Study of Macroinvertebrates Assemblage as an Indication of a Tropical Freshwater Lagoon Water Quality: Ono Lagoon (Côte d'Ivoire, West Africa)

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Abstract— *This study aimed to assess the water quality of Ono lagoon using macroinvertebrates as bioindicators. The Biological Monitoring Working Party (BMWP) scoring system and the Pollution Tolerance Index (PTI) were used to assess the ecosystem health of water. Samples were monthly collected from September 2015 to August 2016. A total of 12145 macroinvertebrates belonging to 47 families, 17 orders, 5 classes and 3 phyla were identified. Macroinvertebrates were mainly composed of Arthropoda, Mollusca and Annelida. The most abundant taxa was Insecta (83.14%) followed by Gastropoda (6.65%) and whereas the least abundant taxa were Achaeta (6.19%), Crustacea (2.39%) and Arachnida (1.62%). The BMWP score was 140, indicating that water was neither very clean nor significantly altered aquatic habitat. According to the PTI, the water was moderately polluted based on the number of moderately pollution-sensitive organisms (52.96%) and the number of aquatic organisms which are fairly and very sensitive to pollution (34.6%). These results showed that biological quality of Ono lagoon can be considered as acceptable.*

Keywords— BMWP scoring system, Macroinvertebrates, Ono Lagoon, Pollution Tolerance Index, Water quality.

I. INTRODUCTION

Macroinvertebrates are diverse array of animals without backbones operationally defined as those that are retained by a sieve or mesh with pore size of 0.2 to 0.5 mm, as used most frequently in stream sampling devices. Lagoon macroinvertebrates include various groups of worms, molluscs, crustaceans, mites, and above all insects (Winterbourn, 2008).

Most invertebrates are important components of lagoon ecosystems. They graze periphyton, assist in the breakdown of organic matter and cycling of nutrients and, in turn, may become food for predators (Hynes and Naba, 2012). Macroinvertebrates are the organisms most commonly used for biological monitoring of freshwater ecosystems worldwide. This is because they are found in most habitats, have generally limited mobility, are quite easy to collect by way of well established sampling techniques, and there is a diversity of forms that ensures a wide range of sensitivities to changes in both water quality (of virtually any nature) and habitats (Hellawell, 1986; Abel, 1999). Studies of aquatic ecosystems macroinvertebrates as biological monitoring techniques have been widely reported and described in the literature (Hart *et al*.,1999; Touzin, 2008; Odountan, and Abou, 2015). Macroinvertebrates assemblages have been widely used as biondicators of the overall health of different aquatic ecosystems within several biotic indices (Raburu *et al*., 2009a, 2009b). Freshwater macroinvertebrates species vary in sensitivity to organic pollution and, thus, their relative abundances have been used to make inferences about pollution loads. In Ono lagoon, increased deforestation and unsustainable agriculture coupled with agro-industrial activities pose threats to the wellbeing of aquatic ecosystems. Major industrial activities include agricultural practices of the Alsacienne Society of Côte d'Ivoire (SALCI) and the Study of Banana Crop (SCB). The proximity of leaching waters of neighbouring agricultural lands is a permanent source of pollution. Given that community livelihoods in Ono lagoon basin revolve around agricultural crop production and fisheries, it is imperative that the wetland ecosystem is closely monitored and conserved to ensure sustainability. Numerous studies have highlighted the importance of using benthic macroinvertebrates for monitoring purposes to support the results obtained regarding physical and chemical variables (Masese *et al*. 2009; Raburu *et al*. 2009a, 2009b; Minaya *et al*. 2013). These organisms were good biological indicators of water quality, due to the fact that they are both abundant and ubiquitous in nature, thereby offering a wide spectrum of observable responses to environmental changes (Turkmen and Kazanci, 2010). Till to date, no study has been undertaken to document the occurrence and distribution of macroinvertebrates assemblage in small lagoon and their response to varying levels of disturbance. The objective of this study is to present the status of water quality and ecosystem health of Ono lagoon using the most community structure indices such as Biological Monitoring Working Party (BMWP) and Pollution Tolerance Index (PTI).

