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FIELD REPORT

EFFECTS OF LAND-BASED TROUT FARMS ON THE BENTHIC MACROINVERTEBRATE COMMUNITY IN A TURKISH BROOK

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Key words: benthic macroinvertebrate, diversity indices, fish farm effluents, rainbow trout *(Oncorhynchus mykiss)*

Abstract

Benthic macroinvertebrates and physico-chemical parameters were surveyed at the source of the Karasu Brook in Bozüyük, Bilecik Province, Turkey, and at the inlets and outlets of five rainbow trout farms that use the brook water and discharge effluents into it. The dissolved oxygen, pH, ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen and total phosphorus in the farm effluents were within effluent standards for trout farming in different countries. The macroinvertebrate community in the brook consisted of Mollusca, Gastropoda (Physidae, Limnaedae, Planorbidae, Neritidae), Bivalvia (Spharidae*)*, Annelidae, Oligochaeta (Tubificidae), Hirudinea (Glossiphonidae, Erpobdellidae), Arthropoda, Insecta (Chironomidae, Ephemerellidae) and Crustacea (Gammaridae, Asellidae). Tubificidae and Chironomidae were generally observed in all sampling stations; the highest abundance was in the inlets and outlets of the two farms nearest the source. The most common measures of biodiversity, i.e., richness, Simpson's index, Shannon-Wiener index and evenness, were used during the year-long study.

Introduction

Aquaculture can impact the environment in a number of ways. It can cause user conflicts, alter the hydrological regime, introduce exotic species to the wild, and pollute water resources (Midlen and Redding, 2000). A river receiving fish farm effluents (fish excreta and waste feed) dilutes the waste and carries it downstream. The ability of the river to dilute and transport the discharge depends on the water flow and other river characteristics, and the amount of discharge. Since the discharge of upstream fish farms becomes the water

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supply of downstream farms, it is important to understand the nature and effects of fish farm effluents on the aquatic environment (Laird and Needham, 1991; Midlen and Redding, 2000) and evaluate the extent to which the upstream farm endangers downstream farms.

Deterioration of water quality is indicated by increased nitrogen and phosphorus fractions, decreased dissolved oxygen, and enhanced biological organic discharge (BOD). Thus, fish farm effluents affect the benthic macroinvertebrate community (Midlen and Redding, 2000). These communities have long been investigated as part of ecological studies in fresh waters because they are particularly sensitive to changes in the physico-chemical environment. Some species, such as the stonefly and mayfly, are especially sensitive whilst others, such as tubificids and chironomidae larvae, are more tolerant to pollution. Various diversity indices, based on different permutations of raw data collected by population sampling techniques, are used to scientifically evaluate benthic macroinvertebrate populations (Hawkes, 1979; Richards et al., 1997).

Karasu Brook in Bozüyük-Bilecik Province, Turkey, a water source for five rainbow trout farms, was selected for this investigation of the effects of fish farm effluents on the benthic macroinvertebrate community in terms of species richness, diversity indices and evenness.

Materials and Methods

Study area. Samples were collected from 11 stations along the Karasu Brook from March 2001 to February 2002 (excluding December when weather conditions prevented sample collection). The first station was the source of the brook (control). The other stations were the inlets and outlets of five rainbow trout farms located along the brook (Fig. 1). Data on the farm yields and feed consumption are given in Table 1.

Biological parameters. Benthic macroinvertebrates were collected monthly with a 0.5 mm mesh hand-net attached to a 15 x 20 x 3 cm frame (modified from Pauw and Vanhooren, 1983). The collected material was washed through a series of sieves ranging from 3.36 to 0.5 mm mesh and

