

OBSERVATIONS ON EFFICACY OF GRASS CARP, *CTENOPHARYNGODON IDELLA* (VAL.)
IN CONTROLLING AND UTILIZING AQUATIC WEEDS IN PONDS IN INDIA**

by

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ABSTRACT

The series of experiments conducted to study the efficacy of grass carp, *Ctenopharyngodon idella* (Val.) in controlling and utilizing various aquatic weeds, either growing naturally or introduced from outside, gave encouraging results. The fish could readily control thick infestations of *Hydrilla*, *Najas* and also *Ceratophyllum* among submerged weeds; and *Wolffia*, *Lemna* and *Spirodela* among the floating ones. Infestations of *Ottelia*, *Vallisneria*, *Nehamandra*, *Utricularia*, *Trapa*, *Myriophyllum*, *Limnophila*, *Azolla* and *Salvinia* could also be cleared by grass carp. The fish was observed to utilize *Potamogeton pectinatus*, *Halophila ovata*, *Nitella*, *Spirogyra* and *Pithophora*. However, the grass carp did not appear to feed actively on *Eichhornia*, *Pistia*, *Nymphoides* nor *Aymphaea*. Information on effective rate and size of grass carp stocking in weed infested waters has also been given.

INTRODUCTION

The grass carp, *Ctenopharyngodon idella* (Val.) is one of the Chinese carps which is now being very widely cultured. The species is a fast growing one and feeds avidly on aquatic weeds thereby utilizing what is considered obnoxious in fishery waters. In addition, the grass carp in combination stocking with other cultivable varieties of fish is reported to contribute indirectly towards their food by way of consuming the water weeds and in a way thereby green-manuring the ponds. The combination of all these qualities has made this vegetarian fish one of the most popular among the cultivable

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species. The observations made in China, Japan, Taiwan, Israel, Thailand, Malaya, India, Pakistan, the U.S.S.R., U.S.A. and recently in U.K. recommend the fish (Lin, 1940; Yashouv, 1957; Swingle, 1957; Kuronuma and Nakamura, 1958; Ling, 1960; Tang, 1960; Hickling, 1962; Sukhoverkhov and Pisarenkova, 1962; Aliev, 1963; Verigin *et al.*, 1963; Alikunhi and Sukumaran, 1964; Avault Jr., 1965a, 1965b; Konradt, 1965; Pentelow and Scott, 1965; Stevenson, 1965; Philipose, 1966). Recent enquiries from Australia (personal Communication) indicate an interest in the use of this fish as a biological control agent against aquatic weeds in the country.

In the tropical countries, particularly in India the 'weed problem' in fishery waters is acute. Therefore, to supplement the other known methods of weed control and to achieve increased fish production, experimental consignments of grass carp were obtained from Hongkong during December, 1959 and January, 1962, and the fingerlings were introduced at the Experimental Fish Farm, Killa, Cuttack. The preliminary observations made suggested the desirability of the new introduction, and the possibility of using the fish for aquatic weed control (Alikunhi and Sukumaran, 1964). Also, the possibility of breeding the fish in ponds by administration of fish pituitary hormones was demonstrated in 1962 (Alikunhi *et al.*, 1963), and later large scale production of its seed was achieved in 1964 enabling its distribution to almost all the States in the country for further observations in different regions (Chaudhuri, *et al.*, 1966). With an adequate stock of grass carp thus built up at the farm, a series of experiments were conducted in the field as well as at Cuttack Fish Farm to study and assess the efficacy of the fish in utilizing and controlling various water weeds.

MATERIALS AND METHODS

The field experiments were mostly conducted in protected ponds infested with aquatic weeds in Killa and Chaudwar (about 20 km. from Cuttack) fish farms and in a few private ponds located in Cuttack proper. The density and species composition of the weed infestation was estimated statistically, wherever possible, by using a 1 meter sq. or $\frac{1}{2}$ meter sq. quadrat frame employing the 'systematic sampling' method.