II. MATERIAL AND METHODS

2.1 Study Site

Ono lagoon (5°22'22"N and 3°33'53"W) is a small freshwater lagoon of 481 ha located in the Southeast of Côte d'Ivoire "Fig. 1". Its surface is invaded by a wide variety of habitat types such as emerged plants, free-floating macrophytes, floating leaf plants, submerged plants and white habitats, which considerably reduce the exploitable surface to 162 ha. The main macrophytes are *Echinochloa pyramidalis*, *Eichhornia crassipes*, *Salvinia molesta*, *Pistia stratiotes* and *Hydrilla verticillata*. This lagoon is irrigated by a small river (Wamon River) and connected in downstream to Comoé River. This lagoon, permanently connected to these rivers has an equatorial climate, including two rainy seasons (April-July and October-November) and two dry seasons (December-March and August-September). The permanent linkage with the Comoé River produces typical freshwater characteristics of this lagoon. Agriculture, trade, fishing and domestic wastes are the main anthropogenic activities affecting the functioning of this lagoon.

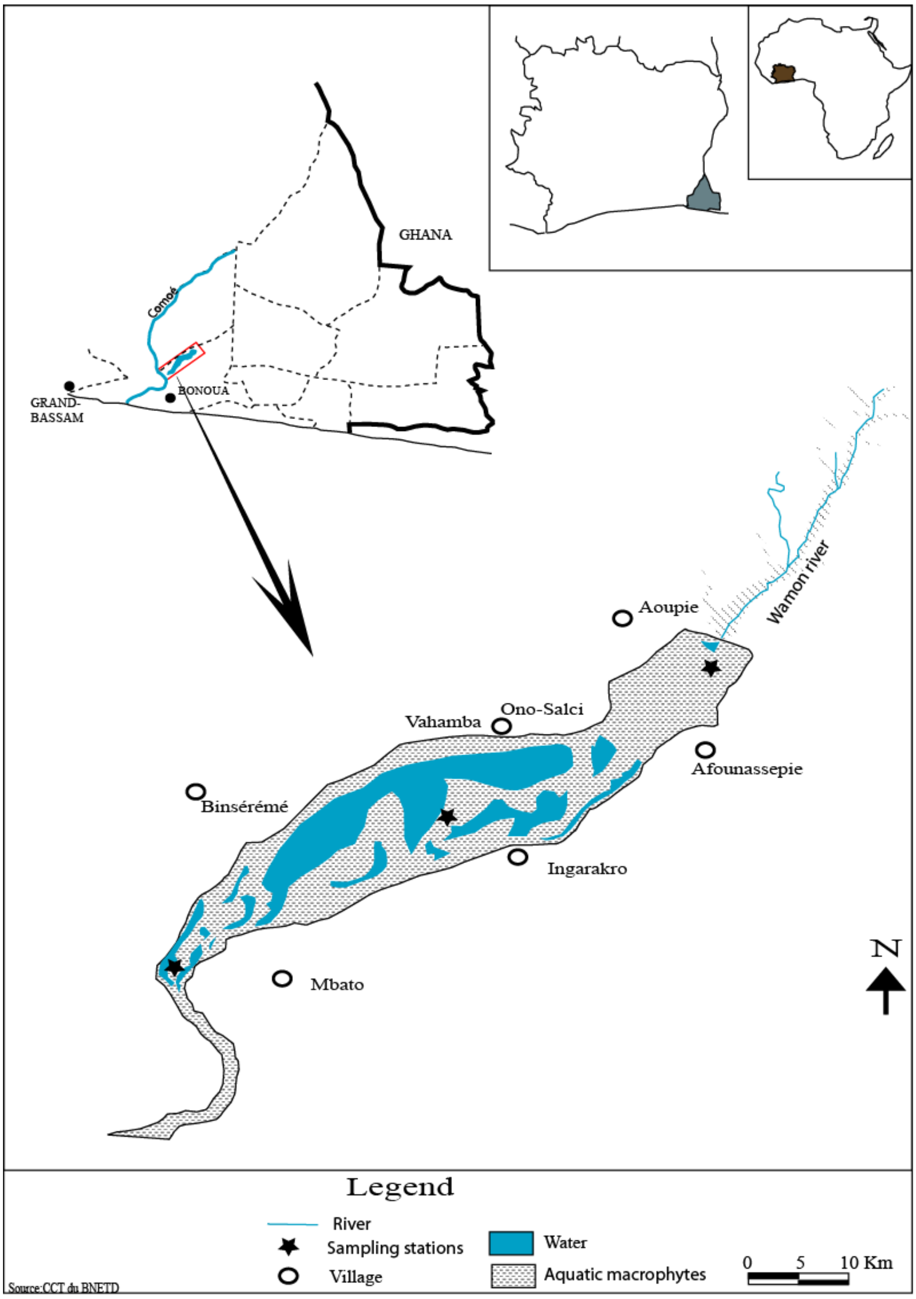

FIG. 1. MAP SHOWING ONO LAGOON AND THE DIFFERENT SAMPLINGS STATIONS

2.2 Measurement of Environmental Variables

The parameters such as transparency, water depth, pH, Total Dissolved Solids (TDS), conductivity and dissolved oxygen were recorded in *situ* between 08.00 am and 10.00 am. Temperature, pH, Total Dissolved Solid (TDS) and electric conductivity were measured using a multi parameter digital meter HANNA 9828 *vs* 2.1. Water transparency was determinate using a 20-cm-diameter Secchi disk. Water samples were taken, stored in polyethylene bottles (500 mL) and kept at a temperature below 4°C for further determination of ammonium-nitrogen (NH_4^+; mg/L), nitrate (NO_3^-; mg/L), nitrite (NO_2^-; mg/L) and phosphate (PO_4^{3-}; mg/L). The samples were filtered through Whatman GF/C fibreglass filters and concentrations were determined using a spectrophotometer Model HACH DR 6000.

2.3 Macroinvertebrates Samples

The macroinvertebrates were monthly sampled from September 2015 to August 2016 in the upstream, the middle and the downstream of the lagoon. The macroinvertebrates were collected using a van Veen grab of 0.10 m^2 internal area, a triangular hand net (10 x 10 x 10 cm, 250 µm mesh, 50 cm length) and an artificial trap (basket). Samples obtained were carefully washed through a set of sieves of mesh size 0.2 mm in the water of lagoon and the retained materiel was bottled and preserved in a 10% formaldehyde