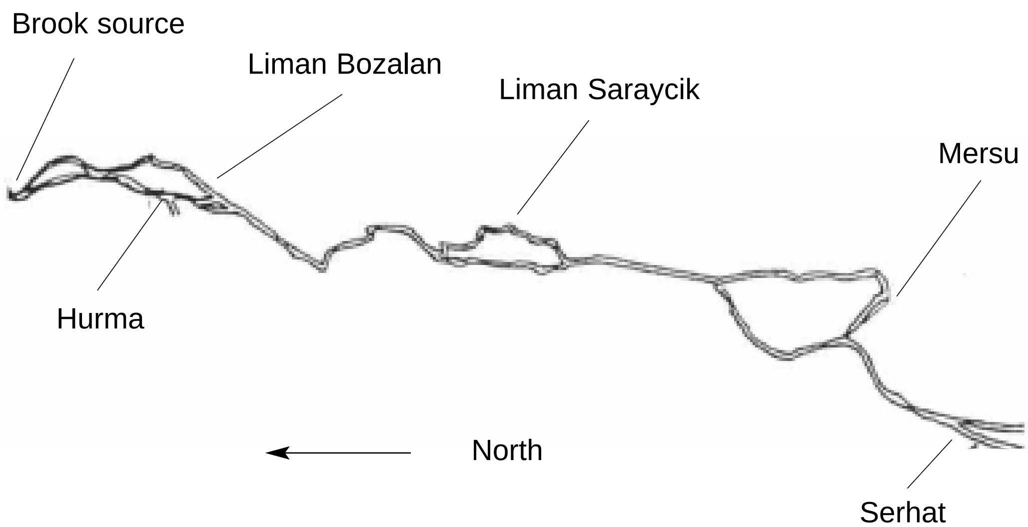

Fig. 1. The location of fish farms along Karasu Brook, Turkey.

Table 1. Yield and feed consumption of five trout farms on Karasu Brook, Turkey, in 2001.

Farm	*Yield (tons/yr)*	*Feed consumption (tons/yr)*
Hurma	40	60
Liman Bozalan & Liman Saraycık	1000	1150
Mersu	200	240
Serhat	60	57
Total	1300	

preserved *in situ* with a 4% formaline solution. The organisms were identified with a stereoscopic microscope and counted (Edmondson, 1959; Macan, 1975). Whenever possible, samples were identified to the family and genus level (Richard et al.,1997; Richards et al., 1997).

Physico-chemical parameters. Water samples from all stations were taken from below the water surface in parallel with the macroinvertebrate samplings. Water temperature, dissolved oxygen and pH were measured *in situ*. Ammonia-nitrogen ($N\text{-}NO_3$), nitrite-nitrogen ($N\text{-}NO_2$) and nitrate-nitrogen ($N\text{-}NH_3$), biological organic discharge (BOD) and total phosphorus were determined by standard methods.

Indices. Estimation of abundance (total number of individuals) and the most common measures of biodiversity (richness, Simpson's index, Shannon-Wiener index and evenness) were used to quantify the response of the community to the quality of its environment (Peckarsky, 1984; Metcalfe-Smith, 1994; Richards et al., 1997).

Richness (S) was calculated at the family level to indicate the number of macroinvertebrate families.

Simpson's index (D) represents the probability that two randomly selected individuals in the community belong to the same category by the equation $D = \text{sum}(P_i^2)$ where P_i is the ratio of individuals of one family to the total number of individuals.

Shannon-Wiener index (H) measures habitat quality that may be degraded by human activity and is expressed as $H = -\text{sum}(P_i \ln P_i)$.

Evenness (E) measures similarities in the abundance of different families where $E = H/\ln S$.

Results

Average water quality values for the study period are shown in Figs. 2 and 3. High temperatures ranged 16.5-19°C in August and low temperatures 11-12°C in January. Macroinvertebrate communities included Mollusca, Gastropoda (Physidae-Physa, Limnaedae-Limnaea, Planorbidae-Planorbis, Neritidae-Theodoxus), Bivalvia (Spharidae-Pisidium), Annelidae, Oligochaeta (Tubificidae), Hirudinea (Glossiphonidae, Erpobdellidae), Arthropoda, Insecta (Chiro-nomidae, Ephemerellidae) and Crustacea (Gammaridae-Gammarus, Asellidae-Asellus).

Pisidium and Planorbis were found throughout the year, except in August. Theodoxus appeared from August to November, especially in Hurma and Liman Bozalan. Tubificidae were found in most stations. Besides Tubificidae and a few organisms of Gastropoda, no other organisms were observed in January and February. Hirudinae, Erpobdellidae and Glossiphonidae were found in a few stations. Beside Gammarus, Asellus appeared in August reaching a high in November. Ephemerellidae reached its highest value in July.

Biodiversity indices are given in Table 2.

