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The effects of climate change on freshwater aquatic biodiversity, case of the Ikopa river, Ambohimanambola, Antananarivo, Madagascar

Abstract

Climate change causes many problems all around the world and Madagascar is also affected. The effect of El Niño, coupled with climate change, generates an increase in temperature and an important heat release. The knowledge of the impacts of climate change on freshwater biodiversity is still limited. The focus of this work was to study the influence of these climate phenomena on diversity and on the composition of aquatic fauna species, such as insects and fish. The sampling activity took place from January 6th to January 8th, 2016.The depth of the river, the temperature of the water. The pH and the rate of dissolved oxygen were significantly different compared to the results obtained from 1982 to 1984. The sensitive taxa, such as *Ecdyonorus, Ephemera, Ephemerella* (Aquatic insects, Ephemeroptera) and *Phryganea* (Aquatic insects, Trichoptera) have disappeared. A reduction in diversity and a modification in the composition of fauna were observed, especially the lack of *Anguilla mossambica,* and two species of *Sarotherodon (mossambicus andniloticus).*Some fish were asphyxiated.

Keywords: biodiversity, climate change, aquatic insects, freshwater fish species, Ikopa River-Ambohimanambola, Madagascar

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Introduction

The current global climate change, in interaction with the climatic phenomenon called El Niño, has significant effects on the global ecosystem and Madagascar is not spared from their influence. This situation is characterized by an increase in air and water temperature, as well as a significant release of heat. The extent of this phenomenon is inseparable from the greenhouse effect responsible for global warming.[1] Globally and in Madagascar, climate change is having an impact on aquatic ecosystems due to changes in rainfall, air and water temperatures. An increase in water temperature causes a degradation of the metabolism of organic matter leading to the rarefaction of dissolved oxygen and an increased evaporation. The El Niño phenomenon often leads to droughts that occur as a result of rainfall deficits.[2] Hydrological drought refers to a decrease in river flows[3] and stream depth.

Aquatic organisms vary in their ability to withstand temperature and rainfall disturbances depending on their tolerance and their capacity to escape or find refuge. Indeed, climate change accompanied by the effect of El Niño can affect the diversity of aquatic species and lead to their disappearance because of the lack of adaptation to this change. Furthermore, data and knowledge on the impacts of global warming on freshwater aquatic biodiversity in Madagascar are scarce. It is in this perspective that this research was conducted, aiming to study the influence of climate change with the action of El Nino on freshwater taxonomic diversity and freshwater composition like aquatic insects and fish. Environmental variables such as water temperature, pH, dissolved oxygen, turbidity, flow, and water depth were measured. Aquatic insects and fish were inventoried.

Materials and methods

The study site was the Ikopa – Ambohimanambola River Figure 1, located between 47°36' East longitude and 18°57' South latitude, with an average altitude of 1240 m. Three stations were sampled in Antananarivo, the capital of Madagascar, in the Ambohimanambola area in the Ikopa River. The sampling took place on January 06th to 08th, 2016. The environmental variables were measured using the following instruments: flow velocity with a current meter, dissolved oxygen with a multi-parameter called JBL, river depth with a tape measure, water temperature with a thermometer, turbidity with the Snellen tube.

Figure 1 Photoof Ikopa River photo by Oliarinony, 2016.

Aquatic insect collections were made three times per station, using a Surber net, with a mesh size of 250 µm. The collection consisted of turning over stones and digging the substrates to a depth of 15 cm to dislodge the insects from the river bottom. The fish were caught using fishing rods and traditional traps for three hours per station. A survey of about 15 fisher men on the species of fish that exist in the river was carried out to complete the information. Diversity was assessed by taxonomic richness and the Shannon-Weaver index, which is recommended by various authors.[4] Species richness is the total number of taxa sampled. The Shannon index is used to express the specific diversity of a studied stand. The specific diversity characterizes the number of species present in a stand. The higher the value of the Shannon index, the more diversified the station is. It is

minimal (equal to zero) if all the individuals captured in the station belong to the same species. The Mann-Whitney test was used for the comparison of environmental variables in the present work (2016) with the work done in 1982 - 1984. The Pearson Correlation test was used to analyze the relationship between temperature and dissolved oxygen on the one hand, and temperature and specific diversity on the other hand.

Results

The pH of the water was slightly acidic (from 5.92 to 5.95), the water was less transparent (from 46 to 49 cm) and quite warm (from 23.5° C to 23.8° C). The dissolved oxygen level (5.9 to 11.07 mg. l-1), the flow rate (15.5 to 20.3 $m^3. s^{-1}$) and the depth of the river (0.7 to 1.1m) Figure 2 were rather low.

Figure 2 Photo of the Ikopa River in shallow water photo by Oliarinony, 2016.

