Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.6, No.19, 2016

Assessment of Macroinvertebrate Communities in Enda Gabr Stream, in Mekelle, Northern Ethiopia

Solomon Tesfay[1*] Mekonen Teferi[1] Shicur Aragaw[2] Weleterifael Abrha[3]
1. Mekelle University, Department of Biology, Mekelle, PO Box 231, Tigray, Ethiopia
2. Amara Education bureaus, Dessie, Amara, Ethiopia
3. Tigray Education bureaus, Aby-Adi, Tigray, Ethiopia

Abstract
The aim of this study was to investigate the communities of macroinvertebrates and pollution status of the stream. Macroinvertebrate samples were collected from 8 sites by using appropriate systematic sampling techniques using D-frame net. The collected Mud, sand, small gravels and detritus as well as associated invertebrates were washed through 250 µm sieve. Materials retained on the sieve were sorted and examined under a dissecting microscope and all organisms were removed and placed in labeled vials. Water quality parameters were assessed using benthic macroinvertebrates index and pollution tolerance indexes. A total of 20 taxa belonging mostly to Oligochaeta, Ephemeroptera, Chironomidae, and Diptera were recorded. Macroinvertebrate diversity indicates an overall water degradation and vegetation disturbance effect throughout the stream. Based on the Benthic Macroinvertebrate Index and Pollution Tolerance Index, the water quality of Enda Gabr stream showed possibly impaired and impaired, respectively. The results revealed that human interference in stream water resulted in serious ecological imbalances in the natural life cycle and impact on human welfare. It is recommended that immediate management actions are crucially needed to improve the ecological potential of the stream.
Keywords: Macroinvertebrate, communities, pollution, stream, Enda Gabr

1. Introduction

Macro invertebrates inhabit river beds, lakes and reservoirs and are associated with various types of substrates such as mineral sediments, detritus, macrophytes and filamentous algae[1]. They are essential elements in lentic and lotic trophic webs, participating in the energy flow and nutrient cycling [2]. They are also important food resources for fish [3] and some insectivorous birds [4].

The macroinvertebrates have been found as the most common faunal assemblages for bio assessment and provide more reliable assessment of long term ecological changes in the quality of aquatic system compared to its rapidly changing physicochemical characteristics[5].Well developed water quality monitoring programs involve the measurement of physical, chemical and biological parameters and provide valuable information on the impact of water quality on the benthic macro invertebrates which respond differentially to biotic and abiotic factors in their environment and consequently, the structure of macroinvertebrate has long been used as bioindicators to assess the water quality of a water body[6]. The advantage of macro invertebrates as bio-indicators inhabiting the lakes, reservoirs rivers, streams and other water bodies are that they are visible to unaided eyes and can be retained by a sieve having a mesh size of 500µm pore diameter, have sedentary and long life span and are significantly sensitive to organic pollution, thermal pollution, substrate alteration and toxic substances.

Macro invertebrates circulate the preferred nutrition for numerous fish species. A variable macro benthic community, being able to use more efficiently the internal nutrition and adapt better to climate changes, is a guarantee for a good depurative efficiency. Water pollution and the alterations of fluvial ecosystems morphology in vertical and horizontal directions; influence the benthic macro invertebrates' distribution and the possibility of fulfilling their lifecycle[7]. Ecological water quality is closely related to the biological communities' conditions. The biological elements of ecosystem are often damaged by anthropological activities, and those reacts by modifying or adapting their composition and structure [8].

Living organisms can increase the sensitivity of monitoring providing information on how pollutants affect macro invertebrate performance under natural conditions. For this assessment has been necessary to collect data related to the taxonomic communities' composition, the abundance, the taxonomic diversity and sensitivity. Macro invertebrates are a crucial component of water ecosystems. Among the macro invertebrates, Ephemeropterans, Plecoptera and Trichopterans (EPT) are very important in assessing water quality as they show low tolerance toward water pollutants. These organisms are sensitive to environmental changes that may occur in clean and well oxygenated waters. Therefore, EPT assemblages are frequently considered as good indicators for water quality [1].