solution in a plastic container for further analysis. At laboratory, preserved samples were washed to remove formaldehyde solution and then screened through a 500 µm mesh size to collect all macroinvertebrates on white plates. They were then fixed in a 70% alcohol solution for identification. Large macroinvertebrates were sorted by the naked eye while smaller fauna was sorted under a binocular loupe. All animals were then sorted out into different taxonomic groups, counted and identified up to lowest possible taxon under binocular loupe according to the keys of (Dejoux *et al*., 1981; De Moor *et al*., 2003; Tachet *et al*., 2003; Moisan et Pelletier, 2008; Moisan, 2010).

2.4 Data analyses

The BMWP was used to determine water quality. This index requires taxonomic identification of the invertebratesto family level and order or class for some groups (Uherek and Gouveia, 2014). The analytical procedures were identification of macroinvertebrates to family level and assign them with the scores following BMWP scoring system. The BMWP score equals the sum of the tolerance scores of macroinvertebrates families in the sample (Mandaville, 2002). A higher BMWP score is considered to reflect a better water quality (Aquilina, 2013). Alba-Tercedor (1996) and Armitage *et al*. (1983) claimed that the total score for a site indicates water quality categories ranging from good to very critical (as cited in Uherek and Gouveia, 2014). Each taxon receives a score that reflect site exposure to pollution; that is, pollution-sensitive taxa receive high scores, while pollution-tolerant taxa are given low scores (Suleiman and Abdullahi, 2011). Table 1 presents BMWP taxa scores (class, order, or family) where each family is given a score between 1 and 10 according to the presence or absence of indicator groups and indicator species in the sample (Uherek and Gouveia, 2014). Table 2 presents class, scores, categories and interpretation of the result that used to classify the water quality of Ono lagoon based on BMWP score system (Uherek and Gouveia, 2014; Junqueira and Campos, 1998). The Pollution Tolerance Index (PTI) is currently used by all Pennsylvania volunteer citizen monitoring groups and the Department of Environmental Protection for their stream organism sampling. It is based on the concept of indicator organisms and tolerance levels. The procedures are designed to be done quickly and easily; they provide a rapid means of sampling riffle and other shallow areas to detect moderate to severe stream quality degradation.

