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Limno-Ecological Properties of Deep Reservoir, Karakaya HEPP, Turkey

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ABSTRACT

Karakaya Dam is the third largest dam lake and the second biggest electric generation plant in Turkey. CCA, UPGMA were explained that the effects of selected environmental factors on the composition and structure of macroinvertebrate communities in ecosystem. While the concentrations of nitrite and ammonium were high, the level of orthophosphate phosphorus was low in lake. Amounts of Zn, Cu, Pb, Fe, Cd, Cr were analyzed from sediment samples and monitor organism in the ecosystem. Consequently, there was a high level of metal pollution in the ecosystem and the organisms living in the sediment were directly affected by this pollution.

Key Words: *Environmental factors, biomonitoring, water quality, metal pollution, Karakaya Dam Lake.*

1. INTRODUCTION

Improving Turkey's water resources, which has hydrostrategic significance, is very important for the protection of the natural balance of ecosystems, as well as for the socio-economic development of our country.

Turkey is gradually drawing away from having rich natural water resources. Various problems emerge in several regions due to irregular precipitation and the effect of geographical conditions. Building dam lakes is considered as the primary solution to these solutions. Dam lakes are generally established for purposes like energy generation (hydro-electric power plant, HEPP), irrigation, providing drinking water and protection from flood. On the other hand, dam lakes have the property of being constantly receptive environments. In other words, they are affected from environmental pollution in the first degree. These pollutants have a negative effect especially on the living beings in water, and come in contact with humans through food chain [1].

The most important rivers are the Euphrates and Tigris, both of which are transboundary rivers originating in Turkey and flowing into the Persian Gulf. The Euphrates River is the most important river in south-eastern part of Turkey. Karakaya Dam (HEPP), which came into activity in 1987 [2], is one of the important water reservoirs on the Euphrates River Basin. After Atatürk Dam, it is the second biggest electric generation plant. City center and other settlement areas located near the dam lake, and the direct transfer of sewer and industry wastes as well as pollutants from agricultural areas into the lake until opening of treatment plant constitute the main reasons of pollution.

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There are several reasons for using biological surveys in monitoring water quality. Conventional water quality surveys do not integrate fluctuations in water quality between sampling periods. Therefore, short-term critical events may often be missed. The biota, especially benthic macroinvertebrates, reflects both long and short term conditions [3-5].

Macroinvertebrates are useful biological monitors because they are found in all aquatic environments, are less mobile than many other groups of organisms, and are of a size which makes them easily collectable. Moreover, chemical and physical analysis for a complex mixture of pollutants is generally not feasible [4]. The aquatic biota, however, shows responses to a wide array of potential pollutants, including those with synergistic or antagonistic effects. Additionally, the use of benthic macroinvertebrates has been shown to be a cost effective monitoring tool. The sedentary nature of benthos ensures that exposure to a pollutant or stress reliable denotes local conditions, and allows for comparison of sites that are in close proximity.

In this study, water quality and benthic invertebrate community structure of Karakaya Dam Lake were examined. Heterogeneous areas in the study area were compared in terms of both water quality variables and trophic level and biological diversity, and ecosystem quality was evaluated.

2. MATERIAL AND METHODS

The effects of selected environmental factors on the composition and structure of benthic invertebrate communities in the Karakaya Dam Lake were investigated in October 2005-November 2006. Samples were taken sampling sites by monthly. In every sampling period, the physical-chemical parameters of water were measured vertically. In the study area, six sampling points were selected and taken in order to define the character of the water system.

Sampling points demonstrating the ecological characteristics of the lake were selected from upper basin to down basin (Figure 1 and Table 1). Stations 1 and 4 were near settlement shore line of the lake. St 2 is demonstrated as the centre of ferry boat transportation between Malatya to Elazığ. Sts 3 and 5 were located far of settlements and the central line of the dam lake. St 6 was located on the upper basin of the dam lake. Thus the sampling stations were shown with respect to their different water qualities in the lake.

Table 1. Coordinates of sampling station in the study area.

