International Journal of Bio-resource and Stress Management

https://ojs.pphouse.org/index.php/IJBSM

Crossref

IJBSM November 2025, 16(11): 01-08

Article AR6603

Research Article

Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2025.6603

Efficacy of Grass Carp (*Ctenopharyngodon idella*) in Controlling Aquatic Weeds in Rural Farm Ponds: A Field Demonstration Study

Alagappan M. and **Sendur Kumaran S.**

Krishi Vigyan Kendra, Tamil Nadu Veterinary and Animal Sciences University, Kundrakudi, Sivaganga, Tamil Nadu, (630 206), India

Open Access

Corresponding alagappan24@gmail.com

0009-0008-4304-0690

ABSTRACT

The study was conducted during November, 2023 to March, 2024 in the farmers' farm ponds at Kalayarkoil and Ilayangudi villages in Sivaganga district, Tamil Nadu, India to evaluate the efficacy of grass carp (*Ctenopharyngodon idella*) in controlling aquatic weeds and enhancing pond productivity under rainfed farming conditions. A total of five farm ponds of 0.1ha each were selected and uniformly stocked with 500 Grass carp fingerlings without supplemental feeding. Over a 120-day culture period, a significant reduction in weed biomass was observed, with a mean decrease of 79.8%, particularly in dominant species such as *Hydrilla verticillata* and *Najas minor*. Concurrently, grass carp showed robust growth performance with average daily weight gains of 2.53–3.07 g day^{-1} and a mean final weight of 427.6 g, achieving a mean survival rate of 89.8%. Economic analysis revealed a benefit-cost ratio (BCR) ranging from 2.9 to 3.5, factoring in both weed control savings and fish harvest revenue. Farmer feedback indicated high satisfaction levels (mean rating 4.4 out of 5), with 100% of participants willing to restock in the following season. Perceived benefits included reduced labour, improved water quality, and enhanced biodiversity. Minor adoption barriers, such as fingerling availability and transport costs, were noted. The study validates grass carp as a sustainable, cost-effective, and farmer-friendly solution for managing aquatic weeds in farm ponds, with strong potential for scaling under participatory extension programs.

KEYWORDS: Grass carp, aquatic weeds, biological control, farm ponds

***Citation* (VANCOUVER):** Alagappan and Sendur, Efficacy of Grass Carp (*Ctenopharyngodon idella*) in Controlling Aquatic Weeds in Rural Farm Ponds: A Field Demonstration Study. *International Journal of Bio-resource and Stress Management,* 2025; 16(11), 01-08. HTTPS://DOI.ORG/10.23910/1.2025.6603.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 31st July 2025 RECEIVED in revised form on 26th October 2025 ACCEPTED in final form on 10th November 2025 PUBLISHED on 24th November 2025

