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Ecological Health Evaluation of Ziarat River Using Water Quality Index, Golestan Province, Iran

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Abstract

Due to decreasing water quality of the Ziarat River, which is one of the most important rivers for drinking water in Gorgan, it is necessary to manage this river. The purpose of this study was to evaluate the ecological health of the Ziarat River of Golestan province via the Water Quality Index (WQI) qualitative index. For this purpose, 6 sampling stations were selected along the Ziarat River, and samples were taken from April to August of 2014 every 45 days at sampling stations. The parameters of dissolved oxygen, nitrate, nitrite and phage were measured at each turn and the data were analyzed by WQI qualitative index and SPSS 21 software. The results showed that water quality of the Ziarat River was relatively good during the spring and summer. Also, the results showed that there was a significant correlation between nitrite and positive qualitative index (with increasing amount of nitrite the numerical value of the qualitative index also increases, which indicates a decrease in water quality). Between the dissolved oxygen and the numerical value of the negative quality correlation index (with increasing amount of solution oxidant, the numerical value of the qualitative reduction index, which indicates the increase of water quality).

Keywords

Water Quality Index, Ziarat River, Physical and Chemical Parameters

1. Introduction

Monitoring the quality of rivers due to the recent drought and urban and rural development is one of the important tasks in the field of environmental management

[1]. Rivers' water quality depends on various conditions including hydrological, physicochemical and biological processes. Water resources have significant impact on social, economic and political developments. Having healthy water resources is an essential prerequisite for environmental protection while surface water is more prone to pollution than other water sources. These resources are very important in terms of social, economic and political development providing [2]. Safe water is one of the basic requirements for the life of human beings, which requires quality control by means of laboratory tests and different indices for controlling it. Therefore, river health assessment can be used as a tool for estimating the water flow quality required for the survival of river ecosystems, and monitoring and continuous monitoring of water quality are considered as the main tools for management and conservation of these valuable resources [3]. One of the very simple methods without mathematical and statistical complexity can describe the qualitative conditions of water and as an advanced tool strong for relevant decisions, use of indicators quality water. Water Quality Indicators are the ways in which Water quality management, can be simplified and reduced information Raw, in addition to expressing water quality, the process of water quality changes during checking the location and time, and the areas that are most contaminated Threatening, identifying and managing [4]. Due to the entry of various pollutants into aquatic ecosystems which, in addition to ecological values, are also of high economic importance, their health value is of great importance [5]. The most important aquatic ecosystems are freshwater rivers, which are considered as biodiversity and drinking water. In this regard, the quantitative and qualitative study of these resources is an important pillar of sustainable development [6]. Quantitative and qualitative changes in physical and chemical properties of water indicated the presence of contamination in ecosystems [7]. And since our country is facing limited water resources and is considered a low-water country, it is inevitable to know the quality of available water resources for their proper management [8]. Ghorbani *et al.* (2015) [2] assessed the health status of the Ziarat Stream based on NSFWQI quality index (Golestan Province). The result showed that the best situation was related to first station (Ziarat waterfall) in June month and the worst situation was related to 5 stations (The most important tourist center) in April. As for present results, quality condition of Ziarat Stream was unsuitable: Salari *et al.* (2013) Quantitative and Qualitative Assessment of Karoon River Water Using National sanitation foundation water quality index (NSFWQI) and Analytic hierarchy process (AHP) Method. Subsequently, the nine present NSF parameters' weights have been changed and modified using the analytical hierarchy process (AHP) method as well as experts' opinions in the field in a way to satisfy local conditions [1]. Also ecosystem health assessment of the Liao River Basin upstream region based on ecosystem services and the result showed that different stations in this ecosystem were different in terms of health. In general, it can be argued that western ecosystems had better health than the eastern regions. Therefore, management should be done to protect the eastern regions [6]. Therefore, it can

generally be stated that due to the increased utilization of river surface resources and the reduction of the flow due to reduced rainfall, climate change and increased pollution. Assessment of river health in different regions of the country and knowledge of the quality of water resources in conservation, planning and management of these resources is very important and from where that the WQI (Water Quality Index) is an attempt to provide a general response to water quality. Therefore, the purpose of this study is to evaluate the ecological health of Ziarat River in Golestan province using the WQI index.

2. Materials and Methods

2.1. Describing the Area under Study

Ziarat River with an area of 9873 hectares is one of the sub-basins of the Ghareh Sou river, located in south of Gorgan. The basin is in the (54˚23-minute and 55-second) intervals to (54˚31', 10 seconds) east longitude and (36 degrees 36 minutes and 58 seconds) to (36 degrees 46 minutes and 11 seconds) north latitude. Sampling stations along the river route were determined based on factors such as elevation, slope, bedding, and water flow rate and land use type of marginal land.

2.2. Sampling Procedures

In this study, six sampling stations were selected and samplings took place from April to August 2014 every 45 days (According to the sampling of water resources of the Water and Wastewater Company of Iran, which can be done monthly for sampling 45 days). Samples were taken in duplicate at the same hour of the day throughout the study. Sampling stations along the river route were determined based on factors such as the location of the settlements, industrial areas, access roads, altitudes, slopes, bedding, water flow rate and land use type of marginal land. In this study physiochemical characteristics and nutrients of water, including DO (mg/L) and pH (mg/L) were measured with Wagtech Laboratory (Model Photometer 7100) and nitrate and nitrite (mg/l) were measured using a spectrophotometer in the laboratory.

2.3. Calculating WQI Indicator

Water Quality Index (WQI) was calculated using 4 parameters of nitrite, nitrate, dissolved oxygen and phage. In the interpretation of the results of this index, it is assumed that with increasing pollution, the WQI quality index also increases, which indicates an increase in pollution and a decrease in water quality

To calculate this index, 4 parameters including nitrate, nitrite, dissolved oxygen and pH were used. Then the required values for calculating the index were calculated based on the following relationships [9].

$$RW = AW \Big/ \sum AW \tag{1}$$

RW1 = Weight ratio of each parameter (**Table 1**)

AW2 = is the weight assigned to each parameter, which is based on expert

Table 1. The weight ratio of water quality parameters [11].

Parameters	RW	AW	Standard drinking water WHO.2004
NO_2 (mg/l)	0/141,844	2	30
NO_3 (mg/l)	0/156,028	2.2	50
DO (mg/l)	0/283,688	4	5
pH	0/148,643	2.1	6/5-8/5

Table 2. Weight assigned to each parameter in different sources and their mean [11].

Research	PH	DO (mg/l)	NO_3 (mg/l)	NO_2 (mg/l)
Abrahão *et al.*, 2007	1	4	2	2
Boyacioglu, 2007	1	4	3	
Chougule *et al.*, 2009	4	4		
Dwivedi and Pathak, 2007	4	4		
Kannel *et al.*, 2007	1	4	2	2
Karakaya and Evrendilek, 2009	1	4	2	2
Pathak and Banerjee, 1992	4	4		
Pesce and Wunderlin, 2000	1	4	2	2
Mean	2/1	4	2/2	2

opinion in previous studies (Table 2) (Fathi, 2011) [10].

$$\mathrm{Qi} = (\mathrm{Ci}/\mathrm{Si}) * 700 \tag{2}$$

$$\mathrm{Qi} = (\mathrm{Ci} - \mathrm{Vi}/\mathrm{Si} - \mathrm{Vi}) * 700 \tag{3}$$

In Equations ((2) and (3)): Qi: the quality level; Ci: the amount obtained from each parameter in the laboratory; Si: reported in the global standard for drinking water, Vi: The optimal value for pH is 7 and for DO it is equal to 14/6. The weight assigned to each parameter and mean used is given in Table 2. Finally, to calculate the WOI, the SLI subcategory was first calculated for each parameter (Equation (4)) and from the total SLIs, the numerical value of WQI was estimated (Equation (5)).

$$\mathrm{SIi} = \mathrm{RW} * \mathrm{Qi} \tag{4}$$

$$\mathrm{WQI} = \sum \mathrm{WiQi} \tag{5}$$

Using Equation (5), the Water Quality Index (WQI) was calculated at different stations and samplings. Finally, the water quality status at stations and different samplings was determined based on the general classification of WQI water quality index (Table 3).

2.4. Statistical Methods

SPSS21 software was used to determine the data normality and correlation coefficient between parameters. The SPSS software was used to analyze data. All parameters were normal according to Kolmogorov Smirnov test. The $P < 0.05$

Table 3. Qualitative classification of natural waters based on the overall score of the WQI index [12].

Qualitative class	The value of the obtained index
Unsuitable	300
Very poor	200 - 300
Poor	100 - 200
Good	50 - 100
Excellent	<50

Table 4. Parameters measured at sampling stations (mean ± SD).

Stations	NO_2 (mg/l)	NO_3 (mg/l)	DO (mg/l)	pH
1	0.06 ± 0.1^{a}	1.65 ± 0.18	14.41 ± 3.11^{a}	8.57 ± 0.08^{a}
2	0.03 ± 0.00^{b}	1.57 ± 0.06	11.81 ± 1.6^{b}	8.53 ± 0.08^{a}
3	0.03 ± 0.00^{b}	1.44 ± 0.06	1.00 ± 1.3^{b}	8.11 ± 0.03^{b}
4	0.03 ± 0.00^{b}	1.47 ± 0.04	10.78 ± 0.6^{b}	8.32 ± 0.07^{ab}
5	0.03 ± 0.00^{b}	1.62 ± 0.05	10.37 ± 0.6^{b}	8.41 ± 0.04^{ab}
6	0.02 ± 0.00^{b}	1.62 ± 0.05	9.57 ± 0.8^{b}	8.33 ± 0.06^{ab}
Mean	0.03	1.56	11.38	8.37

was used as significance level used for data evaluation. One-way ANOVA was employed to analyze data. Then, means were compared by Tukey's test.

3. Results

The results of measuring the physicochemical parameters of water at different sampling stations are given in Table 4.

Significant differences were observed in some of the measured parameters between different sampling stations ($P < 0.05$). Based on the findings of the 6 sampling stations, it can be stated that the numerical value of the quality index The WQI did not make a significant difference between the sampling stations. The maximum WQI quality index at station 1 was 61.56 and the minimum amount was at station 4 with 51/81 (Table 5).

According to Figure 1 and Table 3, the observed differences in the qualitative index between the sampling stations are quantitative and statistical and are within range (50 to 100) and are not excluded from this range, indicating that sampling stations during the time of the present research it has a good quality. In general, it can be stated that according to the results obtained, the water quality of the Ziarat River in the province of Golestan is in good class in terms of time and is suitable for human consumption and drinking purposes.

Data Correlation

Regarding the data are normal, the data from the calculations performed in this study were used to verify the correlation between the physico-chemical parameters

Table 5. WQI index values calculated at different sampling stations (mean ± SD). There was no significant difference in WQI between sampling stations ($p \geq 0.05$).

Stations	Water Quality Index
1	61.56 ± 12.06
2	60.51 ± 2.81
3	55.21 ± 4.19
4	51.81 ± 3.81
5	53.49 ± 2.19
6	52.41 ± 1.14

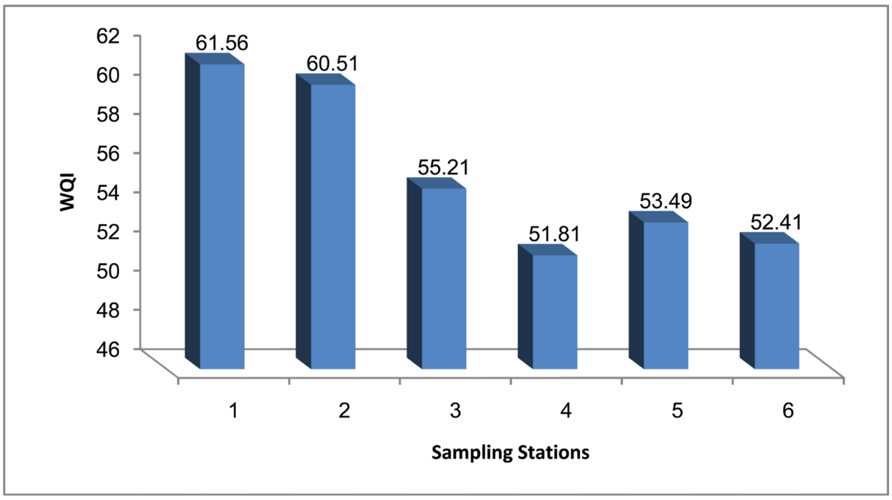

Figure 1. Average WQI water quality index at the stations studied.

Table 6. Correlation between Water Quality Parameters and WQI Quality Index at Study Stations (Significant at 1%).

WQI	PH	DO (mg/l)	NO_3 (mg/l)	NO_2 (mg/l)	
1	0/358	−0/821*	0/588	0/481*	WQI

and WQI water quality index from Pearson correlation coefficient. The results of correlation coefficients are shown in Table 6. The results showed that there was a significant correlation between the parameters of nitrite and dissolved oxygen with the qualitative index between the quality index and the measured parameters at different sampling stations. This correlation between nitrite and positive qualitative index (with increasing amount of nitrite The numerical value of the qualitative index also increases, which indicates a decrease in water quality. Between the dissolved oxygen and the numerical value of the negative quality correlation index (with increasing amount of solution oxidant, the numerical value of the qualitative reduction index, which indicates the increase of water quality) was observed (Table 6).

4. Discussion and Conclusion

Based on the findings of the present study, there was no significant difference in the nitrate level of the Ziarat River in Golestan province at different stations. The average amount of nitrate in the river water was 1.65 mg/L, which was reported as the amount of nitrate in surface water based on available resources and environmental standards was 1 mg/l [13]; more it has been the standard of the environment. It can be stated that the causes of nitrate entry into the river water are human activities around the river and the influence of waste water from agriculture and home. On the other hand, the nitrite content of the Zilat River in Golestan province was significant at the station and the mean nitrite in the river water was equal to 03/0 mg/L. Considering that the amount of nitrite in surface water based on available resources and environmental standards should not be higher than 0.51 mg/L being reported (EPA, 1994) [13] in the environmental standard. In confirmation of these results, it can be noted that Kazhi *et al.* (2009) [14] reported nitrate, nitrite, phosphate and ammonium nitrate levels in Lake Manchar, Pakistan, due to the influence of domestic wastewater and fertilizers used in the agricultural sector. Lodh *et al.* in 2014, [15] on the Indian Ocean Lake Anset, nitrate was regarded as the main nutrient for the growth of algae and phytoplankton, and its concentration could be affected by the fluctuation of plankton. The measured pH during the sampling time at the station was an average of 8.37, located in the alkaline range. This factor plays a significant role in the health and fertility of water and plays an important role in evaluating water quality. The mean phage in the stations studied in this study conformed to the standards of Iran and the world. It is worth noting, however, that the pH of the ecosystems is derived from geological and hydrological properties of the watersheds, the input of acidic substances and the level of lake fertility. The dissolved oxygen content at all stations was 11.38 on average, with a maximum at station 1 and a minimum amount at station 6, except for the station, one of the remaining stations had a steady trend.