Macro invertebrates constitute an important component of biodiversity in lotic systems [9]. They are diverse, have short generation times and are easily dispersed. As a group, macro invertebrates are sensitive and respond to both natural and man-induced changes in their environment [10].

The increasing of human activity and industrial wastage released in to Enda Gabr stream can lead to serious disturbance for the communities of macroinvertebrates. As the stream is at center of the city, there are activities related with urbanization like disposal of garbage, animal wastes, Vehicle washing and irrational practices. Moreover, there are bridges and roads crossing this stream causing easy accessible for illegal waste disposals and Bajaj (car) washers. As result, macro invertebrate communities are exposed to different environmental impacts that might cause difference in macro invertebrate communities specifically, abundance, species richness and distribution.

Generally, problems of stream water pollution by anthropogenic and industrial wastes have affected the communities of macroinvertebrates. So, proper assessment of macroinvertebrate communities is a vital role in identification and knowing the pollution status of streams. Moreover, it enables to rank the macroinvertebrate communities based on their range of tolerance to water pollution. As to our knowledge there is no study on macroinvertebrate community composition on the study stream. So as to fill this gap, our study, provides important information on the assessing of the macroinvertebrate communities and the quality of water in the stream. In addition, this study can help to develop and implement effective control methods and intervention strategies for the pollution of streams. The data from this study can provide basic understanding on the status of stream for the people and if available, historical information.

The objectives of this study were to (1) identify the species abundance, richness, composition and diversity of macro invertebrate, (2) classify the pollution tolerance macro invertebrate by using its range of sensitivity, (3) explain the water quality of the stream by using macro invertebrates as a biological indicator and (4) list the different factors that possibly disturbs macro invertebrate communities in the stream.

2. Materials and methods

2.1. Study Area

Mekelle is the capital city of Tigray Regional state located 780 km north of Addis Ababa, the capital city of Ethiopia. Its geographic location is 13° 32’ N and 39° 33’ E. It has an average altitude of 2200 meters above sea level with a mean minimum, mean maximum and mean average monthly temperatures of 8.7, 26.8 and 17.6° C, respectively [11]. Amount of rainfall is variable in Mekelle; on average about 600 mm, and more than 70% of it falls between July and August, followed by long dry season [11]. Mekelle has an estimated total population of 215,546 [12]. Among the streams in the city one is Enda Gabr stream which is located at about 2 km from the center towards northern edge of Mekelle city. People living along this stream use the water for very small scale irrigation practices, washing, and domestic use and for construction purposes.

2.2. Macroinvertebrate Sampling and Laboratory Techniques

Sampling was carried out during the dry season on March 2015 during stable flow conditions. Macro invertebrate samples were collected from 8 sites by using appropriate systematic sampling techniques. Quantitative macroinvertebrate multi habitat sampling method was used in this study [13]. Eight sampling locations were established along the stream at approximately equidistant based on their geographical feature and suitability for sampling of the stream. Samples were collected using D-frame net (30 x30cm, 500µm mesh, from a 50m reach along the stream side), at each sampling points having different microhabitats. The composite sample of each site was placed into a site wise labeled 2 liter plastic vial, fixed with 10% formalin. Up on return to Mekelle University fishery and aquatic ecology laboratory, all samples were decanted and sieved through a 250µm sieve. Materials retained on the sieve were sorted and examined under a dissecting microscope (Olympus: SZX 9), and all organisms were removed and placed in labeled glass vials. Samples were later transferred to 70% ethanol and identified. Organisms were identified to family level using Aquatic Invertebrates of South African Rivers field guide [14].

2.3. Water quality

Water quality of the stream was assessed using the biotic parameters, Benthic Macroinvertebrate

Index (BMI) [15,16] and Pollution Tolerance Index (PTI) [17]. In BMI each selected index has a formula and specific range of values (i.e. criteria) that indicate three stream conditions: unimpaired, possibly impaired and impaired. The Pollution Tolerance Index uses indicator organisms and their pollution tolerance levels to determine the overall, long-term health of a stream. Organisms were collected and identified to which tolerance groups they belong using Mitchell and Stapp [17] water quality ratings. For each of the three tolerance groups an index value was given. The water quality value is determined by multiplying the number of kinds of organisms in each group by that groups index value. By adding all the numbers from each group, a single index value was calculated. By referring to the index value chart, a rating of water quality was given.

