the irrigation canals, but they can be successfully reared in very large numbers. They are readily accepted by anglers. The conclusion reached is that T. zillii appears to be a good "biological herbicide," but will require annual reapplication just as any other herbicide.

INTRODUCTION

Aquatic weeds are a valuable and important part of the aquatic environment, but they become obnoxious problems when they are present in high densities and interfere with man's activities. The problems may be simple and sometimes ignored, as when they interfere with recreation, diminish aesthetic enjoyment, and reduce property values (Nichols, 1974), but the problem cannot be ignored when navigation channels become obstructed and irrigation canals become blocked (Sculthorpe, 1967). When water supplies are infested, tremendous quantities of water are wasted through evapotranspiration (Holm, Weldon, and Blackburn, 1969; Timmons, 1960), and water needed to meet domestic and agricultural demands is diverted from recreational use. When aquatic weeds are present with food crops such as rice, they compete directly with them for available nutrients and interfere with cultural activities (D. E. Seaman, California Cooperative Rice Research Foundation, Inc., personal communication). The result is diminished crop returns.

When vegetation accumulates to such proportions, action is taken to eliminate it. Today, aquatic weed control techniques fall into one of three broad categories: mechanical, chemical, and biological.

The most common and widespread method of aquatic weed control is by chemicals or herbicides. Chemicals are easy to apply but are expensive to use (Timmons, 1966). Unfortunately, many chemicals which control weeds well are often toxic to fish and other aquatic organisms as well as terrestrial organisms which use the water (Blackburn, 1966). Also, many herbicides have the added undesirable feature of being long-lived in the environment. This is useful to those attempting to control aquatic vegetation, but usually disagreeable to most aquatic ecologists.

An alternative to chemical control of aquatic weeds is that of mechanical control. Mechanical control of aquatic weeds, however, is very costly and usually only briefly effective (Nichols, 1974). The Imperial Irrigation District (I.I.D.) in southern California alone spends nearly half a million dollars annually for mechanical control of aquatic weeds in irrigation ditches (J. M. Sheldon, Water Manager, Imperial Irrigation District, Imperial, CA, personal communication). In irrigation districts, mechanical control of aquatic weeds commonly takes three forms: draglining, disking, and dessication. In the I.I.D., all are utilized in continuous operation, alone and in combination. When canals are dried to control aquatic weeds, fish populations are destroyed and tremendous quantities of water are wasted, first, by evaporation, then by re-wetting the dried portions of the canals. The I.I.D. has 1,700 miles of canals which are dried at monthly intervals. Chemicals cannot be used for weed control because the irrigation water also provides the potable water supply.

Biological control of aquatic weeds may provide a satisfactory alternative. Many organisms have been suggested for the biological control of aquatic plants, but herbivorous fish have shown the greatest overall potential (Holm, et al., 1969). In this country, the fish most widely suggested include the white amur or grass carp (Ctenopharyngodon idella) and the tilapias (Tilapia spp.). Here in California, only two have been tried, Tilapia zillii and the Mozambique mouthbrooder (Tilapia mossambica). Most attempts to control aquatic weeds with tilapia in California have been with T. zillii in the heavily irrigated southern California desert. Avault, Smitherman and Shell (1968) suggested that herbivorous fish for weed control should: control a wide variety of weeds, not interfere with other fish species, be hardy and easy to handle, be economical to use, and add to the fishery. That is, any fish meeting these criteria would be considered a good "biological herbicide" and, I might add, any fish meeting these criteria would do more than replace an herbicide; it would enhance the environment.

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RESULTS AND DISCUSSION

Can tilapia meet the criteria suggested by Avault, et al., (1968)? In particular, can T. zillii meet these criteria? First, does it control a wide variety of weeds? In one laboratory experiment, when given a choice between Eurasian watermilfoil (Myriophyllum spicatum) and sago pondweed (Potamogeton pectinatus), T. zillii consumed sago pondweed at a rate of 0.529 g/g fish weight/24 hr while Eurasian watermilfoil was nearly ignored (0.031 g/g fish weight/24 hr) (Table 1, unpublished data). If only Eurasian watermilfoil was available, it was consumed at a rate of 0.044 g/g fish weight/24 hr and the fish lost weight. When the fish had a choice between sago pondweed and southern naiad (Najas quadalupensis), however, southern naiad was consumed at a much higher rate (0.519 g/g fish weight/24 hr) than sago pondweed (0.016 g/g fish weight/24 hr).

Table 1. Rate of feeding on aquatic weeds by adult Tilapia zillii.
* denotes significant differences in Student's t-Test (P>0.05).