The amount of oxygen dissolved depends on factors such as water temperature (with increasing water temperature, reduced oxygen dissolution), vital activities such as respiration and organic matter decomposition (increasing vital activity of reducing oxygen dissolution). The effect of oxygen on water quality is very influential and can have a significant effect on its color, taste and smell. The results of the changes in dissolved oxygen are consistent with the results of Gajendra *et al.* [16]. The results showed that water quality of the Ziarat River, despite the decrease in spring and summer, was in good condition (between 50 - 100). Khalaji *et al.*, in 1395, evaluated the water quality of Lake Zayandehrood dam using the WQI index and the sign they said that water quality is in good condition and that care should be taken to maintain water quality. Amin Pourshiani *et al.* (2015) [17] evaluated the water quality of Gharbroodbar River using the NSFWQI qualitative index and Liou pollution index. According to the results of this study, the monthly average of the NSFWQI index is in the range of 50 - 50.50 and the monthly average of Liou index ranges from 1.1 to 3.85. Based on these indices, the No. 1 station was of the best quality and the No. 4 station had the worst quality. According to the NSFWQI index, Rudbar gas is ranked in the middle class (70 - 50) and based on the Liou index in a slightly polluted class (2 - 3). Ghorbani *et al.* (2015) [2] to assessment of the health status of the Ziarat Stream based on NSFWQI quality index (Golestan Province). The result showed that the best situation was related to first station (Ziarat waterfall) in Joun month and the worst situation was related to 5 stations (The most important tourist center) in April. As for present results quality condition of Ziarat Straem was unsuitable. Salari *et al.* (2013) [1] performed Quantitative and Qualitative Assessment of Karoon River Water via NSFWQI Index and AHP Method. Subsequently, the nine present NSF parameters' weights have been changed and modified by the analytical hierarchy process (AHP) method as well as experts' opinions in the field in a way to satisfy local conditions Yan *et al.* (2016) [6] Ecosystem health assessment of the Liao River Basin upstream region based on ecosystem services and the results showed that there were significant spatial differences in ecosystem health in this region. In general, the west regions were better than the east, ecosystem health of regions in descending order is as follows: Laoha River sub-basin NXiliao River sub-basin, and Xila Mulun River sub basin N Xinkai River sub-basin. The eastern ecosystems had less health than western ecosystems. Also in the sub-basins, more health was observed than branching sub-basins. Generally, based on the results obtained, it can be stated that the qualitative conditions of the passage of undesirable pilgrimage were introduced. In general, it can be said that according to the results of the present research and their comparison with the water quality standards in Iran and the world, water of the Ziarat River of Golestan province during the period of this research was in terms of quality in good and acceptable conditions. And has the ability to use for human consumption, including drinking. However, due to the changes in the WQI index and the beginning of its exit from the good quality waters, reducing the river's water volume in summer, the dramatic increase of tourism use at the river's margin, uncooperative land use changes in the watershed, etc. Precise and continuous assessments of water quality in this river are necessary.

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Water Quality Assessment in Terms of Water Quality Index (WQI): Case Study; Gorganroud River, Golestan Province, Iran

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Abstract

The most important aquatic ecosystems are freshwater rivers, which are considered as biodiversity and drinking water. In this regard, the quantitative and qualitative study of these resources is an important pillar of sustainable development. Gorganroud is one of the most important rivers in northeastern Iran; therefore the aim of this study was to study survey of Gorgnroud River water quality in Golestan Province using Water Quality Index (WQI). For this purpose, five sampling stations were selected along the Gorgnroud River, and samples were taken from April to August of 2015 every 45 days at sampling stations. The parameters of dissolved oxygen, nitrate, nitrite and PH were measured at each turn and the data were analyzed by WQI qualitative index. The results showed that the Water Quality Index at the first station (91/22); at the second station (85/51); at the third station (89.30); at the fourth station (87/14) and fifth station (81/11). The water quality index indicates that water quality of the Gorgnroud River was in a very good quality class during the spring and summer seasons.

Keywords

Water Quality Index, Gorgnroud River, Physical and Chemical Parameters

1. Introduction

Water is a vital resource for any biological and human phenomenon and is one of the most important and fundamental sources for developing countries, those countries without any long-term plan regarding this specific source will not be able to enjoy more development and progress [12]. It should be mentioned that any change in the level of economic and financial development of a country has direct and indirect effect on the well-being of individuals who are living in that country, so evaluating these resources is really crucial [1] [2]. Safe water is one of the essential requirements for the life of human beings, which requires quality control by means of laboratory tests and different indices for controlling it [3]. A small part of the water resource is about one percent including surface water, current, wetlands and lakes that can be exploited and used directly by humans. So reducing the quality of current water, such as rivers and streams that are heavily influenced by humans, is one of the current concerns [4]. One of the most widely used and simple methods for measuring surface water quality is the use of water quality indicators [5]. Due to the entry of various pollutants into aquatic ecosystems which, in addition to ecological values, are also of high economic importance, their health value is of great importance [6]. The most important aquatic ecosystems are freshwater rivers, which are considered as biodiversity and drinking water. In this regard, the quantitative and qualitative study of these resources is an important pillar of sustainable development [7]. Quantitative and qualitative changes in physical and chemical properties of water indicate the presence of contamination in ecosystems [8] and since our country is facing limited water resources and is considered a low-water country, it is inevitable to know the quality of available water resources for their proper management [9]. Therefore, it can generally be stated that due to the increased utilization of river surface resources and the reduction of the flow due to reduced rainfall, climate change and increased pollution, Assessment of river health in different regions of the country and knowledge of the quality of water resources in conservation, planning and management of these resources is very important and from where that The WQI Water Quality Index is an attempt to provide a general response to water quality. Therefore, the purpose of this study is to evaluate the ecological health of Gorgnroud River in Golestan province using the WQI index. Essentially the WQI is calculated by comparing the water quality data to "Guidelines for Canadian Drinking Water Quality". The WQI measures the scope, frequency, and amplitude of water quality exceedances and then combines the three measures into one score. This calculation produces a score between 0 and 100. The higher the score, the better the quality of water. The scores are then ranked into one of the five categories described below:

Excellent: (WQI Value 95 - 100)—Water quality is protected with a virtual absence of impairment; conditions are very close to pristine levels

Very Good: (WQI Value 89 - 94)—Water quality is protected with a slight presence of impairment; conditions are close to pristine levels.

Good: (CWQI Value 80 - 88)—Water quality is protected with only a minor degree of impairment; conditions rarely depart from desirable levels.

Fair: (WQI Value 65 - 79)—Water quality is usually protected but occasionally impaired; conditions sometimes depart from desirable levels.

Marginal: (WQI Value 45 - 64)—Water quality is frequently impaired; conditions often depart from desirable levels.

Poor: (WQI Value 0 - 44)—Water quality is almost always impaired; conditions usually depart from desirable levels [10]

For Assessment of the health status of the Ziarat Stream based on NSFWQI (National Sanitation Foundation Water Quality Index) quality index (Golestan Province) and Samples were taken from 10 hydrometer stations (in spring and summer 2012) along the Ziarat Stream. At each sampling, DO (Dissolved Oxygen), pH (potential of hydrogen), BOD_5 (Biochemical oxygen demand), NH_3 (Ammonia), NO_3 (Nitrate), PO_4 (phosphate), Water temperature, turbidity and Fecalcoli quality was measured. The data were analyzed by NSFWQI quality index. The result showed that the best situation was related to the first station in the June month and the worst situation was related to 5 stations in April. As for the present results quality condition of Ziarat, Straem was unsuitable and the decision-making process for reducing the pollutant of the Zyarat watershed can be facilitated by taking into consideration the results of this research given the time/budget constraints [3]. Karbasi and Also Compilation of Water Quality Index for River Quality Assessment (Case Study of Gorgan Rood River) and the result showed in the qualitative water index, the fossil foliar coliform and biochemical oxygen demand parameters increased compared to the NSF index [11]. Dadolahi and Arjomand (2011) an article titled Water quality index of Karoon River as indicator of Khorramshahr Soap Factory sewage effects and The comparison of physic-chemical parameters of water and sewage with the standard values defined by Department of Environment, showed that the amount of COD, BOD, and Chlorine (means 1300, 169.8 and 4042.9 ppm, respectively) in sewage is higher than the standard level. Based on water quality index, stations 1, 2, 3 and factory sewage with an annual quality index of 54.63, 40.29, 45.71 and 24.32 were classified as moderate, bad and very bad, respectively. There was a significant difference ($p < 0.05$) in factors such as BOD, COD, nitrate, phosphate, and bicarbonate among the stations during the sampling period. The results also revealed factory sewage has affected the river water quality in spite of high water volume and sewage exit flow. These changes in the quality of river water indicate an increase of many parameters in second station and decrease in the third station which shows Karoon River high ability of self-purification [12].

2. Materials and Methods

2.1. Describing the Area under Study

Gorganroud is one of the most important rivers in northeastern Iran. This river originates from the Aladagh Mountain range in Bojnourd City and after passing 250 km of Turkmen Sahra cluster areas; it flows into the plain of Gorgan and flows from Khwaja Nafs area near the Turkmen port to the Caspian Sea. The total area of the Gorgan River basin is 1,019,700 hectares, 41% of which is forestland and 20% of the pastures, and 39% of it is agricultural land, where cultivars are cultivated annually [13]. The longitude between 54˚3" to 56˚13". Eastern latitude and 37˚45" to 36˚23". North latitude are located in Golestan province.

Table 1. Geographic coordinates of sampling stations in Gorganroud river survey.

Station number	Geographical coordinates	
	N	E
1. (Sourced)	28.36	51.52
2. (Before Golestan Dam)	34.37	55.49
3. (After Golestan Dam)	17.37	55.18
4. (Aq Qala)	28.36	52.51
5. (Khaje Nafas)	14.36	52.35

Geographic coordinates of sampling stations in Gorganroud river survey showed in Table 1.

2.2. Sampling Procedures

In this study, five sampling stations were selected and sampling took place from April to August 2015 every 45 days (According to the sampling of water resources of the Water and Wastewater Company of Iran, which can be done monthly for sampling 45 days) and samples were taken in duplicate at the same hour of the day throughout the study. Sampling stations along the river route were determined based on factors such as the location of the settlements, industrial areas, access roads, altitudes, slopes, bedding, water flow rate and land use type of marginal land. In this study physiochemical characteristics and nutrients of water, including DO (mg/L) and pH (mg/L) With Photometric portable device (Model Wagtech Photometer 7100) and nitrate and nitrite (mg/l) were measured using a spectrophotometer in the laboratory.

2.3. Analytical Methods

Data were analyzed by WQI quality index and spss21 software was used to determine the data normality and correlation coefficient between parameters.

2.4. Calculating WQI Indicator

To calculate this index, 4 parameters including nitrate, nitrite, dissolved oxygen, and ph were used. Then the required values for calculating the index were calculated based on the following relationships [14].

$$\mathrm{RW} = \mathrm{AW} \Big/ \sum \mathrm{AW} \tag{1}$$

RW_1 = Weight ratio of each parameter (Table 2)

AW_2 = is the weight assigned to each parameter, which is based on expert opinion in previous studies (Table 2) [15].

$$\mathrm{Qi} = \left(\mathrm{Ci}/\mathrm{Si}\right) * 700 \tag{2}$$

$$\mathrm{Qi} = \left(\mathrm{Ci} - \mathrm{Vi}/\mathrm{Si} - \mathrm{Vi}\right) * 700 \tag{3}$$

In Equations ((2) and (3)): Qi: the quality level; Ci: the amount obtained from each parameter in the laboratory; Si: The amount reported in the global drinking

Table 2. Weight assigned to each parameter in different sources and their mean [16].

Researcher	PH	DO (mg/l)	NO_3 (mg/l)	NO_2 (mg/l)
Abrahão *et al.*, 2007	1	4	2	2
Boyacioglu, 2007	1	4	3	
Chougule *et al.*, 2009	4	4		
Dwivedi and Pathak, 2007	4	4		
Kannel *et al.*, 2007	1	4	2	2
Karakaya and Evrendilek, 2009	1	4	2	2
Pathak and Banerjee, 1992	4	4		
Pesce and Wunderlin, 2000	1	4	2	2
Mean	2/1	4	2/2	2

Table 3. The weight ratio of water quality parameters [16].

Parameters	RW	AW	Standard drinking water WHO. 2004
NO_2 (mg/l)	0/141,844	2	30
NO_3 (mg/l)	0/156,028	2.2	50
DO (mg/l)	0/283,688	4	5
pH	0/148,643	2.1	6/5 - 8/5

Table 4. Qualitative classification of natural waters based on the overall score of the WQI index [10] [17].

Qualitative class	The value of the obtained index
Poor	0 - 44
Marginal	45 - 64
Fiar	65 - 79
Good	80 - 88
Very Good	89 - 94
Excellent	95 - 100

water standard, Vi: The optimal value for Ph. is 7 and for DO it is equal to 14/6. The weight assigned to each parameter and mean used is given in **Table 3**.

Finally, to calculate the Water Quality Index (WQI), the SLI (is the sub-index of with parameter) subcategory was first calculated for each parameter (Equation (4)) and from the total SLIs, the numerical value of WQI was estimated (Equation (5)).

$$\mathrm{SIi} = \mathrm{RW} * \mathrm{Qi} \tag{4}$$

$$\mathrm{WQI} = \sum \mathrm{WiQi} \tag{5}$$

Using Equation (5), the Water Quality Index (WQI) was calculated at different stations and sampling stages. Finally, the water quality status at stations and different sampling stages was determined based on the general classification of WQI water quality index (**Table 4**).