Sampling stations	GPS coordinates
st 1	N 38° 28".866
	E 38° 23".498
st 2	N 38° 28".742
	E 38 27".749
st 3	N 38° 29".315
	E 38° 26".744
st 4	N 38° 29".680
	E 38° 21".353
st 5	N 38° 30".618
	E 38° 24".861
st 6	N 38° 34".075
	E 38° 21".744

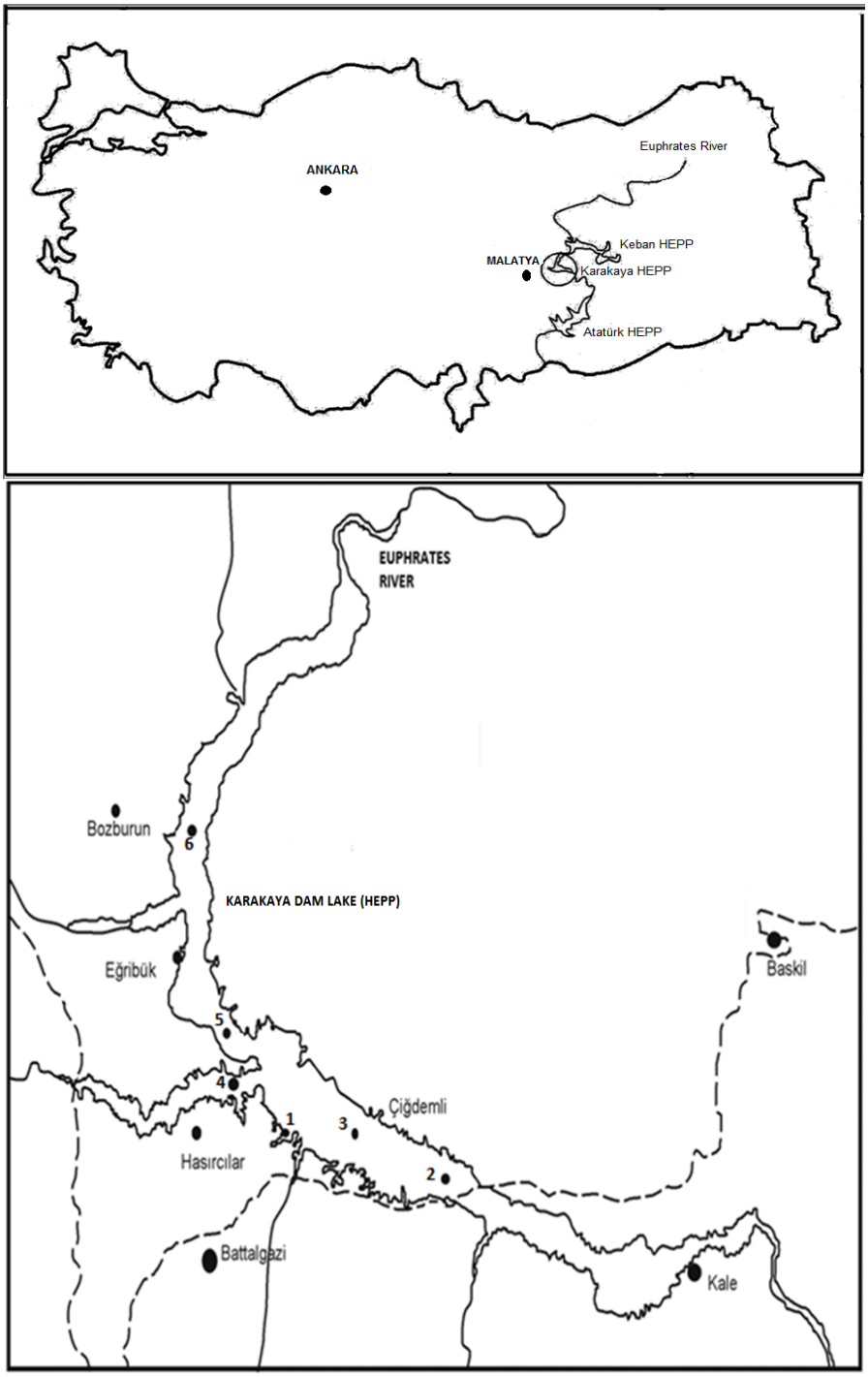

Figure 1. Map of Turkey showing the location of Karakaya Dam Lake and sampling sites.

