Proc. 3rd Int. Symp. Biol. Control Weeds
Montpellier, France, 1973

STUDIES ON THE BIOLOGICAL CONTROL OF AQUATIC WEEDS IN THE NETHERLANDS

J. C. J. van Zon*

THE PROBLEM

Holland has half a million kilometers of ditches and canals which could every year be filled up by a dense mass of submerged, floating and emergent plants and by filamentous algae. Even our lowland streams tend to be overgrown due to increasing eutrophication. Since two of the functions of these waterways are to maintain a carrying capacity and to allow transport of water, it is necessary that the major part of the weeds be removed before summer (June) and before heavy rainfall (mostly in October).

SOLUTION TO THE PROBLEM

Since the Middle Ages cleaning has been done with hand labour repeated up to six times a year. This was not a very realistic approach as submerged species like *Elodea* start growing much faster after cutting. The reason for the repeated cleaning activity was probably the proverbial Dutch purity rather than its agricultural or hydrological importance.

Nowadays there is a tendency to clean less often, because the other functions of the waterways and the water in them are receiving increasing attention from the managing authorities. Especially the recreational and biological functions of the waterways are decreased by cleaning too often and too completely (van Zon, 1973). But even with this decreased demand for manual labour the work cannot be done in the classical way, i.e., by handcleaning. On the one hand the interest in this kind of work has decreased and on the other hand the workmen that are still available have become more and more expensive to use. For these reasons maintenance authorities have looked for other methods for removing aquatic weeds.

Studies on the use of herbicides started about 1950. At the moment in Holland some herbicides are officially approved for use on aquatic vegetation, but the problems connected with the use of these substances in this environment are not simple. The use of biologically persistent herbicides, like diuron, will never receive full official

* I.B.S., Weed Research Department, Wageningen, The Netherlands.

approval because the chance of the active ingredient washing away into non-treated areas (e.g. nature reserves) is high and unpredictable. Moreover, the general influence of this type of chemical on the aquatic ecosystem is very pronounced, since primary production is more or less completely stopped for a considerable time and if treated too late the disintegrating mass of dead plants and plankton causes a lasting shortage of oxygen (Blok, 1967).

Biologically non-persistent herbicides, like paraquat, have the disadvantage of a too short term effect on the weeds and, besides, these substances do not effectively control filamentous algae. As a result of the elimination of competition and the sudden increase in the nutrient content of the water, these lower plants have the opportunity to form thick mats. They block water transport still more than the previous vegetation and they are very difficult to remove by mechanical or chemical means. Because of these consequences the use of paraquat is decreasing now.

GENERAL EVALUATION OF METHODS

From the examples quoted the general objection against the use of chemicals against aquatic weeds is that they cause a release of nutrients accumulated in the plants that is related to the plant-mass at the moment of application. It is precisely such high nutrient levels that cause the aquatic weed problem in the first place and further growth is stimulated rather than combated. Mechanical control by removing organic matter has not the same drawback, but technical development of this method is progressing very slowly. It is not easy to construct machines for cleaning of ditches unless they are all uniform in size which is not the case and furthermore those in Holland have many bridges and culverts and are often bordered by trees or fences. Moreover very few have a passable path alongside. The only remaining alternative is biological control. At the moment all biological methods usable under our Atlantic climatic conditions are being evaluated. The work started in spring 1972, so only preliminary results are presented.

BIOLOGICAL METHODS

It should be pointed out that in biological control of aquatic weeds the principles involved are different from those applying to biological weed control in field crop situations. While on the land weed growth has to be reduced in favour of one crop species, in the water it is the aim to reduce all species present to a lower level, with a minimum decrease in ecosystem diversity. In water, in contrast to the situation on land, the biological agent should not be a host-specific one, but should attack as great a variety of plant species as possible. Even though there are many waters with only one dominating weed species, in the temperate regions, control with a host-specific agent will not be successful because the weed's place will immediately be taken over by one or more other aquatic plants. Therefore it is clear that specific insects and pathogens are not the first agents that should be considered, rather either large herbivorous organisms or methods that affect the environmental conditions by limiting the amount of light or introducing competing plants are necessary. All these alternative techniques are being studied.