1. INTRODUCTION

Farm ponds play a pivotal role in augmenting water availability for agriculture, livestock, and aquaculture, particularly in rainfed regions where water scarcity is a recurring challenge (Dudpal et al., 2020). In India, rainfed areas constitute over 50% of the net sown area and are highly vulnerable to monsoon variability, making farm ponds a critical water resource for climate-resilient rural livelihoods (Rao et al., 2017). However, Aquatic weeds are a persistent constraint in the management of rural farm ponds, particularly in developing regions where these water bodies serve multiple purposes, including irrigation, livestock watering, aquaculture, and domestic use. Controlling vegetation in ponds is a critical aspect of good pond management. The excessive growth of submerged and floating macrophytes such as *Hydrilla verticillata*, *Eichhornia crassipes*, *Najas* spp., and *Potamogeton* spp. impairs water quality, reduces dissolved oxygen, hinders fish productivity, and disrupts pond management practices (Patnaik and Ramaprabhu, 1985; Beem, 2016). Nutrients that could stimulate algae growth that are beneficial for supporting fish production, are instead consumed by weedy aquatic plants, reducing their availability for algae and overall pond productivity. Weed management involves several techniques. Traditional weed control methods, including manual removal (Pompeo, 2008), mechanical harvesting (Pompêo, 2008), and herbicide application (Gettys et al., 2014; Schad and Dick, 2018), are labour-intensive, costly, or pose environmental risks in smallholder contexts (Sims et al., 2018; Ali and Abdelmagid, 2021; Karouach et al., 2022). Moreover, the effect of traditional weed control methods does not last long. Biological control can be an alternative to the traditional methods. Several aquatic animal species either consume aquatic vegetation directly or induce physical damage that contributes to the reduction or elimination of plant biomass in the aquatic body. Biological control through the use of herbivorous fish, particularly the grass carp (*Ctenopharyngodon idella*), has emerged as an ecologically effective method. In Asian countries, this fish is farmed primarily for food, whereas in Europe and the United States, it has been introduced mainly for the control of aquatic weeds (Ali and El-Samman, 2018; Wildhaber, 2023). Numerous studies suggest that these fish can significantly influence aquatic plant communities, and their impact can be effectively managed through careful assessment of vegetation types and responsible stocking and management of the grass carp population (Stott and Robson, 1970; Shireman and Smith, 1983; Moody, 1992; Gupta et al., 1998; Bonar et al., 2002; June-Wells et al., 2017; Zhao et al., 2020; Anonymous, 2022). Grass carp, a fast-growing, herbivorous fish species native to East Asia, has been widely introduced across the globe for weed control due to its high feeding efficiency and compatibility with polyculture systems (Cassani, 1995; Opuszynski and Shireman, 1995; Dochink et al., 2020). Various studies have demonstrated its preference for submerged macrophytes and effectiveness in reducing weed biomass without the adverse ecological impacts associated with chemical control methods (Pipalova, 2006; Shireman and Smith, 1983; Hossain et al., 2020; Lin, 2022). They are known to be especially effective against soft, palatable species such as *Hydrilla* and *Najas*, and are widely used in tropical and temperate regions for biological weed control (Silva et al., 2014). Despite its proven potential, there is limited field-level validation of grass carp for aquatic weed control under real-world conditions in Indian rainfed regions. This study, therefore aimed to demonstrate the efficacy of grass carp in controlling aquatic weeds under field conditions in farmer-managed rural farm ponds

2. MATERIALS AND METHODS

2.1. Study area and site selection

This field demonstration study was conducted from November, 2023 to March, 2024 in the Sivaganga district of Tamil Nadu, a rainfed agrarian region known for its semi-arid climate, erratic rainfall, and increasing reliance on farm ponds for both supplemental irrigation and aquaculture. The study area comprised two villages, viz., Kalaiyarkoil and Ilayangudi, where five farmer-managed farm ponds were purposively selected with an area of about 0.1ha, visible infestation of aquatic weeds (mainly *Hydrilla verticillata*, *Najas minor*, and *Ceratophyllum demersum*), the availability of a minimum water retention period of four months, and the willingness of farmers to participate in the trial. All selected ponds were unlined earthen structures situated in rainfed catchments.

2.2. Baseline data collection

Before the introduction of grass carp, a comprehensive baseline assessment was undertaken. Aquatic weed biomass was estimated using a random quadrat method. In each pond, five 1 m² quadrats were randomly placed, and all macrophytes within each frame were harvested, weighed in the field (wet weight), and averaged to calculate weed biomass (kg m^{-2}). Simultaneously, key water quality parameters, including temperature (°C), pH, dissolved oxygen (mg l^{-1}), turbidity (NTU), and transparency (using Secchi depth in cm) were recorded using portable water testing kits and standard methods prescribed by Anonymous (2017).

2.3. Stocking of grass carp

Healthy 500 numbers of grass carp (*Ctenopharyngodon idella*) fingerlings, with an average weight of 80–100 g, were acclimatized to pond water for 24 hours before release.