In situations where the infestation was rather scattered, sampling of the weed density was done only in the areas infested after assessing by 'eye estimation' the percentage of coverage e.g. 25%, 50%, 75% etc. In the case of patchy or regenerating infestations no detailed sampling was considered necessary, but relevant field notes were made regarding the nature of infestation. The observations on weed species not naturally growing in the protected ponds were made by introducing them in known quantities from other localities. As far as possible, control sets of weeds were maintained in order to form an idea about the natural changes taking place in the weeds (either growing naturally or introduced from outside). This was done by fixing up a 1 meter sq. frame in a corner of the pond enclosing a proportionate sample of the healthy weed present outside the frame. Later, grass carps of known size and number were introduced in the ponds and regular observation on weed clearance were made. When the weeds, under observation, were fully cleared, the ponds were netted and final sampling on the survival and size of the fish was done.

The field observations pertain to control and consumption of natural infestations of various weeds in ponds and also consumption of known quantities of fresh weeds introduced from time to time, by a known number and size of grass carps. In laboratory experiments known quantities of several weeds including filamentous algae and *Witella* were tried for their acceptability by the fish. Further, from field observations on weed-infestations consisting of a number of species occurring together, an idea about the relative preference of various weeds by grass carp could also be formed.

OBSERVATIONS

A. Field Experiments

1. *Hydrilla verticillata*: Observations on control and consumption of *Hydrilla* - one of the most noxious water weeds, by grass carp were made by introducing the fish in ponds having a natural growth of the weed or by introducing the weed from outside.

(i) In one 0.08 ha. pond 450 kg. of fresh *Hydrilla* was introduced and later 97 grass carps (av. length 452 mm. av.wt. 955 g) were released which consumed all the weed within 8 days, and again 425 kg. of the weed was introduced which was consumed within 4 days. The fish, at the end of the experiment, averaged 1070 g.

(ii) Thick growth of *Hydrilla* mixed with *Najas indica* and with scattered patches of *Nymphoides indicum* were noticed in one 0.1 ha. pond in Chaudwar farm. The submerged weeds covered nearly 25% of the entire pond, and systematic sampling of the weeds was done which worked out to 744 kg. in the entire pond, *Hydrilla* being 520 kg. and *Najas* 224 kg. After sampling the weed density, 520 grass carps, average weight 62 gms. (measuring 105 mm to 260 mm) were transported some 20 km. in open fry carriers from Killa fish farm, Cuttack, and were stocked in the pond. In the first week the rate of consumption of weeds was rather slow, but later the clearance was quick, and it took 18 days for the fish to clear all the submerged weeds in the pond. *Nymphoides* was not consumed and was manually removed and the pond was later netted. Altogether 450 grass carps in good health weighing on an average 113 g (measuring 157 mm to 354 mm) were recovered from the pond. One *Wallago attu* of about 2 to 3 kg. size was also caught and could have accounted for the loss of some grass carps from the pond.

The grass carps (425, fish average wt. 113 g) thus reared, were transferred to another neighbouring large pond (0.65 ha.) thickly choked with *Hydrilla* and *Najas* along with an abundant infestation of *Nymphoides indicum*. Systematic sampling of the submerged weeds was done which worked out to 25,300 kg. of *Hydrilla* and 19,100 kg. of *Najas* (total = 44,400 kg. of weeds) in the pond. Within 42 days almost all the submerged weeds were cleared and only some small floating masses of *Hydrilla* and *Najas* were left

out, and a slight decay of older plants was also noticed in the pond. The infestation of *Nymphoides* remained as thick as initially recorded. The pond was netted out and the fish were recovered in good condition weighing on an average 322 g (measuring 205 mm to 510 mm).

The above observations suggested that grass carps greatly relished *Hydrilla* and voraciously fed on it. The same was observed earlier by Alikunhi and Sukumaran (1964).

2. *Najas indica*: It is another obnoxious weed having a very high aggressive capacity. The following observations were made in the field on its control and utilization.

