

The current state of natural ponds of North Unguja, Zanzibar: The alteration due to climate change and anthropogenic events

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ABSTRACT

Natural ponds are a biologically important habitat type for their specialized collection and the considerable numbers of rare and endemic species they support and play critical role in maintaining biodiversity. Continued increases in anthropogenic behavior and climate change, act in concert to cause alteration to pond and pond perimeter. In Zanzibar, there are several ponds that impound rainfall runoff; however, there is slight concern in conservation in spite of its great support to ecosystem and livelihood. This paper aimed to determine the current changes within the natural pond perimeter of both natural and anthropogenic events, in north region of Unguja, Zanzibar. A mixed method approach was employed to collect data from 113 respondents that are community members around the six ponds (Vuga, Kichungwani, Mbiji, Muwanda, Kinyasini, and Ketwa) were involved in the study. The qualitative data collected through observations based on checklist made around the ponds was analyzed using atlas Ti software, whereas quantitative data collected through questionnaires and measurement were analyzed using SPSS software version 20. The study findings revealed that in the northern Unguja ponds, there is a greater decrease in Area size, changing in condition of water, settlement encroachment and change in vegetation cover which alter the ecosystem composition and human livelihood. These findings highlight the fundamental importance to raise awareness of the alteration trend of the northern Unguja pond and Zanzibar in general.

Keywords: Natural ponds, climate, changes (alteration), anthropogenic, freshwater.

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INTRODUCTION

A natural pond is a small body of freshwater that is usually shallow enough for sunlight to reach the bottom and allow rooting plants to grow (Nicholas, 2017), barely reach 12 to 15 feet in-depth (Rajesh and Preethi, 2017), within a confining enclosure (Dubey, 2013; Laura, 2016), with an area between 1 square meter and 8 hectares or quite smaller than a lake (Dubey, 2013) which may be seasonal or permanent (Biggs et al., 2005). Ecological studies highlight that natural ponds are a biologically significant habitat type; renowned both for their specialized collection and the considerable numbers of rare and endemic species they support (Williams et al., 2000) and play critical role in maintaining biodiversity (Kumar and Padhy, 2015) thus regarded as key components of wider landscapes (Ce'réghino et al, 2013).

In some countries including Zanzibar, ponds are

common resources available to all citizens; that is, nobody owns the water. This is a positive way of administering a resource that everyone needs. However, since the resource has no formal owner nobody takes care of it so the main view is that an ordinary resource can be used without responsibility for the consequences (Brönmark and Hansson, 2002). Thus make ponds, which maintain cultural and economic resources, are increasingly becoming threatened freshwater habitat (Kumar and Padhy, 2015; Williams et al., 2000). The climate changes and anthropogenic events may have more profound consequences in ponds because of their small contributing catchments as well as small wetted areas (Kumar and Padhy, 2015). The frequency, intensity, spatial extent, duration and timing of weather and climate extremes are all likely to alter, significantly

affecting biological communities exposed to the new conditions (IPCC, 2013) such that living in natural ponds. Most natural ponds are inherently shallow and the majorities are destroyed even by limited soil drainage for agriculture or urban development (Williams et al., 2000), land reclamation and derived pollution (Dona et al., 2016). Their low water volumes mean that they are highly susceptible to alteration (Williams et al., 2000).

MATERIALS AND METHODS

Description of study sites

The study was conducted in the Northern Region of the Unguja Island which consist two districts, North "A" and North "B" (Figure 1). The region has a total of 426 km² (RGZ, 2010). Due to its relatively higher rainfall compared to others parts of Zanzibar (Haji, 2010; Watkiss, 2012b) the region houses many ponds of Unguja Island. Specifically, the study focused on six ponds found in six village/Shehia of both North "A" and "B". These include: i) Chaani Ketwa pond: found at Shehia of Chaani Masingini in Ketwa village. (ii) Kinduni Kichungwani pond: found at Shehia of Kinduni in Kichungwani village. (iii) Vuga Mkadini pond: found at Shehia of mkadini in Vuga village. iv) Donge Mbiji pond: found at Shehia of Mbiji in Mbiji village. v) Donge Muwanda (Mwananyoto and Mzee Jumanne) pond: found at Shehia of Muwanda in Muwanda village. vi) Kinyasini Ziwani pond: found at Shehia of Kinyasini in Ziwani village. The study encompasses the pond environment and ecosystem service providing units (SPUs) around the pond which include the sum of biodiversity and the associated traits. This includes the pond water area, shorelines and buffer zone. Buffer zones of trees, shrubs, grasses, and forbs around the pond help maintain the pond's water depth and quality (Wolinsky and Bourassa, 2006).

Economy

In Unguja North Region people are engaged in more than one economic activity, with the major economic activities being farming, fisheries, tourism, seaweed farming, and retail trading as well as government employment (NDF, 2014). Local people in these districts rely heavily on ecosystem-based livelihood activities that are influenced or controlled by the climate (Makame, 2013). Fishing and farming are the leading economic activities in this Region (NDF, 2014).

