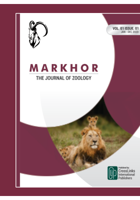
MARKHOR
THE JOURNAL OF ZOOLOGY
https://www.markhorjournal.com/index.php/mjz
ISSN (E): 2790-4385, (P): 2790-4377
Volume 6, Issue 4 (Oct - Dec 2025)



Original Article

OPEN ACCESS

Effects of Canal Lining on Ichthyofaunal Diversity in Southern Punjab, Pakistan

Hafiz Rana Kamran Zahid[1], Abir Ishtiaq[1*], Mehreen Irshad[2], Rehmat[1], Aneela Naz[3], Hafiz Muhammad Faheem Akbar[3], Ayesha Riaz[4], Sidra Abbas[5] and Muhammad Naeem[3]

[1]Department of Zoology, The Islamia University of Bahawalpur, Bahawalnagar Campus, Bahawalnagar, Pakistan
[2]Department of Zoology, Virtual University of Pakistan, Bahawalnagar, Pakistan
[3]Institute of Zoology, Bahauddin Zakariya University, Multan, Pakistan
[4]Institute of Molecular Biology and Biotechnology, The University of Lahore, Lahore, Pakistan
[5]Department of Zoology, University of Jhang, Jhang, Pakistan

ARTICLE INFO

Keywords:
Canal Lining, Ichthyofaunal Diversity, Unlined Canals, Water Quality

How to cite:
Zahid, H. R. K., Ishtiaq, A., Irshad, M., Rehmat, ., Naz, A., Akbar, H. M. F., Riaz, A., Abbas, S., & Naeem, M. (2025). Effects of Canal Lining on Ichthyofaunal Diversity in Southern Punjab, Pakistan: Effects of Canal Lining on Ichthyofaunal. MARKHOR (The Journal of Zoology), 6(4), 08-14. https://doi.org/10.54393/mjz.v6i4.191

***Corresponding Author:**
Abir Ishtiaq
Department of Zoology, The Islamia University of Bahawalpur, Bahawalnagar Campus, Bahawalnagar, Pakistan
abir.ishtiaq@iub.edu.pk

Received Date: 20th September, 2025
Revised Date: 5th November, 2025
Acceptance Date: 12th November, 2025
Published Date: 31st December, 2025

ABSTRACT

Canal lining is extensively applied in order to enhance the efficiency of irrigation, but its ecological effects on aquatic organisms are not studied properly. **Objectives:** To evaluate how canal construction materials influence ichthyofaunal diversity and water quality in Southern Punjab, Pakistan. **Methods:** Lined and unlined canals were compared in terms of a comparative field study, which was carried out through ecological survey and physico-chemical studies. Standard tools and analysis methods were used to measure the water parameters, such as pH, dissolved oxygen (DO), temperature, turbidity, nitrate, phosphate, and ammonia. Gill nets were used to take fish samples that were identified morphologically and measured in terms of diversity using Shannon Wiener (H) and Simpson (1-D) indices. One-way ANOVA with a 95% level of confidence was considered to identify statistical differences between the types of canals. **Results:** Unlined canals exhibited slightly lower mean pH (7.2 ± 0.1; 95% CI: 7.18–7.22) and temperature (28.3 ± 0.2 °C; 95% CI: 28.28–28.32) but higher DO (6.4 ± 0.1 mg/L; 95% CI: 6.38–6.42), turbidity (11.4 ± 0.1 NTU; 95% CI: 11.38–11.42), and nutrient concentrations (nitrate = 7.0 ± 0.1 mg/L; phosphate = 8.1 ± 0.1 mg/L; ammonia = 5.0 ± 0.1 mg/L) than lined canals. ANOVA results indicated significant differences (e.g., pH: p=0.0003; DO: p=0.0167; turbidity: p=0.0077) in several water quality parameters and fish diversity between the canal types. **Conclusions:** Unlined canals harbored more ichthyofaunal diversity, probably because of the availability of natural substrates, vegetation, and more stable microhabitats.

