Evaluating the Aquaculture Effluent Impact on Macroinvertebrate Community and Water Quality Using BMWP index

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Introduction

Growing aquaculture activities to meet the growing global demands for fish consumption have increased the risks of reverse environmental impacts, such as water pollution and biodiversity loss. This concern has attracted great official attention in most nations. In flow-through aquaculture systems like raceways and tanks, effluents are discharged to environment with enhanced concentrations of nutrients and solids. Such effluents may have serious negative impacts on the quality of the receiving water, especially when the discharged is untreated.

There are several useful methods for monitoring the impacts of effluents, among them biological indicators such as benthic macroinvertebrates. These organisms are found in almost all water bodies and are sedentary with reduced or no mobility. Therefore, they indicate local conditions. Since many of these organisms have life spans of a year or more, they are also good integrators of environmental conditions. Besides, they are relatively easy to collect and identify. In order to reduce the effort and taxonomical expertise necessary for routine biological assessments based on the indicator organisms, there is much interest in developing score systems which rely entirely on the identification of family levels and are not specific to any single river catchments or geographical areas. Biological Monitoring Working Party score (BMWP), is a widely used method for assessing ecological integrity, that has been standardized by the International Organization for Standardization (ISO), and can be used to assess the impact of organic pollution resulted from sewage disposal or fish farm waste.

Materials and methods

The main goal of the present research is to investigate the environmental impact of trout farm discharge on the water quality and benthic macroinvertebrate communities of Zayandeh-Rud River. The river which flows from the Zagros Mountains is the largest river on the central plateau of Iran. It has vital effects on the ecology of its region. Three different fish farms, Dimeh, Hojat Abad, and Takab, with different production capacities of 250, 25 and 70 tons respectively, were selected along the river for present study. Among them, Dimeh farm is relatively large enough to be considered as the main source of potential pollution in the upstream of the river.

At each of the three farms, we chose five sampling sites including: site 1, input; site 2, outlet; site 3 upstream station; sites 4 and 5, downstream stations placed approximately 50 meters and 1 km further from the outlet, respectively. Benthic macroinvertebrates were collected in autumn, winter, and spring using a quantitative technique. Taxonomic levels (family level) of invertebrates were identified, and they were classified in total 11 classes, 16 orders and 53 families. The identified families are listed in Table 2. Information on macroinvertebrates of each site was used to calculate the biological monitoring working party (BMWP). This was carried out by summing up the individual scores of all families in the samples. a score between 1 and 10 was allocated to Each group or family according to their sensitivity to environmental disturbances.

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The most sensitive organisms, such as stoneflies, were scored 10 and the least sensitive, such as Oligochaete worms, were scored 1. The scores for each family represented in the sample were then summed up to give the BMWP score. Statistical analyses were performed using the SPSS 15 software package. The BMWP index is ranged from 0 to 100, where 100 represents an excellent water quality and 0 – 40 indicate a low water quality.

Results and discussion

In the Dimeh farm outlet, the most abundant families of macroinvertebrates were Chironomidae and Oligochates. Based on BMWP, the presence of these macroinvertebrates indicates a poor water quality at the farm outlet. However, the macroinvertebrates of the input station of Dimeh farm were mainly dominated by Gammaridae family. The majority of identified macroinvertebrates at all of the sampling sites of the Takab farm were Tubificidae, Chironomidae and Valvatidae. The changes in the BMWP index of different sites using Box and Whisker plots model, are shown in Figs. 1 to 8.

As it is shown in Fig. 1, in autumn, BMWP index decreased at the outfall station of the dimeh farm compared to the input station. The BMWP index also shows a decline at the site 50 m downstream of the farm compared to the site above the farm; however, BMWP index was significantly higher at the site 1 km further downstream, indicating water quality improvement. Similarly in spring and winter sampling, BMWP index was significantly ($p<0.01$) lower at outlet site compared to the input of the Dimeh farm (Figs. 4 and 7). The minimum recorded value for BMWP index at the outlet of Dimeh farm, were 6.03±1.17 and 12.07±3.28 in winter and spring, respectively.

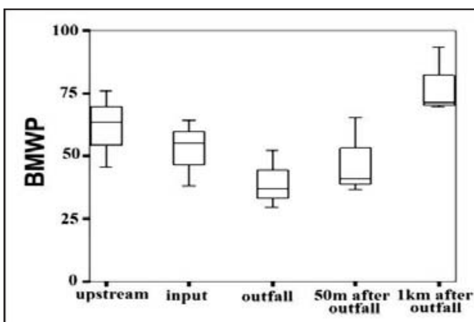

Fig. 1: BMWP index variation of Dimeh farm in autumn

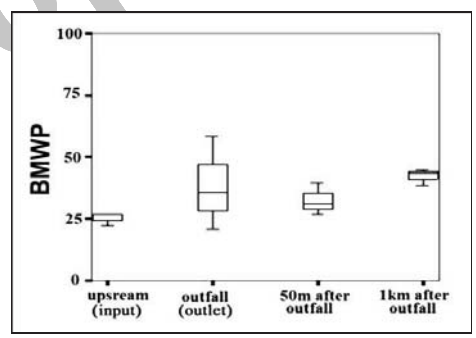

Fig. 2: BMWP index variation of HOJAT Abad farm in autumn

Fig. 2 shows the variation of BMWP index in Hojat Abad farm in autumn. Significant differences in BMWP index between outlet and input were only observed in winter (Fig. 5). Hence it seems that effluent of Hojat Abad farm did not substantially affect water quality or benthic macroinvertebrate community structure during the period of this study. Maximum amount of BMWP index (87.9) occurred in the downstream of Hojat Abad farm in spring (Fig. 8).