(i) Two 0.08 ha. ponds in the Killa fish farm, which were dewatered and deepened earlier, became thickly choked during the early monsoon season with *Najas indica*, and also with small scattered patches of *Nechamandra alternifolia*, *Nymphoides cristatum*, *Marsilea quadrifolia*. In one pond a few *Vallisneria spiralis* clumps were present. The weed density in the two ponds was sampled and was assessed to be 861 kg and 1,103 kg respectively. Control for *Najas* was maintained. Later, 100 grass carps (av. length 210 mm., av. wt. 94 g) were introduced in each pond. Within 6 weeks both the ponds were completely cleared of *Najas*. However, it was noted that in the absence of *Najas*, *Nechamandra* started spreading slowly, so also *Nymphoides*. Both these weeds, which were avoided by grass carp were manually removed at the time of final sampling. The fish in the two ponds measured 341 mm. on an average weighing 470 and 474 gms. respectively. Development of slight algal bloom was noticed in the ponds afterwards. The weeds inside the control remained healthy.

(ii) Two more farm ponds at Killa, each 0.12 ha. in area, were infested with an abundant growth of *Najas indica*. One of these ponds was almost completely choked with weeds consisting of mainly *Najas* with stray patches of *Hydrilla*, *Ceratophyllum*, *Ottelia*, *Nymphaea*, *Nymphoides*, *Spirodela*, *Pistia*, *Monochoria*, *Ipomoea* and *Marsilea*, also *Spirogyra* towards the margins. The total quantity of weed was assessed to be 2,278 kg., and control for *Najas* was maintained. Later 200 grass carps (av. length 415 mm., av. wt. 789 g) were introduced, and within a fortnight all the submerged weeds in addition to *Spirodela*, *Monochoria* and *Ipomoea* (leaves alone) were consumed. *Nymphaea*, *Nymphoides* and *Pistia* remained. Final sampling of the fish was done and the fish on an average measured 436 mm. weighing 989 g. The *Najas* inside control remained healthy.

In the other pond weed infestation was estimated to be nearly 20% of the above pond, the main growth being that of *Najas* with stray patches of *Nechamandra*, *Ottelia*, *Nymphoides*, *Nymphaea* etc. No detailed sampling was done, and 114 grass carps (av. length 272 mm., av. wt. 200 g) were introduced. All the submerged weeds were consumed within 3 weeks, and on final netting the fish measured 318 mm. weighting 410 g on an average.

Among the submerged weeds *Najas* was found to be readily accepted by grass carp probably next to *Hydrilla* in order of preference as was also observed in the Chaudwar ponds.

3. *Nechamandra alternifolia*: A number of field observations were made regarding control of this aggressive weed by grass carp.

(i) *Nechamandra* with mixed growth of *Hydrilla* and *Nymphoides* covered one 0.04 ha. pond. To control the weeds 55 small grass carp (100 - 200 mm in size) were introduced which cleared all the *Hydrilla* within a fortnight. However, *Nechamandra* was avoided and observations with the small fish on *Nechamandra* alone were continued for another month, but the fish exhibited no check on the growth of the weed. Later, 15 adult grass carps (about 2 kg. size) were stocked and took one month to clear all *Nechamandra*. The fish mostly cut up the plants and fed on them, but a proportion of the cut up portions naturally decayed. The fingerlings which initially weighed 20 g grew to 93 g on an average. The adult fish showed slight increase in weight average being 2.1 kg.

Nymphoides was not eaten, but many plants were found uprooted, possibly by the fish.

The same pond was later dewatered, desilted and deepened, but because with commencement of monsoon, it again was infested with a thick growth of the *Nechamandra* along with scattered patches of *Nymphoides*. In order to control the former, 10 grass carps were first introduced, but exercised no marked control on the weed density. After 3 weeks, 10 more adult grass carps were introduced, the average weight for 20 being 1.92 kg. Altogether, it took about 3½ months to clear all *Nechamandra* which was partly consumed, and partly the cut up portions decayed. Most of the *Nymphoides* were avoided but uprooted. The final average weight of 20 grass carps was found to be 2.15 kg., and the fish were recovered in good condition.

After a lapse of near 4 months, *Nechamandra* again started reinfesting the pond vigorously. When the growth became quite thick, 19 grass carps (av. wt. 1 kg.) were first introduced, but the weed growth appeared to increase unchecked. So after one week, 10 more grass carps (av. wt. 525 g) were stocked. The entire period taken to bring *Nechamandra* under control was one month, and at the end the bigger 19 fish weighed 1.1 kg. and the other 10 weighed 570 gms. on an average. One healthy clump of *Ottelia*, present in the pond was consumed quite quickly by the fish in the beginning. The *Nymphoides* patches present in the pond were mostly avoided with a good number of them floating uprooted.