Stocking was conducted during early November to coincide with the post-monsoon weed bloom and optimal water temperatures. In order to maintain their herbivorous feeding behaviour, no supplemental feed was provided throughout the trial period. The fish were expected to feed exclusively on the available aquatic vegetation.

2.4. Monitoring and data collection

The performance of grass carp in controlling aquatic weeds was monitored over four months. Weed biomass was reassessed monthly using the same quadrat methodology employed during the baseline. Changes in biomass were expressed as % reduction relative to initial values. Concurrently, water quality was monitored on a fortnightly basis to assess ecological changes in the pond environment. Fish growth performance was tracked every 30 days by randomly sampling 10 to 15 fishes pond^{-1}, recording their length and weight. At the end of the trial period, the survival rate and total biomass yield of grass carp were recorded.

Farmer perceptions were collected through semi-structured interviews conducted during and after the demonstration period. The feedback focused on perceived ease of weed control, improvements in pond water usability, observations on fish activity, and overall satisfaction with the intervention. A qualitative scoring system was used to capture farmers' willingness for future adoption of grass carp-based weed control.

2.5. Data analysis

Economic analysis was carried out to assess the cost-effectiveness of this biological weed control method. Input costs included the price of fingerlings and transportation. These were compared against estimated cost savings from avoided manual or mechanical weed removal and the economic returns from harvested fish biomass, based on local market prices. A simple benefit-cost ratio (BCR) was calculated by dividing total benefits by the total costs incurred pond^{-1}.

Statistical analysis of quantitative data was performed using one-way analysis of variance (ANOVA) to assess differences in weed biomass reduction and fish growth across the ponds. Descriptive statistics were used for water quality and economic data. Farmer feedback was synthesized thematically and visualized where applicable.

3. RESULTS AND DISCUSSION

3.1. Reduction in aquatic weed biomass

The demonstration of grass carp in selected farm ponds resulted in substantial control of submerged aquatic weeds. Across five farm ponds, the initial weed biomass ranged between 1.85 and 3.25 kg m^{-2}. After 120 days of grass carp stocking, the mean weed biomass was reduced significantly, from 2.73±0.25 kg m^{-2} to 0.55±0.09 kg m^{-2}, corresponding to an average reduction of 79.8±4.2% (Table 1). The most dominant weed species observed were *Hydrilla verticillata*, *Najas minor*, and *Ceratophyllum demersum*, all known to be preferred forage for grass carp (Silva et al., 2014; Sun et al., 2018).

The efficacy of weed reduction ranged from 71.2% to 91.2% with an overall average of 79.0%. These results align with studies that recommend gras carp for effective control of submerged weeds without leading to overgrazing (Kumar and Pradhan, 2018). Importantly, weed control was achieved without the use of chemical herbicides, supporting ecologically sustainable pond management strategies.

The pattern of weed suppression followed a near-linear trajectory during the first two months, after which the rate of decline plateaued, indicating a balance between fish consumption rate and regrowth potential of the residual vegetation. This finding aligns with previous studies by Shireman and Maceina (1981), who reported that grass carp exhibit high efficacy in controlling submerged macrophytes, particularly under tropical and subtropical climates. The observed variability among ponds can also be attributed to species composition, as *Ceratophyllum demersum* was found to be less palatable than *Hydrilla* or *Najas*, leading to slower reduction in those patches.

Table 1: Weed biomass reduction in demonstration ponds

Pond ID	Initial weed biomass (kg m^{-2})	Final weed biomass (kg m^{-2})	% Reduction	Weed biomass - significance ('t' value)	Dominant weed species
P1	3.25	0.62	80.9%	7.93*	*Hydrilla verticillata*
P2	2.95	0.85	71.2%		*Najas minor*
P3	1.85	0.61	67.0%		*Ceratophyllum demersum*
P4	3.10	0.27	91.2%		*Hydrilla verticillata*
P5	2.50	0.38	84.8%		Mixed *(Hydrilla, Najas)*
Mean±SD	2.73±0.25	0.55±0.09	79.8±4.2	7.93*	-

