Influence of trout farm effluents on water quality parameters and benthic macroinvertebrates

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Abstract

The aim of this study was to assess the influence of trout farm effluents on water quality parameters in the Dohezar Stream. In this study two trout farms and 7 stations were selected and physiochemical of water, including air and water temperatures, dissolved oxygen concentration (DO), pH, electrical conductivity (EC), water flow and biochemical oxygen demand (BOD) were measured every 30 days for one year. A combined total of 60 benthic macroinvertebrate taxa were collected from the seven sites of the stream. The results showed that trout farms had a significant impact on EC, pH, water flow and BOD in the water throughout the year and among stations ($p<0.05$). Only DO did not show significant differences in the one year survey. Macroinvertebrates had significant differences in abundance downstream from the trout farm effluent, particularly in stations 1 and 3 compared with others. However, the diversity of benthic macroinvertebrates significantly decreased, particularly in stations of 3, 4 6 and 7. Regarding benthic macroinvertebrates, the abundance percentage of ephemeropterans, plecopterans and trichopterans (expressed as EPT %), and Biological Monitoring Working Party (BMWP) were much lower in station 3 than in other stations.

Keywords: *Oncorhynchus mykiss*, Trout farm, Water quality, Stream, Effluents

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Introduction

Salmonid production statistics include salmonid production in freshwater lakes and thus are not exclusive of land-based production systems which are, however, a major means of production in leading producing countries. Iran is one of the leading producers in Asia – trout production is performed mostly in concrete raceways (Abdolhay, 2005). Salmonid farms commonly discharge their effluents into low order, headwater streams, partly due to the fact that adequate freshwater resources for production are commonly found in undisturbed areas. Small sized streams are important in regulating water chemistry in large drainages because their large surface-to-volume ratio favors rapid nitrogen uptake and processing (Peterson *et al*., 2001). While several reviews have been written on freshwater salmonid farm effluents, their focus has been on the nature of the effluents themselves and/or their treatment, and not necessarily on in-stream ecological effects. Although water physicochemical analyses can provide a good indication of the pollution level in rivers and streams, these analyses do not consider the state of biological communities and, therefore, cannot properly reflect the condition of freshwater ecosystems. In consequence, over the last decades, the use of biological methods has been promoted and recommended as a useful technique for the assessment of freshwater pollution (Rosenberg and Resh, 1993; Ziglio *et al*., 2006). This biological monitoring is usually based on the numerical values of several indices that integrate the ecological responses of aquatic communities (e.g., macrophytes, epilithic diatoms, benthic macroinvertebrates, fish) to pollutants (Schneider and Melzer, 2003; Camargo *et al*., 2004; Griffith *et al*., 2005; Zhu and Chang, 2008). The most used indices are focused on measures of abundance (e.g., coverage, density, biomass), diversity (e.g., species richness, Shannon index), and pollution tolerance.The effects of trout farms on macroinvertebrate of the recipient streams have been less thoroughly investigated. In general, waste water from trout farms causes decline in benthic macroinvertebrate diversity, replacement of more sensitive species by less sensitive ones, and changes in the trophic structure due to increased abundance of collectors and reduced abundance of scrapers and shredders (Camargo, 1992; Loch *et al*., 1996). In Iran, there are currently more than 1000 trout farms that constitute the most important inland aquaculture industry. Many of these trout farms are located in the upper reaches of streams. In spite of the potential environmental impact of these trout farm effluents, their downstream effects on freshwater communities have been seldom studied. In this regard, the main goal of this study was the assessment of the effects of trout farm effluent on water quality parameters and on the water quality sensitive benthic macroinvertebrates.

Materials and methods

Study area

The Dohezar Stream is one of the branches of the Sefidrood River. The length of the stream is 42km with rock-sand substance bed and there are two trout farms on the fringes of the Dohezar Stream; the first trout farm with a capacity of 20 tons and the second trout farm with a capacity of 10 tons per production period.

Sampling procedures

In this study, seven sampling sites were selected and sampling took place from October 2011 to September 2012 every 30 days for one year and samples were taken in duplicate at the same hour of the day throughout the study. One sampling station was located 300 m upstream and another 200 m downstream of the discharge point for each trout farm (1, 2, 4, 5). One station was placed 500 m downstream of the second sampling station (3). Four further stations were selected at 500-1000 m intervals downstream of the second farm.