(ii) Another 0.04 ha. pond nearly 50% covered with a natural growth of *Nechamandra* mixed with *Hydrilla* and *Nymphoides*, was selected for observations. At first 28 small grass carps (100-200 mm size) were introduced into the pond and consumed all the *Hydrilla* within a fortnight, but the fish exercised no control over *Nechamandra* during the period of observation of one and a half months. Later, 12 adult grass carps (av. wt. 2 kg.) were stocked and cleared the *Nechamandra* in 4 weeks. When netted out, the fingerlings had increased

in weight from 35 g to 308 g on an average, and the adult fish weighed 2.1 kg. *Nymphoides* was avoided but several plants were noticed uprooted. No regeneration of *Nechamandra* has been noticed for the last $1\frac{1}{2}$ years.

(iii) Two more nursery ponds became infested with a thick growth of *Nechamandra*, the percentage of coverage being nearly 50 in the first pond (0.06 ha.) and 40% in the other (0.04 ha.). In the two ponds 10 and 16 grass carps of average weight 1.83 kg. and 2.0 kg. respectively were introduced. After 6 weeks and 7 weeks respectively the ponds were free from *Nechamandra*, and the fish averaged 2.6 kg. and 2.25 kg. respectively. As usual the fish started its work by cutting up the vegetation which consisted of young plants of *Nechamandra* without flowers etc. No regeneration of the weed has been noticed in the ponds for the last 10 months.

The observations made so far suggest that *Nechamandra* is another persistent type of weed, that it can be controlled by grass carp, but is not much relished by the fish. The fish weighing about 0.5 kg. and above alone were found to be effective against this weed. Invariably the time taken in clearing *Nechamandra* infestations was quite considerable, and in cases where *Hydrilla* or *Najas* were present along with, the coarser weed was at first avoided by grass carp. Further, younger plants of *Nechamandra* without flowers etc. appeared more acceptable to the fish than old and profusely flowering ones.

3. *Ceratophyllum demersum*: Observations on this submerged, uprooted, abundantly growing weed were also made.

(i) In one 0.04 ha. pond, 540 kg. of *Ceratophyllum* was introduced and 16 grass carps (av.wt. 2.08 kg.) starved for about a month, consumed the weed within a fortnight; however, there was slight decay of the weed. The fish finally weighed 2.78 kg. on an average, the unusually high increase could possibly be due to very avid feeding by starving fish.

The same fish were again sampled after 6 days, and weighed only 2.64 kg. on an average before introducing another 227 kg. of *Ceratophyllum* in the pond. Within 5 days all the weed was consumed, but sampling could be done only after 7 days and the fish weighed less i.e. 2.61 kg. at the end, though found in good condition. The fall in weight was possibly due to the delay in sampling after the introduced weed was completely consumed.

In another 0.08 ha. pond 680 kg. of *Ceratophyllum* was introduced and 100 grass carps (av.wt. 816 g) were stocked. Within 10 days all the weed was cleared and the fish finally weighed 623 g on an average.

In the same pond, again 454 kg. of *Ceratophyllum* mixed with some *Asolla* was introduced, and the fish took 6 days to consume the weeds. The initial and final average weights of the fish were 623 g and 748 g respectively.

7. *Vallisneria spiralis*: In one nursery pond some healthy clumps of *Vallisneria* were growing where 4 adult grass carps were introduced to observe the efficacy of the fish in controlling this weed. The fish were noticed cutting the older leaves and browsing upon the tender ones in addition to uprooting the entire plants occasionally. Later, another nursery having nearly 10% of the area infested by *Vallisneria* along with some growth of *Hydrilla* was selected for further observations. Eleven grass carps weighing between 1.9 to 3.0 kg. were introduced and took about 5 weeks to clear *Vallisneria*. *Hydrilla* was quickly consumed within the first few days of stocking the fish.