3. Results

The results of measuring the physicochemical parameters of water at different sampling stations are given in Table 5.

Significant differences were observed in some of the measured parameters between different sampling stations ($P < 0.05$). Water Quality Index (WQI) was calculated using 4 parameters of nitrite, nitrate, dissolved oxygen, and phage. In the interpretation of the results of this index, it is assumed that with increasing pollution, the WQI quality index also increases, which indicates an increase in pollution and a decrease in water quality. Based on the findings of the 5 sampling stations, it can be stated that the numerical value of the quality index The WQI did not make a significant difference between the sampling stations. The maximum WQI quality index at station 1 was 91/22 and the minimum amount was at station 5 with 81/11. The observed differences in the qualitative index between the sampling stations are quantitative and statistical and are within range (80 - 94) and are not excluded from this range, indicating that sampling stations during the time of the present research it has a good quality (Table 6 and Figure 1).

Table 5. Parameters measured at sampling stations (mean ± SD).

Stations	NO_2 (mg/l)	NO_3 (mg/l)	DO (mg/l)	pH
1	0.09 ± 0.01^a	8.65 ± 1.18^a	5.12 ± 1.11	7.3 ± 0.08
2	0.08 ± 00.0^b	9.55 ± 1.06^{ab}	6.81 ± 1.6	8.53 ± 0.08
3	0.08 ± 0.00^b	12.44 ± 1.02^{ab}	8 ± 8.18	7.11 ± 0.03
4	0.08 ± 0.00^b	10.47 ± 1.04^{ab}	9.78 ± 1.6	7 ± 0.07
5	0.08 ± 0.00^b	20.62 ± 4.05^b	8.73 ± 1.17	7.41 ± 0.04
Average	0.08	12.34	7.68	7.47

Table 6. WQI index values calculated at different sampling stations (mean ± SD), There was no significant difference in WQI water quality index between sampling stations (P > 0/05).

Stations	1	2	3	4	5
WQI	91/22 ± 7.06	85/51 ± 2.81	89/30 ± 4.19	87/14 ± 3.81	81/11 ± 2.16

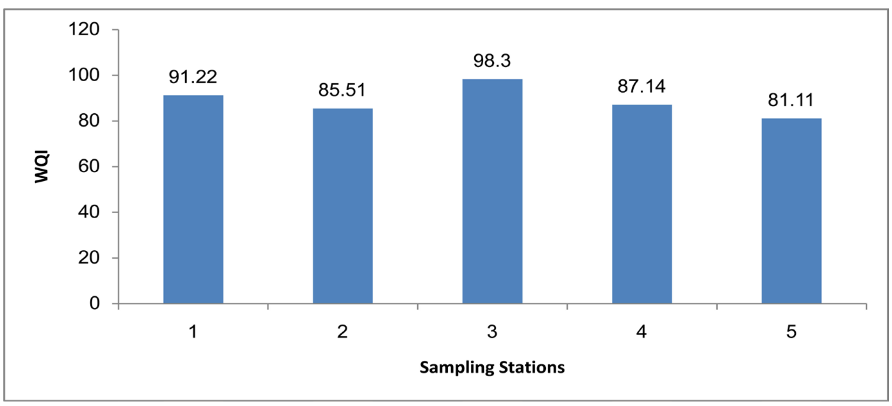

Figure 1. Average WQI water quality index at the stations studied.

In general, it can be stated that according to the results obtained, the water quality of the Gorgnroud River in the province of Golestan is in poor class in terms of time and is unsuitable for human consumption.

4. Discussion and Conclusion

Based on the findings of the present study, there was a significant difference in the nitrate level of the Gorganroud River in Golestan province at different stations. The average amount of nitrate in the river water was 12.34 mg/L, which was reported as the amount of nitrate in surface water based on available resources and environmental standards were 1 mg/l [18]; more it has been the standard of the environment. It can be stated that the causes of nitrate entry into the river water are human activities around the river and the influence of waste water on agriculture and home [12]. On the other hand, the nitrite content of the Gorganroud River in Golestan province was significant at the station and the mean nitrite in the river water was equal to 0/08 mg/L. Considering that the amount of nitrite in surface water based on available resources and environmental standards should not be higher than 0.51 mg/L is reported (EPA, 1994) in the environmental standard have been. In confirmation of these results, it can be noted that Kazhi *et al.* (2009) [19] reported nitrate, nitrite, phosphate and ammonium nitrate levels in Lake Manchar, Pakistan, due to the influence of domestic wastewater and fertilizers used in the agricultural sector. Lodh *et al.* in 2014, [20] on the Indian Ocean Lake Anset, nitrate was considered as the main nutrient for the growth of algae and phytoplankton, and its concentration could be affected by the fluctuation of plankton. The pH measured during the sampling time at the station was an average of 7.47, located in the alkaline range. This factor plays a significant role in the health and fertility of water and plays an important role in assessing water quality. The mean phage in the stations studied in this study conformed to the standards of Iran and the world. It is worth noting, however, that the PH of the ecosystems is due to the geological and hydrological properties of the watersheds; the input of acidic substances and the level of lake fertility. The dissolved oxygen content at all stations was 7.68 on average, with a maximum at station 4 and a minimum amount at station 1. The amount of dissolved oxygen depends on factors such as water temperature (with increasing water temperature, reduced oxygen dissolution), vital activities such as respiration and organic matter decomposition (increasing vital activity of reducing oxygen dissolution). The effect of oxygen on water quality is very influential and can have a significant effect on its color, taste, and smell. The results of the changes in dissolved oxygen are consistent with the results of Gajendra *et al.* [21] in 2014. The results showed that water quality of the Gorganrud River, despite the decrease in spring and summer, was in poor condition (between 100 - 200). Khalaji *et al.*, in 2017 [16], evaluated the water quality of Lake Zayandehrood dam using the WQI index and the sign they said that water quality is in good condition and that care should be taken to maintain water quality.

Amin Pourshiani *et al.* (2016) [22] evaluated the water quality of Gharbroodbar River using the NSFWQI qualitative index and Liou pollution index. According to the results of this study, the monthly average of the NSFWQI index is in the range of 50 - 50 and the monthly average of Liou index ranges from 1.1 to 3.85. Based on these indices, the No. 1 station was of the best quality and the No. 4 station had the worst quality. According to the NSFWQI index, Rudbar gas is ranked in the middle class (70 - 50) and based on the Liou index in a slightly polluted class (2 - 3) (Salari *et al.* (2013) [23] Quantitative and Qualitative Assessment of Karoon River Water Using NSFWQI Index and AHP Method). Subsequently, the nine present NSF parameters' weights have been changed and modified using the analytical hierarchy process (AHP) method as well as experts' opinions in the field in a way to satisfy local conditions Yan *et al.* (2016) [7] Ecosystem health assessment of the Liao River Basin upstream region is based on ecosystem services and the result showed there were significant spatial differences in ecosystem health in this region. In general, the west regions were better than the east, ecosystem health of regions in descending order is as follows: Laoha River sub-basin NXiliao River sub-basin, and Xila Mulun River sub-basin N Xinkai River sub-basin. Moreover, improvements in ecosystem health were greater in the mainstream sub-basins than in the branch sub-basins. Thus, the eastern regions are key areas for ecosystem health conservation, and ecosystem service is the principal constraint for local ecosystem health. Generally, based on the results obtained, it can be stated that the qualitative conditions of the passage of undesirable pilgrimage were introduced. In general, it can be said that according to the results of the present research and their comparison with the water quality standards in Iran and the world, water of the Gorganrud River of Golestan province during the period of this research was in terms of quality in poor and has not capacity of being used for human consumption. However, due to the changes in the WQI index and the beginning of its exit from the good quality waters, the river's water volume in summer is reduced and uncooperative land use changes in the watershed, etc. Precise and continuous assessments of water quality in this river are necessary.

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Factors Determining Coyote (*Canis latrans*) Diets

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Abstract

Although studies have documented the potential for coyote (*Canis latrans*) food use to negatively affect wildlife populations and domesticated animals, they are often equivocal, possibly because most are of small spatial extent, and little is known of factors determining coyote diets. Our objectives were to quantify the diet and identify factors determining coyote food use, particularly game species and livestock, over a large spatial and temporal extent. Contents of gastrointestinal tracts were identified from 263 coyotes opportunistically obtained from hunters, trappers, and as road-kills throughout Florida, 2011-2015. We employed logistic regression in an information-theoretic framework to understand determinants of coyote food use. Coyotes were opportunistic and omnivorous foragers with a diverse diet of vegetation, insects, birds, reptiles, amphibians, and more than 25 species of mammals (including important game species and livestock). They commonly consumed 11 food items (Virginia opossum [*Didelphis virginiana*], non-mast vegetation, feral hog [*Sus scrofa*], northern raccoon [*Procyon lotor*], insects, rabbits (*Sylvilagus* spp.), skunks [*Mephitis mephitis* and *Spilogale putorius*], white-tailed deer (*Odocoileus virginianus*), mast, birds, and cows [*Bos taurus*]). Food use was determined by coyote age, sex, and body mass, season of the year, deer hunting and fawning seasons, livestock calving season, and coyote collection method and location/region. As coyotes expand their range and numbers, conservationists may find it useful to understand how this opportunistic and adaptable predator uses available food sources to reduce conflict across the landscape.

Keywords

Canis latrans, Coyote, Determinants, Diet, Factors

1. Introduction

Historically found west of the Mississippi River, the coyote (*Canis latrans*) has expanded its range throughout most of North America [1]. Increasing numbers of coyotes in areas such as the southeastern United States [2] [3] are a concern as they may feed on a variety of food items, including important game species, livestock, and pets [4] [5]. Coyotes have been implicated in the decline of numerous wildlife species, negatively affecting them through competition for resources (e.g., bobcats [*Lynx rufus*]; [6]), predation (e.g., white-tailed deer [*Odocoileus virginianus*; hereafter, deer]; [7]), and changes in community structure [8] [9] [10].

Although studies have documented the potential for coyote food use to negatively affect wildlife and domesticated animals, they are often equivocal, possibly because most are of small spatial extent, which can mask broader habitat and ecosystem effects [11]. In addition, beyond a limited knowledge of the influence of season and animal sex and age, we lack an understanding of determinants of coyote food use [11]. A better understanding of these determinants is needed to tailor management strategies and mitigate the negative effects of coyotes. Coyotes are often considered to be opportunistic and generalist predators [1] [5] [12]. Some studies have suggested coyotes focus primarily on a relatively few (3 - 5) food types in an area (e.g., large mammals such as deer, insects, rabbits, or small mammals; [13] [14] [15] [16] [17]) while others suggest a more diverse diet, with many food types commonly consumed (e.g., [18] [19]).

Our objectives were to quantify the diet and identify factors determining coyote food use, particularly game species and livestock, over a large spatial and temporal extent. We expected coyotes would be opportunistic and have a diverse diet, where one or few items did not dominate; exhibit age, sex, and size differences in diet, to reduce intraspecific competition for food, with older, more experienced animals consuming larger and more difficult to prey upon items, and coyote size positively related to prey size consumed; and have diets that vary with season and location, to take advantage of available food assemblages, such as deer and livestock calves. Finally, we wished to investigate if some combination of these factors might further affect coyote food use.

2. Materials and Methods

We opportunistically obtained coyote carcasses and gastrointestinal (GI) tracts from hunters, trappers, and as road-kills throughout Florida from December 2011 to February 2015. Road-kills were typically less than 2 days old at the time of collection. Coyote carcasses were sexed and weighed, and a canine from the lower jaw was removed, aged via cementum annuli, and used to assign coyote age class (Matson's Laboratory LLC, Milltown, MT; [20]; **Table 1**). We determined body mass classes arbitrarily (*i.e.*, dividing the range of values into three equal parts), and following Giuliano *et al.* (1989), an ocular kidney fat index was used to assess coyote condition (**Table 1**). Collection date, method, and location (**Table 1**) were documented for all animals. To examine the effects of season on coyote food use, we partitioned collection dates into three relevant season

Table 1. Factors determining coyote (*Canis latrans*) food use in Florida, USA, 2011-2015.