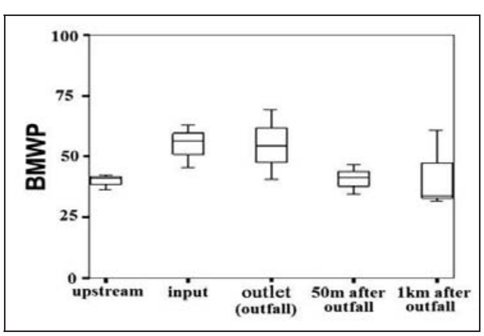

Fig. 3: BMWP index variation of Takab farm in autumn

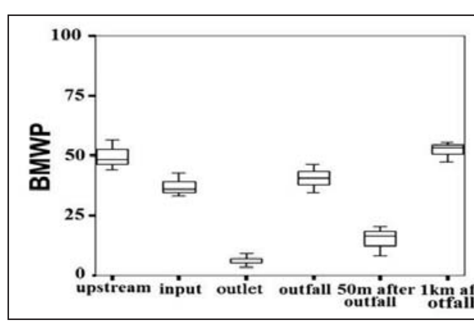

Fig. 4: BMWP index variation of Dimeh farm in winter

In Takab farm, during the autumn sampling, BMWP indices were not significantly different among the sampling sites (Fig. 3). In contrast, a significant ($p<0.01$) decrease was observed in BMWP indices between the input and outlet sites in winter sampling (Fig. 6), from 55.67±4.71 to 31.33±17.9. Results showed no significant difference between the upstream and downstream sites of Takab farm in winter and spring, both of which are of low water quality. Regarding the effect of production levels and time of sampling, analysis of variance (ANOVA) showed significant differences among the farms and times of sampling. BMWP indices were significantly low ($p<0.01$) at sites receiving effluent from a farm of high production capacity. This is more likely due to the higher food supply and metabolic wastes in these circumstances.

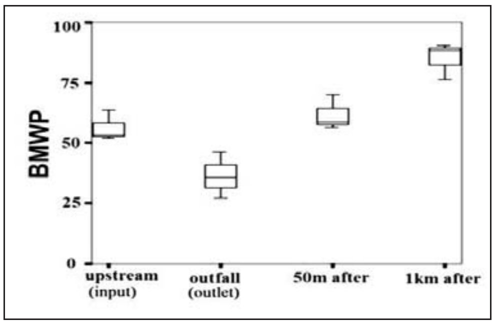

Fig. 5: BMWP index variation of Hojat Abad farm in winter

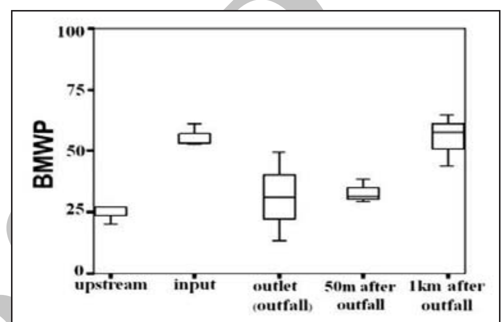

Fig. 6: BMWP index variation of Takab farm in winter

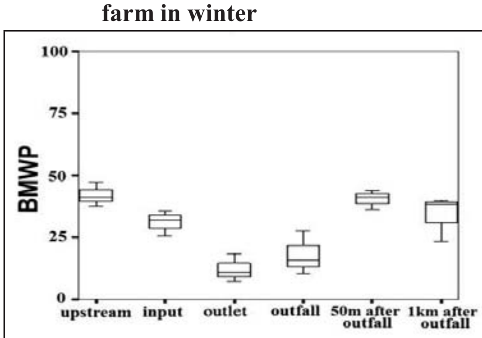

Fig. 7: BMWP index variation of Dimeh farm in spring

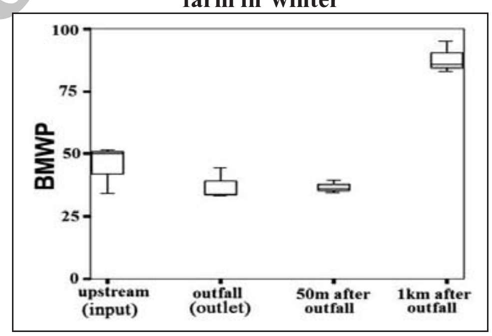

Fig. 8: BMWP index variation of HOJAT Abad farm in spring

The BMWP index was also low at the station 50m downstream, indicating low or no recovery of water quality and community structure, compared to the upstream stations. However, BMWP values at further downstream station (1 km below the fish farm) exhibited a partial recovery of community structure, so that no significant difference with the upstream site was observed. We found that in general, the abundance of tolerant taxa such as Chironomidae, Simulidae, and Oligochaeta increased. In contrast, the abundance of sensitive taxa (Ephemeroptera and Trichoptera) declined in number. A vast majority of the macroinvertebrates collected in the discharge channel were chironomids, oligochaetes, flatworms, and nematodes. This is quite different with macroinvertebrates in upstream and downstream reaches, where they generally contained a higher proportion of Trichoptera and Ephemeroptera.

Conclusions

We conclude that the highest environmental impact of trout farming appears in sites close to farm outlets. However, it seems that self-purification capacity and high water flow rate of the river can dilute effluents to some extents. Therefore, the biotic index showed no alarming condition at the furthest downstream stations. In general, based on the findings of this research, it is believed that the environmental impacts of fish farming is mostly attributed to the production level, dilution rate, and self-purification capacity of effluent to water body.

Key words
Aquaculture, Effluents, Macrobenthic, Fish farms, Water Quality