*: Significant at 5% level ($p\leq0.05$)

3.2. Changes in water quality

Water quality parameters remained within optimal ranges throughout the study period, with minor fluctuations. The average water temperature ranged from 26.8°C to 30.4°C, while pH levels remained between 7.0 and 8.1. Dissolved oxygen showed a slight increase in ponds with greater weed clearance, likely due to improved circulation and reduced plant respiration at night. Turbidity decreased slightly in most ponds as plant decay settled and fish movement limited algal proliferation. The Secchi depth improved by 15–35 cm in weed-cleared ponds, enhancing light penetration and improving the pond's overall ecological condition.

These observations support the hypothesis that biological weed control through grass carp not only reduces excessive plant growth but also stabilizes the aquatic environment. Similar ecological benefits were reported by Bonar et al. (2002), who reported that triploid grass carp led to reduced submerged vegetation and increased water transparency in lake and reservoir systems, supporting ecosystem restoration without requiring herbicides. Additionally, farmers observed improved water quality and light penetration, contributing to better utilization of pond ecosystems. These ecosystem benefits of grass carp integration are increasingly recognized in multifunctional water bodies (Pípalova et al., 2009).

3.3. Growth and survival of grass carp

The grass carp exhibited robust growth performance during the study period. The average individual weight increased from 90.2 g at stocking to 427.6 g at harvest, with an average daily weight gain of 2.87–3.07 g $fish^{-1}$ day^{-1} (Table 2). The analysis of grass carp growth performance revealed a statistically significant difference in average body weight between the initial and final sampling periods. The final biomass yield ha^{-1} ranged from 120 to 205 kg, depending on the stocking density and initial weed availability. Survival rates were high, ranging from 86% to 92%, indicating good adaptability of grass carp to pond conditions and a weed-based diet.

These growth metrics are consistent with earlier findings by Shireman et al. (1980), who emphasized the fast growth potential of grass carp in controlled weed-dominant systems. The absence of supplemental feeding did not adversely affect growth, validating the suitability of this species for low-input aquaculture models with ecological co-benefits.

Also, grass carp exhibited average daily weight gains of 2.53–3.07 g day^{-1}, reaching mean final weights of 427.6 g in 120 days. The mean survival rate was 89.8%, indicating good adaptability of grass carp to farm pond conditions in the Sivaganga region. These results are consistent with performance metrics reported by Kirkagac and Demir (2004).

3.4. Economic evaluation

The economic analysis demonstrated that the intervention was financially beneficial (Table 3). The total cost of fingerlings and transport $pond^{-1}$ was ₹ 3,000, while the value of weed removal saved (based on manual labour rates) was estimated between ₹ 4,500 and ₹ 6,200. Additionally, the fish harvest yielded marketable biomass valued between ₹ 20,488 and ₹ 24,918 $pond^{-1}$. Consequently, the calculated Benefit-Cost Ratio (BCR) ranged from 2.9 to 3.5, reflecting a highly favourable economic return on investment. These outcomes align closely with findings of Dubey et al. (2024) from community-based aquaculture systems in Odisha, where similar BCR values were observed in polyculture schemes that integrated ecological and livelihood benefits.

3.5. Farmer perception and adoption potential

The demonstration of grass carp in weed-infested farm ponds received highly favourable responses from the participating farmers (Table 4). Structured feedback was collected using a semi-structured questionnaire and focus group discussions at the end of the demonstration period. The results reveal that all five farmers observed a significant reduction in aquatic weeds, with perceived weed clearance ranging from 75% to 92%. The average perceived reduction was 84.4%, which closely corresponds with the