INTRODUCTION

Materials used to construct the irrigation canals can be very influential to aquatic ecosystems since they alter the habitat structures, water quality, and species distribution. Canals are covered with lines, and the lines are usually constructed using concrete or other materials that do not allow water to seep into the ground. They also help control the movement of water, and the chemical environment is stabilized [1-3]. However, these structural components also tend to simplify habitats by hindering the diversity of the substrates, disrupting the movement of sediments, and reducing aquatic vegetation, which could also have negative effects on the fish diversity [4, 5]. In contrast, those canals that are unlined and have soil or a natural bottom allow soil deposition, infiltration of water, and vegetation, and create complex microhabitats to enhance biodiversity. The canals can recycle the nutrients and facilitate groundwater recharge, as well as dynamism between aquatic and terrestrial habitats, thus providing shelter, feeding, and breeding sites to other species of fish [6, 7]. The use of non-native fish will also have the effect of affecting the ecology of the canal by disturbing the water quality and vegetation cover, but still, these water systems

DOI: https://doi.org/10.54393/mjz.v6i4.191

with moderate levels of biodiversity can be sustained in even-lined canals through the introduction of native species [8, 9]. This elasticity is a reason why it is necessary to examine the effects of the canal construction on ichthyofaunal diversity in the regional context, such as Southern Punjab in Pakistan, where canals play a role in irrigation and water resource management [10, 11]. All these systems should maintain the ecological integrity, which is acquired by taking steps such as restoring the natural features, hindering invasive species, and inclusion of semi-natural features within lined canals. They can enhance the complexity of the habitat, maintain aquatic biodiversity, and advance ecological and engineering goals [12, 13].

This study aims to compare the effects of construction materials on the canal construction on the ichthyofauna and water quality in Southern Punjab, Pakistan.

METHODS

The study was a cross-sectional comparative observational study undertaken in Southern Punjab, Pakistan, in the canal systems, which were linked to the Rivers Ravi and Sutlej. The data collection and the fieldwork took place between January to March, 2025. In an attempt to compare the ecological nature of lined and unlined canals, five sampling points were randomly chosen respectively to each of the canals to ensure geographical dispersion and representativeness. The site selection criteria were as follows: (1) a distance of at least 2 km between sites to achieve spatial independence; (2) representation of different flow velocity (between head, middle, and tail sections of the canal reaches); (3) difference in riparian vegetation cover (sparse to dense); and (4) nearness to potential anthropogenic sites of influence (e.g. agricultural drain inlets). In each of the 10 definitive sites (5 lined and 5 unlined), spatial replication was applied through the collection of three independent water samples and the placement of the gill net in three various microhabitats (e.g., within close reach of the bank, mid-channel, and within the vegetation if available) within a 100-meter expanse. This method was meant to capture the variation in data within a site and guarantee reliability in data. Surface water samples (bottle-shaped) were taken at every site to undergo physico-chemical analysis in pre-cleaned polyethylene bottles. Parameters such as pH, dissolved oxygen (DO), temperature, turbidity, nitrate, phosphate, and ammonia were chosen as they are the important parameters to monitor the health of aquatic ecosystems and the quality of fish habitat. Calibrated instruments were used to measure to ascertain the data accuracy. Before every use, the pH meter (ECPH70042S) was checked against standard buffer solutions at pH 4.0, 7.0, and 10.0. The dissolved oxygen meter was introduced with the zero-oxygen solution method and 100 percent air saturation method according to the manufacturer's instructions. A waterproof thermometer (LC-990) was compared with a certified thermometer of mercury-in-glass. Turbidity was recorded by means of a standard Secchi disk (2177200). In order to do nutrient analyses, standard colorimetric and titrimetric procedures were used. To establish a calibration curve, the spectrophotometer was calibrated for analyzing nitrate and phosphate using a series of standard solutions to determine the calibration curve. Duplicative precision Analytical precision was assessed by the running of duplicate samples, and in cases where available, certified reference materials were used to validate the methods. Triplicate readings were averaged together at each site to obtain a result for all parameters. Sampling was performed on fish with standardized gill nets (1518m long, 1.52m deep, 1cm mesh size), which were set at each site with an equal length of stay. The net design enabled the preying of species of all sizes and minimized physical damage. Identification of individuals that were captured was done at the species level with the help of standard fish identification keys and field guides. The number of each species was counted to determine the community composition and diversity. To standardize effort, three individual net sets were used in every site and every monthly sampling excursion, and the duration of each set was four hours at daylight (06:00-10:00). This field-based comparative study did not undertake any formal a priori power analysis because the estimates of effect sizes of previous studies in other similar canal systems were not available. The sample (five sites each, with triplication) of the canals type was established through the methodological approaches that were used in similar ecology studies on streams and canals. The design was logistically efficient and offered a solid spatial structure to reflect the heterogeneity in each type of canal and to affect a statistically significant comparison among them with ANOVA. The replication on each location (n=3 water parameters; n=3 net deployments of fish) was introduced to represent variation of the microhabitat and to enhance the reliability of mean results in order to ensure that the data gathered were sufficient to address the aims of the study. Along with quantitative metrics, structured observational data were also collected at every location with the view of describing the habitat characteristics. These were the presence and nature of aquatic and riparian vegetation, the composition of substrate (e.g., clay, silt, sand, concrete), and the structure of banks. These observations were employed to put the quantitative outputs of water quality and fish diversity into perspective, in a holistic manner, to give a holistic idea about the habitat differences that exist in lined and unlined canals. Shannon Wiener (H) and Simpson (1-D) indices were used to measure