LIMITING THE AMOUNT OF LIGHT

Growth of aquatic weeds can be retarded by limiting the quantity of available sunlight. Biologically this can be done in two ways:—

Firstly, by planting shrubs or trees along the waterways. At places where such a vegetation was already present, it was found that even very incomplete shading has a marked effect on the aquatic weeds. The principle objections against this method are that it costs space and that the waterway is less accessible for dredging. Also planting with shrubs or trees is not always suitable in certain landscapes. However, in some areas of the Netherlands and especially along lowland streams shading with shrubs would provide a good solution for the waterweed problem.

Secondly, light can be reduced by using floating plants, like duckweeds (*Lemna* spp.), *Potamogeton natans* L. and waterlilies. These plants cause little obstruction to water transport but they can cover the water surface completely, sometimes too completely for, particularly duckweed, can cause a shortage of oxygen in the water below. This method (stimulating floating plants) can only be practised if the plants concerned can be harvested repeatedly before the surface layer becomes closed. Further studies will therefore have as an aim the development of a use for these floating weeds, (e. g. duckweeds as chickfeed or human protein source, Bhanthumnavin & McGarry, 1971; Truax c.s. 1972), since only such a use would make harvesting economically possible.

INTRODUCING COMPETING PLANTS

Aquatic weed growth can also be restricted by replacing the harmful species by plants which do not obstruct water transport. A plant which is extremely suitable for this object is the needlerush (*Eleocharis acicularis* P. Br.) (Yeo & Fisher, 1970).

This little rush, not exceeding 15 cm. in height, forms such strong root tufts that in autumn the winter buds of some weeds cannot push through them, whilst in spring other weeds cannot grow through the tufts from their root-stocks. Although very common in Holland, there are at any one place usually only a few plants of this rush standing together. Thick mats establish readily in areas which are temporarily dry (for example fish production ponds) but underwater establishment occurs only with human aid, i.e. by planting out the rush and weeding until establishment is ensured. The first experimental results seem promising, especially in ditches which are dry in summer. In ditches permanently carrying water the method seems less suitable because it is biologically undesirable to create a monoculture.

Both the above mentioned methods (light interception and place competition) have, like chemical control, the objection that they do not reduce the actual stimulating cause of aquatic weed nuisance, the high nutrient content of the water.

The effect of this can be compensated for at least in part by using herbivorous fishes which utilise the excess organic matter as food.

STUDIES WITH THE GRASSCARP

With this object in mind, the study was started on the use of the grasscarp (*Ctenopharyngodon idella* Val.) was started, a completely herbivorous fish from the Amur river in China. This work is being done in cooperation with the Organization for Improvement of Inland Fisheries (O.V.B.).

The fish survived very well in the Dutch climate and even in winter, under ice covering, there were no losses. The fish makes nearly no demands on water quality and it can stand low oxygen levels and high salinities (Doroshev, 1963; Liepolt & Weber, 1971). Furthermore, what is very important, it does not reproduce under Dutch conditions.

For mating displays, for hatching of the eggs and for growth of the larvae high temperatures (above 22°C.) are necessary for a few months, which never occurs in Dutch surface waters.

The grasscarp can eat enormous masses of aquatic weeds. At temperatures lower than 14°C it hardly consumes any food, between 14 and 18°C. it prefers soft-tissued submerged plants (including filamentous algae) and above 18°C. the firmer, floating and emergent weeds are eaten as well. At temperatures above 22°C. the fish swallows all vegetation, including reeds and cattails, consuming up to 150% of its body weight daily.

These results are very attractive but there are certain drawbacks to be considered.

The risk of introducing foreign fish diseases and parasites can be considerably reduced by artificial breeding (Antalfi & Tölg, 1971) or by importing eggs or very young larvae.

The sensitivity of grasscarps to native diseases and parasites seems not to be a problem for the time being. The influence of the grasscarp's activity on other fishes has been studied in England and the U.S.A. (Kilgen & Smitherman, 1971). There will be an indirect negative effect, because limiting the vegetation means decreasing the amount of spawning places (Opuszyński, 1972). The biotope of some fish food organisms (snails) will also become smaller. However, probably this effect will not be very critical and in any case the changes come about much more gradually than in chemical or mechanical aquatic weed control.

