The destruction of aquatic vegetation by carp

A comparison between Southern France and the United States

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Abstract

The destruction of submerged vegetation by common carp, *Cyprinus carpio* L. is tested in six enclosures with different biomass (kg ha^{-1}) of carp in a marsh of the Camargue, southern France. After 71 days, a strong negative relationship was found between the biomass of carp and the amount of aquatic vegetation present in the enclosures. The results are compared with similar studies in the United States. The absence of problem of vegetation destruction by carp in Europe, in contrast to North America, may be explained by lower biomass of these populations in Europe, and by a higher weight of carp in North America.

Introduction

Since its introduction in the United States in the 1830's (Moyle & Kuehn, 1964) and its proliferation after 1889, the common carp, *Cyprinus carpio* L. has been accused of destroying submerged vegetation in marshes to the detriment of game fish and waterfowl. After the initiation of programs to remove rough fish especially carp, using rotenone and repeated seining, a renewal of aquatic vegetation and decrease in turbidity were noted (Cahn, 1929; Ricker & Gottschalk, 1940; O'Donnel, 1942; Gerking, 1950; Rose & Moen, 1952; Cahoon, 1953). Experimental exclosures or enclosures have been used to determine the degree of damage on submerged vegetation in relationship to different biomass of carp (Threinen & Helm, 1954; Tryon, 1954; Robel, 1961; King & Hunt, 1967). All investigators have concluded that carp have a negative effect upon aquatic vegetation; however, no significant differences in turbidity were observed. It is generally agreed that carp destroy aquatic vegetation by uprooting plants. Others also suggest that carp eat submerged macrophytes (Forbes & Richardson, 1920; Sibley, 1929; Struthers, 1929; King & Hunt, 1967) or may cause the disappearance of vegetation indirectly by increasing the turbidity (Moyle & Kuehn, 1964).

In Europe where the common carp is widespread and often abundant, destruction of aquatic vegetation has not been reported. As a part of a general study on the biology of carp in the Camargue, southern France, an important wintering waterfowl area (Tamisier, 1965; Crivelli, 1979, 1981a, 1981b) experimental enclosure experiments are repeated. On the basis of the results, reasons are offered why vegetation destruction appears to be more severe in North America.

Methods

A description of the aquatic system of the Camargue can be found in Crivelli (1981a, 1981b). A marsh was selected having an area of 2.1 ha, a depth of 0.3 to 0.8 meters, a mean pH of 9 and a mean water temperature (14 h) of 20.6 °C during the experiment. Six 64 m^2 enclosures of 5 cm wire mesh were placed in a shallow temporary marsh with the bottom wire well buried in the mud. The average water depth in the enclosures was 43 cm with only slight differences among them. At the beginning of May different weights of carp were introduced in five of the enclosures, with the sixth remaining as a control. All the carp released into the enclosures were tagged, and trammel nets were place between the enclosures to be sure that no carp escaped. Due to the death of four carp in three of the enclosures an adjustment of the biomass was calculated according to the following equation:

$$\text{Adjusted biomass (kg ha}^{-1}) = \frac{B_1 \cdot t_1 + B_2 \cdot t_2}{t_1 + t_2}$$

B_1: biomass of carp at the beginning of the experiment
t_1 : number of days of the experiment with B_1
B_2: B_1 – the biomass of dead fish
t_2 : number of days with B_2

The percent species composition and total surface area covered by vegetation were estimated in each enclosure before carp were introduced. After 71 days the aquatic vegetation was sampled with 1 m² metal frame by clipping vegetation close to the bottom at six randomly chosen sites (9.4% of the total surface of each enclosure). The vegetation was washed in running water, dried at 85 °C for 48 hours and weighed to the nearest 0.1 g. The dry weight of aquatic vegetation was adjusted proportionally to 100% cover in enclosures A, B, C, and D using the cover in enclosures E and F as a maximum. This was done in order to compare the enclosures when estimating the effect of carp on vegetation. Turbidity was measured at nine day intervals in the six enclosures using a Hach turbidimeter (FTU unit).

Results and discussion

The most common submerged macrophytes were *Potamogeton pectinatus, Ranunculus baudotii* and *Chara canescens* (Table 1), and of these plants *P. pectinatus* was the most abundant in four of the six enclosures (A, B, E, F). *C. canescens* dominated enclosures C and D. These three species are common throughout Europe. *P. pectinatus* and *R. baudotii* are rooted plants which rise to the surface of the water. *C. canescens*, being an alga, has no roots and is only lightly attached to the substrate, and do not reach the surface.

Table 1. Composition of submerged macrophytes in the six enclosures.