Maximum depth of Karakaya Dam Lake was 45 m in the study period. Water samples were collected using a Ruttner water sampler (Hydrobios) at 5 m depth intervals from the surface to 0.5 m from the bottom. Dissolved oxygen (oxygen meter, YSI 55), temperature, pH (pH meter, YSI 56), and conductivity (conductivimeter, YSI 30) were measured *in situ*. Water samples were filtered by GF/F paper immediately in the laboratory. Phosphate, nitrate, ammonium, Ca^{2+}, Mg^{2+} were determined according to [6], nitrite according to [7], sulphate according to [8].

For each sampling point, macroinvertebrate species were collected from the top layer (10 cm) of the sediment in the lake by Eckman grab [9]. Macroinvertebrates in the lake were sampled in triplicates per sampling point for faunal analysis. Each core was carefully sieved (mesh sized 500 µm) and preserved in 85% alcohol [9, 10]. In the laboratory, the organisms were identified into species– genus level where possible using the standard literature and nomenclature described.

For the analysis of the groups Shannon-Weaver diversity index was applied to estimate the population structure and species changes in the sampling stations [11]. The

effect of the environmental variables on the species abundances were investigated by CCA (canonical correspondence analysis) using the CANOCO 4.5 software [12, 13]. To detect the relationship between communities and the environmental factors Jaccard's Coefficient test of unweigthed pair group mean averages, UPGMA method and NTSYS 2.10 software were used [14] to generate cluster dendogram plots.

3. RESULTS AND DISCUSSION

3.1. Water Quality Variables

According to results of the physical and chemical analysis conducted during the study period, water quality of the area was evaluated with regard to the classification of surface waters. Nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), ammonium nitrogen (NH_4-N) and orthophosphate phosphorus (PO_4-P), which have a restrictive effect on aquatic organisms and which are the main nutrient salts, were determined as water quality criteria [15].

pH value, which is close to neutral in the winter season, was found to be at a high level of alkali (pH 7.55 in st.1,winter - pH 9.24 st.2, summer). Dissolved oxygen amount was observed to be high in every season (6.944 mgL^{-1} in st.3, summer – 11.516 mgL^{-1} in st.1, spring). In st 1, its values measured as PO_4-P, 0.435 μgL^{-1} and NH_4-N 0.597 mgL^{-1} in the winter season were found to be higher compared to other sampling points. This observation was distinctive in December. NO_2-N level was measured 0.124-0.130 mgL^{-1} in st.1, February.

In the autumn season, EC values were found to be 510.00 $mScm^{-1}$, PO_4-P values were found to be 0.241 μgL^{-1} and NH_4-N were measured to be 0.504 mg L^{-1} in st 1. NO_2-N amount was found to be 0.015 - 0.034 mg L^{-1} in st.1 and 4.

In the spring season EC values (419.056 $mScm^{-1}$ in st 1 and 418.978 $mScm^{-1}$ in st 4) were detected to be high and PO_4-P value of (0.884 μgL^{-1}) and NH_4-N value of (0.665 mgL^{-1}) was found to be distinctive in st.1. NO_2-N ion concentration in st.5 was determined as 0.010 mgL^{-1}.

In the summer season PO_4-P (0.141 μgL^{-1}) and NH_4-N (0.267 mgL^{-1}) amounts were found to be high in st.1 as in other seasons due to the increase in pollutant amount and temperature (especially the measurements of June were high). In all stations NO_2-N ion was found to be within the value of 0.004 - 0.008 mgL^{-1}.

NO_3-N, which enters into aquatic systems generally by surface precipitations, is found in low concentrations. NH_4-N amount in water increases usually in anaerobic conditions, and its presence is an indicator of the water pollution. The presence of NO_2-N indicates an active biological activity towards pollution in the environment. A general look at the ecosystem of Karakaya Dam Lake reveals that Secchi disc measurements vary depending on periods with rain and mixture (45 m depth in st.3 in March was measured as 3.09 m, and Secchi disc depth was found to be 5.8 m in November).

3.2. Biological Variables

In the study area a total of 7 macroinvertebrate taxa were identified with Oligochaeta, Bivalvia, Gastropoda and Insecta. Most dominant and abundance species were *Dreissena polymorpha* and *Tubifex* sp. The diversity of macroinvertebrates was calculated based on the Shannon-Weaver diversity index. These results indicate that the highest diversity was recorded in April and October and order to sts 2 > 5 > 4 > 3 > 6 > 1.

