

The Grass-Carp, its effects and side-effects

by

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INTRODUCTION

In Holland the use of herbicides for aquatic weed control has been strongly restricted during the last few years (Van Zon 1974b, Zonderwijk & Van Zon 1975). Search for other control methods started and grass-carp (*Ctenopharyngodon idella*) soon seemed to be an effective agent for many situations (Van Zon 1974c and 1973).

In 1973 an official Working Party was formed to study grass-carp (Van Zon 1974a). The program of this group includes research on practical weed control as well as research to evaluate the risks of introduction of this exotic fish. The latter was set up according to the IUCN-recommendations of Petrides 1968. Until now most of the work has been done in the laboratory and in relatively small field experiments. To collect data in practical field situations the Dutch Ministry of Agriculture and Fisheries has given permission to use grass-carp in practice under guidance of the Working Party and only under certain conditions (Van Zon 1976).

The most important of them are:

- a. The fish has to be bought from the Organization for Improvement of Inland Fisheries (OVB). This means: artificially bred and free of (exotic) parasites and diseases.
- b. The stocked water has to be isolated from other surface waters either naturally or by fish-tight fences.
- c. Nature Conservancy should not have interests in the water concerned.
- d. Transport of living fished grass-carp is prohibited.

EFFICIENCY OF GRASS-CARP

Stocking density

Stocking density depends on a number of factors which are rather constant in Holland. The *wanted level of weed control* is nearly never 100% whereas the control peak has to be reached in late summer under *climatic conditions* relatively similar all over

the country. The grass-carp starts to eat frequently at about 12°C, especially on soft tissue plants and plant-parts (Cross 1969, Van Zon 1973). At higher temperatures selectivity decreases and complete weed control is achieved when temperature exceeds 20°C during summer for at least two weeks.

Young, small fish is more effective than older one, because they eat only parts of the weeds, but enough to kill. This means that stocking density is also determined by *fish-size*. More biomass of bigger fish is needed but too small fish (under 25 cm; Willemsen 1965) is too easy a prey for predator-fishes and birds. At the moment Dutch experimental waters are stocked with 150-250 kg/ha of one-year old grass-carps of about 35 cm (350 gr). From these figures it can be seen that stocking density is also based on factors that are not constant.

First of all *expected weed growth* determines the amount of fish needed. There is no refined prescription for this; stocking density can be lowered when the waterway or pond has been dredged in the year before (less weed-growth and occurring at a later moment), and in waters where only late growing species are expected (normally deep and/or turbid waters).

Secondly *environmental factors* influence density. When they are *biotic* of nature, it is difficult to predict these factors. Generally there should be more fish in waters with a high population of pike or in waters good for sportfishing.

Abiotic factors are easier to quantify. In containers the effect of salinity, change of waterdepth and disturbance on the foodintake of grass-carp was studied (Van Starckenburg & Van der Zweerde 1976). The last two factors only influenced food intake for a short period of time. Increase of salinity, however, had a marked effect: 500, 1000 and 2000 mg Cl .l⁻¹ brought food intake back with some 35% and there was no adaptation during some weeks. These results have to be translated in higher stocking densities, especially for the

Western provinces of Holland, where high salinities very often occur because of seepage of seawater.

Regulation of the stocked grass-carp-population

Stocked grasscarps grow fast and regrowth of weeds decreases, which means overstocking in the following years. This can be postponed by using low stocking densities after dredging, followed by removal of overweight grass-carp after a certain period of time. Fish can be removed by electro-fishing; in the DDR up to 90% of the stocked weight is removed after the first grazing period and the remaining fish is capable to keep weed regrowth under control for a number of years (Höne 1973).

In Holland it is advised to stock only one part of a waterway or polder and to increase the area after one year by taking away the fencing. Furthermore sportfishermen can be enlisted to catch with permission grass-carp in a certain time of the year or above a certain size. Experiments in the coming years will show how to solve this problem best.

Next to this, we have to get insight-information on the necessity of rejuvenation of a stocked population. As long as there is no clear difference in weed preference between 1 and 5 year old fish there seems no need to pursue the matter. Probably it proves to be the easiest way to replace the total stock after a still unknown number of years.