TABLE 1
THE BIOLOGICAL MONITORING WORKING PARTY SCORE (BMWP) TAXA SCORES: CLASS, ORDER, OR FAMILY

Taxa	Score
Ephemeroptera: Leptoplebiidae, Leptohyphidae **Plecoptera:** Perlidae **Trichoptera:** Brachycentridae, Leptoceridae, Odontoceridae and Secicostomatidae	10
Odonata: Coenagrionidae, Calopterygidae, Cordulegasteridae, Gomphidae and Libellulidae **Trichoptera:** Calamoceratidae, Glossosomatidae, Philopotamidae and Psychomyiidae	8
Plecoptera: Nemouridae **Trichoptera:** Polycentropodidae	7
Crustacea **Trichoptera:** Hydrobiosidae, Hydroptilidae	6
Coleoptera: Elmidae, Dryopidae **Diptera:** Simuliidae, Tipulidae **Ephemeroptera:** Euthyplociidae, Polymitarcidae **Platyhelminthes** **Trichoptera:** helicopsychidae, Hydropsychidae	5
Arachnida: Hydracarina **Coleoptera:** Chrysomelidae, Curculionidae and Haliplidae **Diptera:** Anthomyiidae, Ceratopogonidae, Chaoboridae, Dixidae, Dolichopodidae, Empididae, Limoniidae, Psychodidae, Stratiomyidae and Tabanidae **Ephemeroptera:** Baetidae, Caenidae **Megaloptera:** Corydalidae, Sialidae	4
Annelida: Hirudinea **Coleoptera:** Dytiscidae, Gyrinidae, Helodidae, Hydrophilidae and Noteridae **Hemiptera:** Belostomatidae, Corixidae, Gerridae, Hydrometridae, Mesoveliidae, Naucoridae, Nepidae, Notonectidae, Pleidae and Veliidae **Mollusca**	3
Diptera: Chirominidae, Culicidae, Ephydridae, Muscidae and Thaumaleidae	2
Annelida: Oligochaeta **Blattaria:** Blattidae **Diptera:** Sciomyzidae, Syrphidae and Rhagionidae **Lepidoptera**	1

Source: Uherek and Gouveia (2014).

TABLE 2
VALUES FOR INTERPRETING THE RESULTS OF BMWP INDEX.

CLASS	BMWP score	CATEGORY	INTERPRETATION	COLOR
I	> 150 101 – 150	Good	Very clean (pristine waters) Clean or not significantly altered	Blue
II	61 – 100	Acceptable	Clean but slightly impacted	Green
III	36 – 60	Questionable	Moderately impacted	Yellow
IV	15 – 35	Critical	Polluted or impacted	Orange
V	< 15	Very critical	Heavily polluted water (seriously affects system)	Red

Source: Junqueira and Campos (1998) and Uherek and Gouveia(2014).

III. RESULTS

3.1 Physical and chemical variables

The variations of environmental parameters are given in Table 3. Water temperature ranged between 25.86±0.71°C (low dry season) and 27.82±1.49°C (high dry season). The lowest dissolved oxygen values were recorded in high dry season (1.56±1.15 mg/L) and the highest values were observed in low rainy season (3.25±3.22 mg/L). The electric conductivity varied from 13.77±9.09 µS/cm (low dry season) to 21.60±2.25 µS/cm (low rainy season). High dry season presented low values of pH (5.60±0.16) while high values (7.01±0.46) were recorded in high rainy season. Water transparency fluctuated between 0.89±0.05 cm (low rainy season) and 2.03±0.12 cm (low dry season). Total Dissolved Solid value was higher in low rainy season (10.83±1.07 mg/L) and lower in low dry season (6.88±4.67 mg/L). Water deep was more important in low rainy season (2.75±0.21 m). Nitrite values varied between 0.01±0.00 mg/L (low dry season) and 0.45±0.64 mg/L (high dry season). Phosphate oscillated between 0.39±0.32 mg/L (low dry season) and 0.53±0.83 mg/L (low rainy season). Ammonium value varied from 0.05±0.05 mg/L (high dry season) to 0.12±0.13 mg/L (low dry season). Nitrate value was higher in low dry season (3.76±1.50 mg/L). The variables such as pH, electric conductivity, Total Dissolved Solid, water transparency and water deep showed significative difference between the different seasons.