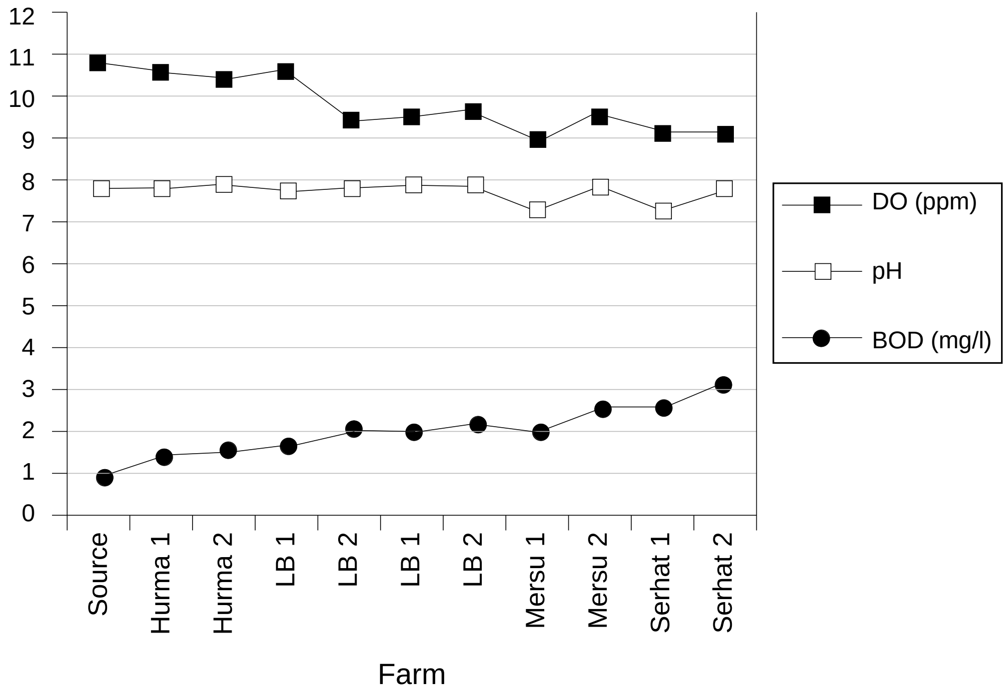

Fig. 2. Average dissolved oxygen (DO), pH and biological organic discharge (BOD) throughout the study at the source and at the inlets and outlets of five trout farms on a Turkish brook.

Discussion

Cummins (1994) indicated that different invertebrates are affected differently by organic enrichment. Depletion of oxygen is probably the major affected factor. In this study, in spite of organic enrichment from fish feeds and fish wastes at all five fish farms, the differences in dissolved oxygen (DO) between the inlets and outlets were relatively low, ranging from 0.03 mg/l at Serhat to 1.22 mg/l at Liman Bozalan. The DO values decreased gradually from 10.8 at the source to 9.09 ppm at the outlet of Serhat farm, the farthest downstream station. These levels are well above the minimum standards reported by Davis (1993). pH values were constant around 7.7 and within the standard values of 6.5-8.0 reported by Lawson (1995). These parameters had no drastic effect on the benthic macroinvertebrates in the brook.

Cripps and Kelly (1995) reported that BOD values range 3-20 mg/l and total phosphorus 0.050-0.150 mg/l in aquaculture effluents. In Denmark, Sweden and Ireland, BOD values fluctuate around 0.110 mg/l. In this study, the maximum BOD (3.16 mg/l) and total phosphorus (0.117) occurred in the effluent of the farm furthest downstream. The maximum allowable BOD increment between the inlet and outlet of land-based salmonid farms is 1.0 mg/l in Denmark and 2.0 mg/l in England (Midlen and Redding, 2000). The maximum allowable total phosphorus increment is 0.05 mg/l in Denmark. The BOD and total phosphorus increments between the