Costs

The use of grass-carp is a very inexpensive method of aquatic weed control. To obtain successful weed control 5 years after stocking of 250 kg/ha artificially bred one-year old fish, the yearly costs will only be a quarter of those incurred by mechanical control and half of the costs of chemical control (with herbicides that are approved in water in Holland). In this price-comparison the construction of fences and the loss of interest on invested capital are included.

Also in the DDR the use of grass-carp has proved to decrease the costs of aquatic weed control with 50-70% (Höne 1973, Jähnichen 1974).

SIDE-EFFECTS

All following data are compared with those of undisturbed control-situations; comparison with the side-effects of other weed control methods should still be carried out.

Macroflora

Table 1 shows, that the effect of grass-carp on macroflora is of a quantitative nature: species di-

versity has not clearly decreased over a period of 3 years (data derived from optimum (June) and end (September) of weed growing season).

Table 1. Macroflora: coverage (%) and diversity in ditches with (GC) and without (C) grass-carp.

		1973		1974		1975	
		Jun	Sep	Jun	Sep	Jun	Sep
Total coverage	GC	18	2	32	20	2	24
	C	46	69	72	78	14	77
submerged	GC	18	1	32	20	1	16
	C	38	30	68	69	11	30
floating	GC	8	2	2	2	2	16
	C	28	61	29	47	13	65
emergent	GC	6	1	2	3	2	5
	C	8	4	7	9	4	8
nr. of species	GC	30	30	25	30	23	31
	C	31	31	30	29	27	29

Table 2 shows the general influence of 3 years grass-carp activity on the spread of the most important plants in the ditches of table 1. There was no or little effect on the plants that grow close to the banks. The important reduction of growth was seen in submerged and small floating species and in grasses that intrude the water from the banks. In these ditches no clear selectivity in grass-carp-feeding was observed, although at lower stocking densities (180 kg/ha) *Nuphar luteum* could form a collar along the banks. In other experiments it

Table 2. Coverage and spread of plant species in ditches with grass-carp after a period of 3 years:

<i>Higher than in control ditches:</i>	
Hydrocharis morsus-ranae	Sagittaria sagittifolia
Nuphar luteum	
<i>Lower than in control ditches:</i>	
Azolla filiculoides	Oenanthe aquatica
Ceratophyllum demersum	Phalaris arundinacea
Elodea nutallii	Polygonum hydropiper
Glyceria fluitans	Potamogeton pusillus
Glyceria maxima	Sium erectum
Lemna gibba	Spirodela polyrhiza
Lemna trisulca	Wolffia arrhiza
<i>Equal to those in control ditches:</i>	
Agrostic stolonifera	Juncus effusus
Bidens tripartitus	Lysimachia nummularia
Carex acuta	Myosotis palustris
Filamentous algae*	Nasturtium microphyllum
Galium palustre	Polygonum amphibium
Juncus articulatus	Sparganium erectum

*In spring higher than in controls.

was shown that *Utricularia* and *Ranunculus* species are not eaten (Van Zon 1973). Cagni, Sutton & Blackburn (1971) quote studies of Krupauer from which it proves that *Ranunculus fluitans* is shunned only by younger fish.

Aquatic plants play an important role in the aquatic ecosystems (Van Zon & Zonderwijk 1973). They provide for many organisms food, shelter, hiding places or substrate. Too many aquatic plants, however, can diminish the life-possibilities for various organisms. Ecologically speaking, a vegetation with structural diversity and a rich species composition can be classified as high. On both aspects the influence of grass-carp is small or even positive, particularly in ditches where normally a thick layer of one or two submerged or floating species appears (Van Zon 1976).

Fish

Field experiments to determine the effect of grass-carp on survival, growth and breeding of endemic fishes are still in progress. Table 3 presents data from one experiment set up on a Dutch fishfarm, where grass-carps were stocked together with other fishes in four 0.1 ha ditches. No negative effects were observed.

Large negative effects were not anticipated. Food-competition can be excluded, since there are no typical herbivorous fishes in Western Europe (Scheer 1964). The number of other fishes in polycultures with grass-carp was increased (Nikolsky & Verigin 1968, Bohl 1971, Teodorescu-Leonte 1971, Bailey 1972, Gryierek 1973), probably because of better availability or production of food (Cure, Snaider & Chiosila 1970, Surber 1971). Better growth of other fish is also observed in surface waters (Swingle 1957, Tolg 1967, Bosbrova 1968, Crowder & Snow 1969, Greenfield 1971, Stott, Cross, Iszard & Robson 1971, Prowse 1971, Bailey 1972, Stott 1974). Also breeding of European fish is probably not influenced, because of the ending of the normal breeding period before weed control by grass-carp is achieved.