TABLE 3
PHYSICOCHEMICAL CHARACTERISTICS (MEAN ± (SD)) OF ONO LAGOON AT VARIOUS SEASONS ; HDS : HIGH DRY SEASON ; HRS : HIGH RAINY SEASON ; LDS : LOW DRY SEASON ; LRS : LOW RAINY SEASON.

Parameters	Seasons			
	HDS	HRS	LDS	LRS
Temperature (°C)	27.82±1.49 [a]	26.98±1.65 [a]	25.86±0.71 [a]	27.60±1.49 [a]
Dissolved Oxygen (mg/L)	1.56 ±1.15 [a]	2.44±1.40 [a]	2.47±1.72 [a]	3.25±3.22 [a]
pH	5.60±0.16 [a]	7.01±0.46 [b]	6.58±1.06 [b]	6.11±0.44 [a]
Conductivity (µS/cm)	21.37±3.62 [b]	15.19±4.58 [a]	13.77±9.09 [a]	21.60±2.25 [b]
TDS (mg/L)	10.76±2.25 [b]	7.49±2.34 [a]	6.88±4.67 [a]	10.83±1.07 [b]
Transparency (m)	1.91±0.49 [b]	1.33±0.41 [a]	2.03±0.12 [b]	0.89±0.05 [a]
Water Deep (m)	2.36±0.10 [a]	2.53±0.08 [a]	2.19±0.25 [a]	2.75±0.21 [b]
Nitrite (NO2) (mg/L)	0.45±0.64 [a]	0.17±0.29 [a]	0.01±0.00 [a]	0.02±0.03 [a]
Nitrate (NO3) (mg/L)	2.53±0.52 [a]	3.71±1.44 [a]	3.76±1.50 [a]	2.29±0.89 [a]
Ammonium (mg/L)	0.05±0.05 [a]	0.07±0.04 [a]	0.12±0.13 [a]	0.10±0.06 [a]
Phosphate (mg/L)	0.46±0.33 [a]	0.49±0.20 [a]	0.39±0.32 [a]	0.53±0.83 [a]

[a,b]: letters showed the difference between the seasons as regards the parameter indicated.

3.2 Macroinvertebrates composition

A total of 12145 macroinvertebrates belonging to 47 families, 17 orders, 5 classes and 3 phyla were collected and identified in Ono lagoon. The phyla were Arthropoda, Mollusca and Annelida while the classes were Insecta, Crustacea, Arachnida, Gastropoda and Achaeta. The most diverse class was Insecta with 6 orders and 29 families. The most abundant taxa was Insecta (83.14%) followed by Gastropoda (6.65%) and Achaeta (6.19%) whereas the least abundant taxa were Crustacea (2.39%) and Arachnida (1.62%). The group of Insecta was mainly composed of Hemiptera (36.28%), Coleoptera (21.52%), Diptera (21.11%) and Odonata (18.27%) representing about 97.19% of the total abundance. Ephemeroptera and Megaloptera are presented about 2.81% of total Insecta.

3.3 Ono lagoon water quality

The aquatic macroinvertebrates collected from Ono lagoon and the biological scores allocated to each family of aquatic macroinvertebrates are presented in Tables 4 and 5. These scores present the presence of indicator groups and indicator species in the sample. The total BMWP score of Ono lagoon is 140 (Table 5), indicating that this lagoon is within class I (101-150) represented the category of good with the interpretation of clean or not significantly altered aquatic environment (Table 2 and Table 6). The analysis of PTI breaks **macroinvertebrates** into 4 groups (Table 7): **Group I was composed by** Intolerant to pollution **(**Riffles beetles, Mayfly larva, Caddisflies, Dobsonflies, Gilled Snails **), Group II was** Moderately intolerant to pollution (Dragonfly, Damselfly, Craneflies, Water scavenger beetles, Water scavenger beetles, Predaceous diving beetles, Leaf Beetles, Shrimps), Group III was Fairly tolerant to pollution (Midges) and Group IV was Very tolerant to pollution **(**Syrphid Flies, Worm**).** Moderately intolerant to pollution group was more abundant (52.96%) and Very tolerant to pollution was less abundant (8.46%). Fairly tolerant to pollution and Very tolerant to pollution represented 34.6% of total abundance.