Water quality parameters assessment

Water temperature, conductivity, pH and dissolved oxygen were measured in situ according to standard methods (Wetzel and Likens, 2000). Four independent measures were taken at each sampling site, for water temperature, conductivity, pH, dissolved oxygen and BOD determinations were made according to Standard Methods for the Examination of Water and Wastewater (Young, 1989). Water flow through the farm was estimated by measuring the depth of the water in inches as it passed over the leading edge of the raceway damboard and the width of the damboard in feet. These measurements were used in the formula for determining flow in Piper *et al*. (1982).

Biological indices

Kick samples of macroinvertebrate were collected from each site with a D-frame net (800 lm mesh) within an approximately 25-m wadeable portion of the river. Four 3-min samples were taken at each sampling visit to include all different substrata and flow regime zones. This sampling strategy was evaluated by previous samplings performed prior to the main study and two replicates were established to be good enough to capture the maximum number of different macroinvertebrate taxa. As the substrate was disturbed by kicking, the required samples collected from the net were preserved in 10% formalin. In the laboratory, samples were washed in a 500 µm mesh sieve to remove formalin and macroinvertebrates were then picked from the substrate with the aid of forceps. All animals were enumerated and identified to lowest practical taxon under a binocular dissecting scope following Durand *et al*., 1981; Merritt and Cummins 1996; Hawking 2000; Gerber and Gabriel 2002; Huxley 2003. Certain dipterans and oligochaete worms were identified under a compound microscope after mounting on a slide using polyvinylchloride.

Abundance of benthic macroinvertebrates were estimated for the whole macroinvertebrate communities; macroinvertebrate abundance is expressed as the total density (number of individuals) per square meter of benthic substratum; macroinvertebrate diversity or richness is expressed as the total number of families per Surber sampler; abundance percentage of ephemeropterans, plecopterans and trichopterans (EPT%).

Data analysis

All statistical analyses were conducted using the SPSS 17.0 software. Mean values of physicochemical parameters were compared between sampling sites by means of oneway analysis of variance (ANOVA). The same statistical approach was performed for mean values of biological indices, including mean abundances and densities of benthic macroinvertebrates.

Results

Air and water temperatures over a twelve-month span (October 2011–September 2012) fluctuated between 7.6 and 16.9^{o}C in the seven sites sampled and were not significantly different among the sites during the one year study, although site 6 had slightly higher temperatures (Fig. 1). Mean water flow was significantly different among the sampling sites and throughout the study period (Fig. 2). Most of the chemical variables (EC, pH, BOD_5) were significantly different (p<0.05) among the sampling sites and throughout the study period (Figs. 3, 4, 5). There was no significant difference in DO among sampling sites and throughout the study period (Fig. 6). A total of 60 macroinvertebrate taxa, representing 18 orders in 32 families were recorded during the 12-month study.Most of these were insects; other major groups were Ostracoda, Gastropoda and Bivalvia. The overall abundance of macroinvertebrates was significantly different among sites. Ephemeropterans contributed the highest percentage of individuals (%43) followed by Tricoptera (%18) and Plecopterans (%10) at stations 1 and 3, respectively.The effect of trout farm pollution on the absolute abundance of other macrobenthic families was evident, as individuals of the families Chironomidae, Tipulidae, Hydrophilidae, Simuliidae, Empididae, Tabaniidae, Lumbriculidae and Planaridae were dominant in downstream stations (4, 5, 6 and 7). Taxa (families) abundance percentage of ephemeropterans, plecopterans and trichopterans (EPT %), and values of BMWP index were significantly (p<0.05) higher at stations 1-2 than in other sites, their values tending to decrease with increasing downstream distance from the trout farm (Figs. 7, 8).