Factors[a]	Food Group
Age[b]	Small mammals[c]
Sex[d]	Medium mammals[e]
Body mass (Mass)[f]	Large mammals[g]
Condition class (Condition)[h]	Birds
Calendar season (CSeason)[i]	Reptiles and Amphibians
Deer season (DSeason)[j]	Insects
Livestock season (LSeason)[k]	Vegetation (non-mast)
Collection method (Method)[l]	Mast (Fruits, seeds, and nuts)
Collection location (Location)[m]	Small game[n]
Age + Sex	Large game[o]
Age + Condition	White-tailed deer (*Odocoileus virginianus*)
Sex + Condition	Livestock[p]
Sex + CSeason	
Sex + DSeason	
Sex + LSeason	
CSeason + Location	
DSeason + Location	
LSeason + Location	
DSeason + Method	
LSeason + Method	
DSeason + Method + Location	
LSeason + Method + Location	

[a]Predictor variables in *a priori*, single- and multiple-variable candidate models used to determine coyote food use. [b]Juveniles (J; <1 year old), young adult (YA; 1 year old), and adult (A; ≥2 years old). [c]*Blarina* sp., mole sp., cotton rat (*Sigmodon hispidus*), eastern woodrat (*Neotoma floridana*), Florida mouse (*Podomys floridanus*), marsh rice rat (*Oryzomys palustris*), and round-tailed muskrat (*Neofiber alleni*). [d]Male (M) and female (F). [e]Nine-banded armadillo (*Dasypus novemcinctus*), Virginia opossum (*Didelphis virginiana*), rabbits (*Sylvilagus spp.*), northern raccoon (*Procyon lotor*), skunks (striped [*Mephitis mephitis*] and spotted [*Spilogale putorius*]), squirrels (*Sciurus* spp.), weasels (*Mustela* spp.), and domestic cats (*Felis catus*). [f]Small (S; <11.34 kg), medium (M; 11.34 - 15.88 kg), and large (L; >15.88 kg). [g]Coyote (*Canis latrans*), domestic dog (*Canis lupus familiaris*), white-tailed deer (*Odocoileus virginianus*), feral hog (*Sus scrofa*), cow (*Bos taurus*), and horse (*Equus caballus*). [h]0 (no fat = poor condition), 1 (minimal fat = fair condition), 2 (some fat deposits = good condition), and 3 (large fat deposits = excellent condition). [i]Coyotes collected in winter (W; December, January, or February), spring (SP; March, April, or May), summer (SU; June, July, or August), or fall (F; September, October, or November). [j]Coyotes collected in the deer fawning (F; birthing period), hunting (H; general gun hunting period), or other (O; outside of birthing and general gun hunting periods) season, as determined by location and date of collection. [k]Coyotes collected during the livestock calving (C; October-February) or other (O; March-September) season. [l]Coyotes collected by hunting (H), trapping (T), or as road-kill (R). [m]Coyotes collected in north (N; Alachua, Bradford, Citrus, Clay, Duval, Flagler, Jefferson, Madison, Marion, Sumter, Taylor, and Union counties), central (C; Brevard, Desoto, Hardee, Highlands, Manatee, Okeechobee, Osceola, Pasco, and Polk counties), or south (S; Charlotte, Glades, and Palm Beach counties) Florida. [n]Nine-banded armadillo, Virginia opossum, rabbits, northern raccoon, skunks, and squirrels. [o]White-tailed deer and feral hog. [p]Cow and horse.

classifications: calendar, deer, and livestock (**Table 1**). Coyote use of deer may increase during the deer fawning season when adult females and fawns are particularly vulnerable to predation [7] [22], and during deer hunting seasons, as entrails from harvested animals may be left in the field and deer may be left wounded and easily killed. We used both the coyote's location and date of collection to determine the deer hunting and fawning seasons, using the Florida Fish and Wildlife Conservation Commission's Deer Management Plan, which contains fawning seasons by region, and deer management unit regulations as a guideline ([23]; **Table 1**). Similarly, coyote use of livestock may increase during the livestock calving season, as there are more calves available at that time. Calving seasons were determined by the University of Florida, Agricultural Extension Service (J.R. Selph, Florida Cooperative Extension Service, University of Florida, Arcadia, FL [personal communication, 2015]; **Table 1**).

We removed gastrointestinal tracts from carcasses, rinsed contents with warm water, and separated materials using a 4-sieve kit (Hubbard #3076 Screen Four Sieve Kit). After air-drying for 24 hours, we sorted samples into components (e.g., hair, bone, plant material, insects, etc.). Items were identified micro- and macroscopically using attributes such as hair length, color, and scale patterns by comparison to reference collections [21] [24]. We separated deer fawns and adults based on hair characteristics following Wilkins *et al*. (1982). Dietary items were grouped for analyses, with some items appearing in multiple groups. Because we were particularly interested in factors determining coyote use of game species and livestock, we separately examined these groups (**Table 1**). We counted any type of item found within a coyote GI tract only once, regardless of how many of the individual food item were in the GI tract. All dietary items (e.g., Virginia opossum [*Didelphis virginiana*]) and food groupings (e.g., small mammals) were expressed as percent (%) occurrence (*i.e.*, number of coyotes with the food item or group/total number coyotes).

To understand determinants of coyote dietary habits, we employed logistic regression in an information-theoretic framework [25]. For each food group (*i.e.*, consumed or not consumed), we developed and evaluated the same set of 22 a priori, single- and multiple-variable candidate models (**Table 1**) based on the literature, prior knowledge and field experience, and study objectives. Individual models were limited to 3 predictor variables to reduce the likelihood of overfitting. We examined Akaike's Information Criterion with small-sample correction (AIC_c) values, AIC_c differences (ΔAIC_c), Akaike weights (w_i), and model goodness of fit (−2 log-likelihood; when $P \leq 0.10$, models were considered to fit) for models with different combinations of predictor variables, and considered models with $\Delta AIC_c < 2$ supported. Where multiple models were supported, we used model averaging to increase precision of inference and examine the relative contribution of each variable from all supported models [25]. When 85% confidence intervals (CI) for variables within supported models overlapped with zero, we considered them to have a weak effect on the dependent variable and be uninformative [26]. For brevity and clarity, we only present results of supported models. All analyses were conducted using R software [27].

All research and animal welfare protocols were reviewed and approved: University of Florida Animal Research Permit (003-11WEC) and Florida Fish and Wildlife Conservation Commission Research Permit (SPGS-11-68).

3. Results

Coyotes (n = 263) had a diverse diet, consuming vegetation, insects, mammals (≥25 species), birds, amphibians, and reptiles, with 11 foods commonly consumed (occurring in >10% of coyotes). Frequently used food items included Virginia opossum, feral hog (*Sus scrofa*), northern raccoon (*Procyon lotor*), rabbits (*Sylvilagus* spp.), skunks (striped skunk [*Mephitis mephitis*] and spotted skunk [*Spilogale putorius*]), deer (adults and fawns), insects, mast, and other vegetation (**Table 2**).

Table 2. Food items identified in gastrointestinal tracts of coyotes (*Canis latrans*) from Florida, USA, 2011-2015.

Food Item	% Occurrence (n = 263)
Virginia opossum (*Didelphis virginiana*)	31.6
Vegetation (non-mast)	28.1
Feral hog (*Sus scrofa*)	24.7
Northern Raccoon (*Procyon lotor*)	22.1
Insects	17.5
Rabbits (eastern cottontail [*Sylvilagus floridanus*] and marsh [*Sylvilagus palustris*])	15.6
Skunks (striped [*Mephitis mephitis*] and spotted [*Spilogale putorius*])	15.6
White-tailed Deer (*Odocoileus virginianus*)	14.8
Adult	11.8
Fawn	3.0
Mast (fruits, seeds, and nuts)	14.1
Birds	11.0
Cow (*Bos taurus*)	10.3
Reptiles and amphibians	6.5
Rodents (cotton rat [*Sigmodon hispidus*], eastern woodrat [*Neotoma floridana*], Florida mouse [*Podomys floridanus*], marsh rice rat [*Oryzomys palustris*], and round-tailed muskrat [*Neofiber alleni*])	6.1
Squirrels (eastern gray [*Sciurus carolinensis*] and fox [*Sciurus niger*])	5.3
Nine-banded Armadillo (*Dasypus novemcinctus*)	2.7
Weasels (long-tailed [*Mustela frenata*] and mink [*Mustela vison*])	2.3
Non-rodent small mammals (*Blarina* sp. and mole sp.)	1.5
Canids (coyote [*Canis latrans*] and domestic dog [*Canis lupus familiaris*])	0.8
Domestic cat (*Felis catus*)	0.4
Horse (*Equus caballus*)	0.4

Young adult coyotes were less likely than adults to eat medium-sized mammals and small game, and juveniles were less likely than adults to eat birds. Age was not a factor determining use of any other food groups. Compared to females, male coyotes were less likely to consume small mammals and more likely to consume medium-sized mammals and small game. Use of any other food groups was not determined by sex. Small coyotes were less likely than larger animals to use large game, and mass was not a factor determining use of any other food groups. While animal condition appeared in 2 supported models predicting bird use by coyotes, it was an uninformative individual predictor variable, and condition was not a factor determining use of any other food groups (Table 3 and Table 4).

Coyotes were less likely to ingest mast during the spring and winter than fall, and calendar season was not a factor determining use of any other food groups. Coyotes were more likely to eat small mammals, large mammals, deer, and livestock and less likely to consume reptiles and amphibians during the deer hunting season than during the deer fawning season. Outside of the deer hunting and fawning seasons, coyotes consumed more small mammals and mast and less deer than during the fawning season. While deer season appeared in 2 supported models predicting vegetation use by coyotes, it was an uninformative individual predictor variable, and use of any other food groups was not determined by deer season. Consumption of insects was more likely and small mammals, large mammals, large game, and livestock by coyotes was less likely outside of the livestock calving season than during the calving season. While livestock season appeared in 1 supported model predicting bird use and 1 supported model predicting mast ingestion, it was an uninformative individual predictor variable. Livestock season was not a factor determining use of any other food groups (Table 3 and Table 4).

Trapped coyotes were more likely to consume large mammals, birds, vegetation, and livestock and less likely to eat reptiles and amphibians, insects, and mast than hunted coyotes. While collection method appeared in 1 supported model predicting large game use by coyotes, it was an uninformative individual predictor variable, and coyote collection method was not a factor determining use of any other food groups. Coyotes in northern and southern Florida were more likely to eat birds than coyotes in central Florida. In northern Florida, consumption of reptiles and amphibians and mast were more likely and livestock less likely than in central Florida. While collection location appeared in 2 supported models predicting small mammal use, 1 supported model of large mammal use, and 1 supported model of deer use, it was an uninformative individual predictor variable, and use of any other food groups was not determined by location of coyote collection (Table 3 and Table 4).

4. Discussion

Coyotes had a diverse diet, consuming vegetation, insects, mammals (≥25 species), birds, amphibians, and reptiles. Similar to other studies (e.g., [13] [16] [18]

Table 3. Supported models[a] of factors determining coyote (*Canis latrans*) food use in Florida, USA, 2011-2015.

Food Group[b]	Model[c]	K[d]	AIC_c	ΔAIC_c	w_i[e]	Model Fit (P)[f]
Small mammals						
	LSeason	2	141.367	0.000	0.200	0.041
	Sex + LSeason	4	142.016	0.649	0.144	0.054
	DSeason	3	142.845	1.479	0.095	0.093
	DSeason + Location	5	142.857	1.490	0.095	0.064
	LSeason + Location	4	142.227	1.860	0.079	0.093
Medium mammals						
	Age + Sex	6	306.947	0.000	0.375	0.015
Large mammals						
	LSeason + Method	4	356.832	0.000	0.324	0.001
	DSeason + Method	5	357.342	0.510	0.251	0.002
	DSeason + Method + Location	7	358.356	1.525	0.151	0.002
Birds						
	Condition	5	184.002	0.000	0.236	0.012
	Age + Condition	8	184.770	0.768	0.161	0.010
	LSeason + Method + Location	6	185.171	1.168	0.132	0.017
	Location	3	185.876	1.873	0.092	0.032
	Age	4	185.929	1.926	0.090	0.030
Reptiles and Amphibians						
	DSeason + Method + Location	7	123.593	0.000	0.895	≤0.001
Insects						
	LSeason + Method	4	227.884	0.000	0.375	≤0.001
	Method	3	228.435	0.551	0.285	≤0.001
Vegetation (non-mast)						
	DSeason	3	319.925	0.000	0.259	0.051
	DSeason + Method	5	320.801	0.876	0.167	0.056
	Method	3	321.121	1.196	0.143	0.093
Mast						
	DSeason + Method + Location	7	187.635	0.000	0.272	≤0.001
	CSeason + Location	6	188.236	0.601	0.201	≤0.001
	LSeason + Method + Location	6	188.434	0.799	0.182	≤0.001
	Method	3	188.785	1.150	0.153	≤0.001
Small game						
	Age + Sex	6	306.947	0.000	0.381	0.015
Large game						
	LSeason	2	352.496	0.000	0.349	0.033

Continued

	LSeason + Method	4	354.173	1.677	0.151	0.072
	Mass	4	354.448	1.952	0.132	0.082
White-tailed deer						
	DSeason	3	214.285	0.000	0.403	≤0.001
	DSeason + Location	5	214.442	0.157	0.372	≤0.001
Livestock						
	LSeason + Method	4	179.609	0.000	0.281	0.002
	LSeason + Method + Location	6	180.733	1.125	0.160	0.003
	DSeason + Method + Location	7	181.066	1.458	0.136	0.003
	DSeason + Method	5	181.162	1.553	0.129	0.003

[a]Akaike's Information Criterion [AIC]; $\Delta AIC_c \le 2$. [b]Food groups defined in Table 1. [c]Model predictor variables described in Table 1. [d]Number of model parameters. [e]Akaike weight. [f]When $P \le 0.10$, models were considered to fit.

Table 4. Model-averaged variable coefficients from supported models[a] of factors determining coyote (*Canis latrans*) food use in Florida, USA, 2011-2015.

Food Group[b]	Variable[c]	β	SE	85% CI Lower	85% CI Upper
Small mammals					
	Sex (M)	−0.804	0.490	−1.509	−0.099
	DSeason (H)	1.675	1.085	0.114	3.237
	DSeason (O)	2.020	1.101	0.436	3.604
	LSeason (O)	−1.179	0.641	−2.102	−0.256
	Location (N)	0.513	0.581	−0.323	1.349
	Location (S)	−15.140	1131.103	−1643.398	1613.119
Medium mammals					
	Age (J)	0.231	0.406	−0.353	0.814
	Age (YA)	−0.723	0.418	−1.325	−0.122
	Sex (M)	0.597	0.295	0.172	1.022
Large mammals					
	DSeason (H)	1.059	0.366	0.533	1.585
	DSeason (O)	0.301	0.376	−0.240	0.843
	LSeason (O)	−0.752	0.270	−1.141	−0.363
	Method (R)	−0.474	0.751	−1.555	0.608
	Method (T)	0.721	0.308	0.278	1.165
	Location (N)	−0.455	0.320	−0.915	0.006
	Location (S)	0.603	0.653	−0.336	1.542
Birds					
	Age (J)	−1.052	0.540	−1.829	−0.274