8. *Spirodela polyrhiza*: Two 0.08 ha. rearing ponds, located side by side which had been infested by an uniformly thick growth of *Najas* and had been cleared by grass carp simultaneously, were selected for observations on *Spirodela*. In each pond 520 kg. of healthy *Spirodela* mixed with some *Wolffia* was introduced, later 100 grass carps were stocked in each pond (av. length 341 mm.) weighing on an average 474 g and 470 g respectively. Control for *Spirodela* was maintained. In the first pond the weed started multiplying for sometime and later the older fronds were noticed decomposing. The fish took 20 days to clear the pond completely and increased in weight to an average of 616 g (av. length 373 mm.). In the other pond, the weeds started multiplying very fast and it took 43 days to clear the weeds completely. The fish at the end averaged 830 g (av. length 408 mm.). The grass carps were observed to consume *Spirodela* and *Wolffia* very voraciously.

9. *Lemna trisulca*:

(i) One 0.1 ha. pond developed a thick cover of *Lemna* mixed with stray fronds of *Spirodela* and *Wolffia*. The total quantity of the weed was assessed by systematic sampling at 170 kg. for the entire pond. Control for the weed was maintained and 100 grass carps (av. length 211 mm., av. wt. 124 g) were introduced. The fish were observed feeding avidly on the duckweed, and the feeding activity was more vigorous during the morning hours. Within 11 days the pond was completely cleared of all the weeds, and on final sampling all the fish were recovered weighing on an average 145 g (av. length 218 mm.). The weed inside the control remained healthy and showed some increase in weight during the period of observation.

(ii) Further observations were made in one 0.04 ha. pond by introducing *Lemna* from outside. In the pond, 164 kg. of *Lemna* and 60 kg. of *Wolffia* (total 224 kg.) were introduced, and 100 grass carps (av. length 196 mm., av. wt. 87 g) were stocked. Within 12 days all the weed the consumed and the fish at the end weighed 150 g (av. length 232 mm.). The weeds inside the control remained healthy.

In the same pond again 140 kg. of *Lemna* mixed with 40 kg. of *Wolffia* were introduced. The 100 grass carps (av. length 232 mm., av. wt. 150 g) present in the pond consumed all the weeds within 11 days, and the fish attained an average weight of 200 g (av. length 268 mm.).

Lemna weighing 144 kg. was introduced in another 0.04 ha. pond and 80 grass carps were stocked which consumed the weed completely within 9 days. Initially the fish weighed 100 g (av. length 201 mm.) and at the end 169 g, measuring 252 mm. on an average.

The above observations clearly indicated that all the duck-weeds tried were greatly relished by grass carp, and of these *Wolffia* was readily accepted even by early fingerlings (see also below).

10. *Azolla pinnata*: In two ponds (0.035 ha. and 0.04 ha.) 350 kg. and 418 kg. of *Azolla* were introduced, and control frame was fixed enclosing 1 kg. of the weed. Afterwards 100 grass carps (av. size 172 mm., 45.5 g, and 168 mm., 45.4 g) were introduced in each pond. A few days later, the weed started turning unhealthy and decaying, and in about 16 days all the weed completely disappeared including what was inside the frame. However, feeding of the fish on *Azolla* was directly observed in the pond. At the end all the grass carps were netted out in healthy condition weighing on an average 87 g (196 mm.) and 100 g (201 mm.) respectively. This indicated that *Azolla* was utilized by grass carps possibly both in fresh and semi-decaying form.

In another 0.04 ha. pond fresh *Azolla* weighing 360 kg. was introduced. Control was maintained, and 20 grass carps (av. length 463 mm., av. wt. 995 g) were stocked. As noticed above, after a few days the weed started naturally dying off and within 3 weeks no weed was left in the pond nor in the control. On final netting the fish weighed 1,066 g (466 mm.) on an average.

The above experiments demonstrate that grass carps feed upon *Azolla*.

11. *Salvinia cucullata*: Fresh fronds of *Salvinia* weighing 250 kg. along with stray plants of *Trapa natans* were introduced in one 0.08 ha. pond, and control for the weeds was maintained. In the pond, 95 grass carps (av. wt. 958 g) were stocked. Within 17 days all the *Salvinia* and *Trapa* were consumed, though the weeds were not very actively fed upon. On final sampling the fish weighed 1 kg. on an average. The weeds inside the control remained healthy.