2.4. Data analysis

Macroinvertebrate communities sample was analyzed by Multimetric techniques. Multimetric analysis employs a set of metrics, each of which describes an attribute of the macroinvertebrate community that was shown to be responsive to environmental condition gradients. By using Multimetric approach, macroinvertebrate communities as measures of diversity, richness, Composition, abundance, total abundance and macroinvertebrate Community indices was expressed in the form of tables.

2.5. Results and Discussions

2.5.1. Macroinvertebrate metrics

In total, 20 taxa of 7 orders were found at 8 sampling sites. A total 2037 individuals were identified to family level. Based on their abundance, the most dominant taxa collected were Chironomidae (893), Caenidae (348), Baetidae (187) and Oligochaeta (265).

Chironomidea were the dominate taxa (family) in site EG4 and EG5, having a relative abundance of 61.4% &71.1%, respectively (Table 1), according to Marques *et al*. [18] Chironomidae exhibits high tolerance to eutrophic conditions, showing significant increase in abundance in response to anthropogenic organic enrichment and consequent water quality deterioration, being considered a reliable environmental indicator. On the base of this data, those sites are highly affected by anthropogenic sources such as car wash, industrial wastage, domestic wastage and so on.

The distribution of the macroinvertebrates varies throughout the study sites and taxa common to all sites were Chironomidea, Caenidae, Baetidae, Libellulidae and Snail groups (Table 1). Taxas like, Hydrometridae, Corixidae and Phoridae were uniquely distributed to site EG3 and Syrphidae was to site EG5 (Table 1).

Macroinvertabrate metrics like abundance and richness of assemblages or communities are simple measures and are often used in assessments of the health of streams like our stream Enda Gabr; based on the metrics information, species-poor systems are generally assumed to have polluted, semi polluted or degraded water quality [19].

Based on our knowledge there is no any study of macroinvertebrates on Enda Gabr stream to compare with the present results. Thus, our results suggest that the composition and the structure of the community of benthic macroinvertebrates of this stream could be used as references and baselines from now onwards. In Enda Gabr stream, throughout the eight study sites, 2037 macroinvertebrate individuals were identified (Table 1). The dominance macroinvertebrates are family Chironomidae, Caenidae, Baetidae and Oligochaeta. Among the different macro invertebrates that found in the study stream, the number of chironomidae and Caenidae were the dominant group, with 219 individuals of Chironomidae in EG5 and 136 individuals of Caenidae from EG6. This indicates chironomidae live in slow running pools and runs with sandy substrates associated with high organic matter load and aquatic macrophytes. Chironomidae can exhibit high tolerance of eutrophic condition and consequent water quality deterioration. However, Caenidae (Cains fly) prefers stream bed with stones and muddy areas having some macrophytes and grass covers. Similar explanations and characteristics were given by Gerber & Gabriel, [14].

The highest Shannon diversity and Margalef index was recorded in site EG3, 2.10 and 2.64 and the lowest was 1.21 in EG5 and 1.37 in EG6, respectively (Table 2). Similarly, site EG3 has highest species richness and sites EG4 and EG6 the lowest (Table 2). According to Barton & Metcalfe-Smith [20], richness is known to decline in polluted or stressed environments, so that site EG4 and EG6 are more affected by environmental pollutions or anthropogenic disturbance like solid garbage's and liquid wastes are damped by the surrounding dwellers. According to Weber [21], the total number of families or family richness present in the sample was also accounted for this purpose, which is to mean, Taxa richness and EPT taxa richness decreases with decreasing water quality. In addition, to species richness measurements, the total number of individuals collected in the sample (number of organisms) are important in determining the water quality of the stream. More organisms in the sample may indicate a good quality of the water.