DOI: https://doi.org/10.54393/mjz.v6i4.191

the species diversity. The ANOVA one-way was conducted to determine the difference in the water quality and diversity parameters between lined and unlined canals at a 95 percent confidence level ($p<0.05$). The statistical analysis was performed with SPSS version 27.0.

RESULTS

Lin accords were found to be more stable in terms of pH, with a mean of 7.23 ± 0.01 in comparison with a slightly lower and more diverse pH of 7.20 ± 0.01 in unlined canals. The statistical analysis proved that there is a considerable difference ($p=0.0003$) in the pH of lined and unlined canals and insinuates that the lining of canals is stabilizing the chemical composition of water. In the case of dissolved oxygen, the mean of unlined canals is statistically significantly greater than that of lined canals ($p=0.0167$), with a statistically significant difference between the two systems (6.40 ± 0.01 mg/L and 6.38 ± 0.01 mg/L, respectively), which may be due to greater aeration and microbial activity in unlined canals. The temperature was found to be more or less similar between the lined and unlined canals, with an average temperature of 28.31 + 0.02°C in lined canals and 28.30 + 0.02°C in unlined canals, and no statistical significance of canal structure on temperature was found. The turbidity in the canals that were not lined (11.39 ± 0.01 NTU) was greater than that in lined canals (11.38 ± 0.01 NTU), and the difference value was statistically significant ($p = 0.0077$) and indicating that unlined canals were more likely to carry the sediment with them (Table 1).

Table 1: pH, DO, Temperature levels (ºC), and Turbidity Levels Observations at Different Sites of Lined and Unlined Canal

Canal Type	Site	S.1	S.2	S.3	Mean ± SD
pH					
Lined Canal	A	7.23	7.21	7.21	7.22 ± 0.01
	B	7.24	7.23	7.22	7.23 ± 0.01
	C	7.22	7.23	7.22	7.23 ± 0.01
	D	7.23	7.23	7.22	7.22 ± 0.01
	E	7.22	7.23	7.23	7.23 ± 0.00
	Total				7.23 ± 0.01
Unlined Canal	A	7.21	7.17	7.20	7.19 ± 0.02
	B	7.23	7.20	7.20	7.21 ± 0.02
	C	7.20	7.20	7.18	7.20 ± 0.01
	D	7.20	7.24	7.22	7.22 ± 0.02
	E	7.20	7.20	7.21	7.20 ± 0.01
	Total				7.20 ± 0.01
DO					
Lined Canal	A	6.37	6.41	6.39	6.39 ± 0.02
	B	6.38	6.38	6.41	6.39 ± 0.02
	C	6.36	6.40	6.38	6.38 ± 0.02
	D	6.36	6.39	6.41	6.38 ± 0.03
	E	6.40	6.37	6.33	6.36 ± 0.03
	Total				6.38 ± 0.01
Unlined Canal	A	6.42	6.40	6.39	6.40 ± 0.01
	B	6.40	6.41	6.42	6.41 ± 0.01
	C	6.39	6.43	6.41	6.41 ± 0.02
	D	6.40	6.39	6.39	6.39 ± 0.01
	E	6.36	6.38	6.41	6.38 ± 0.03
	Total				6.40 ± 0.01
Temperature levels (ºC)					
Lined Canal	A	28.31	28.30	28.33	28.31 ± 0.02
	B	28.36	28.32	28.32	28.33 ± 0.02
	C	28.32	28.28	28.32	28.31 ± 0.02
	D	28.30	28.29	28.31	28.30 ± 0.01
	E	28.34	28.32	28.29	28.32 ± 0.02
	Total				28.31 ± 0.02
Unlined Canal	A	28.29	28.31	28.32	28.30 ± 0.02
	B	28.29	28.29	28.28	28.29 ± 0.00
	C	28.32	28.29	28.29	28.30 ± 0.02
	D	28.31	28.31	28.31	28.31 ± 0.00
	E	28.26	28.32	28.32	28.30 ± 0.03
	Total				28.30 ± 0.02
Turbidity Levels					
Lined Canal	A	11.39	11.38	11.37	11.38 ± 0.01
	B	11.38	11.40	11.37	11.38 ± 0.02
	C	11.39	11.39	11.38	11.39 ± 0.00
	D	11.40	11.37	11.35	11.38 ± 0.03
	E	11.38	11.39	11.35	11.37 ± 0.02
	Total				11.38 ± 0.01
Unlined Canal	A	11.39	11.42	11.40	11.41 ± 0.02
	B	11.38	11.40	11.38	11.39 ± 0.01
	C	11.40	11.40	11.41	11.40 ± 0.00
	D	11.39	11.38	11.39	11.39 ± 0.01
	E	11.38	11.39	11.40	11.39 ± 0.01
	Total				11.39 ± 0.01