The comparison of the means of each environmental variable from the results obtained in 2016 with those from previous work showed a significant difference with probability p = 0.05. About the diversity of aquatic fauna, the taxonomic richness of aquatic insects was equal to 29. As for fish, the specific richness was equal to 7 and the Shannon index was equal to 1.9. The result of the Mann-Whitney test showed a significant difference in the diversity of aquatic fauna sampled in 2016, compared to that of the 1982-1984 samplings Table 2 with probability p = 0.05. Regarding the Pearson Correlation test, the taxonomic richness of aquatic insects and the specific richness of fish Figures 3 & 4 showed a negative correlation. In other words, when the water temperature increases, the taxo nomic richness of the aquatic fauna decreases. It is the same with the Shannon index and the quantity of dissolved oxygen Figures 5 & 6. This means that following an increase in water temperature, there is a decrease in the Shannon index and the dissolved oxygen level. Freshwater insects and fish present in 1982-1984 were no longer recorded during the 2016 sampling Table 1.

Table 1 List of aquatic insect and fish taxa absent in 2016

Taxa (genusorspecies)	
Aquatic insects	**Fish**
Ecdyonorus (Ephemeroptera)	Anguilla mossambica (Anguillidae)
Ephemera (Ephemeroptera)	Sarotherodon mossambicus (Cichlidae)
Ephemerella (Ephemeroptera)	Sarotherodon niloticus (Cichlidae)
Phryganea(Trichoptera)	

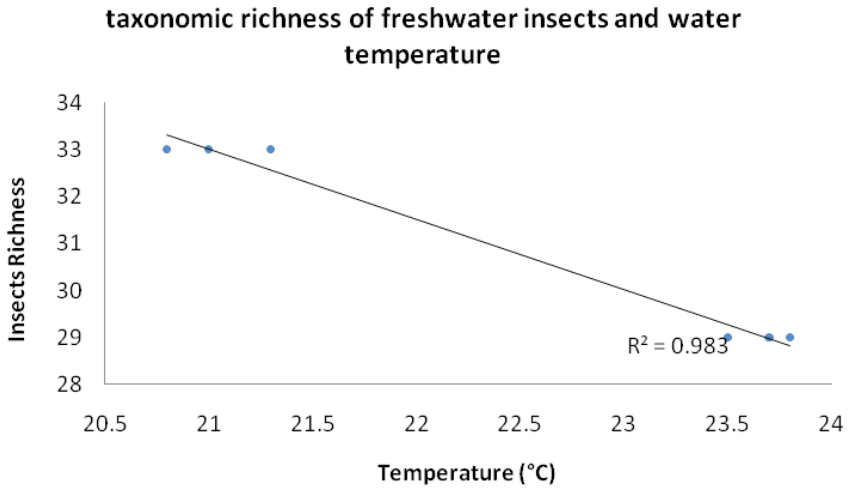

Figure 3 Correlation between taxonomic richness of aquatic insects and water temperature.

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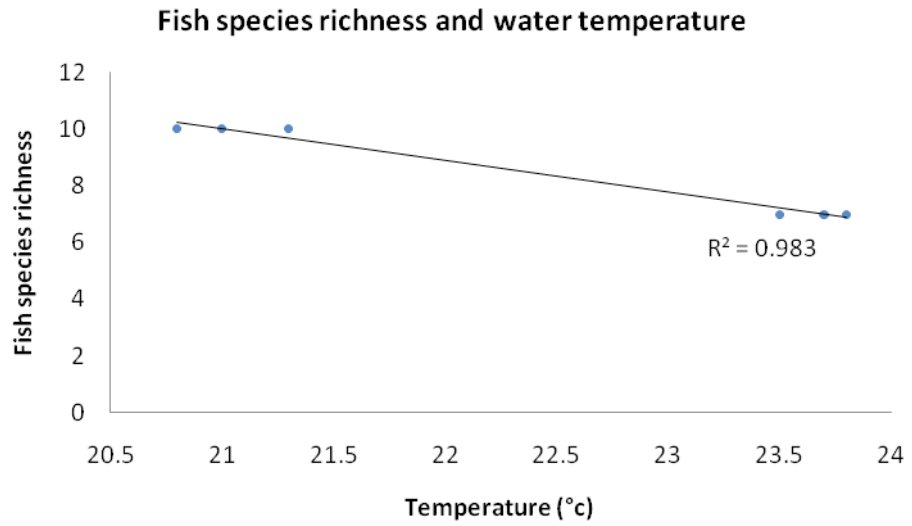

Figure 4 Correlation between fish species richness and water temperature.