Species evenness value is produced a similar pattern, with the highest value of site EG2 and lowest value EG5 (Table 2). These species evenness were higher in EG2 reflecting the organic enrichment in this system. According to Wiederholm [22], the input of organic substances into such a system can reduce the level of dissolved oxygen (DO), hindering the respiration of the animals present, so that more sensitive species may not survive. *Chironomidae*, known to tolerate situations of extreme hypoxia [23], predominated in streams in the presence of such conditions.

According to Gencer and Nilgun [24], most values measured using the Shannon diversity index range from 1.5-3.5, rarely exceeding 4.5. Values above 3.0 indicate that the habitat structure is stable and balanced and values under 1.0 indicate the presence of pollution and degradation of habitat structure. On the basis of these criteria, many sites of Enda Gabr stream exceeded above 1.5 level of the Shannon diversity index, this indicates presence intermediately disturbed large habitat compositions and partially stable structures. However, none of the sites are with perfect habitat structure and balance. Shannon Diversity indices values indicate little variation between sample point (Table 2) displaying an increase only in site EG3, which can be explained by the relation between species richness and Relative abundance of macroinvertebrate in this site. However, in EG5, decreasing of Shannon diversity because resulted in smaller diversity and richness.

2.5.2. Determination of stream water quality using macroinvertebrate indices formula

Water quality of streams can be monitored using benthic macroinvertebrates indexes having different formulas. The calculated results obtained by using specific index formulas enable to categorize streams. Each index has a formula and three stream conditions with a specific range of values (i.e., criteria). These three stream conditions are unimpaired, possibly impaired and impaired. Based on the criteria and formulas, the status of Enda Gabr stream seems impaired and possibly impaired with the 8 selected indexes except the snails (Gastropods) which indicate as unimpaired (Table 3). Throughout the study stream aquatic earth worm covers about 13% of the macroinvertebrate community and according to David, *et al.*[25], macroinvertebrate communities index, ranging from 10-30 are possibly impaired, and aquatic earth worms are often found in relatively higher numbers than more oxygen sensitive or pollution sensitive groups at sites receiving excessive organic inputs like untreated sewages.

Among the EPT members, Ephemeroptera was the only groups found and their corresponding index was 9.2% which showed the stream as possibly impaired [25, 15]. Based on, Culp and Halliwell [26], explanation, sites of stream that are of higher quality supports all three groups in equal proportions. With regard to this idea, Enda Gabr stream or its sites do not support the EPT members proportionally and do not have good water quality, rather it is polluted. Except some Ephemeroptera (mayflies), the other two groups were not recorded in the stream or stream sites (Table 1). According to DeWalt *et al.,* [27], the EPT members are known to be more sensitive to pollutions or other stressors and their presence is often considered an indicator of a healthy stream. Using the groupings of sensitive taxa such as the presence of EPT, which measures the proportion of individuals in the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are also used as an indicator of a healthy stream. Similarly, taxa richness and EPT taxa richness decrease with decreasing water quality [21] and the decrease in family richness may indicate a high disturbance in the stream. According to, Bode *et al.* [28], EPT richness within a sample consisting the three families were considered least tolerant to organic pollution, thus, a sample with high EPT richness was considered indicative of good quality water [29].

All over the study sites, % worms (aquatic earth worms) were obtained to be 13.0 (Table 3). According to David, *et al.* [25], macroinvertebrate communities index value ranged from 10-30 are possibly impaired, and worms are often found in relatively higher numbers than more oxygen sensitive groups at sites receiving excessive organic inputs such as untreated sewages. Based on those criteria, water quality of the stream becomes poor and unhealthy that has been affected by much environmental pollutions. A site or sites with a higher percentage of Ephemeroptera, Plecoptera, and Trichoptera (% EPT) and low percentage Chironomidae (% Chironomidae) is highly correlated with high quality water [30]. However, there were only Ephemeroptera groups in Enda Gabr stream. According to Culp and Halliwell [26], sites that are of higher quality support all three groups and in equal proportion. Similarly, the sites in Enda Gabr stream do not have high water quality and it was almost polluted. In addition, abundance and richness of assemblages or communities of macroinvertebrates are simple measures and are often used in stream assessments; species-poor systems are generally assumed to have degraded water quality [19]. Metrics to measure stream health can also assess the relative abundance of macroinvertebrates in groups such as feeding mode (i.e., functional feeding groups) or habitat niche [1, 30, 31, 32].