Feed offered		Feeding rate (g of weed/24 hr/g of fish)
Potamogeton pectinatus (Sago pondweed) alone		.324
Myriophyllum spicatum (Eurasian watermilfoil) alone		.044
Potamogeton pectinatus	together	.529*
Myriophyllum spicatum		.031
Potamogeton pectinatus	together	.016*
Najas guadalupensis (southern naiad)		.519

Thus, the answer to the first criteria appears to be no. In a field experiment, however, T. zillii were stocked in a section of the Flax Canal, I.I.D., at the equivalent density of 108.6 kg (4740 fish)/ha (97 lb./acre, 1,920 fish/acre) on 11 June 1974. By 30 October 1974 the fish were effective in controlling all species of aquatic weeds (Table 2, unpublished data). Good control was possibly achieved as early as mid August. Weeds in the test section were reduced from 27 to 4% coverage while weeds in the control section became so dense by mid October that the canal was reduced to 20 cfs less than full capacity and the irrigation district was forced to clear that section of the canal mechanically. All species of weeds were found in the control section, and the growth was lush. Only poor, thin stands of Eurasian watermilfoil were present in the test section. Apparently, T. zillii can reduce or contain Eurasian watermilfoil in canals through constant "harassment", probably while foraging for any available material.

In another experiment, a mixed population of T. zillii and T. mossambica was effectively used in a rice-rearing pond to control filamentous algae and submerged higher aquatic weeds. If the weeds became emergent, the tilapia were no longer effective. Finally, a number of irrigation drainage ditches have been maintained in a weed-free condition by tilapia for as much as several years. The correct answer, therefore, to the first criteria is really yes; tilapia are capable of controlling a wide variety of weeds. This conclusion is supported by studies of these and other Tilapia (Sills, 1970; Swingle, 1957; Shell, 1962; Avault, et al., 1968).

In the Flax Canal, I.I.D., while T. zillii were present in sufficient numbers to control aquatic weeds, associated game and non-game species also increased markedly (Table 3, unpublished data). Spawning by these species apparently was successful in the canal. Successful reproduction by game species has also been observed in other areas where T. zillii are abundant. These studies indicate that criteria 2 is met; T. zillii do not interfere with other fish species.

T. zillii, while easy to handle, only partially meet the third criteria, hardiness. Experimental evidence and field observations indicate that T. zillii will not survive most winters in irrigation canals in southern California. Recent experiments indicate that feeding declines when water temperatures drop below 17 C (Table 4, unpublished data). At water temperatures below 13 C, T. zillii become lethargic and vulnerable to predation; approximately half the fish die when the water temperature drops to 10 C,

Table 2. Characteristics of the weed population in Flax Canal, Imperial Irrigation District, 1974. Area above test section was cleared mechanically on approximately 15 October 1974.

	11 June 1974				30 October 1974			
Location	Percent coverage	Biomass (g/sq M)	Species present	Condition	Percent coverage	Biomass (g/sq M)	Species present	Condition
Above test section	17.9	1236	Eurasian water-milfoil	Young	29.1	2280	Eurasian water-milfoil; Sago pond-weed; southern naiad	Lush
Test section	27.0	861	Eurasian water-milfoil; Sago pondweed (trace)	Young	3.8	368	Eurasian water-milfoil	Poor
Below test section	8.2	299	Eurasian water-milfoil	Young, poor	22.3	1724	Eurasian water-milfoil; Sago pondweed (trace); southern naiad (trace)	Lush (in parts)

Table 3. Changes in the fish population in a section of the Flax Canal, Imperial Irrigation District, 1974.

Species	Number of fish	
	11 June	1 November
Threadfin shad (*Dorosoma pretense*)	0 - captured	458 - captured
Carp (*Cyprinis carpio*)	0 "	3 - captured
Channel catfish (*Ictalurus punctatus*)	15 "	170 - captured and estimated
Largemouth bass (*Micropterus salmoides*)	13 "	28 - captured
Tilapia zillii (>40 mm in length)	1920 - stocked	2923 - estimated

Table 4. Effect of low water temperatures on *Tilapia zillii*.

Activity	Water temperature (C)
Reduced feeding	Approximately 15-17
Lethargic condition	" 12.5-13
Most deaths	10
Complete mortality	7.5

and all fish die when the water temperature reaches 7.5 C for even brief periods. Survival of *T. zillii* at water temperatures below 10 C depends on acclimation temperatures, rate of temperature change, and duration of exposure. Cridland (1962) and Fukusho (1968) observed reduced growth, feeding, and swimming performance by *T. zillii* when water temperatures were lower than 20 C. Few *T. zillii* survived the mild-to-average winter of 1973-74 in Imperial Irrigation District canals where average water temperatures rarely dropped below 10 C.