Table 2: Growth and survival performance of grass carp

Pond ID	Initial average weight (g)	Final average weight (g)	Average daily weight gain (g day^{-1})	Survival rate (%)	Biomass at harvest (kg ha^{-1})	Average weight-significance ('t' value)
P1	90.1	434.7	2.87	89.2	193.88	27.21*
P2	88.7	403.5	2.62	91.0	183.59	
P3	92.4	395.2	2.53	86.4	170.73	
P4	89.6	445.8	2.97	92.0	205.07	
P5	90.5	458.9	3.07	90.5	207.65	
Mean±SD	90.3±1.4	427.6±26.7	2.81±0.20	89.8±2.0	191.99±14.6	27.21*

* Significant at 5% level ($p \leq 0.05$)

Table 3: Economic evaluation of grass carp demonstration

Pond ID	Fingerling cost (₹)	Weed removal cost saved (₹)	Fish sales revenue (₹)	Total benefit (₹)	BCR
P1	3,000	6,000	23,266	29,266	3.3
P2	3,000	5,500	22,031	27,531	3.1
P3	3,000	4,500	20,488	24,988	2.9
P4	3,000	5,700	24,608	30,308	3.4
P5	3,000	6,200	24,918	31,118	3.5
Mean	3,000	5,580	23,062	28,642	3.0

1US$=INR 83.03 (Average for March, 2024)

Table 4. Farmer perception and adoption potential based on grass carp demonstration

Farmer ID	Perceived weed reduction (%)	Satisfaction level (1–5)*	Observed benefits	Willingness to restock next season	Adoption barriers noted
F1	90	5	Weed clearance, fewer mosquitoes, fish harvest	Yes	None
F2	85	4	Improved water access, increased bird activity	Yes	Initial fingerling cost
F3	75	4	Easier irrigation, less manual cleaning required	Yes	Availability of quality fingerlings
F4	92	5	Clean pond, increased biodiversity	Yes	None
F5	80	4	Reduced weed growth, cleaner water	Yes	Transport cost of fingerlings
Mean	84.4	4.4	-	100% expressed willingness	-

*Satisfaction Level rated on a scale of 1 (very dissatisfied) to 5 (very satisfied)

biophysically measured weed biomass reduction reported in earlier sections.

On a satisfaction scale of 1 to 5, where 5 indicates very high satisfaction, the average rating was 4.4, reflecting broad approval of grass carp as a natural weed control method. Farmers particularly appreciated reduced manual labour for pond cleaning, improved water access for irrigation, and better pond aesthetics. Farmers also reported enhanced water quality, improved biodiversity, and overall better ecosystem regulation through integrated pond management, observations supported by recent studies showing stronger ecosystem stability and trophic efficiency in grass carp polyculture systems (Xiao et al., 2024) and measurable ecosystem service gains in wetland aquaculture with grass carp (Karnatak et al., 2022). These findings reinforce the value of participatory, nature-based solutions to pond management challenges.

Most importantly, 100% of farmers expressed willingness to continue or upscale grass carp stocking in subsequent seasons, indicating strong adoption potential when integrated with other pond-based livelihood activities. However, minor concerns reported by farmers were primarily the initial cost of fingerlings and the lack of local availability. These findings align with Dubey et al. (2024), who identified that input access, scarcity, and inconsistent quality of fish fingerlings limited the adoption of improved pond management practices

Overall, the demonstration reinforced the relevance of participatory technology validation, where farmers not only witness outcomes but actively engage in assessing suitability and benefits. As supported by Chambers et al. (1989) and Vidyawati et al. (2025), such farmer-led demonstrations enhance trust, adaptation, and long-term scaling of sustainable aquaculture practices in rural settings.

4. CONCLUSION

The integration of grass carp in farm ponds proved to be an effective, eco-friendly strategy for managing submerged aquatic weeds while enhancing fish production under rainfed conditions. The approach significantly reduced manual weed removal costs and generated substantial economic returns with minimal inputs. High survival rates and satisfactory growth performance demonstrated the biological and financial viability of this intervention.