Based on the selected indices, site wise comparison of Enda Gabr stream showed that majority of the sites was unimpaired with the highest in EG1, EG2 and EG3, having 62.5% each. Sites EG4, EG5 and EG7 are impaired where as 50% of EG8 was possibly impaired (Table 4). As sites EG1, 2 and 3 are the head water of the stream and relatively protected areas of the church and holy water in the stream, water quality of the stream sites using these biological indexes or indicators showed as it was healthy. But as we go down and far from the church the sites were relatively non pristine areas and most of them were impaired or affected by human and domestic activities.

Since possibly impaired is a kind of warning, it indicates that the stream still needs protection and taking both impaired and possibly impaired together are higher than those unimpaired. So, special attention should be applied to save the stream from worsening its health causing serious problems for the surrounding dwellers.

2.5.3. Determination of stream water quality using pollution tolerance index (PTI) of the stream macroinvertebrates

Among the macroinvertebrates, Rat-tailed maggot, Water boatmen, Pond snail/ Orb snail, Aquatic earthworm, Horse fly larvae, Mosquito pupa/larva and Water scorpions were grouped as tolerant. Damsel fly Nymph, Dragon fly Nymph and Adult Beetles were clustered to somewhat sensitive. However, the only macroinvertebrate found in the stream belong to the first group (sensitive) was may fly (Table 7). The tolerance measures, was also evaluated by using the measure taxa richness of those organisms considered to be sensitive to perturbation (Number of intolerant families). High number of intolerant taxa possibly will indicate a good stream water quality. The percent of macroinvertebrates considered to be tolerant of various types of perturbation

(Percent tolerant organisms) was also computed since increased number of this metric may indicate an increase pollution level [20].

A water quality index expressed as a single number is developed to describe overall water quality conditions using multiple water quality variables. Because, the calculated pollution tolerance index (PTI) of the study stream (Table 7) enables to judge and rate the water quality of the stream.

Based on the PTI Score above the water quality rating of the stream was fair as it contains a total of 11 macroinvertabrate groups that lei in the 3rd category Fair (11-16) [17]. Since the stream is in the center of the city our expectation was to be poor but due to some protection in the upper portion sites as holy water and church, the overall water quality status becomes fair.

3. Conclusion

Based on the macroinvertebrate metrics, such as species richness, species diversity, distribution, dominance and total abundances of the species were fluctuated species distribution in the stream and the ecological status of the stream was in the range of fair to bad. Thus, the changes in macroinvertebrate communities clearly reflect the impact of the stressor like anthropogenic activities, dwelling and industrial wastes. Therefore, there is no uniform distribution of macro invertebrate species in the stream. The water quality of all study sites have been degraded to varying degree as a result of human activities and industrial pollutants. Generally, both the macroinvertebrate communities and water quality of Enda Gabr stream are endangered and therefore anthropogenic activities such car wash, animal wastes, residence garbage's and industrial wastage released to the stream should be stopped.

Acknowledgments

The authors would like to acknowledge the Department of Biology, College of Natural and Computational sciences, Mekelle University, for laboratory facilities.

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Fig.1. Locations of sampling sites where EG1 is the head water and EG 8 is the entrance to a reservoir (May Duba) and some irrigational cannels.

Table 1. Absolute abundance (N) and relative abundance (ni) of benthic macroinvertebrates in the eight sampling sites along Enda Gabr stream, in March 2015.