12. *Eichhornia crassipes*, *Pistia stratiotes* and *Colocasia antiquorum*: The general field observations made earlier at the Research Station indicated that these weeds are not accepted by grass carp as feed, and that the fish could hardly control them in ponds. The first two weeds are amongst the most obnoxious ones, so field experiments were conducted again to study whether these weeds could be utilized by the fish as feed. In nursery ponds, free from other aquatic weeds, grass carps (size range 121 mm. to 305 mm.) were stocked @50 per pond, and cut bits of *Eichhornia*, *Pistia* and also *Colocasia* were introduced in separate ponds as feed regularly, but none of these appeared acceptable to the fish which lost condition during the period of observation. However, the grass carps were noticed occasionally to gulp in bits of water hyacinth. (*Eichhornia*) but these were mostly disgorged subsequently.

B. Laboratory experiments

(i) Inside a plastic pool (height = 60 cms., diam. = 80 cms.) grass carps ranging between 160 mm. to 170 mm. were fed upon *Potamogeton pectinatus* and *Halophila ovata* growing abundantly in the brackish water of Chilka Lake (Orissa), and also on *Myriophyllum tuberculatum*, *Utricularia stellaris*, *Ottelia alismoides*, *Nitella sp.*, *Spirogyra* and *Pithophora*. The last three algal forms were quickly consumed, and the fish were observed to browse upon the other species.

Inside glass aquaria and plastic pools observations on the acceptability of cut bits of *Eichhornia* and *Pistia* by grass carp were repeated. The fish (av. length 165 mm.) were observed to take in bits of *Eichhornia* occasionally but these were mostly disgorged later.

(ii) In glass jars advanced fry and fingerlings of grass carp (27 mm. - 42 mm. size range) were observed to feed on *Wolffia*. The early fingerlings could also consume *Lemna*, but bits of *Spirodela* and *Najas graminea*, but preferred plankton to any other feed.

Separately in jars, fingerlings of grass carp (av. 65 mm.) were given *Nitella*, *Spirogyra* and *Pithophora* which were actively fed upon by the fish.

From these observations it has been possible to calculate roughly the numbers and size of grass carp per hectare required to control various types and density of weed infestations. The details are presented in Table I.

The rates shown above are to be judiciously employed and the number and size of fish to be varied according to the size of the water area and nature and extent of weed infestation. Also, in the case of duck-weed infestations, the rate of stocking may at times need considerable adjustment when the weeds multiply at a fast rate.

For the following weeds, the per day consumption by grass carp has been calculated in Table II.

From Table II some idea can be formed regarding daily consumption of several weeds by grass carps of varying sizes. However, no calculations regarding 'forage ratio' etc. are attempted, because the results given are tentative and only meant to show the trends in the feeding of the fish on certain weeds.

TABLE I

INFORMATION ON EFFECTIVE RATE OF STOCKING OF GRASS CARP
TO CONTROL VARIOUS WATER WEEDS

Weed species	Initial av. wt. of fish	Stocking rate/ha.	Weed quantity in tons/ha.	Duration of Clearance	Remarks
<i>Hydrilla verticillata</i>	995 g	1,210	11	10 days	Weed introduced
<i>Hydrilla + Najas indica</i>	62 "	5,200	7.4	18 days	natural infestation
-do-	113 "	654	68.3	42 days	-do-
<i>Najas indica</i>	94 "	1,250	10.8	41 days	-do-
-do-	94 "	1,250	13.8	41 days	-do-
-do-	789 "	1,667	19.0	14 days	-do-
<i>Ceratophyllum demersum</i>	2,640 "	400	5.7	5 days	Weed introduced
-do-	616 "	1,250	8.5	10 days	-do-
-do-	830 "	1,250	5.7	6 days	-do-
-do-	623 "	1,250	5.7	6 days	-do-
-do-	974 "	250	37.2	49 days	natural infestation
<i>Nechamandra alternifolia</i>	1,830 "	250	6.8	43 days	-do-
-do-	2,000 "	400	3.8	18 days	-do-
<i>Utricularia stellaris</i>	948 "	725	3.1	9 days	Weed introduced
<i>Spirodela polyrhiza</i>	474 "	1,250	6.5	20 days	-do-
<i>Lemna trisulca</i>	124 "	1,000	1.7	11 days	natural infestation
-do-	100 "	2,000	3.6	9 days	Weed introduced
<i>Lemna + Wolffia arrhiza</i>	87 "	2,500	5.6	12 days	-do-
-do-	150 "	2,500	4.5	11 days	-do-
<i>Salvinia cucullata</i>	958 "	1,190	3.1	17 days	-do-