Enclosures	Macrophytes % cover							
	Pp	Pt	Ssp	Cc	Cf	Rb	Csp	C%
A	25	2	+	+		15	-	40
B	80	-	-	15	-	15	10	80
C	20		+	60	20	10	20	90
D	30		+	60	-	5	7	70
E	100	3		-	-	5	3	100
F	100	3			-	5	5	100

Pp = *Potamogeton pectinatus;* Pt = *Potamogeton trichoides;* Ssp = *Scirpus sp.;* Cc = *Chara canescens;* Cf = *Chara fragilis;* Rb = *Ranunculus baudotii;* Csp = *Cladophora sp.;* C% = total surface area covered by aquatic vegetation; - = less than 1%.

Carp feed on benthic organisms, disturbing the bottom mud. This activity uprooted some of the plants which were found regularly floating on the enclosures. Feeding activity did not increase water turbidity, however. A statistical analysis of 48 measurements in the enclosures suggested that turbidity was essentially the same in all of them ($F = 0.55$ with 5 and 46 d.f., $P < 0.05$). This is the same conclusion reached by Tryon (1954) and Robel (1961) in the United States. Forester & Lawrence (1978) observed the opposite results in ponds in Alabama. High turbidity depends largely on the type of substrate and on meteorological conditions which may explain the difference in results.

The stomachs of mature carp (328–512 mm) present in the marsh, where the enclosures were built, contained no green aquatic vegetation (Crivelli, 1981a). Of the plant material only dead aquatic vegetation and a high percentage of seeds were consumed. Many authors either claim that carp feed on plants or cite the presence of vegetation in stomach contents (Forbes & Richardson, 1920; Sibley, 1929; Struthers, 1929; Moyle & Kuehn, 1964; King & Hunt, 1967). None of these authors however distinguished between the presence of green or dead vegetation.

The experiment was terminated by harvesting the plants and the carp. A strong negative relationship ($r = -0.95$ with 5 d.f., $P < 0.05$) existed between the biomass of carp and the amount of vegetation that remained (Table 2, Fig. 1). Although the carp did not eat the plants directly, their feeding activities evidently were responsible for the destruction of the plant beds. Robel (1961) reached the same conclusion in similar experiments in Utah. When results are compared with those in Utah (Table 3), amount of destruction is strikingly similar in the two experiments for the same experimental duration (71 days) in spite of differences in the mean weight of carp and the biomass of vegetation. Somewhat more destruction was noted in the longer (92 days) Utah experiments. Since the

Table 2. The effect of different biomass of carp on aquatic vegetation in six enclosures in a Camargue marsh. Thus is not included four carp which died in enclosures B, C, E.

Enclosures	Biomass of carp ($kg \cdot ha^{-1}$)	Number of carp	Dry weight of vegetation ($g\ m^{-2}$) calibrated to 100% cover
A	432.8	3	903.8
B	580.9	1	646.0
C	596.0	2	735.1
D	0	0	1193.9
E	725.6	2	588.8
F	646.8	7	601.3

Table 3. Impact of carp on submerged vegetation. Data calculated from Robel (1961): $Y_{1959} = 26.3 - 0.023\ X$; $Y_{1960'} = 17.25 - 0.021\ X$; $Y_{1960''} = 11.76 - 0.015\ X$; and Camargue: $Y = 1213.02 - 1.87\ X$.

Density of carp ($kg \cdot ha^{-1}$)	Percentage of destroyed vegetation			
	Utah			Camargue
	1959	1960′	1960″	1977
50	3.9	5.4	5.7	3.6
100	7.8	10.9	11.4	7.2
150	11.7	16.3	17.1	10.8
200	15.6	21.7	22.8	14.3
250	19.5	27.2	28.5	17.9
300	23.4	32.6	34.2	21.5
350	27.3	38.0	39.8	25.1
400	31.2	43.5	45.5	28.7
450	35.1	48.9	51.2	32.3
Duration of experiment (days)	72	92	92	71
Average weight of carp used in the experiment (kg)	2.4	3.4	3.8	1.6
Theoretical dry weight of aquatic vegetation in absence of carp ($g\ m^{-2}$)	283.0	185.6	126.5	1213.0
Number of enclosures	4	4	12	6