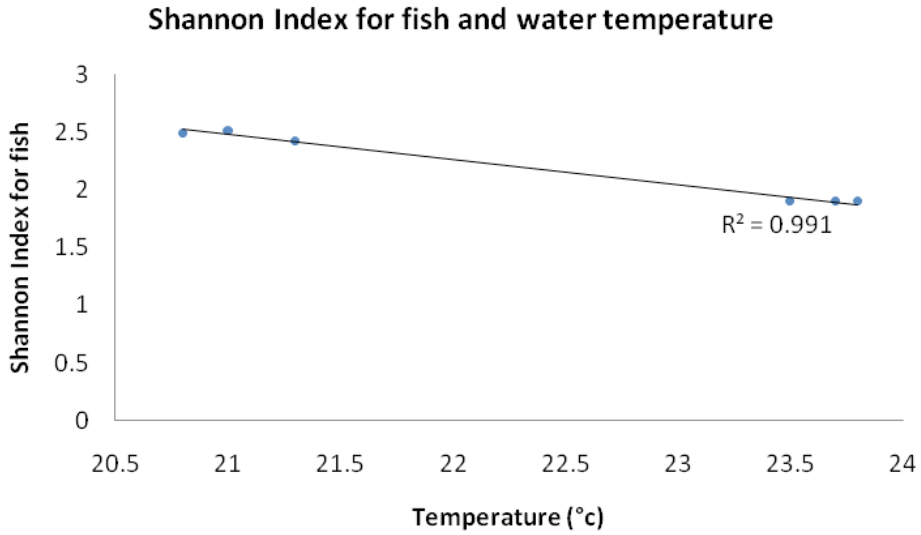

Figure 5 Correlation between the Shannon biodiversity index and water temperature.

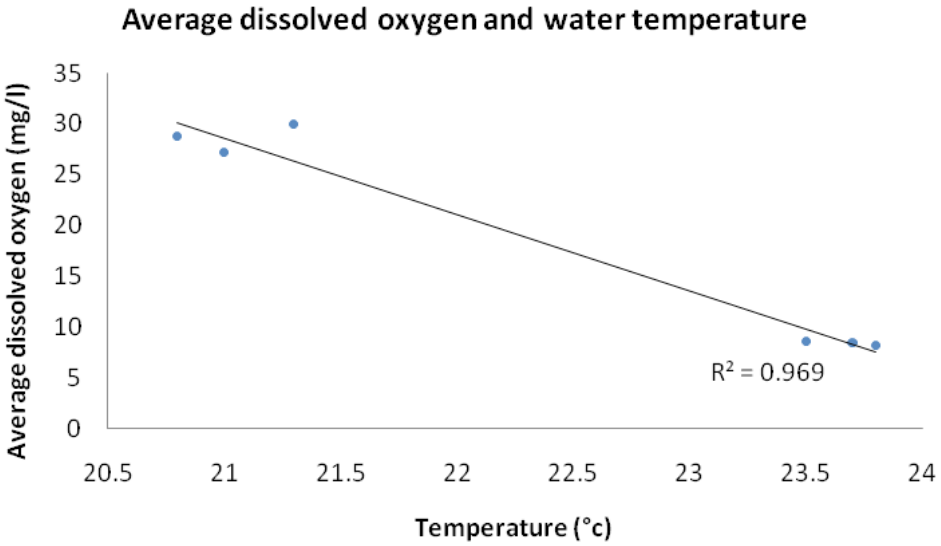

Figure 6 Correlation between the dissolved oxygen quantity and water temperature.

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Table 2 Recapitulation and comparison of environmental parameters, taxonomic richness and Shannon index between the present work (2016) and the previous work (1982 - 1984)

Date	pH	Water T° (°C)	Turb (m)	O_2 dissolved (mg. l^{-1})	Flow velocity ($m^3.s^{-1}$)	Water depth (m)	Taxon Richness	Sh Index
2016	5.92 - 5.95	23.5 - 23.8	0.46 - 0.49	5.9 - 11.07	15.5 - 20.3	0.7 - 1.1	29 (Aq.I) 7 (Fish)	1.9
1982 - 1984	6.4-6.8	20.8-21.3	9.2-9.5	from 9.3-9.5 to 45-48	26.3-87.5	2.2-2.9	33 (Aq.Ins) 10 (Fish)	from 2.42 to 2.51

Aq I -Aquatic Insect,

Sh Index - Shannon Index

Turb - turbidity,

Water T° - water temperature

Discussion

Climate warming affects hydrological parameters: flow velocity, turbidity, physicochemical water parameters such as water temperature, dissolved oxygen, and pH[5]. This phenomenon was also observed during the course of this study. The following table Table 2 shows the change in environmental parameters and aquatic fauna diversity over 30 years.