Two more important problems of the use of grasscarp are its food selectivity and its excrements. The food selectivity of the fish at higher temperatures is not very pronounced but there are a few plant species which are not or barely eaten. In the Dutch experiments they are the bladderwort (*Utricularia vulgaris* L.), which is rather rare and the water crowfoots (*Ranunculus circinatus* Sibth. and *R. aquatilis* L.), which can be a nuisance and could be supported in their competition by the grasscarp. In Austria this problem is overcome by local paraquat treatments, once every four or five years (pers. comm. Neururer).

The excrements of the grasscarp contain some 60% of the swallowed weeds in the form of partly-digested vegetable materials. This produces a strong manuring of the water which in Holland normally leads to an outburst of filamentous algae. Since these are then eaten by preference, there is a chance of producing blooms of the very undesirable (sometimes toxic) blue-green algae. How realistic this chance is and whether it can be prevented is incalculable at the moment.

RESULTS OF EXPERIMENTS WITH THE GRASSCARP

Results of the experiments in model ditches of 0.1 ha are presented in Table 1. Due to the differences in the vegetation of the models there was no control, but there was no doubt that the weeds were reduced to an acceptable level. From August onwards all ditches were even emptier than in spring. The differences in the results are caused by the differences between ditches situation at the start and by the two fish stocking densities.

TABLE 1

Plant coverage (1% of bottom surface) in grasscarp experiments in ditchmodels, 1972. Stocking at 28/4.

No.	Fish-stocking kg/ha	14/3	5/4	25/4	24/5	7/6	27/6	14/7	7/8	8/9	13/10
1	360	30.9	27.5	39.6	46.3	46.4	54.3	34.3	20.9	22.7	22.0
2	180	30.9	21.6	54.6	40.2	57.2	43.8	25.2	14.0	15.1	12.5
3	360	8.0	5.7	42.8	12.4	9.1	10.8	11.9	0.2	0.3	0.1
4	180	2.0	2.0	2.8	16.0	7.2	16.0	4.5	2.4	1.9	2.0

Most of the plant species were completely or almost completely consumed. Among these were various species of algae, *Chara*, *Glyceria fluitans* R. Br., *Alisma* *plantago aquatica* L., *Callitriche* sp. and *Polygonum amphibium* L. At the end of the experiment mainly *Typha latifolia* L. remained. The grasscarp ate these cattails, but there was such a thick stand bordering the ditches that they could not destroy it completely. The fish data are presented in Table 2. The mean weight increase was highest in the ditches with low stocking densities, which is normal in fish production, even when food is in excess. The total increase per ha, which is more important in connection with weed control, was highest in ditch 1, where plant material was available until the end of the experiment. It was lowest in the empty ditch 3, where the fishes must have lacked food.

TABLE 2

Fish data in grasscarp experiments in ditchmodels, 1972.

No.	Stocking		Recapture			Total increase	Mean increase
	number	weight (kg)	number	weight (kg)	loss	kg/ha	(gr)
1	37	35.7	37	45.2	0	95	257
2	20	17.8	20	25.5	0	77	385
3	37	35.3	37	40.6	0	53	143
4	20	18.5	20	27.2	0	87	435

Quantitative and qualitative analysis of plankton (every 3-4 weeks) showed that no groups disappeared or were stimulated directly by grasscarps: there were no differences in high and low stocking densities. On the other hand there was a marked indirect effect: the two ditches with low plant coverage (3 and 4) had from the moment that they were nearly empty a bloom of *Chrysophyta* and *Rotatorae*, both groups of important food chain organisms. Blue-green algae showed no tendency to bloom in spite of a clear increase of the phosphorus content of the water during the course of the year.

Analysis of macrofauna (samples every 6-8 weeks) suggested that ditches 3 and 4 had too little vegetation. At the end of the year there was only a small diversity in the fish food organisms left. From this result it is concluded that, if in practice the risk to other fishes needs to be reduced, the stocking density of grasscarp will have to be adapted to the expected quantity of vegetation. Under these conditions the best results (biologically speaking as well) will be obtained in larger waters (complete polders, vast lakes) and not in closed ponds and ditches unless the grasscarp population is managed well.