Continued

	Age (YA)	−0.346	0.547	−1.134	0.441
	Condition (1)	0.542	0.798	−0.607	1.691
	Condition (2)	−0.127	0.840	−1.337	1.082
	Condition (3)	−15.189	980.887	−1427.207	1396.828
	Method (R)	−15.799	1206.684	−1752.858	1721.261
	Method (T)	0.818	0.529	0.0565	1.579
	Location (N)	1.161	0.458	0.502	1.820
	Location (S)	1.961	0.937	0.612	3.310
	LSeason (O)	−0.176	0.431	−0.796	0.444
Reptiles and Amphibians					
	DSeason (H)	−2.740	0.895	−4.028	−1.452
	DSeason (O)	−0.289	0.557	−1.092	0.513
	Method (R)	−0.563	1.026	−2.040	0.914
	Method (T)	−1.943	0.597	−2.802	−1.085
	Location (N)	1.646	0.602	0.779	2.512
	Location (S)	−15.507	1096.569	−1594.053	1563.039
Insects					
	LSeason (O)	0.560	0.345	0.064	1.056
	Method (R)	0.262	0.691	−0.733	1.257
	Method (T)	−1.683	0.358	−2.198	−1.168
Vegetation (non-mast)					
	DSeason (H)	−0.393	0.403	−0.972	0.187
	DSeason (O)	0.351	0.352	−0.156	0.858
	Method (R)	−0.091	0.838	−1.297	1.115
	Method (T)	0.576	0.318	0.118	1.033
Mast					
	CSeason (SU)	−0.206	0.708	−1.225	0.814
	CSeason (SP)	−2.636	0.628	−3.541	−1.732
	CSeason (W)	−2.057	0.474	−2.739	−1.375
	DSeason (H)	0.218	0.574	−0.609	1.044
	DSeason (O)	0.869	0.562	0.060	1.678
	LSeason (O)	−0.089	0.414	−0.685	0.507
	Method (R)	0.036	0.731	−1.016	1.089
	Method (T)	−2.273	0.451	−2.922	−1.624
	Location (N)	1.161	0.458	0.502	1.820
	Location (S)	0.755	0.716	−0.276	1.785
Small game					
	Age (J)	0.231	0.406	−0.353	0.814

Continued

	Age (YA)	−0.723	0.418	−1.325	−0.122
	Sex (M)	0.597	0.295	0.172	1.022
Large game					
	Mass (S)	−0.895	0.419	−1.498	−0.292
	Mass (M)	−0.318	0.321	−0.781	0.144
	LSeason (O)	−0.574	0.275	−0.970	−0.178
	Method (R)	−0.901	0.828	−2.094	0.291
	Method (T)	0.194	0.280	−0.210	0.597
White-tailed deer					
	DSeason (H)	0.814	0.439	0.182	1.445
	DSeason (O)	−0.864	0.550	−1.656	−0.072
	Location (N)	0.419	0.385	−0.136	0.973
	Location (S)	−15.335	1100.391	−1599.383	1568.712
Livestock					
	DSeason (H)	1.600	0.812	0.431	2.769
	DSeason (O)	0.859	0.879	−0.407	2.124
	LSeason (O)	−1.192	0.568	−2.009	−0.374
	Method (R)	1.076	1.261	−0.739	2.891
	Method (T)	1.516	0.661	0.565	2.467
	Location (N)	−0.972	0.576	−1.801	−0.143
	Location (S)	0.221	1.312	−1.667	2.110

[a]Akaike's Information Criterion [AIC]; $\Delta AIC_c \leq 2$. [b]Food groups defined in Table 1. [c]Model predictor variables described in Table 1.

[19] [28] [29] [30] [31] [32]), we found coyotes often used mast, non-mast vegetation, insects, birds, medium-sized mammals (e.g., Virginia opossums, rabbits, skunks, and northern raccoons), and larger mammals (e.g., feral hogs, deer, and livestock). However, our results suggest that Florida coyotes had a broad diet, with many (11) food types commonly consumed, which contrasts studies that suggested relatively few (3 - 5) types were important food items to coyotes (e.g., [13] [14] [15] [16] [32]). Additionally, our findings are in partial contrast to several studies that noted a greater importance of deer, insects, small mammals, and mast in coyote diets (e.g., [13] [14] [15] [16] [17] [28] [32] [33]). These differences may be due to differences in food availability among regions, limited spatial and temporal extent of the contrasting studies, and examination of scats to determine diets in most studies. The latter will lead to differing diet composition as some items are digested fully and do not appear in scats as opposed to GI tracts, and may reflect the preference of a single or a few animals, rather than the habits of the entire population. In addition, our study is not subject to predator misidentification, a substantial problem with most scat-based studies, as they do

not genotype scats to species [34]. Furthermore, we established the importance of coyote age, sex, and body mass, season (*i.e.*, calendar, livestock calving, and deer fawning and hunting), coyote collection method (*i.e.*, hunted, trapped, or road-killed), and location (*i.e.*, region of Florida) as determinants of coyote food use, which may also explain differences relative to other studies that typically could not examine these factors.

Physical characteristics of coyotes (*i.e.*, age, sex, and body mass) were important factors determining food use. The lower consumption by young adults of medium-sized mammals and small game and juveniles of birds compared with adults, the reduced use by males of small mammals and greater use of medium-sized mammals and small game compared with females, and the lower consumption by small coyotes of large game compared to larger (*i.e.*, medium and large) animals suggest that coyotes may be partitioning resources to reduce intraspecific competition [17] [35]. Additionally, foraging ability may differ depending on the age, sex, and size of coyotes, which may lead to differential effects on important prey (e.g., rabbits, deer, etc.) depending on coyote population structure. The lower consumption of birds and medium-sized mammals and small game such as armadillos, Virginia opossums, rabbits, squirrels, skunks, weasels, and northern raccoons, may reflect the inexperience of younger animals at finding and capturing prey [36]. Further, the greater use of large game species (*i.e.*, deer and hogs) by larger than smaller coyotes likely reflects smaller individuals not being able to physically handle such large prey and exclusion by dominant (*i.e.*, larger) individuals of deer and hog kills or carcasses. In contrast with other studies, we did not find that coyote age and sex were important in determining the use of other food groups. For example, Metzger *et al.* (2017) noted an overall difference in diet between males and females, and Albers (2012) noted juveniles using less mast and more deer than adults.

Seasonal variations (*i.e.*, calendar, deer, and livestock) were the more important type of factors determining coyote food use. Coyotes were less likely to consume mast during spring and winter than fall, which likely reflects its greater availability during the fall masting season [37] [38]. Although not noted in this study, Whitaker *et al.* (2015) suggested greater use of deer in fall and winter and hogs in spring and summer than other seasons, but statistical tests were not performed.

Similar to calendar season effects, availability likely increased use of large mammals, deer, and livestock and decreased use of reptiles and amphibians by coyotes during the deer hunting season compared to the fawning season, and led to greater mast and reduced deer use outside of both the deer hunting and fawning seasons. Deer hunting season was generally during fall-early winter and provided less than ideal conditions for most reptiles and amphibians to be active (*i.e.*, dryer and cooler; [38]). However, a large portion of the deer season outside of both hunting and fawning seasons included parts of spring and fall masting periods [37] [38]. The increased use of large mammals (comprised primarily of deer, hog, and cow), deer, and livestock in the deer hunting compared with deer fawning season may often reflect coyote scavenging habits, availability of livestock calves, hunting of deer and hogs, and landowner control programs of coyotes and hogs. During the deer hunting season, which overlaps with much of the livestock calving season, agricultural land managers kill many feral hogs and leave their carcasses in pastures while monitoring calving operations and use hog as bait while conducting coyote control programs leading up to and during the livestock calving season (J.R. Selph, Florida Cooperative Extension Service, University of Florida, Arcadia, FL, personal communication, 2015). Further, during much of this period, livestock are calving and deer are physically stressed with the conclusion of the breeding season, and hunters are harvesting (and wounding) deer and hogs during the hunting season [23]. Coyotes may be taking advantage of these easily obtained food sources by scavenging the remains of hogs used as bait, hogs and deer left in the field, and opportunistically depredating livestock calves and weak or wounded deer and hogs [33]. The greater use of deer by coyotes during the hunting season (26 % occurrence) than other seasons supports this conclusion [11].

Our findings regarding deer use are similar to those of Swingen *et al.* (2015), who found the greatest deer use in winter, but in contrast to Hidalgo-Milhart *et al.* (2001), Schrecengost *et al.* (2008), and Wooding *et al.* (1984), who noted greater deer use by coyotes during the deer fawning season. Although we documented adult and juvenile deer in coyote GI tracts, other items (e.g., medium-sized mammals, feral hogs, insects, and vegetation) were found more often [14] [39] [40]. The relative amount of deer consumed by coyotes in Florida was less than in other studies (e.g., [13] [14] [15] [18] [28] [32]). Florida is a large state with a diversity of ecosystems [41] that offer a variety of food from which coyotes can choose, possibly explaining differences with other studies. Additionally, in more northerly portions of coyote range, deer are easily preyed on in deep snow [42] [43] [44] [45] and other foods important to Florida coyotes (e.g., hogs and Virginia opossums) may be less abundant [46], partially explaining why deer are relatively less important to coyotes in Florida. Huebschman *et al.* (1997), Schrecengost *et al.* (2008), and Thornton *et al.* (2004) found deer fawns to be an important component of coyote diets, and recent studies have found coyotes to be important predators of deer fawns (e.g., [7] [22] [47] [48] [49] [50]). Our data partly support this conclusion, finding deer use to be greater in the deer fawning season compared with outside of both the deer hunting and fawning seasons, as fawns may be easy prey for coyotes [7]. However, deer fawns were generally, infrequently consumed in Florida, which is similar to that of Swingen *et al.* (2015).

Coyotes may be using deer and other food items more evenly through time as the fawning seasons in Florida can occur during 3 calendar seasons (e.g., spring, summer, and into fall; [51]), and food availability during each season may be dominated by other food items (e.g., mast in fall). Additionally, fawn remains may be digested at different rates than other prey items [52] [53], leading to a loss of evidence, and may be a reason why deer generally do not appear to be important in coyote diets. Gier (1968), and to some extent Albers (2012) and Litvaitis and Shaw (1980), suggested that livestock were more important to coyote diets, particularly in winter when calves are most vulnerable and heifers are physically stressed and most likely to abort or abandon a calf, providing inexperienced animals with an easy meal [54]. The deer hunting season, when livestock use was high, includes much of the early winter period. Similar to deer hunting season, and to some extent deer fawning season, during the livestock calving season, coyotes consumed more large mammals, large game, and livestock than during the non-calving season, likely for the reasons described above for deer seasons.

Method and location of coyote collection also affected what coyotes consumed. Land managers consistently kill hogs, use their remains as bait to trap coyotes, and place traps and bait for coyotes around livestock carcasses to increase capture success. In addition, remains of harvested birds and poultry are often used as bait for coyotes. A portion of coyote consumption of hogs, livestock, and birds may be due to baited traps, as seen by the greater use of large mammals (including hogs), livestock, and birds by trapped than hunted coyotes. Further, the greater ingestion of vegetation by trapped than hunted coyotes often reflects trapped animals biting at anything within reach, while in a trap.

When compared to other regions of the Southeast, Florida may contain a greater variety of ecosystems and climatic conditions, explaining some of the observed differences in coyote food use [41]. North Florida exhibits more seasonality and is more forested compared with the remainder of the state [41] [55], contributing to increased mast production, and explaining the greater use of mast by coyotes in this region compared to the central region. In addition, the majority of the state's large-scale agricultural production, including livestock, occurs outside of north Florida [56], explaining why coyotes use livestock less in the north region. A superficial comparison of coyote food habits among the many studies with local extents suggests regional differences in coyote diets, and Metzger *et al.* (2017) noted regional differences in coyote diets in their larger scale Pennsylvania study.

As hypothesized, coyotes were opportunistic and omnivorous foragers with a diverse diet of vegetation, insects, birds, reptiles, amphibians, and more than 25 species of mammals (including important game species and livestock), with 11 food items commonly consumed (Virginia opossum, non-mast vegetation, feral hog, northern raccoons, insects, rabbits, skunks, deer, mast, birds, and cows). Food use was determined by coyote age, sex, and body mass, season of the year, deer hunting and fawning seasons, livestock calving season, collection method, and location/region, and suggests that coyotes are opportunistic, generalist predators that forage on the most available foods.

White-tailed deer is often the most utilized food of endangered red wolves (*Canis rufus*), with feral hogs also consumed but to a much lesser extent. Where red wolves and coyotes coexist, they often have very similar diets. However, red wolves rely more heavily on both deer and hogs [35]. To increase the availability of these important food sources for red wolves, targeting for removal coyotes during the deer-hunting season may be a viable strategy. For deer managers and livestock producers, targeting for removal coyotes during the deer hunting and livestock calving seasons may relieve pressure on deer and calves, particularly in areas with little other seasonal coyote foods. As coyotes expand their range and numbers, conservationists may find it useful to understand how this opportunistic and adaptable predator uses available food sources to reduce conflict across the landscape.

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Invasion of Water Hyacinth (*Eichhornia crassipes*) Is Associated with Decline in Macrophyte Biodiversity in an Ethiopian Rift-Valley Lake—Abaya

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Abstract

Macrophytes play critical ecological role in inland water bodies, especially in shallow systems. Water hyacinth (*Eichhornia crassipes*) is an invasive plant species introduced to Ethiopian water bodies around the mid 20th century with recently exacerbated devastating ecological and economic consequences. Here we report the impact of the invasive plant species on macrophyte species assemblage and biodiversity in Lake Abaya, southwestern Ethiopia. We compared four sites in Lake Abaya, two hyacinth infested and two non-infested, each site consisting of 15 plots. Our results showed that water hyacinth affects the macrophyte community composition, abundance and diversity negatively. Even though some macrophyte species from the Poaceae and Cyperaceae families appear to coexist with the alien plant, the invasive species has reduced macrophyte abundance and diversity at the infested sites, and in some cases changed the community to nearly monotypic flora. Our data affirm that water hyacinth has the potential to alter macrophyte composition, abundance and diversity in the wider Ethiopian aquatic ecosystems. A broad & closer, systematic and comprehensive look at the short and long term consequences of its expanding invasion within the framework of specific local environmental, ecological and societal conditions is long-overdue.

Keywords

Macrophytes, *Eicchornia crassipus*, Composition, Abundance, Wetland

1. Introduction

Wetland ecosystems are dynamic in their physical and chemical conditions [1].

Macrophytes, as an integral component of wetlands and shallow lakes, play critical ecological role such as nutrient cycling, and nitrogen removal through denitrification coupled with nitrification. They possess a set of complex adaptations that enable them flourish under a set of dynamic environmental factors: frequent water wave disturbance, siltation and exposure to chemical effluents from terrestrial systems. Competition within the community is also a common feature, especially within plant species having similar ecological strategies, a factor well recognized to affect species distribution in aquatic habitats [2]. Competition among aquatic plant species, however, is much more complex than known for terrestrial plants because aquatic ones can acquire inorganic carbon and nutrients in water [3]. Often, outcompeting species have better morphological and physiological adaptations for nutrient utilization; allelopathic resistance and resistance to anoxic condition than the rest.