Phosphate and nitrate were found (on unlined canals) to have higher concentrations than in lined canals, and the differences between the canals ($p=0.0111$ phosphate and $p=0.0139$ nitrate) were significant and implied that the lining of the canals was taking advantage of the relationship between the canals and the surrounding soils (Figure 1).

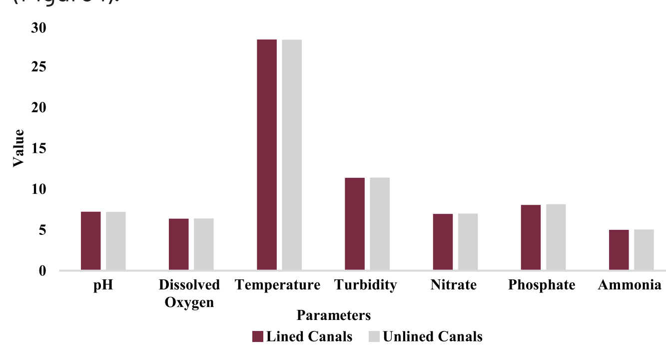


Figure 1: Variation in Physicochemical Water Quality Parameters Between Lined and Unlined Canals

DOI: https://doi.org/10.54393/mjz.v6i4.191

The comparison of lined and unlined canals indicated that unlined canals had a larger number of fish, with 395 individuals observed compared to 285 in lined canals, despite the two habitats having 14 fish species. Other fish species that were significantly higher in the unlined canals included *Labeo rohita*, *Catla catla*, *Wallago attu*, and *Cirrhinus mrigala*. This implied that natural substrates, aquatic plants, and more stable microhabitats were found in unlined canals, suggesting their suitability to the fish environment. These characteristics offered more favorable conditions to feed, breed, and shelter, particularly to the bottom-dwelling and native species. In contrast, lined canals did not provide these natural characteristics and resulted in less complexity of the habitat and fewer resources for fish. Consequently, although species diversity did not change, unlined canals promoted healthy and more prolific fish communities, and as an ecological concern, it is important to maintain natural canal systems to maintain freshwater biodiversity (Table 2).

Table 2: Comparative abundance of Fish Species from Lined and Unlined Canal

Scientific Name of Fishes	Lined Canal						Unlined Canal					
	Number of Fishes from Sites					Sum	Number of Fishes from Sites					Sum
	A	B	C	D	E		A	B	C	D	E	
Labeo rohita	5	6	5	8	3	27	9	12	9	9	8	47
Gibelion catla	4	5	6	5	6	26	8	6	9	8	11	42
Channa punctata	5	3	5	7	6	26	7	9	5	7	5	33
Oreochromis niloticus	4	2	6	7	5	24	5	4	6	7	5	27
Mastacembelus armatus	5	3	2	4	5	19	6	3	3	4	5	21
Wallago attu	3	2	4	3	4	16	4	6	5	9	8	32
Cyprinus carpio	9	7	9	8	9	42	9	7	8	8	9	41
Ctenopharyngodon idella	3	5	2	4	2	16	4	5	3	7	2	21
Hypophthalmichthys molitrix	2	4	1	2	3	12	5	4	5	3	3	20
Sperata sarwari	5	2	3	4	5	19	6	3	3	4	5	21
Clarias batrachus	4	1	3	4	3	15	4	5	4	3	5	21
Cirrhinus mrigala	3	2	3	1	6	15	6	5	3	5	4	23
Labeo calbasu	3	2	5	1	3	14	5	6	4	6	4	25
Rita rita	4	5	1	2	2	14	3	6	4	5	3	21
Total Fishes						285	Total Fishes					395