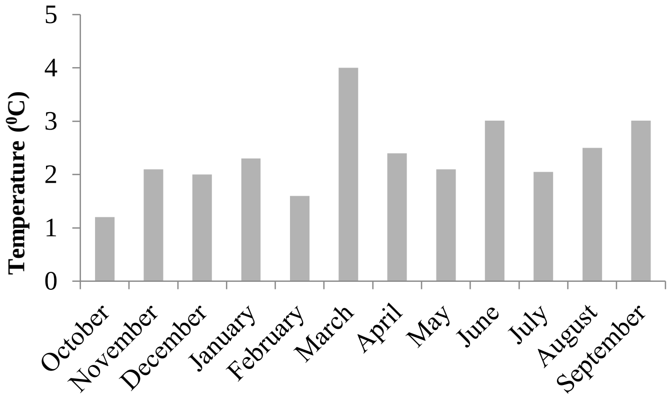

Figure 1: Variation of air and water temperature in Dohezar Stream, October 2011–September 2012.

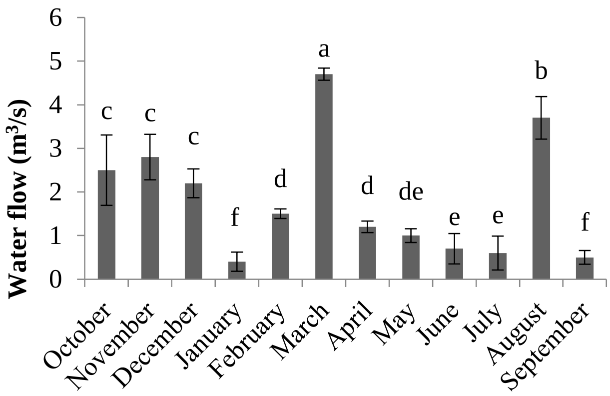

Figure 2: Variation of water flow in Dohezar Stream, October 2011–September 2012.

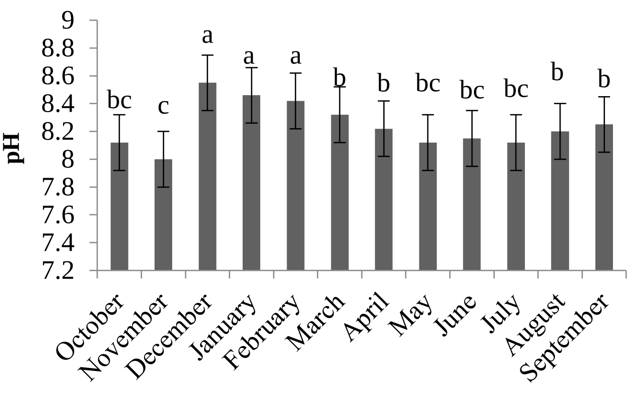

Figure 3: Variation of pH in Dohezar Stream, October 2011–September 2012. Means with the same letters are not significantly different (p<0.05).

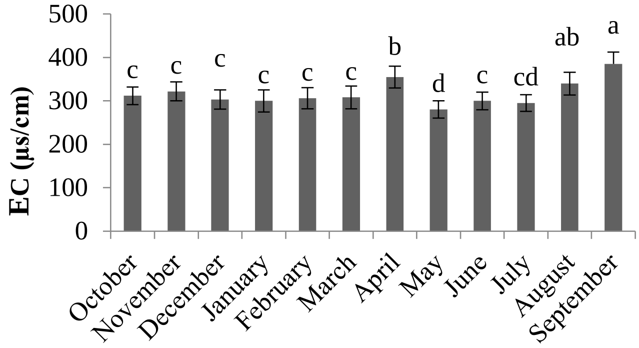

Figure 4: Variation of EC in Dohezar Stream, October 2011–September 2012. Means with the same letters are not significantly different (*p*<0.05).

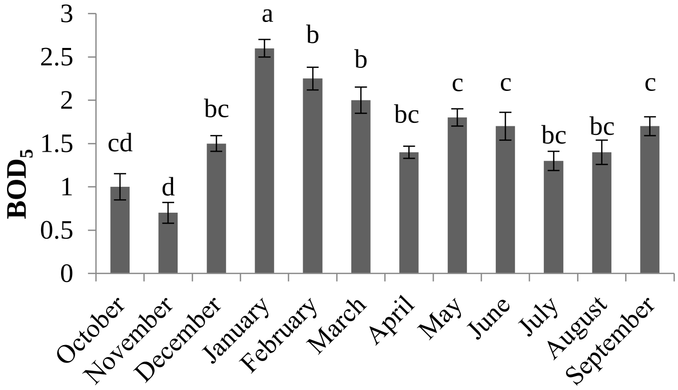

Figure 5: Variation of BOD_5 in Dohezar Stream, October 2011–September 2012. Means with the same letters are not significantly different (*p*<0.05).