Invasion of aquatic habitats by non-native species is a global environmental challenge with serious ecological, social and economic consequences [4]. They do this by altering soil and water chemistry, nutrient cycling, hydrology and disturbance regime of the infested ecosystem. Besides, they affect seedling recruitment blocking seed dispersal through their thick mat growth of stem, root and rhizome [5]. As a result, they often outcompete native plant species and establish a monotypic community.

Water hyacinth (*Eichhornia crassipes*), as an introduced non-native, is a menace to global aquatic environments with serious and devastating consequences. The genus *Eichhornia* has seven species and only one, *i.e. E. crassipes*, seems to hold the exceptional ability to be invasive. This species has the potential to multiply aggressively through clonal means of reproduction, has high growth rate and a highly dispersive floating form [6] [7]. The ecological, social and economic impact of this invasive species is complex and multifaceted: it drastically affects the physical & chemical properties of the water by reducing temperature, pH, biological oxygen demand and nutrient level. High organic load can lead to anoxic conditions that impact not only denizens of the water column, such as fish and zooplankton, but those in the sediment too. Water hyacinth can create unimpenetrable fortress in shallow areas making it difficult to access deeper parts of water bodies for recreation, fishing, transportation etc. The mat can even hamper water flow to hydo-electric dams. In some areas it can provide excessive surface area for intermediate hosts such as snails that transmit waterborne diseases such as schistosomiasis. Its control has been a continuous challenge to ecologists and there seem to be a recent shift in focus from eliminating this invasive plant to making use of its excessive biomass: source of biofuel, carbon for cellulase, electricity, food, antioxidants, medicine, animal feed, fertilizer, and for the manufacture of household articles [8].

Water hyacinth has been reported to invade two major areas of Ethiopia: the Nile basin and the Awash basin extending down to the rift-valley region [9]. Studies on this invasive species in Ethiopia have addressed various aspects such as economic impact, biodiversity loss etc. However there is almost no data on how this aquatic weed is impacting other macrophytes in invaded water bodies. Here we report findings of a comparative study that assessed macrophyte community abundance and biodiversity in one of the most southern Ethiopian lakes, Lake Abaya. We hypothesized that water hyacinth, when present, will outcompete other macrophytes and will overall reduce the biodiversity of macrophyte communities.

2. Materials and Methods

2.1. Description of Study Area

2.1.1. Location of the Study Area

Lake Abaya is one of the two southernmost Rift Valley lakes in Ethiopia. It is the second largest lake in the country next to the non-rift valley—Lake Tana, a lake that has recently been overrun by water hyacinth, similar to Lake Abaya. Abaya is located between 5˚55'9"N to 6˚35'30"N latitude and 37˚36'90"E to 38˚03'45"E longitude (**Figure 1**). The lake, including its islands, has a total area of 1108.9 km^2 [10]. It has a maximum length of 79.2 km and with the maximum width of 27.1 km. The mean and the maximum depth are 8.6 m and 24.5 m, respectively [11]. It is located at an average altitude of 1235 meter above sea level [10]. The study was conducted on Lake Abaya, from May to June 2016.

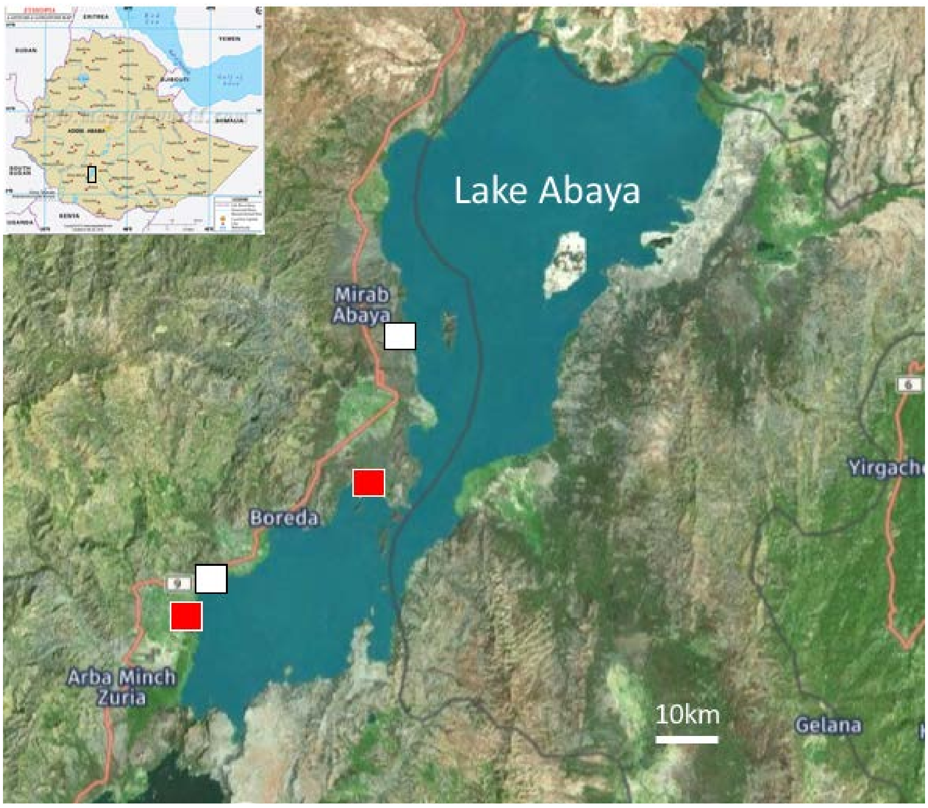

Figure 1. Map of study area showing Lake Abaya and sampling sites (red rectangles are sampling sites infested with water hyacinth, white rectangles are non-infested sites; most southern site is numbered 1 in both cases with northern sits as 2). Inset is map of Ethiopia with study area marked in rectangle.

2.1.2. Climate

Based on ten years climate data, (2001-2010), the Lake Abaya basin experiences a bimodal rainfall pattern (**Figure 2**). It has an average annual temperature of 22.9˚C and an average rainfall of 768 mm. The rainy season of the study area ranges from March to November with mean minimum monthly rainfall in January and maximum in May. Hot and dry season is prominent from December to February. The mean minimum daily temperature of the coldest month and the mean maximum temperature of the warmest months are 15.0˚C and 32˚C, respectively.

2.2. Data Collection

For macrophyte sampling, a belt transect was laid along the side of the lake (**Figure 1**). Samples were collected early mid of September and early January. Four study sites were selected: two water hyacinth-infested and other two sites free from water hyacinth. A picture of the study sites was taken using cannon 10X pixel camera along the western coast of the lake. In each of the four sites 15 plots were laid, each plot (quadrats) with a size of 0.5 × 0.5 m^2 and 25 meter apart from each other [12]. In the field, macrophytes were counted within each plot. A total of 60 quadrats 15 from each site were studied. Collected plant specimens were pressed and tagged and taken to Addis Ababa University National Herbarium for identification using the guide to Flora of Ethiopia and Eritrea.

2.3. Data Analyses

Macrophyte species richness, abundance and Simpson's diversity index, and similarity index for plots was calculated using SPSS version and 17 Multiple

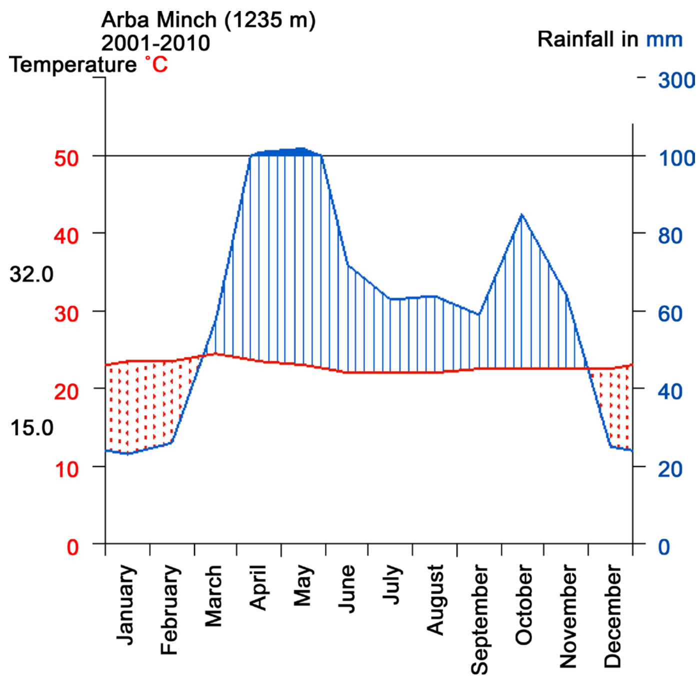

Figure 2. Climate diagram of the study area (from 2001-2010).

Correspondence Analyses with two Dimensions was computed. Correlation of degree of the invasive infestation with species abundance of macrophytes was computed Using Microsoft Excel. Ordination by non-parametric multidimensional scaling and clustering of samplings sites based on macrophyte community composition and abundance was done using Primer (version 6) [13]. Macrophyte plant distribution with respect to plant category was analyzed also using orbit lab software.

$$\text{Abundance}(\text{A}) == \frac{\sum \text{individual species}}{\text{Sampled plots}} \tag{1}$$

$$\text{Proportion}(\text{P}) = \frac{\sum \text{individual species}}{\sum \text{all individuals of all species}} \tag{2}$$

$$\text{Relative density}(\text{R}) = \frac{\sum \text{individual species}}{\sum \text{all individuals of all species}} \times 100 \tag{3}$$

$$\text{Dominance} = \frac{\sum \text{plots occupied by a species}}{\sum \text{all plots}(\text{m})} \tag{4}$$

$$\text{Simpson's index}(D) = \frac{\sum n(n-1)}{N(N-1)} \tag{5}$$

$$\text{Evenness} = \frac{D}{S'} \tag{6}$$

$$\text{Richness} = (\text{Dmg}) = \frac{(S-1)}{\text{In}N} \tag{7}$$

where N = total number of organisms; n = number of particular species; s = total number of spp

$$\text{Sorensen index} = \frac{2\text{C}}{\text{A}+\text{B}} \tag{8}$$

where *A*—species number in community ‘*A*’; *B*—species number in community ‘*B*’; *C*—common species number in both communities.

3. Results and Discussion

We recorded a combined total of 23 macrophyte species belonging to 15 families in all the sites. Out of these, 16 species were observed in the water hyacinth-infested sites whereas 17 were observed in the non-infested sites. Thirteen of the 15 families recorded at Lake Abaya were monospecific, only two families, Cyperaceae and Poaceae, were represented by more than one species. Cyperaceae dominated in terms of diversity with 6 species followed by Poaceae with four species (**Table 1**).

Both the infested sites and non-infested sites had a unique combination of macrophyte communities. Presence of seven macrophyte species, *i.e. Sagittaria latifoli* (Alismaceae), *Cyperus esculentus* (Cyperaceae), *Lemnae equinoctialis* (Lemnaceae), *Pistia stratoides* (Araceae), *Polygonum punctatum* (Polygonaceae), *Potamogeton crispus* (Potamogetonaceae), and *Spharganium americanum* (Sparginaceae), characterized the non-infested sites. These seven species were absent from infested sites.

On the other hand, six other macrophyte species, namely *Bacopa monnieri* (Scrophulariaceae), *Bulbine abyssinica* (Aspodelaceae), *Eichhornia crassipe* (Pontederaceae), *Echinochloa rotundiflora* (Poaceae), *Isoetes* sp. (Isoetaceae), *Leptochloa difusca* (Poaceae) were found only in infested sites. The remaining ten macrophyte species belonging to five families were recorded in both infested and non-infested sites. Of these, with five species in both habitats, the family Cyperaceae seems to flourish under both conditions.

More than half of the macrophyte species at the studied sites in Lake Abaya were emergent, with the remaining 44% comprised of equal proportions of submerged and free floating forms (**Figure 3**). It was interesting to note that seven of the ten species common to both infested and non-infested sites were emergent macrophytes.

3.1. Species Richness

Our results showed that species richness in infested sites was 80% - 85% of non-infested sites (**Table 1**). A similar reduction in species richness in plant communities was also reported by [14].

Eleven species were recorded from each of the two infested sites. *E. crassipes* dominated site 1 followed by *Cynodon plectostachyus and Cypress difformis.* Whereas *C. diffusa, B. abyssinica* and *E. rotundiflora* had lower abundance than the three species (**Table 2**). Macrophyte distribution at site 1 was patchy in that though some macrophytes exhibited considerable abundance in some plots, they were rare in most plots. For example, *C. plectostachys* occurred only in 8 plots whereas *E. crassipes* was found in all studied 15 plots of site 1.

E. crassipes and *Typha latifolia* dominated the second infested site—site 2, together contributing over 50% of the observed abundance (**Table 2**). The species with the broadest occurrence was *T. latipholia*, with a distribution spanning over nine plots; the remaining nine species had restricted distribution in the studied plots. *Isoetes* sp. is the most abundant species at the site but its distribution within the site was limited confirming the patchy nature of macrophyte distribution in Lake Abaya.

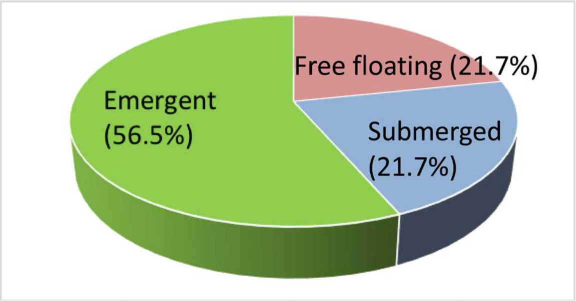

Figure 3. Relative abundance of macrophytes with respect to plant category.

Table 1. Macrophyte taxa recorded in the four sites of Lake Abaya, Ethiopia. (FF = free floating, Em = emergent, Sm = submerged: + = present, − = absent, Inf = infested site, Noinf = non-infested sites).