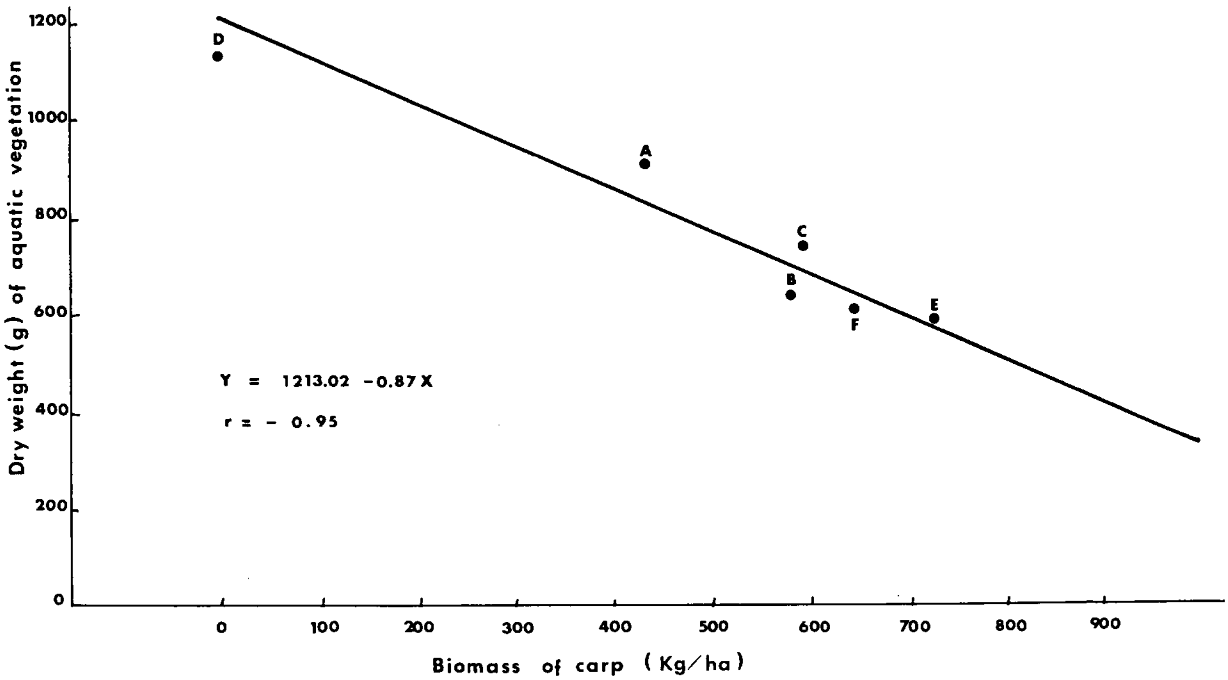

Fig. 1. The relationship between biomass of carp (kg/ha) and dry weight (g) of submerged aquatic vegetation.

Table 4. Selected references concerning weight of carp (kg ha $^{-1}$) in some natural waters of Europe and the United States.

Carp in biomass in Europe (kg ha $^{-1}$)	Reference	Carp biomass in U.S.A. (kg ha $^{-1}$)	Reference
30 (Danube river)	Holcik 1972	466	Sigler 1958
9 (reservoir)	Holcik 1972)	up to 138	Orth 1980
11–58	Crivelli 1981a	218–434	Moyle & Kuehn 1964

strength and the surface area of the mouth for sucking are a function of body size, uprooting may be more extensive by larger carp. This was tested by comparing the amount of vegetation destroyed with the average weight of the carp. At each weight of carp (Table 3) there is a positive linear relationship ($r = 0.97$ with 6 d.f., $P < 0.05$) between the two variables. Our measurements did not address the question as to whether or not areas of scarce vegetation are more easily destroyed than areas of dense vegetation.

Some other factors contribute indirectly to the seriousness of the damage on aquatic vegetation. Water depth can influence carp feeding behaviour. For example, deep water (10 m) is a negative factor for the proliferation of carp (Gerking, 1950), and therefore will prevent high densities of this species and consequent damage to vegetation. It is reasonable to expect that aquatic vegetation will be more easily destroyed in shallow water (20–50 cm) where carp preferentially feed and spawn.

The destruction of aquatic plants may be selective according to the plant community (King & Hunt, 1967; McCrimmon, 1972). The strength of the root system and susceptibility to uprooting in relationship to soil type is a determining factor for perennial plants. For annual species, however, the phenology, or the timing of seed production in relation to the seasonality of carp activity, may determine the impact on these species.

In conclusion, carp populations seem to be less dense and the average weight of the individuals is smaller in Europe than in the United States, and differences in destruction of vegetation in the two locations may be explained by these two factors. The weight can be up to ten times greater in natural waters in North America than those reported in Europe (Table 4); the average can be up to three times greater in North America than in Europe (e.g. North America: 2.99 kg in Wisconsin, Cahn, 1929; 3.3 kg in Indiana, Ricker & Gottschalk, 1940; 3.9 kg in Oregon, Moyle & Kuehn, 1964. Europe: 1.6 kg in Czeckoslovakia, Holcik, 1972; 0.9–1.2 kg in southern France, Crivelli, 1979). It is difficult to explain why growth rate and biomass in the United States is so much greater than in Europe. Huet (1958) speculates that high temperature in spring and North America favours reproduction and rapid growth (see comparative data in Carlander, 1964). Furthermore Pike, *Esox lucius* L., does not seem to regulate the carp population in the United States as it does in most of the natural european waters. Apparently this is due mainly to the rapid growth rate of carp, to more turbid waters in North America, and to the absence of pike in southern and western states of the United States. The reasons for the proliferation of carp in North America remains still obscure. Certainly more ecological studies on carp are needed in North America in order to improve our understanding of the carp proliferation problem there.

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