Unlined canals (Shannon-Wiener Diversity Index of 2.592) had a greater Shannon-Wiener Diversity Index as compared to lined canals (2.574), and it was greater than that of lined canals. It alluded to the fact that natural substrates, improved shelter, and more stable ecological conditions provided unlined canals with a more favorable or diverse habitat. In unlined canals, the species were more dispersed, which led to an increased score of diversity. Whereas lines canals restricted the complexity of the habitats, and species richness and evenness were impacted. That was a small difference; it described the possibility of canal construction affecting aquatic biodiversity and ecosystem well-being in a rather subtle way (Table 3).

Table 3: Shannon-Wiener Diversity Index (H') Calculations

Scientific Name of Fishes	Lined Canal				Unlined Canal			
	f	Pi	lnPi	Pi*lnPi	f	Pi	lnPi	Pi*lnPi
Labeo rohita	27	0.1	-2.357	-0.223	47	0.12	-2.129	-0.253
Gibelion catla	26	0.1	-2.4	-0.22	42	0.11	-2.241	-0.24
Channa punctata	26	0.1	-2.4	-0.22	33	0.08	-2.5	-0.21
Oreochromis niloticus	24	0.1	-2.5	-0.21	27	0.07	-2.7	-0.18
Mastacembelus armatus	19	0.1	-2.708	-0.2	21	0.05	-2.934	-0.16
Wallago attu	16	0.056	-2.9	-0.2	32	0.08	-2.513	-0.20
Cyprinus carpio	42	0.147	-1.915	-0.28	41	0.10	-2.3	-0.23
Ctenopharyngodon idella	16	0.056	-2.9	-0.16	21	0.05	-2.934	-0.16
Hypophthalmichthys molitrix	12	0.042	-3.2	-0.13	20	0.05	-2.983	-0.15
Sperata sarwari	19	0.1	-2.708	-0.18	21	0.05	-2.934	-0.16
Clarias batrachus	15	0.053	-2.944	-0.15	21	0.05	-2.934	-0.16
Cirrhinus mrigala	15	0.053	-2.944	-0.15	23	0.06	-2.843	-0.17
Labeo calbasu	14	0.049	-3.013	-0.15	25	0.06	-2.8	-0.17
Rita rita	14	0.049	-3.013	-0.15	21	0.05	-2.934	-0.17
Total	285	1	–	-2.57	395	1.00	–	-2.59
Shannon Index	-(-2.57) = 2.574				-(-2.592) = 2.592			

DOI: https://doi.org/10.54393/mjz.v6i4.191

Fish species diversity in lined and unlined canals was calculated by use of the Simpson Diversity Index of both canals. The findings revealed that the index value of the unlined canals (D = 0.0762) was slightly lower when compared to lined canals (D = 0.0785) and indicated a high index value in the unlined canals. The smaller the Simpson Index, the better the distribution of individuals within the community was, and no dominant species existed. Anthropogenic canals (unlined canals) hosted more fish in this study (395 individuals of 14 species) than treated canals (285 individuals). The ecological variety of species was given by the existence of natural substrates, a superior complexity of habitat, and enhanced ecological circumstances that strengthened the more diverse and balanced species distribution in unlined canals. Whereas lined canals with concrete or artificial constructions provided few niches and low diversity of species. These results indicated that unlined canals were more beneficial towards favoring aquatic biodiversity (Table 4).