Cluster analyses based on macroinvertebrate species distribution divided the stations into 2 main groups with macroinvertebrate assemblages varying in density, composition and tolerance to environmental variables (Figure 2). Species with similar characteristics tended to cluster with these from similar habitats; for instance, st 1 was differenced from the other stations. The CCA results also revealed similar relationships. Other stations belong Group II. Stations 3 and 5, which have similar sedimental structure, were found to belong to the same branch due to their similar species composition.

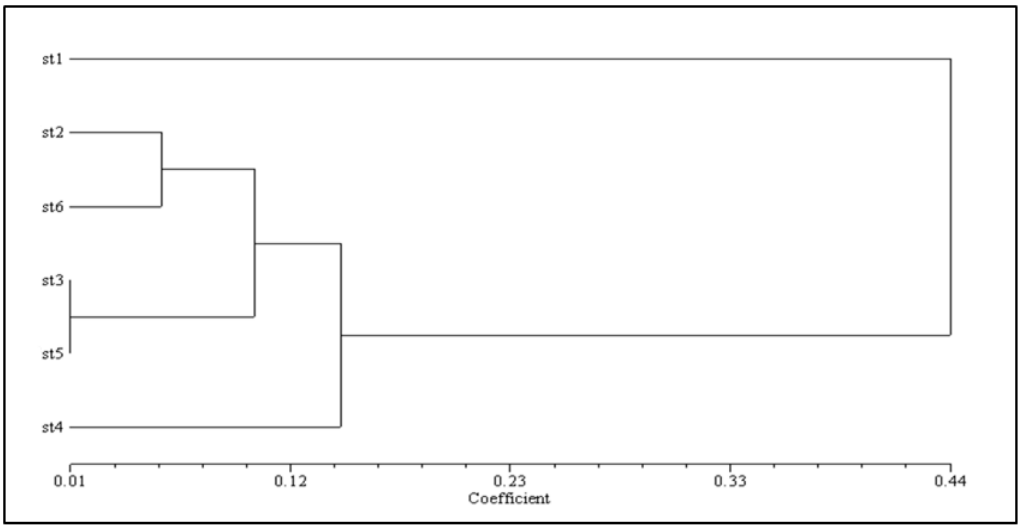

Figure 2. UPGMA classification based on benthic macroinvertebrate community reported during study period.

The influence of 10 environmental variables on the distribution of macroinvertebrate in Karakaya Dam Lake was assessed using canonical correspondence analyses. The CCA scores for species and sites were observed to be similar to UPGMA results. Polluted sts 1 and 4 were separated in CCA triplot (Figure 3). *Chironomus anthracinus* was DO and *Chironomus plumosus* was closely related to PO_4-P and NO_2-N. *D. polymorha* and *Tubifex* sp. were located in the centre of CCA diagram due to their abundancy and high frequency behavior.