Carnivorous behavior of grass-carp is asserted in literature, although mostly for young grass-carp and in laboratory set-ups (a.o. Nikolsky 1956). A

total of 100 ordinary carp larvae were evenly distributed over 4 containers with and without Elodea. To each of the 2 x 4 containers 2 grass-carps (10 cm) were added. After two weeks 99 carp larvae remained in the 4 containers *with* Elodea whereas only a total of 71 (25,24,17,5) in the 4 containers *without* Elodea (Van Starckenburg & Van der Zweerde 1976). Edwards (1973) suggested less carnivorous behavior under field conditions, where hiding places are available. Prowse (1971) observed that grass-carps lost weight in ponds without plants but with many animal organisms. Under similar conditions in Holland grass-carps are often seen eating grass from the waterwaybanks, as is also quoted by Kilgen & Smitherman (1971). Bailey and Boyd (1971) found a gut-content of tree leaves and twigs when few aquatic plants were present.

Macrofauna

Tables 4 and 5 present data on quantitative sampling of macrofauna. From table 4 it is clear, that grass-carp affected the breeding of various organisms: less individuals than in the controls, but of the same weight. Most of the animals in the controls were Asellus and worms (Tricladida and Hirundinea). It is probable, that the grass-carps ate a part of the stocked macrofauna, since we used very small fish (2 grams), known to be carnivorous (Bailey 1972, Opuszynski 1968 and 1972). Eating of Asellus under aquarium-conditions was reported by Bohl (1967) and Cross (1969).

From table 5 it can be seen that in practice the effect is smaller, although also here the number of animals has decreased. Here biomass of macrofauna is reduced in the same proportion, so that it can be concluded that animals of all weight are

Table 4. Macrofauna in ditchmodels in containers (equally stocked) after one year of grass-carp (fingerlings).
(Per 0.5 m³ or 1.5 m²).

grass-carp	individuals	biomass (g)
360 kg/ha	222	33.75
180 kg/ha	201	29.96
0	12,334	25.56

Table 3. Fish-yield (kg/0.2 ha) of equally stocked ditchmodels with or without grass-carp, one year after experiment was started. (Experiment by the Organization for Improvement of Inland Fisheries).

grass-carp	bream			roach		rudd			pike	cyprin.	total
	ad.	4 yr.	2 yr.	ad.	2 yr.	ad.	4 yr.	2 yr.	1 yr.	0 yr.	
+250 kg/ha	6.9	1.7	0.245	2.1	1.460	2.0	4.3	0.851	8.3	5.4	33.2
0	3.3	1.5	0.234	2.1	1.386	3.0	4.7	0.523	7.2	4.2*	28.1

*Controls difficult to fish; probably more 0 yr-cyprinids.

Table 5. Macrofauna (per 2 m²) in ditchparcels with (GC) and without (C) grass-carp (Stocking in May, 1973).

	March 1974		Sept. 1974		Sept. 1975		March 1976	
	GC	C	GC	C	GC	C	GC	C
Individuals	3187	3708	3302	9538	8293	19450	4548	610
Biomass (g)	6.476	6.378	6.410	15.349	11.059	27.460	11.413	5.573
Nr. of taxa	38	54	61	68	60	71	51	40

removed. At least part of this reduction is due to an increase of endemic fish in the grass-carp parcels.

Species diversity is not strongly affected and in wintertime the differences between grass-carp and control ditches have levelled off completely. Ahling & Jernelöv (1971) observed in a Swedish lake no influence on bottom macrofauna during 2 subsequent summers, but an increase in wintertime in the grass-carp plots. They tend to attribute the latter to better oxygen conditions.

Within the macrofauna population the decrease is spread over all ecological groups, although not everywhere at equal rates. At the end of the season there is relatively more detritivorous and omnivorous macrofauna (Van Zon 1975). Number and biomass of herbivores are relatively low; the influence on carnivores is not clear.