5. ACKNOWLEDGMENT

The authors express their sincere gratitude to the administrative and technical support extended by the Tamil Nadu Veterinary and Animal Sciences University (TANUVAS) for the successful execution of this study. We also extend our special thanks to the Director, ICAR-Agricultural Technology Application Research Institute (ATARI), Zone X, for their guidance and encouragement throughout the study. Financial assistance and field-level inputs provided under the ICAR-KVK scheme are gratefully acknowledged. This study would not have been possible without the active participation and valuable cooperation of the farming community of Sivaganga district during the field demonstration, which is deeply appreciated.

6. REFERENCE

Anonymous, 2017. Standard methods for the examination of water and wastewater (23rd ed.). Washington DC: American Public Health Association. Available at: https://yabesh.ir/wp-content/uploads/2018/02/Standard-Methods-23rd-Perv.pdf (Accessed on 01.08.2025).

Anonymous, 2022. Using grass carp to control weeds in Alabama ponds. The Alabama Cooperative Extension System. Available at: https://www.aces.edu/wp-content/uploads/2022/05/ANR-0452_UsingGrassCarp_051222L_G.pdf (Accessed on 05.05.2025).

Ali, Y.M., Abdelmagid, A.H., 2021. Performance and costs of grass carp in controlling aquatic weeds compared to mechanical control in some Egyptian canals (case study). International Journal of Fisheries and Aquaculture Research 7(1), 28–46. Available at: https://ssrn.com/abstract=3861139.

Ali, Y.M., El-samman, T.A., 2018. Biological weed control utilizing grass carp (*Ctenopharyngodon idella*) in Egyptian waterways. Journal of American Science 14(11), 9–19. Doi: 10.7537/marsjas141118.03.

Beem, M., 2016. Grass carp for pond weed management. Oklahoma Cooperative Extension Service. Available at: https://extension.okstate.edu/fact-sheets/grass-carp-for-pond-weed-management.html (Accessed on 01.08.2025).

Bonar, S.A., Thomas, P.A., Thiesfeld, S.L., 2002. Effects of triploid grass carp on aquatic plants, water quality, and public satisfaction in Washington State. North American Journal of Fisheries Management 22(1), 96–105. Available at: https://academic.oup.com/najfm/article-abstract/22/1/96/7847362.

Cassani, J.R., 1995. Problems and prospects for grass carp as a management tool. American Fisheries Society Symposium 15, 407–412. Available at: https://lchcd.org/wp-content/uploads/2011/12/Problems-and-Prospects-for-GC-as-Management-Tool0001.pdf

Chambers, R., Pacey, A., Thrupp, L.A., 1989. Farmer first: farmer innovation and agricultural research. The Institute of Development Studies and Partner Organisations, Monograph. Available at: https://hdl.handle.net/20.500.12413/701.

Dubey, S.K., Padiyar, A., Chadag, V.M., Shenoy, N., Gaikwad, A.B., Ratha, B.C., Belton, B., 2024. Scaling community-based aquaculture for enhanced nutrition and women's empowerment: lessons from Odisha, India. Frontiers in Sustainable Food Systems 8, 1412686. Doi: 10.3389/fsufs.2024.1412686.

Dochink, K., Ivanova, A., Yankova, M., 2020. Effects of the application of polyculture with grass carp to control aquatic vegetation in fishpond on their phytoplankton and macrozoobenthos. Annual of Sofia University, Faculty of Biology, Book 2 – Botany, 104.

Dupdal, R., Patil, S.L., Naik, B.S., Ramesha, M.N., 2020. Role of farm ponds in improving productivity and farm income in dryland areas. Life Sciences Leaflets 128, 9–14. Available at: https://petsd.org/ojs/index.php/lifesciencesleaflets/article/view/1527/1341.

Gettys, L.A., Haller, W.T., Petty, D.G., 2014. Biology and control of aquatic plants: a best management practices handbook (3rd Edn.). Aquatic Ecosystem Restoration Foundation, Marietta, GA. ISBN 978-0-615-99766-7. Available at: https://mymlsa.org/wp-content/uploads/2015/05/AquaticPlantManagementBMPs2014.pdf.