In 2016, the evolution of all environmental parameters was considerable. For example, the water temperature had increased by about 2° C compared to the values measured about thirty years ago. This remarkable warming of river water comes not only from climate change but also from the combination of climate change effect intensified by the Niño effect. Although the sampling campaign was small in 2016, similar results were found in another work done by other researchers[6] Aude D reported that the water temperature of the river in France (Le Rhône) has been measured since 1977 for nuclear power plant monitoring and has been reconstructed by statistical modelling since 1920. The analysis highlighted a great increase in mean annual temperature downstream (+ 2.1 °C) and upstream (+ 0.4 °C).According to this author, the increase in temperature has been significant since the 1980s.

The values of other parameters such as pH, turbidity, dissolved oxygen, river flow, and water depth have decreased from those of 1982-1984. The water in the river was three times shallower in 2016 compared to the 1980s. Macura[7] observed that water depth has a much greater effect on in-stream habitat quality. Given the shallow depth of the river in 2016, this change in water depth was also observed in the same year in the wetland of the Mahavavy Kinkony Complex located in the north-western part of Madagascar[8] because of the drought in Madagascar. It should be mentioned however that the Ikopa River is under threat from anthropogenic activities such as water pollution[9] from household products dumped in the river, and chemical pollution from the surrounding industries. It should be noted that the human use is high in the Ikopa river area. In addition, this river is the source of sand for most people living in the capital. The sand of the Ikopa river supplies several house building projects. Therefore, the impact of these anthropogenic activities affects the evolution of environmental variables as well as the evolution of the diversity of aquatic fauna (freshwater insects and fish) in the Ikopa River. In fact, a future study will be useful to further investigate this topic. The results from this current study focused on the negative relationship between water temperature and dissolved oxygen[10] found the same results. Water pH plays an important role in influencing many biological and chemical activities in freshwater areas. For example, a low pH value increases the solubility of metals; it may also indicate an increase in nutrients for aquatic organisms.[11] Although a reduction in pH values was recorded (about 6 in 2016, and about 7 in the 80s), these values are within the recommended range of 6.0 to 8.5 for normal life in fresh water.[12]

In[13] Chhy and their colleagues showed the regression analysis existing between aquatic insect taxonomic richness and dissolved oxygen concentration. These two parameters are positively associated, which means that the higher the dissolved oxygen level, the higher the taxonomic richness. This observation is similar to the results obtained in the 1980s (1982-1984) and the opposite of the results obtained in 2016. Changes in water flow and temperature have a negative influence on the diversity and distribution of some fish.[14]

Ficke[15] have observed the asphyxiation of some fish due to the lack of dissolved oxygen in the water because of the increase in water temperature. Indeed, the decrease in dissolved oxygen levels in the Ikopa River affects the survival status of some fish located downstream of the sampling site. The people at the river's edge were able to catch them without difficulty by hand and they were found very fragile and asphyxiated. Some climate change opportunistic species, especially generalist species, expand their area of distribution.[16]

Conclusion

This study found that global warming has caused an increase in water temperature, a decrease in pH value, turbidity, dissolved oxygen, and water flow velocity and depth in the Ikopa River. In addition, the disturbance of environmental variables led to a decrease in the taxonomic richness of aquatic insects and fish,[17] in the specific diversity, and in the modification of the freshwater faunal composition. This study can be said to be pioneering in Madagascar in terms of research on the influence of the El Niño phenomenon on freshwater aquatic biodiversity. It serves as a database for future research. This research is innovative and at the same time efficient in the sense that the cost of the research is not high. The punctual effect of the increase of the temperature, which harms the quantity of dissolved oxygen, is tangible, characterized by the asphyxiation of certain fish located downstream. The long-term effect of the increase in temperature and heat release was also noted, it was proven by the change in the diversity and composition of aquatic insects. Nevertheless, some limitations of the study are worth noting. The number of sampling days in 2016 was low. As already pointed out, the loss of biodiversity comes from several causes, not only global warming. There are among others, water pollution, overfishing, and the removal of sand for house building. Distinguishing between the effects of climate change and the impact of anthropogenic pressures

is not easy in the natural environment. However, studies show that the physiology, phenology and distribution of fish species will be directly or indirectly impacted by climate change, mainly through increased temperatures and hydro-morphological conditions. A predictive study of the long-term impact of global warming would be desirable. It is recommended that research be conducted on these three points mentioned for fish in the Ikopa River, and that regular and continuous monitoring of aquatic macro invertebrates be conducted at least twice a year (during the dry period and the rainy period) and over five successive years. Population structure, trophic guild and targeting of indicator taxa of environmental changes should be established to facilitate the monitoring of river health.

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Conflicts of interest

Author declares there is no conflict of interest.

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