Taxon name	Family	Habit	Category	Infested	Non-infested
Bacopa monnieri	Scrophulariaceae	Herb	Sm	+	−
Bulbine abyssinica	Aspodelaceae	Shrub	Em	+	−
Commelina diffusa	Commelinaceae	Herb	Sm	+	+
Costus lucanusianus	Costaceae	Shrub	Em	+	+
Cynodon dactylon	Poaceae	Forb	Sm	+	+
Cynodon plectostachyus	Poaceae	Forb	Sm	+	+
Cyperus difformis	Cyperaceae	Herb	Em	+	+
Cyperus dives	Cyperaceae	Herb	Em	+	+
Cyperus esculentus	Cyperaceae	Herb	Em	−	+
Eichhornia. crassipes	Pontederaceae	Herb	FF	+	−
Echinochloa rotundiflora	Poaceae	Forb	Em	+	−
Eleocharis obtuse	Cyperaceae	Herb	Em	+	+
Isoetes sp.	Isoetaceae	Herb	FF	+	−
Lemna equinoctialis	Lemnaceae	Herb	FF	−	+
Leptochloa difusca	Poaceae	Forb	Sm	+	−
Pistia stratoides	Araceae	Herb	FF	−	+
Polygonum punctatum	Polygonaceae	Herb	Em	−	+
Potamogeton crispus	Potamogetonaceae	Herb	FF	−	+
Rhynchospora corymbosa	Cyperaceae	Forb	Em	+	+
Sagittaria latifolia	Alismaceae	Herb	Em	−	+
Schoenoplectus corymbosa	Cyperaceae	Herb	Em	+	+
Spharganium americanum	Sparginaceae	Herb	Em	−	+
Typhalatifolia	Typhaceae	Herb	Em	+	+

Fourteen macrophyte species were recorded at non-infested site 1 (Table 2). *C. plectostachyus* followed by *C. esculentus,* and *cynodon dactylon* were the most abundant macrophytes at this site. *Polygonum punctatum* and *Lemna equinoctialis* have good number of individuals but were recorded in less than ten plots. *C. lucanusianus, S. americanum* and *S. latifolia* were the least abundant species. Similarly regarding the relative density and dominance, *C. plectostachyus*, *Eleocharis obtusa* and *Isoetes* were at higher rank, respectively, whereas *Rhynchospora corymbosa* and *Sagitaria latifolia* were lower.

Non-infested site 2 had 13 species macrophyte species with *C. plectostachys, S. corymbosa* and *C. difformis* as the most abundant taxa. On the other hand, *R. corymbosa*, *P. punuctatum* and *R. corymbosa* were the three least abundant species at the site (Table 2). Even though *R. corymbosa* and *S. latifolia* seem to have higher abundance value, the relative density and dominance value clearly indicated

Table 2. Distribution profile of encountered macrophyte species in the four sites (for formula of parameters refer to "Data Analysis".

Macrophyte species	Infested Site 1						Infested Site 2						Non-infested Site 1						Non-infested Site 2					
	Total № Species	Observed plots	Abundance (A)	Proportion (P)	Relative density (R)	Dominance	Total № Species	Observed plots	Abundance (A)	Proportion (P)	Relative density (R)	Dominance	Total № Species	Observed plots	Abundance (A)	Proportion (P)	Relative density (R)	Dominance	Total № Species	Observed plots	Abundance (A)	Proportion (P)	Relative density (R)	Dominance
Bacopa monnieri	---	---	---	---	---	---	10	4	2.50	0.11	11.11	0.27	---	---	---	---	---	---	---	---	---	---	---	---
Bulbine abyssinica	4	2	2.00	0.02	2.27	0.13	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Commelina diffusa	3	2	1.50	0.02	1.70	0.13	---	---	---	---	---	---	---	---	---	---	---	---	9	5	1.80	0.05	4.89	0.33
Costus lucanusianus	12	3	4.00	0.07	6.82	0.20	---	---	---	---	---	---	11	8	1.38	0.04	4.35	0.53						
Cynodon dactylon	13	7	1.86	0.07	7.39	0.47	4	2	2.00	0.04	4.44	0.13	14	8	1.75	0.06	5.53	0.53	17	6	2.83	0.09	9.24	0.40
Cynodon plectostachyus	19	8	2.38	0.11	10.80	0.53	5	4	1.25	0.06	5.56	0.27	65	15	4.33	0.26	25.69	1.00	31	7	4.43	0.17	16.85	0.47
Cyperus difformis	14	7	0.52	0.08	7.95	0.47	5	4	1.25	0.06	5.56	0.27	---	---	---	---	---	---	25	11	2.27	0.14	13.59	0.73
Cyperus dives	15	7	2.14	0.09	8.52	0.47							---	---	---	---	---	---	18	5	3.60	0.10	9.78	0.33
Cyperus esculentus	---	---	---	---	---	---	---	---	---	---	---	---	17	6	2.83	0.07	6.72	0.40	---	---	---	---	---	---
Echinochloa rotundiflora	5	3	1.67	0.03	2.84	0.20	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Eichhornia crassipes	75	15	5.00	0.43	42.61	1.00	34	12	2.83	0.38	37.78	0.80	---	---	---	---	---	---	---	---	---	---	---	---
Eleocharis obtuse	---	---	---	---	---	---	3	3	1.00	0.03	3.33	0.20	29	11	2.64	0.11	11.46	0.73	16	7	2.29	0.09	8.70	0.47
Isoetes sp.	---	---	---	---	---	---	3	1	3.00	0.03	3.33	0.07	21	10	2.10	0.08	8.30	0.67	13	7	1.86	0.07	7.07	0.47
Lemna equinoctalis	---	---	---	---	---	---	---	---	---	---	---	---	18	9	2.00	0.07	7.11	0.60	---	---	---	---	---	---
Leptochloa difusca	---	---	---	---	---	---	1	1	1.00	0.01	1.11	0.07							---	---	---	---	---	---
Pistia stratoides	---	---	---	---	---	---	---	---	---	---	---	---	8	5	1.60	0.03	3.16	0.33	8	3	2.67	0.04	4.35	0.20
Polygonum punctatum	---	---	---	---	---	---	---	---	---	---	---	---	19	8	2.38	0.08	7.51	0.53	5	2	2.50	0.03	2.72	0.13
Potamogeton crispus	---	---	---	---	---	---	---	---	---	---	---	---	15	8	1.88	0.06	5.93	0.53						
Rhynchospora corymbosa	---	---	---	---	---	---	2	2	1.00	0.02	2.22	0.13	6	3	2.00	0.02	2.37	0.20	3	1	3.00	0.02	1.63	0.07
Sagittaria latifolia	---	---	---	---	---	---	---	---	---	---	---	---	2	2	1.00	0.007	0.79	0.13	6	2	3.00	0.03	3.26	0.13
Schoenoplectus corymbosus	6	3	2.00	0.03	3.41	0.20	5	4	1.25	0.06	5.56	0.27	14	7	2.00	0.06	5.53	0.47	30	10	3.00	0.16	16.30	0.67
Spharganium americanum	---	---	---	---	---	---	---	---	---	---	---	---	14	9	1.56	0.06	5.53	0.60	---	---	---	---	---	---
Typha latipholia	10	6	1.67	0.06	5.68	0.40	18	9	2.00	0.20	20.00	0.60	---	---	---	---	---	---	---	---	---	---	---	---

that they a clearly limited distribution at the site.

As it can be seen from the above result, *E. crassipes* was the most dominant macrophyte species in the two infested sites. Infested site-2 seems to be most affected by the invasion of *E. crassipes*, it has the lowest species composition and total number of individuals. Even though the species number is comparable to infested site-1, the total number of individuals is less than observed at infested site-1. The proportion analyses showed that the ratio of water hyacinth over the other macrophytes is 0.43 and 0.38 in infested sites 1 and 2, respectively. This finding also agrees with [15].

In the present study *Pistia stratiodes* was observed only in 5 plots of non-infested sites. Arille [16] discussed the reasons how *E. crassipes* outcompetes other macrophytes like *P. stratiodes* for available nutrients. *Isoetes* is a submerged macrophyte which is affected by the amount of available light. Most likely the thick mat growth of *E. crassipes* in sites-1 and 2 affected the growth of *Isoetes.* This species had higher abundance in non-infested site-1 where there was no shading influence. It is understandable that submerged plants would be more prone to the effect of shading than emergent macrophytes [17]. Our current study confirmed this general notion: the abundance of emergent macrophytes was more than twice that of the submerged ones (**Figure 3**).

At infested site 2, *T. latifolia* had a comparable number of individuals and seems to co-exist with the dominant invasive species (**Figure 4**). Tellez *et al.* [18] indicated that *T. latifolia* is a beneficial plant for the alien species as mechanical supporter during early growth stage. On the other hand, *C. plectostachys* is possibly competing with *E. crassipes* with a clear suppression by the latter when they occur together. For instance, at infested site-1 the number of individual plants of *C. plectostachys* was 19 whereas that of *E. crassipes* was 75 individuals (**Table 2**), but in non-infested site-1 the number of *C. plectostachys* was much higher, *i.e.* 65, in the absence of the invasive species (**Table 2**). However, in infested site-2 the number of *E. crassipes* was reduced by half in the presence of only 5 individuals of *C. plectostachys* (**Table 2**). At the proximate non-infested site-2 *C. plectostachys* seems to recover to 31 individuals in the absence water hyacinth (**Table 2**).

The number of macrophyte species in the community showed significant but negative correlation at ($r = 0.904$ Pearson correlation) (**Figure 5**). As the number of water hyacinth per plot increases the total number of other macrophyte species in the site decreased. This shows that *E. crassipess* has serious impact on floral diversity. Arille [16] and [18] reported a similar species reduction when invasive species colonize wetlands. Also, Gichugi [17] and Shibu [5] showed, the

Figure 4. *Eichornia crassipes* (water hyacinth) infestation in Lake Abaya, Ethiopia.

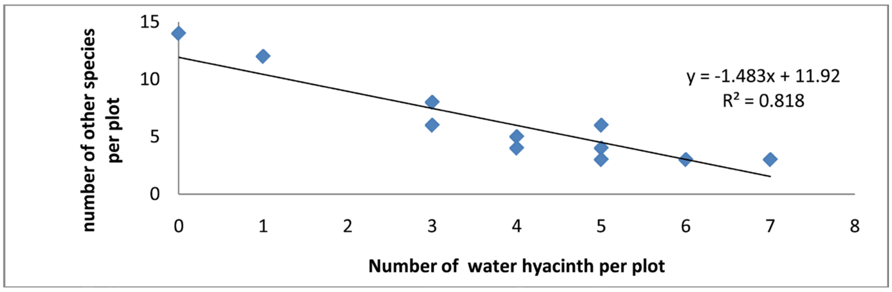

Figure 5. Correlation of the number of observed macrophyte species per plot against the density of water hyacinth in Lake Abaya, Ethiopia.

former in Africa lake environment, that the invasion of water hyacinth and other related alien species affect the abundance and diversity of macrophytes resulting in largely monotypic floral community structure.

3.2. Community Structure, Similarity & Diversity

Macrophyte communities of the two non-infested sites are more similar with each other than with any of the two infested sites. Furthermore, the level of similarity among non-infested sites was much higher (60%) than macrophyte communities at the two infested sites (45%) (**Table 3**, **Figure 6(a)** & **Figure 6(b)**). Our data also showed that whether a site was infested or non-infested affected macrophyte composition and similarity than physical proximity of sites.

Species diversity at infested sites was lower than diversity at non-infected sites (**Table 4**). Furthermore, evenness of macrophyte communities at infested sites was lower than non-infested sites, indicating the drastic impact of invasive water hyacinth on diversity. However, whether the observed community difference at the two infested sites is related to the length of time since first infestation is currently unknown. A clear understanding of time of infestation and direction of invasion certainly will help us understand better the level of impact and direction of impact progression in the context of local environmental conditions. Macrophyte assemblages are indicated to be impacted by competition [20].

3.3. Implications within Local Context

Our data clearly showed that water hyacinth (*E. crassipes*) greatly affects the floristic composition, abundance and diversity of Lake Abaya. Despite the fact that many macrophyte species might have been outcompeted by the invasive species, this study also showed that some macrophyte species, for example, members of the Poaceae and Cyperaceae family, have the ability to co-exist with the alien plant and even possibly control its further spread. This could be due to a number of potential factors such as the specific growth habit of the macrophyte taxa, that may potentially make those tolerant species less prone to the shading effects and other forms of competition of water hyacinth.

We recognize that wetland ecosystems, especially shallow freshwater lakes in the tropics, continue to face sustained human infraction because of their close ties with local economies and the livelihood of communities. Nevertheless, despite

Table 3. Sorensen [19] similarity indexes of macrophyte communities the four study sites (beta diversity) at Lake Abaya, Ethiopia.

	Infested Site-1	Infested Site-2	Non-infested Site-1	Non-Infested Site-2
Infested Site-1	1	0.45	0.4	0.58
Infested Site-2		1	0.4	0.58
Non-infested Site-1			1	0.66
Non-infested Site-2				1

Table 4. Macrophyte diversity, evenness and richness in the four study sites at Lake Abaya, Ethiopia.