Plankton

Plankton is sampled and analysed quantitatively (Van Dord, Hoogers & Van Zon 1971). Table 6 shows the results of an experiment in closed waterways. The tendency observed in these data compares with that of other experiments. The most striking phenomenon is that some groups (especially Chrysophytes and Rotifers) do not end their spring-bloom; samples give the impression of a spring-situation continuing through the summer, although the transparency was mostly not lowered.

Table 6. Plankton in closed canals with and without grass-carp after one year (4 replicates)
In grass-carp parcels more than (+), less than (-) or equal to (=) controlparcels:

	quantity	diversity
Desmidiaceae	=	=
Chlorococcales	+	+
Volvocales	+	=
Euglenales	=	=
Cryptomonadales	=	=
Dinoflagellates	=	=
Chrysophyta	+	=
Centrales	+	=
Pennales	+	+
Blue-greens	=	=
Protozoans	=	=
Ciliates	=	=
Rotifers	+	=
Crustaceans	=	=

This was also found by Avault (1965) with much higher stocking densities and by Lagerwey (1971), Michewicz, Sutton & Blackburn 1972 and Johnson & Laurence (1973).

The diversity of the plankton did not decrease; disappearance of species in grass-carp parcels has never been observed. Groups that are characteristic for hypertrophic or polysaprobic situations (Euglenales, blue-greens) did not increase. Ahling & Jernelöv (1971) found no clear influence of grass-carp on phytoplankton and no influence at all on zooplankton. Grygierek (1973) observed more daphnids in fishproduction ponds with grass-carp, probably as a consequence of more bacteria.

Water quality

From all experiments water was analysed to determine various chemical parameters. Table 7 presents averaged data from 3 different experimental plots. No dramatic changes occurred, except in the small containers. Since it is known from other experiments (Nikolsky 1956, Hickling 1966, Michewicz, Sutton & Blackburn 1972, Fischer & Lyakhovich 1973, Van Rijn, Werumeus Buning & Van der Zwerde 1975) that at least 50% of the plant phosphorus and nitrogen taken in by grass-carp flows back into the water, it has to be assumed that these elements under natural conditions are used again and are fixed into organisms rather quickly. Sneed (1971) supposed the same. Also Avault, Smitherman & Shell (1968) found no N- and P-increase in pools after 2 months grass-carp. Michewicz, Sutton & Blackburn (1972) observed no changes in total-P in pools and Ahling & Jernelöv (1971) found in a Swedish lake only a shortlasting increase in organic P and no change in N-content.

The only increase found in all Dutch experiments is that of iron and manganese, for which no satisfactory explanation can be given.

SUMMARY

In the past years results have indicated that grass-carp under Dutch eutrophic conditions is an effective weed control agent with no adverse side-effects to other fish, macrofauna and waterquality.

Table 7. Quality of water with (GC) and without (C) grass-carp after one year, in % of the initial determinations.
 —Ditchmodels: containers with 250 l; 180-360 GC/ha; 3 repl.
 —Ditches: 0.1 ha; closed with fences; 180-360 kg GC/ha; 6 repl.
 Canals: 0.4 ha; closed with partitions; 250 GC/ha; 8 repl.

	Ditchmodels		Ditches		Canals	
	GC	C	GC	C	GC	C
O ₂ (% saturation)	83	76	29	35	123	117
Conductivity (μS. cm ¹)	145	113	133	124	91	84
COD (mg. l ¹)	241	55	90	43	75	78
Total-P (")	20	38	98	78	135	155
Total-N (")	51	46	283	285		
K (")	145	36	75	80	96	92
Na (")	174	152	148	134	81	75
Ca (")	124	95	106	108	111	112
Mg (")	182	137	108	116	85	84
Mn (")	675	100	230	139	160	101
Fe (")	3,450	112	221	185	192	160
Si (")	6	45	110	93	265	176
HCO ₃ (me. l ¹)	150	117	91	98	91	102
Cl (mg. l ¹)	106	107	128	141	87	92
SO ₄ (mg. l ¹)	334	130	32	38	64	132

All data presented here are determined on the basis of hydrobiological ideal, undisturbed controls, which make it rather difficult to interpret the recorded influences of grass-carp on macrofauna and plankton more accurately. More research is necessary in the coming years, especially in comparison with the ecological effects of other methods of aquatic weed control.

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