Gupta, M.V., Sollows, J.D., Abdul Mazid, M., Rahman, A., Hussain, M.G., Dey, M.M., 1998. Integrating aquaculture with rice farming in Bangladesh: Feasibility and economic viability, its adoption and impact. ICLARM Technical Report, 55, 90 p. Available at: https://www.researchgate.net/publication/227641494

Hossain, M.M., Ali, M.L., Khan, S., Haque, M.M., Shahjahan, M., 2020. Use of Asian watergrass as feed of grass carp. Aquaculture Reports 18, 100434. Doi: 10.1016/j.aqrep.2020.100434.

June-Wells, M., Simpkins, T., Coleman, A.M., Henley, W., Jacobs, R., Aarrestad, P., Buck, G., Stevens, C., Benson, G., 2017. Seventeen years of grass carp: an examination of vegetation management and collateral impacts in ball pond, new fairfield, connecticut. Lake and Reservoir Management 33(1), 84–100. https://doi.org/10.1080/10402381.2017.1284966.

Karnatak, G., Das, B.K., Sarkar, U.K., Borah, S., Roy, A., Parida, P., Lianthuamluaia, L., Das, A.K., Behera, B.K., Pandit, A., Sahoo, A.K., Bhattacharjya, B.K., Chakraborty, S., Mondal, K., Chandra, P., 2022. Integration of pen aquaculture into ecosystem-based enhancement of small-scale fisheries in a macrophyte dominated floodplain wetland of India. Environmental Science and Pollution Research 29(50), 75431–75440. Doi: 10.1007/s11356-022-21112-1.

Karouach, F., Ben, B.W., Ezzariai, A., Sobeh, M., Kibret, M., Yasri, A., Hafidi, M., Kouisni, L., 2022. A comprehensive evaluation of the existing approaches for controlling and managing the proliferation of water hyacinth (*Eichhornia crassipes*): Review. Frontiers in Environmental Science 9, 767871. Doi: 10.3389/fenvs.2021.767871.

Kirkagac, M., Demir, N., 2004. The effects of grass carp on aquatic plants, plankton and benthos in ponds. Journal of Aquatic Plant Management 42, 32–39. Available at: http://hdl.handle.net/1834/19542.

Kumar, S., Pradhan, A., 2018. Aquatic weeds problems in India - Challenge for management. Indian Farming 68(11). Available at: https://epubs.icar.org.in/index.php/IndFarm/article/view/85350.

Lin, S., Milardi, M., Gao, Y., Wong, M.H., 2022. Sustainable management of non-native grass carp as a protein source, weed-control agent and sport fish. Aquaculture Research 53(17), 5809–5824. https://doi.org/10.1111/are.16080.

Moody, K., 1992. Fish-crustacean-weed interactions. In: De la Cruz, C.R., Lightfoot, C., Costa-Pierce, B.A., Carangal, V.R., Bimbao, M.P. (Eds.), Rice-fish research and development in Asia. ICLARM Conference Proceedings 24, 185–192. Manila. Available at: https://scienceon.kisti.re.kr/srch/selectPORSrchArticle.do?cn=NPAP01699641.

Opuszynski, K., Shireman, J.V., 1995. Herbivorous fishes: culture and use for weed management. CRC Press, Boca Raton, Florida. https://doi.org/10.1201/9780429266461.

Patnaik, S., Ramaprabhu, T., 1985. Aquatic weed management and optimisation of fish culture operation. In: Sinha, V.R.P. (Ed.), Lecture notes on composite fish culture and its extension in India. Network of Aquaculture Centres in Asia, Bangkok, Thailand, pp. 194. Available at: https://www.fao.org/4/ac229e/AC229E04.htm

Pipalova, I., Kvet, J., Adamek, Z., 2009. Limnological changes in a pond ecosystem caused by grass carp (*Ctenopharyngodon idella* Val.) low stocking density. Czech Journal of Animal Science 54(1), 31–45. Doi: 10.17221/1737-CJAS.