TABLE 11

DAILY CONSUMPTION OF SOME WEEDS BY GRASS CARP

Name of the weed	Consumption in g/day/ fish	Initial av.size in g	Final av.size in g	Period of observation
<i>Hydrilla verticillata</i>	903	955	1,070	Apr. 22 - May 4, 1966
<i>Najas indica</i>	210	94	470	July 7 - Aug.17, 1965
<i>Najas indica</i>	269	94	474	-do-
<i>Najas indica</i>	813	789	989	Oct. 28 - Nov.11, 1965
<i>Hydrilla verticillata</i> + <i>Najas indica</i>	80	62	113	Apr. 23 - May 11, 1965
<i>Ceratophyllum demersum</i>	680	616	623	Sept.17 - 27, 1965
<i>Ceratophyllum demersum</i>	757	830	892	Oct. 12 - 19, 1965
<i>Ceratophyllum demersum</i>	757	623	748	-do-
<i>Spirodela polyrhiza</i>	260	474	616	Aug. 17 - Sept. 7, 1965
<i>Lemna trisulca</i>	155	124	145	Apr. 6 - 17, 1965
<i>Lemna trisulca</i>	200	100	169	Sept.15 - 24, 1965
<i>Lemna trisulca</i> + <i>Wolffia arrhiza</i>	187	87	150	Sept.10 - 22, 1965
-do-	164	150	200	Oct. 6 - 19, 1965
<i>Utricularia stellaris</i>	479	948	975	May 23 - June 1, 1966
<i>Salvinia cucullata</i>	155	958	1,000	May 30 - June 16, 1966

DISCUSSION

The series of experiments described in the foregoing clearly demonstrate the possibility of utilizing grass carp as an effective biological agent to control several noxious aquatic weeds.

The observations made with floating weeds in the field as well as in the laboratory indicated that advanced fry and early fingerlings (27 mm. - 42 mm.) of grass carp accepted *Wolffia*, and as they grew they could take bigger duckweeds viz; *Lemna* and *Spirodela*, but still appeared to prefer zooplankton most as food. The advanced fingerlings, juveniles and adults of grass carp which are predominantly herbivorous in habit, were found to relish and effectively control the duckweeds, and the fish could also assist in clearing *Azolla* infestations. The observations made on *Salvinia* suggested that grass carp could control this weed too. Ling (1960) mentions the use of *Salvinia* in China as alternative feed for grass carp in the absence of other suitable water plants.

Among the submerged weeds, *Hydrilla* and *Najas* are perhaps the most obnoxious ones, but these were found to be avidly consumed and controlled by grass carp. The other troublesome weeds namely, *Ceratophyllum* and *Ottelia* were preferred next, and the grass carp also appeared to be effective against infestations of *Nechamanara* and *Utricularia*, possibly *Vallisneria* also, though the fish did not seem to relish them much. It may be mentioned here that grass carps weighing nearly 0.5 kg. and above alone were found effective against *Nechamanara* whereas, the fingerlings could hardly exercise any check on its growth.

From the experiments conducted, the possibility of utilization and control of *Trapa*, *Myriophyllum* and *Limnophila* by grass carp also appeared likely. The fish was also observed to feed on the leaves of *Monochoria* and *Ipomoea*, though the data available is rather scanty. *Potamogeton pectinatus* and *Halophila ovata*, which often grow abundantly in brackish waters, are also taken by the fish. This information is quite useful as grass carp is already known to withstand a good range of salinity (see Doroshev, 1963). The algal forms such as *Nitella*, *Spirogyra* and *Pithophora* were also actively consumed by grass carp. However, in nursery ponds the fish was noticed to feed on *Spirogyra* and *Pithophora*, but whether it could curb their growth was not definitely established.