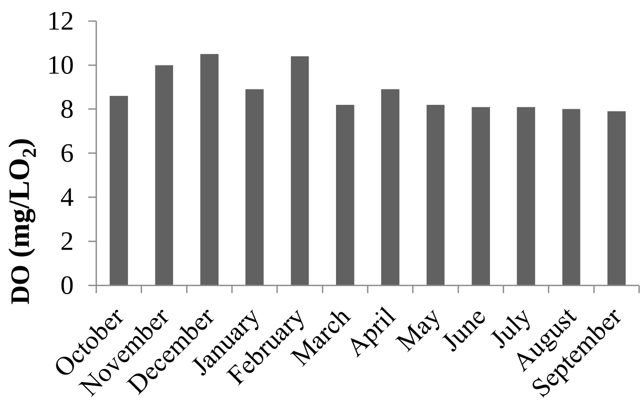

Figure 6: Variation of DO in Dohezar Stream, October 2011–September 2012.

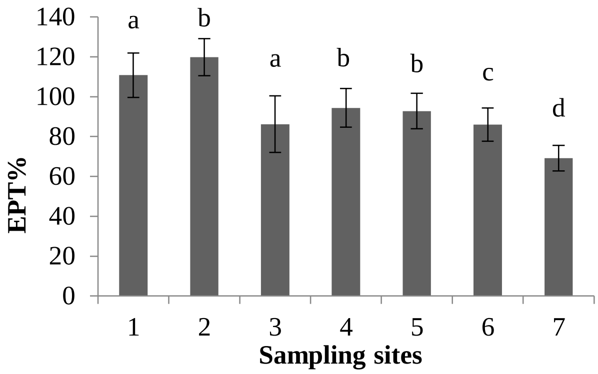

Figure 7: Changes in EPT% among sampling sites. Means with the same letters are not significantly different (*p*<0.05).

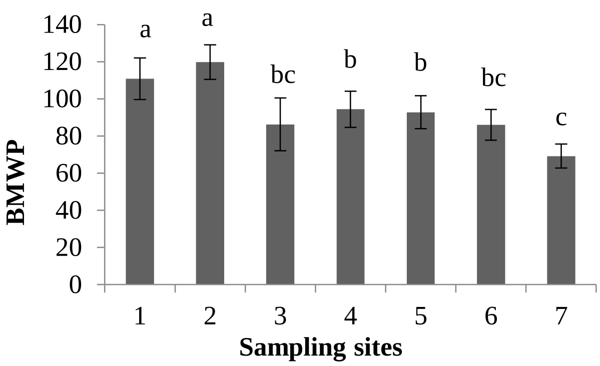

Figure 8: Changes in BMWP index among sampling sites. Means with the same letters are not significantly different (*p*<0.05).

Discussion

Increase in inorganic nutrients and suspended solids (i.e., turbidity), a decrease in dissolved oxygen, and a settlement of suspended solids on the river bottom leads to changes in physicochemical characteristics of rivers and streams receiving fish farm effluents (Selong and Helfrich, 1998; Bartoli *et al*., 2007; Ruiz-Zarzuela *et al*., 2009). In our study, these physicochemical alterations were more evident just below the trout farm, with a clear tendency to be reduced with increasing downstream distance from the trout farm effluent (Table 1). The high levels of BOD_5 values, and low values in dissolved oxygen observed in sites 5, 6 and 7 are an indication of deterioration of the water quality as a result of various anthropogenic activities in these sites. The total number of macroinvertebrate taxa reported in this study (60) compares favorable with 88 and 98 taxa reported by Adakole and Annune (2003) and Ogbeibu and Victor (1995), respectively in various freshwater systems.

Table 1: Water quality parameters (mean ±SD) of Dohezar Stream at different stations.