Site	H' (Shannon-Weiner Diversity Index)	D (Simpson's index)	Evenness	Richness
Infested Site-1	1.925	0.22	0.40	1.93
Infested Site-2	1.91	0.20	0.43	2.22
Non-infested Site-1	2.388	0.11	0.60	2.35
Non-infested Site-2	2.29	0.11	0.67	2.13

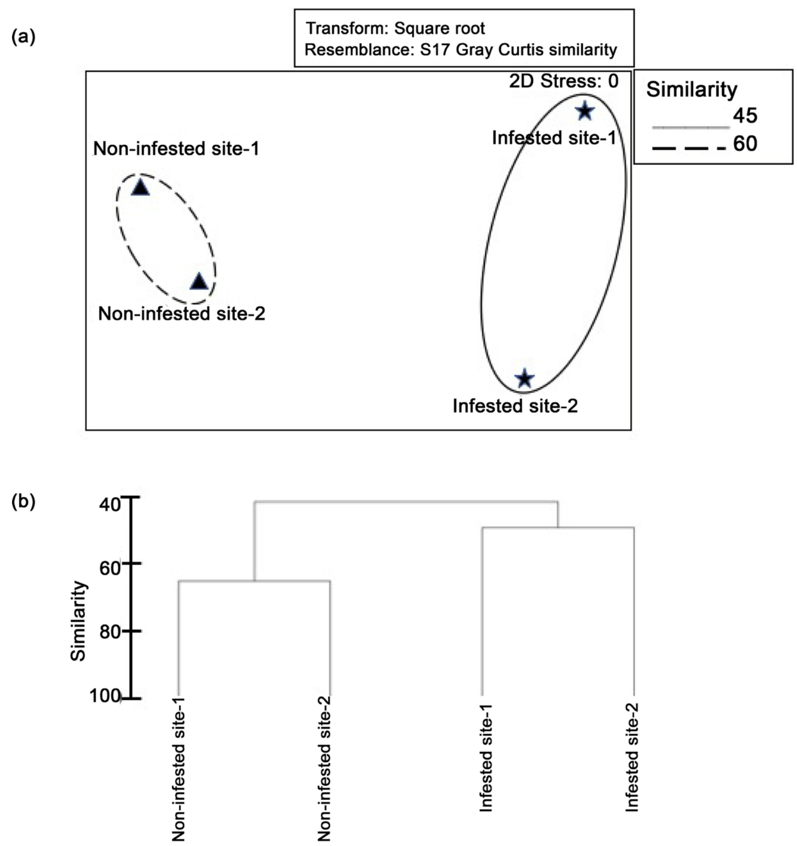

Figure 6. Multivariate analysis of community structure. (a) Non-metric Multidimensional Scaling (MDS) based on Bray-Curtis similarities of macrophyte abundance showing the clear distinction between infested and non-infested sites. Non-infested sites appear to be more similar (60%) that infested sites (45%). (b) Cluster Analysis based on Bray-Curtis similarities using square root transformed data clearly separating macrophyte communities of infested sites from non-infested sites.

their critical economic benefits, freshwater bodies largely remain unexplored in terms of what level of human disturbance tilts their sustainability balance and what level of potential resilience they exhibit towards specific kinds and level of environmental disturbances. Consequently, a comprehensive look at the wider environmental, economic and other impacts of the invasive water hyacinth in Ethiopia is currently not only warranted but overdue.

Water hyacinth has now reached the entire rift valley system and ventured to the largest lake in the country located outside the rift valley—Lake Tana. This has triggered a certain level of local outcry in response to the environmental and economic devastation this invasive species caused in Lake Tana [21]. As a result, researchers are now busy investigating the species where its invasion and impact is deemed critical [22] [21]. These efforts are certainly commendable and encouraging. Studies on this species within the framework of local environmental and social conditions, however, need to go beyond recording status quo of occurrence or impact on fisheries and should be able to develop comprehensive models that predict its temporal invasion expansion patterns within the context of specific water body in question, ecosystem impact and potential disruption.

Invasive macrophytes, apart from their myriad of impacts on non-living anthropocentric values of aquatic habitats, they also impact the living component, *i.e.* microbial, phytoplankton, zooplankton, benthos, macrophytes, fish and other vertebrates, by modifying the physical and chemical environment. Nonetheless, the impact of water hyacinth on ecological communities is known to be non-linear [23]. Availability of specific nutrients, trophic status of water bodies, dominant food web structure, overall community structure and degree of human impact can affect and direct the specific outcome of invasive species such as water hyacinth [24] [25].

Dissecting these and fleshing out the damage by invasive species and their proportional contribution to the overall ecosystem level changes will be key in making an informed decision towards how to address the invasion of water hyacinth in the specific Ethiopian lake ecosystems. For example, aquatic invertebrates generally increase associated with water hyacinth invasion. The refuge effect of submerged macrophytes in lakes on enhancing zooplankton communities and the control of phytoplankton has been demonstrated to be positive [26]. In some cases, invasive, submerged macrophyte species have impacted zoobenthos positively but not the zooplankton [27]. The impact on fish communities, however, is not straightforward and depends largely on original community composition and food web structure. Gerard, and Triest [23] stated "the response of fish communities to water hyacinth is highly dependent on the pre-existing fish community, preferred and available fish habitat, food requirements and availability, physical & chemical conditions and, likely although not proven, water hyacinth density". In addition, "dominant non-native macrophytes may cause significant changes in food web structure of invaded ecosystems" [25]. The impact of an ever-dynamic climate on the macrophyte-phytoplankton productivity balance is also not straight forward and complicates the predictive power of research [28]. All this can be complicated even further by the fact that floating macrophytes in tropical habitats [29] may play key ecological role as a carbon sink—an ecosystem function not in the forefront of concerns in relation to immediate & local human suffering.

Therefore, the need to quantify damage at every level of ecosystem services, impact on human livelihood and disruption of normal human activities cannot be over emphasized. Questions addressing specific environmental conditions in the geographically and limnologically different lakes, Abaya and Tana, for example, would contribute to a better understanding of impact and the development of scalable control measures. Given these generalities, it will be only through critical, systematic, fundamental and comprehensive research that implementable models can be developed that will provide policy makers the needed tools not only to ameliorate the impact on already infested water bodies, but even more to fight the spread of water hyacinth to other uninvaded water bodies through all means including public policy and extensive outreach.

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The Importance of Environmental English Public Signs to Xiong'an New Area's Ecological Environment in China

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Abstract

With the establishment and development of Xiong'an New Area in China, more foreign industries and visitors will be attracted to come here. Investigations made in our study show that the environmental English public signs are very important. They can offer directions for foreigners who can't understand Chinese well because they have these three functions: indication, suggestion and prohibition. In order to help Xiong'an New Area play its "eco card", the translators are supposed to attach great importance to the translation of environmental English public signs.

Keywords

Xiong'an New Area in China, Environmental English Public Signs, Eco Card

1. Introduction

"Public Signs" is a kind of public language appearing in public places. It intends to convey some special meaning to the public and it is a special style of communication [1].

The translation of public signs reflects the civilization and the culture level of a city, so it becomes more and more important. Meanwhile, environmental problems, energy problems, ecological balance problems, etc. become a common concern with the global environmental deterioration. Creating a good natural and friendly cultural environment will become one of the focuses of the whole world. The purposes of environmental English public signs are to better publicize the concept of environmental protection, strengthen readers' awareness of environmental protection and arouse the reader to protect the environment with practical action. Most importantly, they can offer directions for foreigners who are not able to understand Chinese well. In this way, it is expected to create a harmonious ecological environment and discourage actions hostile to the environment.

On April 1st, 2017, the Central Committee of the Communist Party of China and the State Council decided to set up a Hebei new security zone, Xiong'an New Area [2]. It is another new district with national significance after Shenzhen Special Economic Zone and Shanghai Pudong New Area. It is a historic strategic choice for carrying out the Millennium Program and state affairs. There are seven important tasks in Xiong'an construction and planning. The first two tasks are related to Environmental protection industry. Xiong'an New Area strives to become a green city.

In "Opinions on expanding opening to the outside world and actively use foreign capital adopted by the State Council" [3], it is clearly stated that implementation of foreign investment policy to build an open area of New Development Zone is very important. With the establishment and development of Xiong'an New Area, it will attract more and more foreign visitors and industries from every corner of the world coming into China. With the increasing number of the foreigners, the environmental English public signs will become more important, because they offer foreigners more information on where and how to do to be friendly with the local environment in English which foreigners can understand easily.

2. Ecology Is the Key Point in the Development of Xiong'an New Area

Yunzhong Liu, dean of Development Strategy Research Center and Regional Economic Research Department of the State Council Development Research Center, believes that Xiong'an New Area in China plays a critical role in the process of constructing world class urban agglomerations in Jing-Jin-Ji. There are three points. First, Xiong'an New Area is an important base in developing high-end high-tech industry, and it will absorb and gather a great deal of innovation factor resources and become a new momentum of economic growth and an important innovation driven place. Second, Xiong'an New Area will be the benchmark and model in construction ecological and intelligent city. It will improve the world influence and competitiveness of Jing-Jin-Ji. Third, Xiong'an New Area will be the benchmark and model of governance structure innovation in metropolitan areas, urban agglomerations and urban continuous belts in the world.

2.1. The New District Planning Should Play "Eco Card"

The green development concept should be integrated into the planning, compilation, approval, implementation, supervision and assessment of the integrated development plan [4]. The most important thing is to form a joint effort to promote the construction of ecological civilization, and all kinds of behavior subjects, especially the government's public decision-making, should be green.

The development of Xiong'an New Area is a Millennium Project and a major national event. Chairman Xi Jinping pointed out that we should use the most advanced concepts and world-class design to create an innovative development demonstration zone for the implementation of the new concept of development. As we can see, the ecology has been placed in an important position in the construction of Xiong'an New Area. Green development concept should and must be integrated in the process of planning, preparation, approval, implementation, supervision and assessment.

2.2. With Culture as the Driving Force, It Will Become a Whole City of Tourism Integrating History with Modern Times

One of the important positions of Xiong'an New Area is to share part of the function of Beijing. Universities, research institutions and even government departments will move from Beijing to Xiong'an New Area, which will make a large number of elite permanent residents live here. Where there are people, there must be a new culture. The elite from Beijing will also bring forth a new culture of Xiong'an New Area. This is the core driving force of the tourism industry in the new district. The connotation of Xiong'an culture can be divided into the following three parts: First, there are a lot of reformers like Jiao Zhang, Bei Liu, Kuangyin Zhao, Zhidong Zhang, Dazhao Li. They all played important roles in different social change in different historical periods. Second, there are a great number of heroes and heroines such as Ke Jing, Sui Mao, Zheng Wei, Mulan Hua. Third, there are lots of poets and writers like Yu Han, Hanqing Guan, Xueqin Cao. All of these famous people contribute to the tourism of Xiong'an New Area and it will attract more and more foreigners to come to China. As a result, the environmental English public signs will be very critical and important for the improvement of ecological environment.

3. The Important Functions of Environmental English Public Signs in the Ecological Development of Xiong'an New Area

English is an international language. The environmental English public signs play very critical roles in the ecological development of Xiong'an New Area. They affect many aspects of people's life. With the rapid development of Xiong'an New Area in China, a lot of visitors, industries and workers will probably come into here. In order to offer more information for foreigners about environment protection, the existence of Environmental English public signs will be very necessary because they have the following functions: indicative function, suggestive function and prohibitive function.

3.1. The Indicative Function

The indicative function of environmental English public signs offers considerate information, and there is no prohibition [5]. Its main purpose is to help foreigners feel easily and comfortably which contributes to the ecological development of Xiong'an New Area.

Such public signs as “Trashcan on the right”, “Please feel free to smoke in the lounge”, “Save water”, “NON RECYCLABLE” are indicative environmental English public signs. They will help foreigners get enough information on where to throw their garbage and where to smoke.

3.2. The Suggestive Function

The suggestive environmental English public signs can be widely used in many cases. They have no strict restriction and they offer a lot of information. Public signs like “Recycle bins are located in the area between tower A (basement floor) and B”, “Look for the blue rectangular containers”, “Thank you for helping out our environment”, “Just like Santa Claus and the Easter Bunny, the cleaning fairy DOES NOT EXIST!!”, “Please keep area clean and tidy at all times.”, “Please keep this office tidy and use the bins provided” [6] etc. play an very important function in helping foreigners keeping the environment clean and clear.

3.3. The Prohibitive Function

The prohibitive environmental English public signs clearly put forward requirements and standards for the public’s behavior. There are some restrictions. The language is direct but not rude and impolite. Such public signs as “Quiet, please.”, “Keep off the grass” are typical environmental English public signs. They keep people from doing some things which is harmful to the environment.

The environmental English public signs are not only used in social life, but also used in industries, agriculture and so on. Its purpose is to make Xiong’an New Area develop in the right orbit. With the development of society and economy, environmental pollution and ecological energy crisis have become urgent and urgent matter to be solved. Environmental protection English public signs follows the footsteps of the times, reflecting the common existence of mankind and the earth and the sustainable development vision. In addition, it also shows the urgency of human survival in terms of positive action and propaganda of environmental protection which reflects the coordinated development of human survival and environmental protection.

4. Some Statistics on the Importance of Environmental English Public Signs

In order to test the importance of environmental English public signs, we made an investigation on it.

We interviewed 56 travelers who came from different countries. The following four questions were asked. 1) Is it easy for you to find trash cans in a place where there are no environmental English public signs are? 2) Is it easy for you to find trash cans in a place where there are environmental English public signs? 3) Do you think environmental English public signs are necessary especially in scenic spots or industrial area? 4) Is it easy for you to understand environmental Chinese public signs? The statistics of the four questions are listed in **Tables 1-3**.

Table 1. Comparisons between environmental English and Chinese public signs.

questions	Very Easy (%)	Easy (%)	So So (%)	Difficult (%)	Very Difficult (%)
1	4%	7%	3%	20%	66%
2	80%	15%	5%	0	0

Table 2. The necessity of environmental English public signs.

question	Very necessary (%)	Necessary (%)	So So (%)	Unnecessary (%)	Completely unnecessary (%)
3	52%	40%	3%	3%	2%

Table 3. Foreigners' Understanding for environmental English public signs.

question	Very Easy (%)	Easy (%)	So So (%)	Difficult (%)	Very Difficult (%)
4	2%	9%	30%	41%	18%

The above four tables show that it is difficult for foreigners to understand environmental Chinese public signs. Environmental English public signs will be very helpful for foreigners to get enough directions to find where to drop litter or to smoke, etc., so environmental English public signs are necessary and helpful in offering more directions for foreigners.

5. Conclusions

English is an international language. Translation aims at expressing the content and thought of the original language text clearly and explicitly, so as to eliminate the gap between languages and cultural differences. So, Environmental English public signs translation plays an important role in building a green and low-carbon blueprint for sustainable development. Chinese and English have their own unique cultural background and origin, so only on the basis of mastering and applying translation language and combining with the purpose of environmental protection translation can we realize and develop the purpose of environmental English translation.

With regard to the functions of environmental English public signs and the different languages and cultures, the translation of the public signs is very critical and important. So many people coming from different fields, translator, research institutions, related government departments, media, will be responsible for it [7]. They need cooperate with each other and take their own responsibilities.

Environmental English public signs are an important part of social language reflecting the rapid development of the Chinese government and the public in the current industrialized society. With the rapid development of Xiong'an New Area, there will be more and more industries and foreigners gathering in Xiong'an New Area. Most importantly, the new district planning plays "eco card" [8], which means environmental protection is one of the key factors in the process of its development. As a result, the environmental English public signs become very important and necessary. By paying attention to environmental protection, we try to achieve the coordinated development of material civilization and spiritual civilization construction.

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