Table 4: Simpson's Diversity Index (D) for Fish Species

Scientific Name of Fishes	Lined Canal			Unlined Canal		
	Number (n)	n-1	n (n-1)	Number (n)	n-1	n (n-1)
Labeo rohita	27	26	702	47	46	2162
Gibelion catla	26	25	650	42	41	1722
Channa punctata	26	25	650	33	32	1056
Oreochromis niloticus	24	23	552	27	26	702
Mastacembelus armatus	19	18	342	21	20	420
Wallago attu	16	15	240	32	31	992
Cyprinus carpio	42	41	1722	41	40	1640
Ctenopharyngodon idella	16	15	240	21	20	420
Hypophthalmichthys molitrix	12	11	132	20	19	380
Sperata sarwari	19	18	342	21	20	420
Clarias batrachus	15	14	210	21	20	420
Cirrhinus mrigala	15	14	210	23	22	506
Labeo calbasu	14	13	182	25	24	600
Rita rita	14	13	182	21	20	420
Total	285	271	6356	395	381	11860
Simpson Index	n=285, n-1= 284, n (n-1)=80940 Simpson Index(D) = 0.0785			n=395, n-1= 394, n (n-1) = 155630 Simpson Index (D)= 0.0762		

Statistical test ANOVA showed that there was a significant difference between species abundance and diversity, and a p-value of less than 0.05 and supporting the hypothesis that unlined canals enhanced biodiversity. Unlined canals had more complicated regimes and facilitated positive nutrient cycling and water quality. Although the lined canals proved to be more effective in the delivery of water since the seepage was less, and also caused a severe decrease in groundwater recharge. Unlined canals also encouraged replenishment of groundwater and enhanced retention of sediments, and were also more susceptible to erosion in some soils. Although lined canals were initially more costly to build, their performance in the long run was found to save on water delivery costs and render them beneficial to large-scale irrigation systems (Figure 2).

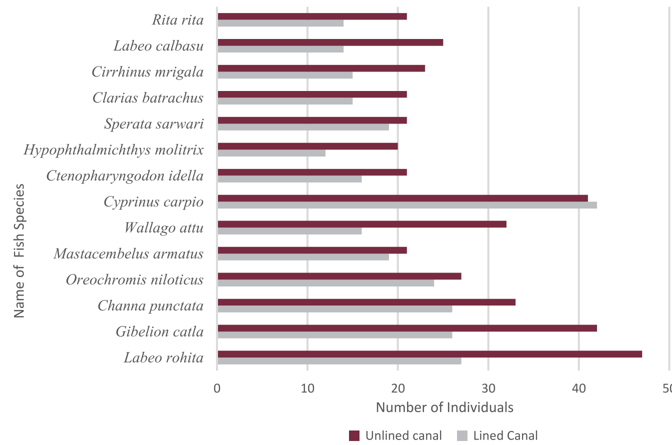


Figure 2: Species Richness and Abundance of Fish Assemblages in Lined and Unlined Canals

On the whole, the research noted the ecological and hydrological benefits of unlined canals in sustaining a variety of aquatic life, and design decisions in canals were made to strike a balance between both ecological and hydrological values of biodiversity and water delivery.

DISCUSSION

Construction materials that are used in canals have a significant impact on the ecological state of water bodies. As it was demonstrated in the current research, unlined canals exhibited greater diversity of fish and a slightly better set of water quality parameters than lined canals [14]. According to the findings, the heterogeneity of habitats, and hence ichthyofaunal composition, directly depend on the design of a canal and the type of substrates [15]. Lined canals are homogenous and physically rigid environments, due to their smooth impervious surface, as well as, hydrologically effective. These designs reduce seepage and interaction of sediments, reduce habitat complexity and ecological niches [16]. Absence of aquatic plants and unstable substances reduces food and cover of fish and invertebrates that resulting in decreased species richness. Unlined canals, on the other hand, promote ecological heterogeneity through seepage of water, exchange of sediments, and colonization by aquatic flora. All these lead to increased diversity of microhabitat, cycling of nutrients, and the level of dissolved oxygen conditions that are favorable to support a variety of fish communities [17]. The Shannon and Simpson indices are slightly greater in the unlined canals, with a numerically small value, which is indicative of greater evenness and ecological stability in the species. These are not new tendencies of the present work but a reflection of the previous work on riverine systems in Pakistan and Nepal, which demonstrated that the parameters of the habitat