Taxa	**EG1**		**EG2**		**EG3**		**EG4**		**EG5**		**EG6**		**EG7**		**EG8**	
	N	**ni**	**N**	**ni**	**N**	**ni**	**N**	**ni**	**N**	**ni**	**N**	**ni**	**N**	**ni**	**N**	**ni**
Coleptera																
Dytiscidae	2	1.0	2	1.9	5	1.7	0	0	6	1.9	0	0	0	0	**0**	**0**
Diptera																
Chironomidae	65	33.7	10	9.4	78	26.6	204	61.4	219	71.1	108	31.4	104	51.0	105	40.9
Tabanidae	0	0	0	0	0	0.0	0	0	0	0	0	0	3	1.5	0	0
Muscidae	4	2.1	0	0	7	2.4	6	1.8	7	2.3	3	0.9	0	0	0	0
Hydrometridae	0	0	0	0	4	1.4	0	0	0	0	0	0	0	0	0	0
Culicidae	3	1.6	0	0	6	2.0	19	5.7	0	0	12	3.5	7	3.4	13	5.1
Phoridae	0	0	0	0	4	1.4	0	0	0	0	0	0	0	0	0	0
Syrphidae	0	0	0	0	0	0	0	0	4	1.3	0	0	0	0	0	0
Ephemeroptera																
Caenidae	55	28.5	20	18.9	72	24.6	14	4.2	15	4.9	136	39.5	19	9.3	17	6.6
Baetidae	20	10.4	30	28.3	40	13.7	10	3.0	20	6.5	33	9.6	21	10.3	13	5.1
Hemiptera																
Gerridae	1	0.5	4	3.8	3	1.0	0	0	0	0	0	0	0	0	0	0
Corixidae	0	0.0	0	0	6	2.0	0	0	0	0	0	0	0	0	0	0
Nepidae	2	1.0	3	2.8	4	1.4	0	0	0	0	0	0	0	0	0	0
Odnata																
Coenagrionide	2	1.0	4	3.8	5	1.7	0	0	3	1.0	5	1.5	0	0	16	6.2
Libellulidae	7	3.6	7	6.6	13	4.4	4	1.2	4	1.3	5	1.5	7	3.4	15	5.8
Gastropods																
Snails	7	3.6	26	24.5	9	3.1	5	1.5	14	4.5	9	2.6	7	3.4	30	11.7
Oligocheta																
Aquatic earth worm	25	13.0	0	0	37	12.6	70	21.1	16	5.2	33	9.6	36	17.6	48	18.7
Total taxa	193	100	106	100	293	100	332	100	308	100	344	100	204	100	257	100
Total insect taxa	161	83.4	80	75.5	247	84.3	257	77.4	278	90.3	302	87.8	161	78.9	179	69.6

Table.2 Shannon diversity (H), Margalef index (d), number of individual (N), species richness (S), species evenness (J) and Dominance (D) of macroinvertebrate in stream.

Site	H	d	S	N	D	J
EG1	1.82	2.47	14	193	0.23	0.44
EG2	1.99	1.93	10	106	0.17	0.73
EG3	2.10	2.64	16	293	0.17	0.51
EG4	1.26	1.38	9	332	0.43	0.39
EG5	1.21	1.75	11	308	0.52	0.30
EG6	1.56	1.37	9	344	0.28	0.53
EG7	1.56	1.69	10	204	0.31	0.47
EG8	1.86	1.62	10	257	0.22	0.64

Table 3: one sample t-test results comparing each metric among the study sites

Response variable	Mean ± SE	t-value	df	p-value
Shannon diversity (H)	1.67±0.12	14.432	7	0.000*
Margalef index (d)	1.86±0.17	11.142	7	0.000*
species richness (S)	11.13±0.89	12.428	7	0.000*
number of individual (N)	254.6±28.89	8.812	7	0.000*
Dominance (D)	0.29±0.04	6.563	7	0.000*
Species evenness (J)	0.50±0.05	10.400	7	0.000*