Parameters	1	2	3	4	5	6	7
Air temperature	13.52±8.88	13.68±8.52	15.18±8.57	15.08±7.95	16.91±9.23	16.85±7.95	17.01±7.70
Water temperature	8.48±1.44	8.84±1.42	10.26±1.35	10.38±1.35	11.99±1.40	11.97±1.36	12.36±1.33
Water flow (m^3/s)	0.84±0.23	0.94±0.74	1.89±1.17	3.97±0.59	6.82±1.76	4.68±2.14	6.07±1.14
pH	8.28±0.17	8.30±0.15	8.24±0.14	8.15±0.14	8.25±0.10	8.24±0.14	8.06±0.13
EC	335.75±32.3	337.67±30.9	318.92±34.4	322.67±33.9	339±45.26	346.92±37.2	377.75±36.6
BOD	0.94±0.17	1.3±0.12	1.05±0.18	1.6±0.23	1.9±0.20	2.1±0.21	2.7±0.14
DO	9.93±0.72	9.64±0.87	9.77±0.74	9.47±0.98	9.34±0.98	9.57±1	9.40±1.09

Table 2: Mean values (± SD) of biological indices (based on benthic macroinvertebrates) for each sampling site.

Station Parameters	1	2	3	4	5	6	7
%EPT	68.81±20.38	45.32±9.05	70.66±14.6	43.92±22.66	45.44±20.99	37.18±12.5	23.08±11.40
BMWP	110.75±28.6	119.83±18.1	86.25±18.6	94.42±14.72	92.75±17.63	86.00±12.8	69.25±22.04

Dipterans and Oligochaetes were the abundant groups recorded in sites 1 to 3. Studies elsewhere (Ravera, 2001; Rueda *et al*., 2002; Ruggiero *et al*., 2003) have revealed that orders of Plecoptera and Trichoptera abundance are attributed to considerable load of organic particles from untreated sewage and livestock effluents. Results obtained from this study showed similarities in macroinvertebrates groups recorded in the perturbed sites 1 and 3. This was however different from other sites with their peculiar species which reflected the nature of the habitats and levels of organic enrichment. According to Chessman *et al*. (2002), the composition of a community from any given point in a river is a reflection of the pollution status of the water body. The abundance of mayflies particularly, Coleoptera (Gyrinus, Gerris lacustris) and the near restriction of Trichoptera (Hydropsyche and Stenophylax) to site 1 and 3 is an indication that these sites are relatively free from gross pollution. Related studies conducted in similar freshwater bodies in other studies (Umeozor, 1996; Edema *et al*., 2002) and elsewhere (Rueda *et al*., 2002; Walsh *et al*., 2002; Nelson and Roline, 2003) have associated the presence of these organisms in a site to clean water conditions. These species are very sensitive to reductions in dissolved oxygen and are not found in areas where oxygen levels are consistently low. Changes in the value of biological indices based on the macroinvertebrate community (Figs. 7, 8) reflect a substitution of sensitive macroinvertebrates for tolerant ones. For example, sensitive planarians, amphipods, ephemeropterans, plecopterans, trichopterans, coleopterans and dragonflies decreased in abundance, whereas the abundance of tolerant tubificid worms, leeches, dipterans (mainly chironomids), caddisflies and molluscs increased. Reductions in dissolved oxygen concentrations would be responsible, in part, for these changes in the abundance of benthic macroinvertebrates downstream of the trout farm. Alterations in other environmental factors, such as food resources, could also be responsible (Selong and Helfrich, 1998; Roberts *et al*., 2009). In terms of species diversity, sites 1 and 3 were more diverse comprising of organisms that cannot tolerate degrading water conditions, especially the EPT organisms. These organisms were sporadically present in other sites. Due to the impact on the stream at these sites only the non-sensitive species survived while the sensitive species were prone to danger of being eliminated. Overall we can conclude that metrics and indices based on benthic macroinvertebrates (such as EPT% and BMWP indices) may be more suitable for the biological monitoring of trout farm pollution in the ecosystems, since the higher diversity of benthic macroinvertebrates inhabiting the river bottom would permit this community to exhibit a better indicator performance regarding the environmental stress caused by trout farm effluents.

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