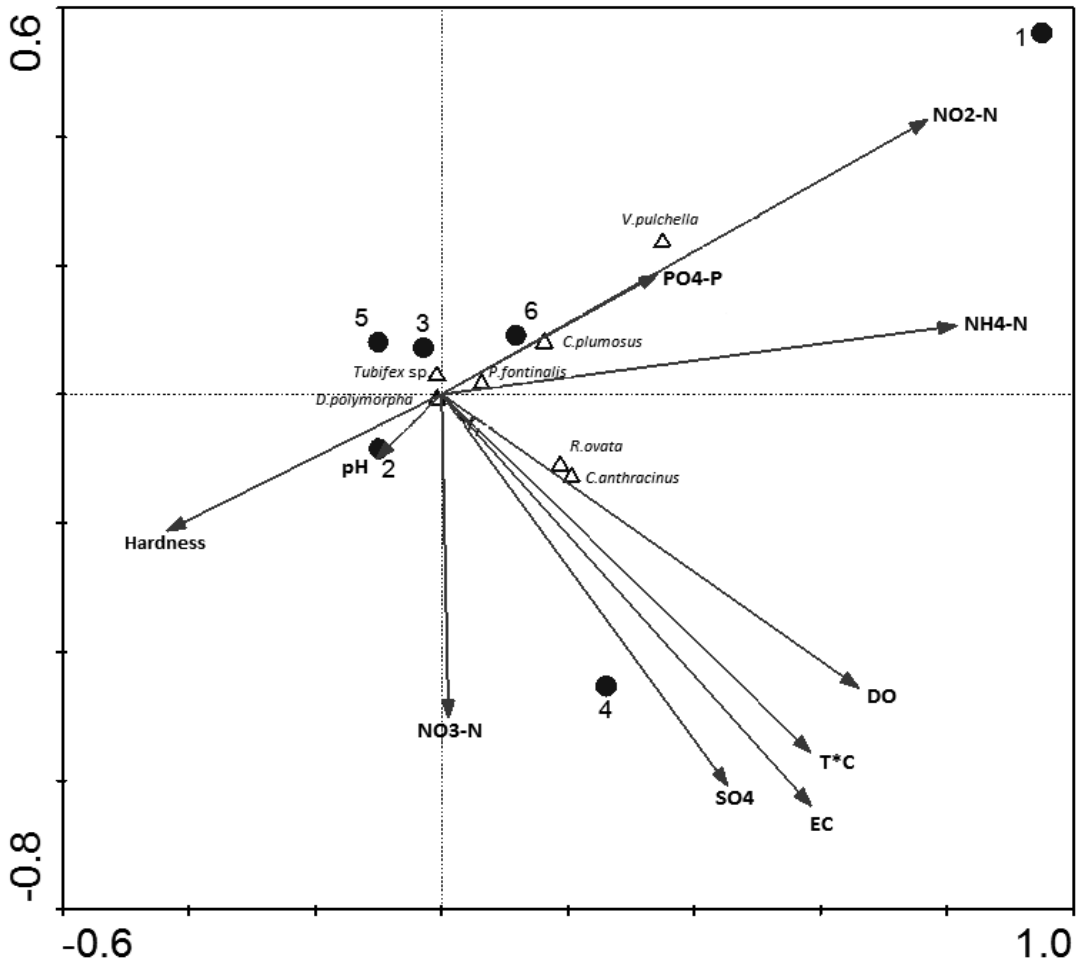

Figure 3. CCA triplots of macroinvertebrate and physicochemical variables (TºC, DO, EC, pH, NO_3-N, NO_2-N, NH_4-N, PO_4-P, SO_4, hardness) showing the species with the highest scores in the axes and the triplot scores of variables.

Dam lakes in agriculturally used catchment areas are subject to various stressors. During heavy rainfall, runoff from agricultural fields may introduce soil, nutrients and pesticides, and increases the discharge. Also sewage and boat traffic emerges as another important pollution factor [16, 17]. It has been shown that the impact of pollutant is an important parameter which influences the aquatic fauna [3, 4].

The indication of non-point source contamination via chemical analysis is costly. Hence, the indication via benthic macroinvertebrate biomonitors could give evidence over a longer period and therefore would be more cost-efficient. Furthermore, it would indicate not only the concentration of chemicals, but also the toxicity of the contamination [18].

Environmental effects of *Dreissena polymorpha*, the most intensely found species, on dam lake ecosystem are directly related to its bio-ecological characteristics: being a fouling organism, having high potency of reproduction, being easily transported, having free-floating larvae, having high ecological tolerability. *D. polymorpha* is a species frequently seem in natural lakes and dam lakes in our country. It causes big problems in the Euphrates river basin especially in Atatürk and Birecik Dam plants. Thus, it was determined as a monitor organism as it would reflect the water quality of Karakaya Dam Lake.

In the study period, analysis of amounts of Zn (mgL^{-1}), Cu (mgL^{-1}), Pb (mgL^{-1}), Fe (mgL^{-1}), Cd (mgL^{-1}) and Cr (mgL^{-1}) were obtained from sediment samples taken once from sampling points due to the high cost of analysis. Concentrations of pollutants in monitor organism in the habitat were determined (Table 2).

Table 2. Metal concentration (mgL^{-1}) of sediments and *D. polymorpha* (sample in st 6 could not taken).