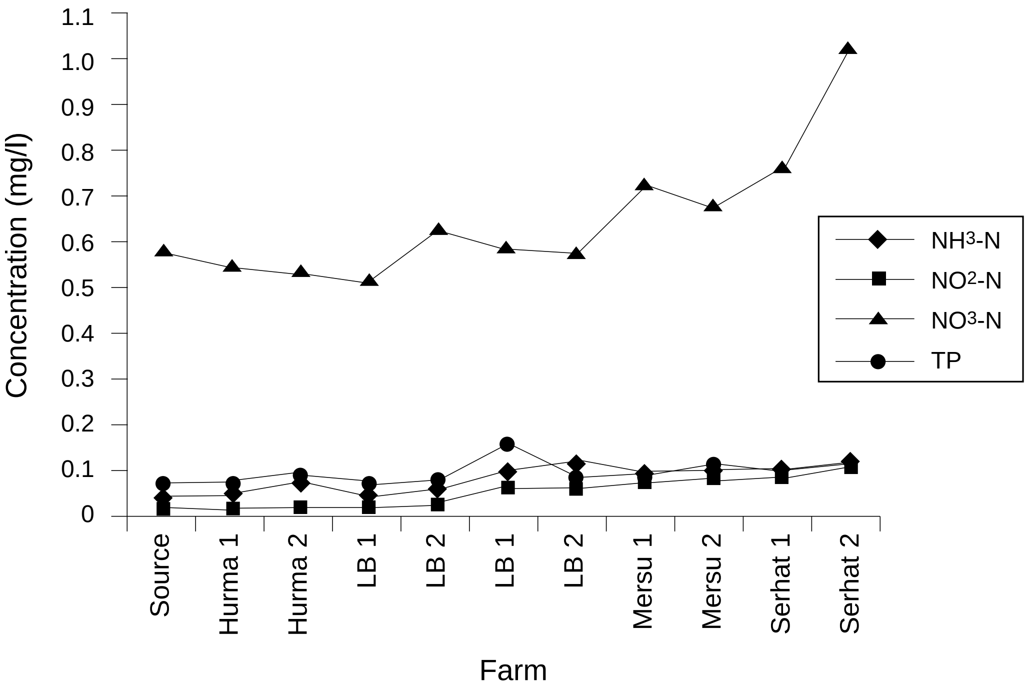

Fig. 3. Average nitrogen and total phosphorus (TP) levels throughout the study at the source and at the inlets and outlets of five trout farms on a Turkish Brook.

inlets and outlets of each of the studied farms were below 1 mg/l and 0.05 mg/l, respectively. The measured N-NH^3, N-NH^2 and N-NH^3 in the farm effluents were within the standard limits of 1.77 mg/l, 0.83 mg/l and 16.9 mg/l, respectively (Schwartz and Boyd, 1994).

Mollusca such as Limnaea, Physa, Pisidium (snails), Oligochaeta (worms), Chironomid larvae and Hirudinea (leeches) are tolerant to organic pollution and low oxygen. The major factor determining the distribution of leeches is probably the availability of prey. Members of Glossiphonidae feed predominantly on snails and members of Erpobdellidae feed on oligocheata and chironomid larvae, all of which are associated with organically enriched waters (Hawkes, 1979; Reynoldson and Zarull, 1989; Whitehurst and Lindsey, 1990; Richards et al., 1997; Yıldız and Kırkagaç, 2001).

During the investigation, Mollusca were found in all stations and changes in the Mollusca genera were considered seasonal. Tubificidae was observed in all sampling stations throughout the study but the highest abundance was observed in the inlets and outlets of Liman Bozalan and Liman Saraycık farms. Chironomidae were also most abundant in these stations. This result is believed to be related to the relatively higher amounts of discharged fish fecal wastes, as described by Midlen and Redding (2000) and Laird and Needham (1991). The presence of Erpobdellidae and Glossiphonidae can

Table 2. Measures of biodiversity of benthic macroinvertebrates: richness (S), Simpson's index (D), Shannon-Weiner index (H) and evenness (E) at the source and at the inlets and outlets of five trout farms along Karasu Brook, Turkey.

Month	*Measure*	*Source*	*Hurma*		*Liman Bozalan*		*Liman Saraycik*		*Mersu*		*Serhat*	
			inlet	*outlet*	*inlet*	*outlet*	*inlet*	*outlet*	*inlet*	*outlet*	*inlet*	*outlet*
Mar	S	3	3	4	4	4	3	3	3	3	3	2
	D	0.42	0.44	0.57	0.87	0.80	0.61	0.70	0.50	0.42	0.54	0.52
	H	0.95	0.94	0.73	0.28	0.45	0.62	0.55	0.86	0.95	0.80	0.67
	E	0.86	0.86	0.53	0.26	0.32	0.56	0.50	0.78	0.87	0.73	0.97
Apr	S	5	5	3	2	4	4	4	3	3	3	4
	D	0.21	0.36	0.92	0.62	0.34	0.60	0.34	0.78	0.40	0.37	0.52
	H	1.55	1.19	0.19	0.56	1.18	0.76	1.18	0.40	0.97	1.03	0.87
	E	0.96	0.74	0.17	0.81	0.85	0.54	0.85	0.36	0.88	0.94	0.63
May	S	4	4	3	2	2	3	3	1	3	4	4
	D	0.27	0.51	0.40	0.88	0.72	0.34	0.66	1	0.42	0.30	0.33
	H	1.34	0.80	0.99	0.22	0.44	1.07	0.62	0	0.94	1.27	1.23
	E	0.96	0.57	0.90	0.32	0.64	0.98	0.57	0	0.85	0.92	0.89
Jun	S	5	5	3	3	3	4	3	3	2	4	3
	D	0.41	0.36	0.42	0.37	0.38	0.73	0.44	0.40	0.54	0.46	0.55
	H	1.15	1.30	0.94	1.04	1.02	0.57	0.94	0.97	0.63	1.00	0.79
	E	0.71	0.80	0.85	0.94	0.93	0.41	0.86	0.88	0.91	0.72	0.72
Jul	S	5	3	3	2	2	4	4	4	3	4	3
	D	0.36	0.52	0.34	0.86	0.94	0.85	0.29	0.35	0.63	0.36	0.69
	H	1.19	0.82	1.07	1.15	0.12	0.31	1.28	1.10	0.67	1.17	0.57
	E	0.74	0.75	0.98	0.36	0.18	0.22	0.92	0.79	0.60	0.85	0.52