The fourth criteria, economical to use, has not yet been fully tested, especially considering the tremendous number of fish necessary to obtain good control of aquatic weeds over the extensive areas. I.I.D. personnel, however, during 1974 produced 370 kg (818 lb) of *T. zillii* in an earth-bottom pond 9.2 x 30 m (30 x 100 ft), equivalent to 13,303 kg/ha (11,877 lb/A). The cost of this production has not been calculated, but it is not expected to be great. I believe that eventually this biological herbicide would be as economical to use as other weed control techniques. Sheffer (1960) predicted that the Mozambique mouthbrooder could be produced on a large scale basis at a cost of $.50/lb. Avault, et al., (1968) cited a report which demonstrated a tremendous savings from the use of *T. mossambica* for weed control.

Finally, though quantitative data are lacking, tilapia are readily accepted by anglers, and they have added to the fishery in southern California.

The conclusion, therefore, is that tilapia, in particular, T. zillii is an effective biological control agent for aquatic weeds in irrigation waters in southern California if they can be efficiently raised in sufficient numbers. It is definitely no panacea, but it has been proven effective in a variety of situations. The major limitation to its effectiveness as a biological control agent is its inability to overwinter in large numbers, but this results in a management problem and implies annual application--as with any herbicide.

A major objection to the use of tilapia for biological control has been the fear that they will become widespread and that extensive stunted populations will result. In light of the inability of T. zillii and T. mossambica to survive temperatures lower than 7.5 C and 10 C (Chimits, 1955), respectively, I doubt that these species will ever become widely distributed in California. Among limited populations which have successfully overwintered in southern California, some stunting has been observed, but it appears no worse than that observed among native centrarchids--themselves exotics in California. Tilapia in these "stunted" populations, however, are still large enough to continue to attract anglers, and this fishery apparently has not displaced any previous fishery, but rather, it has been added to the fishery of the area.

Finally, let's re-examine the situation on a philosophical note. We, as scientists, are predicting an imminent world food crisis, a water shortage, and a world energy crisis. Concurrently, we, as aquatic ecologists, are restricting the use of herbicides in irrigation water forcing the use of mechanical removal techniques. The net result of this is the increasingly difficult production of food with an increased waste of water and greater expenditure of energy. It occurs to me that the replacement of this mechanical effort with a biological herbicide would indeed be valuable.

LITERATURE CITED

Avault, J., Jr., R. Smitherman, and E. Shell. 1968. Evaluation of eight species of fish for aquatic weed control. F. A. O. Fisheries Report. VII/E-3:109-122.

Blackburn, R. 1966. Weed control in fish ponds in the United States. Proc. F. A. O. World Symp. on Warm-water Pond Fish Culture. Rome. VII/R-1:1-17.

Chimits, P. 1955. Tilapia and its culture. A preliminary bibliography. F. A. O. Fisheries Bull. 8:1-35.

Cridland, C. 1962. Laboratory experiments on the growth of Tilapia spp. The effect of light and temperature on the growth of T. zillii in aquaria. Hydrobiologia 20:155-166.

Fukusho, K. 1968. The specific difference of temperature responses among cichlid fishes genus Tilapia. Bull. Jap. Sci. Fisheries. 34(2):103-111.

Holm, L., L. Weldon, and R. Blackburn. 1969. Aquatic weeds. Science. 166: 699-709.

Nichols, S. 1974. Mechanical and habitat manipulation for aquatic plant management, a review of techniques. Wisconsin Dep. Nat. Resources. Madison. Tech. Bull. 77:1-34.

Scheffer, P. 1960. Factual information concerning the use of Tilapia in the biological control of algae and aquatic weeds in Arizona farm ponds, reservoirs, and ditches. U. S. Dep. Agr. Soil Conserv. Service. Tech. Notes. 21 p.

Sculthorpe, C. 1967. The biology of aquatic vascular plants. Edward Arnold (Publishers) Ltd., London. 610 p.

Shell, E. 1962. Herbivorous fish to control Pithophora sp. and other aquatic weeds in ponds. Weeds. 10(4):326-327.

Sills, J. 1970. A review of herbivorous fish for weed control. The Prog. Fish-Cult. 32:158-161.

Swingle, H. 1957. Control of pond weeds by the use of herbivorous fishes. Proc. Southern Weed Conf. 10:11-17.

Timmons, F. 1960. Weed control in western irrigation and drainage systems: losses caused by weeds and benefits of control. Joint Rep. Agr. Res. Service. U. S. Dep. Agr. and Bur. Reclam. U. S. Dept. Interior. Washington, D. C. ARS 34-14:1-22.

Timmons, F. 1966. Control of weeds harmful to water uses in the west. J. Waterways and Harbors Div. Proc. Amer. Soc. Civil Eng. 92(WWI):4645-4658.