DOI: https://doi.org/10.54393/mjz.v6i4.191

diversity and water quality were closely correlated with the structure of the fish assemblage [4]. The present findings match the data in the River Kurram and River Indus systems, where Cyprinidae prevailed in different assemblies and environmental parameters as turbidity, flow, and temperature, played a major role in the allocation of species [18, 19]. Similarly, in Nepal, studies have also been employed to bring out the fact that habitat heterogeneity and good quality water are very important aspects that stimulate fish diversity in semi-natural water systems [4]. The current results are similar to data in the River Kurram and River Indus systems, where Cyprinidae was dominant in various assemblages and environmental parameters, including turbidity, flow, and temperature, had a significant influence on the distribution of species [18, 19]. On the same note, research has also been used in Nepal to highlight the fact that habitat heterogeneity and quality water are critical factors that drive fish diversity in semi-natural aquatic systems [4]. Unlined canals also have operational problems, particularly when it comes to loss of water through seepage, and this is a major problem in very dry regions like Pakistan [20]. A middle ground on conservation of water and biodiversity will be reached by having a hybrid canal. Such systems can combine the hostile effectiveness of lined canals with ecological features of unlined canals, like the use of vegetated banks, bioengineered substrates, or partial lining to introduce higher levels of habitat complexity with lower seepage. Increasingly, the method has been suggested in the eco-engineering literature to trade off irrigation efficiency with environmental sustainability. The increased fish presence and diversity in unlined canals, measured by Shannon Wiener and Simpson indices, is consistent with the field data of complex natural substrates, pithy aquatic vegetation, and dissimilar bank forms. These characteristics of the observed habitats would be a legitimate explanation of the quantitative findings because they would provide deeper niche occupancy, protection against predators, and breeding areas to fish than the simplified, concrete-lined habitats.

CONCLUSIONS

The unlined canals allow greater fish diversity and habitat complexity because of the natural substrates, vegetation, and hydrological variability, whereas lined canals prefer water delivery with lower nutrient levels and lower habitat diversity. High nutrients in unlined canals would make them more productive, but with the risks of local pollution. The hybrid canal design, where water efficiency and conservation of biodiversity would be balanced in the construction of lined systems, would offer a viable solution to irrigation and management of aquatic ecosystems.

Authors Contribution

Conceptualization: HRKZ
Methodology: HRKZ, AI, R
Formal analysis: KRKZ, MI, F, AN, HMFA, AR, SA, MN
Writing review and editing: HRKZ, AI, MI, R, AN, HMFA, AR, SA, MN

All authors have read and agreed to the published version of the manuscript

Conflicts of Interest

All the authors declare no conflict of interest.

Source of Funding

The author received no financial support for the research, authorship and/or publication of this article.

REFERENCES

[1] Debnath A, Sarkar D, Talukdar G. Biodiversity and Habitat Quality Assessment of Unlined Lower Ganga Canal. Available at SSRN 4183211. 2022 Aug. doi: 10.2139/ssrn.4183211.

[2] Ahmad M. Ichthyofaunal Diversity and Conservation Status in Rivers of Khyber Pakhtunkhwa, Pakistan. Proceedings of the International Academy of Ecology and Environmental Sciences. 2020 Dec; 10(4): 131.

[3] Hayat S, Malik A, Ali Q, Ishtiaq A, Akhtar MN. Length-Weight Relationships of *Cyprinus carpio* from the Indus River at Chashma Lake, District Mianwali, Punjab, Pakistan. Journal of Wildlife and Biodiversity. 2020 Nov; 4(4): 72-80.

[4] Thapa GB, Singh D, Raza M, Rajbanshi D, Khalid MS. Correlates of Ichthyofaunal Diversity with Relation to Environmental Variables of Badigad River, Nepal. International Journal of Zoology. 2025; 2025(1): 3898768. doi: 10.1155/ijz/3898768.

[5] Chitrakar P, Khalid MA, Labh SN. Spatiotemporal Variability in Water Quality, Ichthyofaunal Diversity, and Its Conservation in the Rivers of Nepal: A Mini Review. Iranian Journal of Fisheries Sciences. 2024 Jul; 23(4): 633-48.

[6] Ullah A, Ullah W, Bibi A, Rehman HU, Ahmed MB. Ichthyofaunal Diversity of Muzaffargarh and Taunsa Punjab (TP) link canals, Punjab, Pakistan. Journal of Entomology and Zoology Studies. 2016; 4(2): 11-12.

[7] Zaidi AZ, Zafar S, Arslan M, Malik S, Shah SU, Ullah A. Impact Assessment of Watercourse Rehabilitation Programs in Sindh, Pakistan Using Geospatial Techniques. Arabian Journal of Geosciences. 2022 Nov; 15(21): 1640. doi: 10.1007/s12517-022-10904-x.