Table 2. Cont'd

Aug	S	5	3	3	5	5	4	3	3	2	4	2
	D	0.24	0.52	0.45	0.55	0.53	0.53	0.84	0.90	0.68	0.32	0.61
	H	1.50	0.82	0.88	0.91	0.92	0.84	0.30	0.21	0.50	1.19	0.57
	E	0.93	0.75	0.80	0.56	0.57	0.61	0.27	0.19	0.72	0.86	0.83
Sep	S	2	3	3	3	5	4	4	3	5	7	4
	D	0.56	0.34	0.77	0.38	0.30	0.74	0.50	0.50	0.28	0.35	0.41
	H	0.64	1.07	0.45	1.03	0.34	0.53	0.84	0.76	1.38	1.19	1.00
	E	0.93	0.98	0.41	0.93	0.83	0.38	0.61	0.70	0.83	0.61	0.72
Oct	S	3	2	3	2	2	4	7	2	6	3	5
	D	0.33	0.62	0.46	0.93	0.76	0.79	0.81	0.78	0.41	0.61	0.72
	H	1.09	0.56	0.87	0.14	0.39	0.39	0.44	0.37	1.10	0.70	0.61
	E	1.00	0.80	0.79	0.20	0.56	0.28	0.22	0.54	0.61	0.64	0.38
Nov	S	1	2	3	2	1	3	3	3	3	4	4
	D	1	0.50	0.42	0.83	1	0.91	0.42	0.82	0.42	0.36	0.53
	H	0	0.69	0.94	0.30	0	0.20	0.94	0.37	0.94	1.13	0.71
	E	0	1.00	0.85	0.43	0	0.18	0.85	0.34	0.85	0.82	0.51
Jan	S	1	1	2	1	2	1	2	1	2	2	2
	D	1	1	0.57	1	0.95	1	0.66	1	0.55	0.72	0.67
	H	0	0	0.67	0	0.11	0	0.52	0	0.63	0.44	0.47
	E	0	0	0.97	0	0.16	0	0.75	0	0.91	0.64	0.68
Feb	S	1	2	2	2	1	2	1	2	2	2	2
	D	1	0.55	0.52	0.62	1	0.62	1	0.89	0.64	0.82	0.53
	H	0	0.63	0.67	0.56	0	0.56	0	0.21	0.54	0.32	0.66
	E	0	0.91	0.97	0.81	0	0.81	0	0.30	0.74	0.46	0.95

probably be related to the presence of prey such as Mollusca, Tubificidae, Chironomidae spp.

Gammarus and Asellus react differently to organic enrichment. Asellus, being more tolerant than Gammarus, may survive in the better aerated riffles of organically enriched streams (Hawkes, 1979). In this study, Gammarus was mostly present at the source of the brook but not in high abundance. Asellus was observed at some stations between August and November

Ephemerellidae that are more tolerant to organic enrichment than other Ephemeroptera (mayflies) families (Hawkes, 1979) were found only during the spring and at the last sampling station.

Indices were used to determine the effects of fish farm effluents on the environment. In spring and summer, richness and the Shannon-Wiener index decreased while the Simpson's index increased in the Serhat Farm outlet, in contrast to the source of the brook. The succession of macroinvertebrates in spring and summer were probably caused by the high richness and Shannon-Wiener values. On the other hand, these values generally increased as Simpson's index decreased in the Serhat Farm outlet in autumn and winter. The low richness and diversity at the outlet of Serhat Farm may be caused by the lack of transportation of detritus from the upper reaches, that decreased the quantity of available food. This result is supported by Kazancı and Dügel (2000). Evenness values were generally higher than 50%, showing that organic enrichment is more likely to enhance the number of tolerant than less tolerant groups.

In conclusion, all the groups of benthic macroinvertebrates found during the study were tolerant to the organic enrichment. Among the organisms, Tubificidae and Chironomidae were especially higher in farms with higher yields. From the point of view of water quality parameters, the trout farms did not seem to negatively affect the brook. The extent of the effects of the farm effluents on the Karasu Brook should be monitored on a long-term basis.

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