For practical reasons our 1973 experiments were again in closed polder ditches. The same stocking densities were used but under the most unfavourable circumstances that could be offered to the grasscarp in Holland. The ditches (parcels of which were closed in by wire-screened fences) are located in the western part of the country where summer temperatures are the lowest. The ditches are shallow and have a thick layer of organic material at the bottom. They are overgrown every year by *Elodea*, *Ceratophyllum*, duckweeds, *Azolla* and filamentous algae while grasses intrude into the water from the banks.

Weed control data for these experiments are presented in Table 3.

TABLE 3

Plant coverage (% of bottom surface) in grasscarp experiments in ditchparcels, 1973. Stocking at 25/4.

No.	Fishstocking kg/ha	Fishstocking number	14/3	16/4	11/5	26/6	2/8	24/8	20/9	23/10
gk 1	180	14	0	0	3.5	77.8	77.6	76.0	47.1	21.5
gk 2	360	28	0	0	4.9	15.2	2.3	4.3	1.1	0.3
c 1	0	0	0	0	2.0	76.6	92.8	88.0	81.0	41.7
gk 3	180	19	0	0	2.3	20.2	0.7	0.8	0.3	0.0
c 3	0	0	0	0	12.5	15.2	45.2	54.7	51.0	20.4
gk 4	360	23	2.4	19.4	65.8	23.2	81.8[1]	95.0	..	..
c 4	0	0	0.6	8.3	69.2	93.2	52.9[2]	66.6	..	..

1 Dead fishes; 2 Partly cleaned.

Plankton data from this year's experiments did not show any adverse effect, but this may be due to the fact that the excrement filled water can flow away through the fences. This experiment will continue one more year to study the effect of overwintering in shallow waters and to see how the regrowth of the vegetation will progress. In the meantime, the Organization for Improvement of Inland Fisheries will collect data on the sport fishing value of the fish, (the sport fishermen will probably get a role in managing the grasscarp population) and this Organization is breeding the fish in glasshouses. Within four to five years it is hoped that enough will be known about the efficiency, economics and side-effects of this type of biological weed control to allow a decision to be made to use this fish as a weed control agent.

REFERENCES

Antalfi, A. and I. Tolg. 1971. Graskarpfen. Gunzburg, 207pp.

Bhanthumnavin, K. and M. G. McGarry. 1971. *Wolffia arrhiza* as a possible source of inexpensive protein. *Nature*, **232** : 495.

Blok, E. 1967. Experiments with herbicides in fishing waters (1964-1967). *2nd Int. Symp. Aqu. Weeds, EWRC, Oldenburg*, 51-65.

Doroshev, S. I. 1963. The survival of white amur and tolstolobik fry in Sea of Azov and Aral Sea water of varying salinity. Problems of the Fisheries Exploitation of Plant-eating fishes in the water bodies of the USSR, Ashkhabad : 144-149.

Kilgen, R. H. and R. O. Smitherman. 1971. Food habits of white amur stocked in ponds alone and in combination with other species. *Progr. Fish Cult.*, **33** : 123-127.

Liepolt, R. and E. Weber, 1971. Bisherige Erfahrungen mit den weissen Amur (*Ctenopharyngodon idella*) in Oesterreich. *Oesterr. Fisherei*, **24** : 159-162.

Opuszynski, K. 1972. Use of phytophagous fish to control aquatic plants. *Aquaculture*, **1** : 61-74.

Truax, R. E., D. D. Culley, M. Griffith, W. A. Johnson and J. P. Wood. 1972. Duckweed for chick feed? *Louis. Agric.* **16** : 8-9.

Yeo, R. R. and T. W. Fisher. 1970. Progress and potential for biological weed control with fish, pathogens, competitive plants and snails. *1st FAO Int. Conf. Weed Contr.* 15 pp.

Zon, J. C. J. van. 1973. Visies op de bestrijding van waterplanten in eutroof oppervlaktewater in Nederland. *Landbk. Tijdschr.* **85** : 165-171.