Samples	Zn (mgL^{-1})	Cu (mgL^{-1})	Pb (mgL^{-1})	Cd (mgL^{-1})	Fe (mgL^{-1})	Cr (mgL^{-1})
st 1	43	16.2	20.1	11.2	9555	52
st 2	26	15.8	17	11.3	9700	62
st 3	20.3	14.7	33.2	10	9400	56
st 4	28.1	16	21.8	13.4	10110	81
st 5	32.5	17.9	42	5.6	10160	101
D.polymorpha	15.6	7.2	11.1	6.3	1420	2

According to the results, there was a high level of metal pollution in the ecosystem and the organisms living in the sediment were directly affected by this pollution. The accumulation of heavy metals in mussels is determined by the supply from the sediment. In study area, the major input comes from the boat traffic, near lake settlement, and city, whose load strongly influences the enrichment of heavy metals in *D. polymorpha*. The results achieved so far indicate a balance between the heavy metal concentrations in the food and breathing water on the one hand and those found in the mussel bodies on the other hand. In addition, the dam lake was observed to be getting polluted also in terms of concentration of nitrogenous compounds.

4. CONCLUSION

In water quality studies, the changes in nitrogen and phosphor amounts are used in determining the trophic level of the lake [19, 20]. Karakaya Dam Lake has ultraoligotrophic level of phosphate amount, mesotrophic level of nitrate amount, and oligotrophic level of ammonium.

It was detected that PO_4-P (μgL^{-1}) and NO_3-N (mgL^{-1}) concentration of the lake was low, and NH_4 ion amount periodically increases depending on surface rainfalls. NO_2-N (mgL^{-1}) ion concentration was found to be high in all sampling periods. Several villages benefit economically from the dam lake. Moreover, there are agricultural areas situated parallel to the lake shore. Therefore, the pollutants coming from the villages and agricultural areas caused NO_2-N values to be high.

Water quality was identified as PO^{-3}_4-P, NO^{-}_3-N and NH^{+}_4-N amounts which show parallelism with the trophic level.

Saprophic level of aquatic organisms is the most important factor affecting the trophic level of ecosystems. Similarly, patterns in species diversity were better explained by intra-lake habitat variables than by water chemistry [4, 21]. More dominant and abundant species were found at β-mesotrophic level in the lake. According to these findings, Karakaya Dam Lake was established as a β-mesotrophic point.

In Karakaya Dam Lake, sewer wastes of Boran (st 1) and Hasırcılar (st 4) villages are deposited to the dam lake (interview with the villagers). Limnological studies conducted in Karakaya Dam Lake have revealed that Boran and Hasırcılar Villages carry a pollution load. Due to its ecological tolerance values and superiority of spreading to the habitat, *D. polymorpha* as a monitor species is essential in terms of providing healthy results in long term studies conducted in the dam lake [3, 4, 9, 10].

According to the results, in March 29 - April 02, 2010, algal bloom was occurred due to increasing nutrient and water temperatures in Boran village (st 1). *Peridinium* (Myzozoa) has been found high density and dominant species in the period. This short term eutrophication killed some little size fish, *Alburnus* species in the pool near st 1 [22].

Karakaya Dam (HEPP), which is situated on the Euphrates River that is one of the rare river basins in the world, is an important aquatic ecosystem used for irrigation, fishing and recreation purposes by the province of Malatya and surrounding settlements. It is also one of the dams included within the scope of the Southeastern Anatolia Irrigation Project. Thus, the protection of the area gains further significance.

Based on the results obtained, it was confirmed that benthic macroinvertebrate communities are strongly affected by the occurrence of highly polluted conditions. Urbanization and anthropogenic activities, whether industrial chemical productions or agricultural processes, can have a marked effect on the quality of the Karakaya Dam Lake's waters. Inevitably, these effects influence the dam lake communities. The results confirm that the role of macroinvertebrate monitoring as a means of evaluating the impacts of anthropogenic activities could be regarded as a good method for freshwater and sediment biomonitoring.

Moreover, to determine the future position of the dam lake, aquatic ecosystem quality as well as the qualitative and quantitative composition of living beings should be followed by long term monitoring studies, and necessary measures should be taken by comparing the results of these studies with those of available studies.

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