Pompeo, M., 2008. Monitoramento e manejo de plantas aquáticas. Oecologia Brasiliensis 12(3), 406–424. Available at: https://revistas.ufrj.br/index.php/oa/article/view/5734.

Rao, C.S., Rejani, R., Rama Rao, C.A., Rao, K.V., Osman, M., Reddy, K.S., Kumar, M., Kumar, P., 2017. Farm ponds for climate-resilient rainfed agriculture. Current Science 112(3), 471–477. Doi: 10.18520/cs/v112/i03/471-477.

Schad, A.N., Dick, G.O., 2018. Aquatic vegetation community structure response to hydrilla management with triploid grass carp, herbicide, and native vegetation planting. Lake and Reservoir Management 34(4), 417–425. https://doi.org/10.1080/10402381.2018.1475434.

Shireman, J.V., Colle, D.E., Maceina, M.J., 1980. Grass carp growth rates in Lake Wales, Florida. Aquaculture 19, 379–382. https://doi.org/10.1016/0044-8486(80)90086-1.

Shireman, J.V., Smith, C.R., 1983. Synopsis of biological data on the grass carp *Ctenopharyngodon idella* (Cuvier and Valenciennes, 1844). FAO Fisheries Synopsis, 135. Available at: https://www.fao.org/4/ap938e/ap938e.pdf.

Shireman, J.V., Maceina, M.J., 1981. The utilization of grass carp, *Ctenopharyngodon idella* Val., for hydrilla control in Lake Baldwin, Florida. Journal of Fish Biology 19(6), 629–636. https://doi.org/10.1111/j.1095-8649.1981.tb03829.x.

Silva, A.F., Cruz, C., Pitelli, R.L.C.M., Pitelli, R.A., 2014. Use of grass carp (*Ctenopharyngodon idella*) as a biological control agent for submerged aquatic macrophytes. Planta Daninha 32(4), 765–773. doi:10.1590/S0100-83582014000400011.

Sims, B., Corsi, S., Gbehounou, G., Kienzle, J., Taguchi, M., Friedrich, T., 2018. Sustainable weed management for conservation agriculture: options for smallholder farmers. Agriculture 8(8), 118. https://doi.org/10.3390/agriculture8080118.

Stott, B., Robson, S.G., 1970. Efficiency of grass carp (*Ctenopharyngodon idella* Val.) in controlling submerged water weeds. Nature 226(5248), 870. Doi: 10.1038/226870a0.

Sun, J., Wang, L., Ma, L., Huang, T., Zheng, W., Min, F., Zhang, Y., Wu, Z., He, F., 2018. Determinants of submerged macrophyte palatability to grass carp Ctenopharyngodon idella. Ecological Indicators 87, 132–140. Available at: https://www.researchgate.net/publication/322864453.

Vidyawati, S., Singh, P., Jadoun, R.S., 2025. Participatory agricultural extension: A catalyst for sustainability and farmer empowerment. International Journal of

Agriculture Extension and Social Development 8(4), 333–341. https://doi.org/10.33545/26180723.2025.v8.i4e.1790.

Wildhaber, M.L., West, B.M., Ditter, K.K., Moore, A.P., Peterson, A.S., 2023. A review of grass carp and related species literature on diet, behavior, toxicology, and physiology focused on informing the development of controls for invasive grass carp populations in North America. Fishes 8(11), 547. https://doi.org/10.3390/fishes8110547.

Xiao, S., Liu, X., Zhou, R., Zhao, Y., Sun, Z., 2024. Energy flow analysis of grass carp pond system based on Ecopath model. Environmental Science and Pollution Research 31, 10184–10197. https://doi.org/10.1007/s11356-023-27154-3.

Zhao, Y., Zhang, L., Wang, C., Xie, C., 2020. Biology and ecology of grass carp in China: a review and synthesis. North American Journal of Fisheries Management 40(6), 1379–1399. https://doi.org/10.1002/nafm.10512.