TABLE4
TAXA OF AQUATIC MACROINVERTEBRATES COLLECTED FROM ONO LAGOON AND THEIR ABUNDANCE.

Phyla	Classes	Orders	Families	Abundance
Arthropoda	Insecta	Heteroptera	Belostomatidae	1326
			Naucoridae	580
			Hydrometridae	89
			Notonectidae	556
			Gerridae	333
			Corixidae	512
			Veliidae	31
			Mesovellidae	70
			Nepidae	167
		Diptera	Chironomidae	1760
			Tabanidae	23
			Ceratopogonidae	13
			Culicidae	311
			Syrphidae	15
			Tipulidae	10
		Coleoptera	Hydrophilidae	974
			Dytiscidae	841
			Helodidae	45
			Chysomelidae	37
			Curculionidae	150
			Elmidae	126
		Odonata	Libellulidae	935
			Corduliidae	362
			Aeshnidae	42
			Cordulegasteridae	6
			Coenagrionidae	500
		Ephemeroptera	Baetidae	247
		Trichoptera	Hydroptilidae	31
		Megaloptera	Corydalidae	6
	Crustacea	Amphipoda	Gammaridae	7
		Decapoda	Atyidae	38
			Crangonidae	78
			Penaeidae	167
	Arachnida	Aranae	Tetragnatidae	15
			Pissauridae	47
Mollusca	Gastropoda	Mesogastropoda	Ampullariidae	125
			Physcidae	281
			Hydrobiidae	28
		Basommatophore	Planorbidae	354
			Lymnaeidae	20
Annelida	Achaeta	Oligochaeta	Oligochaeta	234
			Tubificidae	325
		Clitellata	Haplotaxidae	102
			Lumbricidae	51
		Pharyngobdelliforme	Herpodelidae	31
		Rhynchobdellida	Glossiphoniidae	9
Total=3	**5**	**17**	**47**	**12145**

TABLE 5
BIOLOGICAL SCORES ALLOCATED TO GROUPS OF AQUATIC MACROINVERTEBRATES COLLECTED FROM ONO LAGOON.

Phyla	Classes	Orders	Families	Scores
Arthropoda	Insecta	Heteroptera	Belostomatidae	3
			Naucoridae	3
			Hydrometridae	3
			Notonectidae	3
			Gerridae	3
			Corixidae	3
			Veliidae	3
			Mesovellidae	3
		Diptera	Chironomidae	2
			Tabanidae	4
			Ceratopogonidae	4
			Culicidae	2
			Syrphidae	1
			Tipulidae	5
		Coleoptera	Hydrophilidae	3
			Dytiscidae	3
			Chrysomelidae	4
			Curculionidae	4
			Elmidae	5
		Odonata	Libellulidae	8
			Cordulegastridae	8
			Coenagrionidae	8
		Ephemeroptera	Baetidae	4
		Trichoptera	Hydroptilidae	6
		Megaloptera	Corydalidae	4
	Crustacea	Amphipoda	Gammaridae	6
		Decapoda	Atyidae	6
			Crangonidae	6
			Penaeidae	6
Mollusca	Gastropoda	Mesogastropoda	Ampullariidae	3
			Physidae	3
			Hydrobiidae	3
		Basommatophore	Planorbidae	3
			Lymnaeidae	3
Annelida	Achaeta	Oligochaeta	Oligochaeta	1
			Tubificidae	1
Total				**140**

TABLE6
VALUE OF BMWP SCORE OBTAINED WITH MACROINVERTEBRATE COLLECTED IN ONO LAGOON AND IT INTERPRETATION.