[8] Khan AM, Ali Z, Shelly SY, Ahmad Z, Mirza MR. Aliens: A Catastrophe for Native Freshwater Fish Diversity in Pakistan. The Journal of Animal and Plant Sciences. 2011 Jan; 21(2): 435-40.

DOI: https://doi.org/10.54393/mjz.v6i4.191

[9] Bibi F, Nazir MM, Ahmad AN, Akhtar M. Freshwater Fish Diversity and Their Conservation Status in Southern Punjab, Pakistan: A Review. Pakistan Journal of Life and Social Sciences. 2018 May; 16(2).
[10] Tölgyesi C, Torma A, Bátori Z, Šeat J, Popović M, Gallé R *et al.* Turning Old Foes into New Allies—Harnessing Drainage Canals for Biodiversity Conservation in A Desiccated European Lowland Region. Journal of Applied Ecology. 2022 Jan; 59(1): 89-102. doi: 10.1111/1365-2664.14030.
[11] Zakir-Hassan G, Kahlown MA, Punthakey JF, Shabir G, Aziz M, Sultan M *et al.* Evaluation of Hydraulic Efficiency of Lined Irrigation Channels-A Case Study from Punjab, Pakistan. Hydrology Research. 2023 Apr; 54(4): 523-46. doi: 10.2166/nh.2023.105.
[12] Naz S, Chatha AM, Khan RU, Iqbal S, Amjad N, Kiran A *et al.* Current Status of Fish Diversity and Abundance at Panjnad Headworks, Bahawalpur, Punjab, Pakistan. Pakistan Journal of Zoology. 2023 Dec; 55(6): 2651-9. doi: 10.17582/journal.pjz/20220411080448.
[13] Ijaz U, Shahid S, Ali S, Osman O, Alsubai S, Rasheed J. Evaluating the Socioeconomic and Environmental Sustainability of Barrages Using Analytical Hierarchy Process with A Rating Approach. Discover Sustainability. 2025 Jun; 6(1): 550. doi: 10.1007/s43621-025-01350-2.
[14] Ullah M, Yousafzai AM, Muhammad A. First Comprehensive Study on Ichthyofaunal Diversity of River Khurram, Khyber Pakhtunkhwa, Pakistan. Journal of Wildlife and Biodiversity. 2025 Jan; 9(1): 300-13.
[15] Waheed A, Ali N, Ahmad A, Khan N, Iqbal H, Khan A. Ichthyofaunal Diversity of the River Indus at District Swabi, Khyber Pakhtunkhwa, Pakistan: A Baseline Study for Biodiversity Conservation and Ecological Sustainability. Indus Journal of Bioscience Research. 2025 Jan; 3(1): 14-9. doi: 10.70749/ijbr.v3i1.397.
[16] Ishtiaq A, Naeem M. Effect of Dietary Protein Levels on Body Composition of Catlacatla from Pakistan. Sindh University Research Journal-SURJ (Science Series). 2019; 51(2). doi: 10.26692/sujo/2019.6.51.
[17] Mehmood S, Ahmed I, Ali MN. Length-Weight Relationship, Morphometric and Meristic Controlling Elements of Three Freshwater Fish Species Inhabiting North Western Himalaya. Egyptian Journal of Aquatic Biology and Fisheries. 2021 Nov; 25(6). doi: 10.21608/ejabf.2021.211325.
[18] Hamayoon M, Ahmad O, Khan S, Nawaz K. Comprehensive Assessment of Fish Diversity and Water Health in River Indus, Khyber Pakhtunkhwa, Pakistan. Environmental Monitoring and Assessment. 2024 Dec; 196(12): 1221. doi: 10.1007/s10661-024-13409-0.
[19] Choudhary M, Thakur K, Brar B, Kumar S, Sharma D, Kumar R *et al.* Status of Fish Assemblage Structure in the Ganga and Indus Riverine Systems of the Western Himalaya. World Water Policy. 2023 Aug; 9(3): 613-38. doi: 10.1002/wwp2.12116.
[20] Khan F, Gabriel HF, Akhtar H, Zaheer M. Evaluation of Seepage Losses from Lined and Unlined Irrigation Canal. International Journal of Advanced Natural Sciences and Engineering Research. 2024; 8(7): 228-32.