From the above account it is clear that the problem of controlling most of the noxious weeds, especially the submerged ones where clearance is very expensive, can be effectively tackled by grass carp. However, the 'weed problem' of *Eichhornia* (water hyacinth), *Pistia*, *Nymphoides* and *Nymphaea* does not seem yet to be solved. Ling (1960 & 1966) reported the use of young leaves of *Eichhornia* and *Pistia* for feeding grass carps. Avault Jr. (1965a, 1965b) observed control of *Eichhornia* by grass carp, but separately states that this plant was least preferred by the fish. As regards *Pistia*, he cites the observations of Lin (1946) that the Chinese use this weed to feed grass carps. The acceptability and suitability of *Eichhornia* and *Pistia* as feeds by grass carps were however, not demonstrated during the present investigations. The density of infestations of *Nymphoides*

was mostly not affected by the fish, however, some plants of *N. cristatum* were observed uprooted in ponds where grass carps were stocked.

In Japan, Kuronuma and Nakamura (1958) observed in farm ponds that grass carp proved very effective in control water weeds, and among these, *Myriophyllum specatum*, *Ceratophyllum demersum*, *Potamogeton* spp., *Hydrilla verticillata* and *Trapa* spp. were brought under control by the fish.

Hickling (1962 and Avault Jr. (1965a) reported effective control of *Chara* by grass carp. Stevenson (1965) observed eradication of *Chara*, *Najas* and *Anacharis* by the fish, but not that of *Spirogyra*.

Interesting observations with grass carp have been made in Russia where the fish has been stocked in large reservoirs, tanks and even in the sea (see Aliev, 1963; Doroshev, 1963; Konradt, 1966; Sukhoverkhov and Pisarenkova, 1962; and Verigin, 1963). Aliev (1963) reported that in the Karakum canal, choked with pond weed (*Potamogeton pectinatus* and *P. perfoliatus*), water milfoil, hornwort, reeds, rushes etc., the submerged weeds were readily destroyed and further spread of the weed was checked. Verigin et al. (1963) studied food selectivity and daily ration of grass carp inside specially designed cages, and arranged the various weeds in the order of preference exhibited by the fish. He classified *Potamogeton pectinatus*, *Ceratophyllum demersum*, *Elodea canadensis* and *Lemna trisulca* as most preferred; and *Vallisneria spiralis* and *Myriophyllum* sp. as average. Sukhoverkhov and Pisarenkova (1963) reported that two year old grass carps chiefly consumed *Potamogeton* and *Ceratophyllum*, but not *Lemna trisulca*, and he further stated that three year old grass carps at greater population densities also ate *Lemna*. During the present investigations, no such difference between the feeding habit of two year old and three year old grass carps has been noticed and the above observation on *Lemna* could possibly be due to lower rate of stocking of grass carp and fast rate of multiplication of the weed.

In the present study quantitative estimates of weed density were made and detailed records of number and size of fish used etc. were maintained. In predator free ponds grass carps weighing on an average 62 g and above were found effective against a number of duckweeds and submerged plants. However in waters where presence of predators is apprehended, the stocking of suitable sizes of grass carp, big enough to escape predation is essential to give satisfactory results. Alikunhi and Sukumaran (1964) in their preliminary observations reported that ponds choked with *Hydrilla* could be cleared by grass carps stocked at 300-375, weighing between 78.8 to 173 kg. per hectare in one month's time. Further, they observed that grass carp did not prefer *Najas* and *Nechamandra* in the presence of *Hydrilla*, also the fish could grow satisfactorily when fed on *Hydrilla*, *Lemna* and *Azolla*. Aliev (1963) mentioned that 30.6 kg. of grass carps (weighing between 110-200 g) per hectare consumed 12.5 tons of submerged weeds within a short time and considerably raised the fish productivity of the body of water. Kuronuma and Nakamura (1958) make a tentative statement that grass carps stocked at 30 per hectare weighing in total about 35 kg. could ensure satisfactory control of weeds.

In tropical waters of India where large numbers of highly predatory fishes such as *Wallago attu* and *Ophicephalus spp.* exist, it is important to ensure the release of grass carps which are big enough in size to escape predation. Further, a higher rate of stocking of grass carps may be necessary as compared to temperate waters, because of the vigorous rate of growth of weeds in warm waters.

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