CLASS	CATEGORY	BMWP score	INTERPRETATION	COLOR
I	GOOD	140	Clean or not significantly altered	

TABLE 7
FOUR GROUPS OF MACROINVERTEBRATES BASED ON WATER POLLUTION TOLERANCE: INTOLERANT TO POLLUTION, MODERATELY INTOLERANT TO POLLUTION, FAIRLY TOLERANT TO POLLUTION AND VERY TOLERANT TO POLLUTION ACCORDING TO LEWIS (2014).

Group	Collected macroinvertebrates	Total number of taxa	Abundance in %
Intolerant to pollution	Riffles beetles	126	1.86
	Mayfly larva	247	3.64
	Caddisflies	31	0.46
	Dobsonflies	6	0.09
	Gilled Snails	434	6.40
Total		**844**	**12.44**
Moderately intolerant to pollution	Dragonfly	941	13.87
	Damselfly	500	7.37
	Craneflies	10	0.15
	Water scavenger beetles	974	14.36
	Predaceous diving beetles	841	12.40
	Leaf Beetles	37	0.55
	Shrimps	290	4.27
Total		**3593**	**52.96**
Fairly tolerant to pollution	Midges	1773	26.14
Total		**1773**	**26.14**
Very tolerant to pollution	Syrphid Flies	15	0.22
	Worm	559	8.24
Total		**574**	**8.46**
Total number of all macroinvertebrates		**6784**	

IV. DISCUSSION

This study showed that several species of aquatic macroinvertebrates belonging to 47 families, 17 orders, 5 classes and 3 phyla (Arthropoda, Mollusca and Annelida) colonize Ono lagoon. Arthropoda, Mollusca and Annelida were generally collected in lagoon (Berame, 2017). Insecta was qualitatively and numerically the most dominant group among macroinvertebrates. This finding is similar to previous studies in which Insecta was found to be the most dominant group in some streams (Türkmen and Kazanci, 2010; Kalyoncu and Zeybek, 2011; Zeybek *et al*., 2014). Based on the BMWP score, the ecosystem health of Ono lagoon can be placed into category "Good", indicating clean or not significantly altered aquatic environment. Since the BMWP score lay between 101 and 150, it can be interpreted as "Clean or not significantly altered" aquatic ecosystem. This means that water of Ono lagoon is not very clean (>150). This interpretation is mirrored by large number of moderately intolerant to pollution organisms (52.96%) as well as fairly tolerant to pollution and Very tolerant to pollution organisms which represented 34.6% of macroinvertebrates abundance. Similarly, the stream is not significantly altered because it supports some macroinvertebrates individuals which are sensitive to pollution (Czerniawska-Kusza, 2005; Bonada *et al*., 2006). Therefore, water of Ono lagoon can be interpreted as being moderately polluted based on the number of moderately pollution-sensitive organisms and BMWP score (Sandin and Hering, 2004). This pollution can be due to agricultural activities developed nearly the stream. Agricultural activities alter physico-chemical parameters of the stream and hence changing the abundance of macroinvertebrates as well as the quality of water (Dahl *et al*., 2004; Ojija, 2015). Farming activities nearly the stream causes soil erosion and consequently increasing suspended particles into the stream. Farming that employs the use of synthetic fertilizers, pesticides, and weedicides, and settlements that demand space are another factors contributing to pollution of the aquatic environment of Ono lagoon (Ojija and Laizer, 2016). Kripa *et al*. (2013) argued that human intervention in the name of development has largely affected many natural aquatic ecosystems over the world.

V. CONCLUSION

In conclusion, the present study reports 47 macroinvertebrates famillies belonging to 3 phyla, 5 classes and 17 orders in the different inventoried stations. Insecta was the most diversified group. This group was numerically the most abundant in Ono lagoon. The calculated total BMWP score of Ono lagoon is 140. Ono lagoon is in class I, category of good with the interpretation of clean or not significantly altered aquatic environment. According to the Pollution Tolerance Index, the water of Ono lagoon can be interpreted as being moderately polluted. This water is not very clean, but it biological quality can be considered as acceptable. However, the anthropogenic activities should be controlled and the Ono lagoon regularly monitored by the relevant authorities.

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