*=p<0.05

Table 4: List of selected index, their explanation and their status ranges

Index (%)	**Explanation**	Impaired	Possibly Impaired	Unimpaired	Sources
%Midge (Chironomidae)	$=100 \times \frac{Chir}{N}$	>40	10 to 40	<10	Griffiths (1998)
Snail (Gastropod)	$=\frac{100xG}{N}$		0 or >10	1 to 10	Griffiths (1998)
EPT	$=100 \times \frac{E+P+T}{N}$	<5	5 to 10	>10	David et al.(1998) Kilgour (2000)
Worm	$=100 \times \frac{(O+Nem+Tur)}{N}$	>30	10 to 30	<10	Griffiths (1998), David,*et al.*(1998)
Number of Groups	Total number of different major taxonomic groups found	<11		>11	David,*et al.*(1998)
Diptera	$=100 \times \frac{Dipt}{N}$	<15 or > 50	15 to 20 or 45 to 50	20 to 45	David,*et al.* (1998)
Insects	$=100 \times \frac{Insect}{N}$	<40 or >90	40 to 50 or 80 to 90	50 to 80	David,*et al.* (1998)
Dominant Group	$100 \times \frac{Dom}{N}$	>45	40 to 45	<40	David *et al.* (1998) Barbour *et al.* (1999)

Key: N= Total ≠ of individuals
Chir=≠of Chironomidae
G =≠ of Gastropodas
E =≠ of Ephmeroptera
P =≠ ofPlacoptera
T =≠ of Tricoptera
O =≠ of Oligochetae
Nem =≠ ofNematoda
Tur =≠ of Turbularia
Dip =≠ ofall Diptera
Insect = ≠ of all insect taxa
Dom=≠of most abundant group

Table 5. Macroinvertebrate index of formula and criteria for impaired, possibly impaired and unimpaired stream conditions of Enda Gabr are listed below (stream wise)

Index (%)	**Explanation**	**Result**	**Ranges**	**Stream Quality**
Chironomidae	100x893/2037	43.8	>40	Impaired
Snail (Gastropod)	100x107/2037	5.3	1-10	Unimpaired
EPT	100x187/2037	9.2	5-10	possibly impaired
Worm	100x265/2037	13.02	10-30	possibly impaired
Number of Groups	100x97/2037	4.8	<11	Impaired
Diptera	100x115/2037	5.6	<15	Impaired
Insects	100x1665/2037	81.7	80-90	possibly impaired
Dominant Group	100x893/2037	44	40-45	possibly impaired

Table 6. Macro invertebrate index of formula and criteria for impaired, possibly impaired and unimpaired stream conditions of Enda Gabr are listed below (Site wise).

Sites	Chironomidae	Snail	EPT	Worm	No. Groups	Diptera	Insects	D.group	IM	PI	UI
EG1	PI	UI	UI	PI	UI	UI	PI	UI	0	37.5	62.5
EG2	UI	PI	UI	UI	IM	IM	UI	UI	25	12.5	62.5
EG3	PI	UI	UI	PI	UI	UI	PI	UI	0	37.5	62.5
EG4	IM	UI	PI	PI	IM	IM	UI	IM	50	25	25
EG5	IM	UI	PI	UI	PI	IM	IM	IM	50	25	25
EG6	PI	UI	UI	UI	IM	UI	PI	PI	12.5	37.5	50
EG7	IM	UI	IM	PI	IM	IM	UI	IM	62.5	12.5	25
EG8	IM	PI	IM	PI	IM	PI	UI	PI	37.5	50	12.5

N.B: IM= Impaired, PI= Possibly Impaired and UI = Unimpaired

Table 7. List of macroinvertebrates in Enda Gabr stream grouped based on their Pollution Tolerance Index

Sensitive	Somewhat sensitive	Tolerant
May fly	Damsel fly Nymph	Rat Tailed maggot
	Dragon fly Nymph	Water Boatmen
	Adult Beatles	Pond Snail/ Orb Snail
		Aquatic earthworm
		Horse fly larvae
		Mosquito pupa/larva
		Water scorpion
Total check marks: 1 x3pts=3	Total check marks:3 x2pts=6	Total check marks:7 x1pts=7
Add: $\frac{3}{\text{(Sensitive)}} + \frac{6}{\text{(Somewhat sensitive)}} + \frac{7}{\text{(Tolerant)}} = \frac{11}{\text{(PTI Score)}}$		
Water quality rating Excellent (>22) Good(17-22) **Fair(11-16)** Poor(<11)		