Climate

In general the climate of Zanzibar Island can be categorized as tropical lowland with somewhat high temperature and high relative humidity (Haji, 2010; Watkiss, 2012a; Watkiss, 2012b; RGZ, 2010; Makame, 2013). There are four seasons in a year, namely "Masika" (spring) which is the main rainy season, experienced between March and May; "Kipupwe" (winter) the cold season, in the months of June to August; "Vuli" (autumn), short rainy season during the months of September to November and "Kaskazi" (summer), the hot season which is experienced from December to February (RGZ, 2019, Haji, 2010, Watkiss, 2012b, Makame, 2013, RGZ, 2010 and NDF, 2014).

Rainfall

The average annual rainfall for the nearest weather station, at

Zanzibar Airport, ranging from 704 mm to 2,500 mm (Haji, 2010; NDF, 2014; Hendriksen et al., 2016; UNISDR, 2015), with monthly rainfall peaks in April and May (main wet season) and November to December (short rains), reflecting a clear predominantly bi-modal rainfall pattern (NDF 2014). There is slight decrease of average annual rainfall from 1980 to 2019 (Figure 2).

Temperature

Average monthly temperature data, from Zanzibar weather station (Zanzibar Airport) show ranges from a low of around 20.5 to 24.1°C during the coolest months of June to August. The highest monthly means of 31.6 to 33.0°C during the hot season from December to February (NDF, 2014; Hendriksen et al., 2016; UNISDR, 2015). Zanzibar has fairly constant average temperatures across the year (Watkiss, 2012a), however, the hottest month, January and February show the rise of average temperature from 1980 to 2018 (Figure 3).

Data collection

For the purpose of this research, both primary and secondary data have been collected. The secondary data i.e books, journal papers and technical reports contributed toward the formation of background information. Primary data of questionnaires, measurements and observation were collected in three ways. Firstly, a questionnaire survey which conducted with members of communities around the ponds. Secondly, observation carried out within study area. Thirdly, a measurement, used to determine ponds area and depth. The tools and techniques used to collect the data for each method, describe hereunder.

Administration of data collection tools

Observations

An observation checklist prepared and observations made at ecosystem service providing units surrounding natural pond areas. Field Observations focused on the general condition of natural pond, livelihood activities such as fishing, agriculture, conservations activities, livestock's, pollution, biodiversity and settlements. Spatial indication (using Google satellite image of February 2020) have been used to locate and indicate the mark points of the pond and it's position and Digital camera have been used to take pictures for future analysis.

Questionnaire

The questionnaire used to capture different change from past to the presence in pond environment and sources of economic activities for livelihood incomes. The questionnaire also used to capture issues on climate variability and anthropologic activities impacts to pond ecosystem services and community livelihoods with their vulnerability and used to access the community perception to the changes and efforts to adaptation. In this study, participants were asked to respond to all questions in detail.

Measurements

The data related to area coverage and water volume obtained directly by taking measurement around the pond. The actual area in m² has been obtained using the geographical information programs on the internet, (Google Earth - using Google satellite

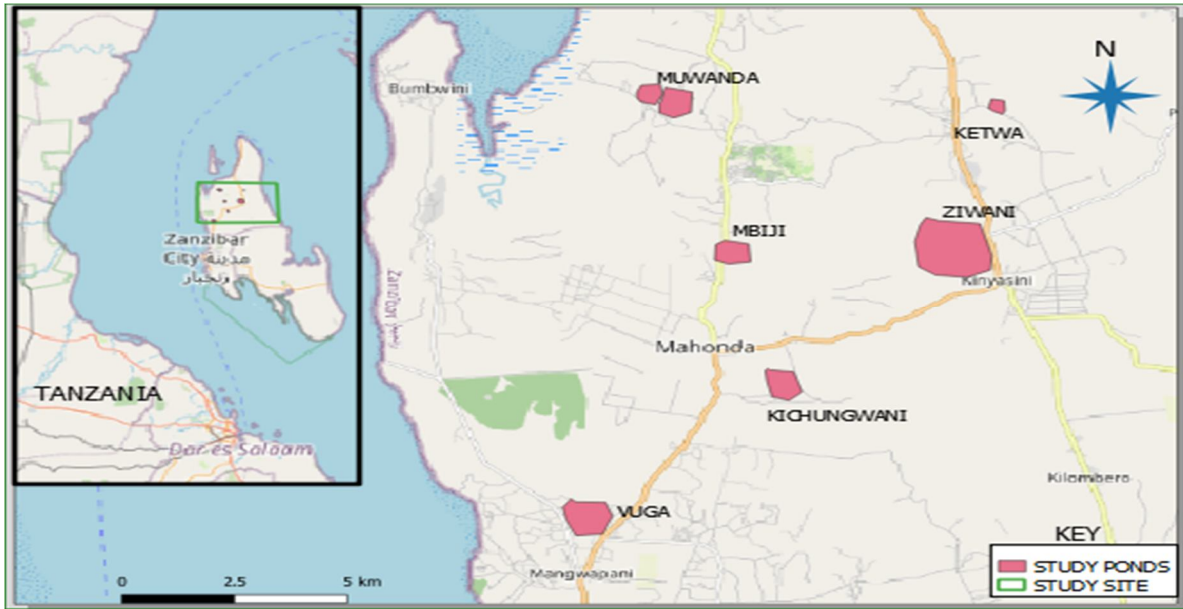


Figure 1. Map of study site to show individual pond in north region of Unguja Zanzibar. Source: Authors 2020 SUZA GIS.

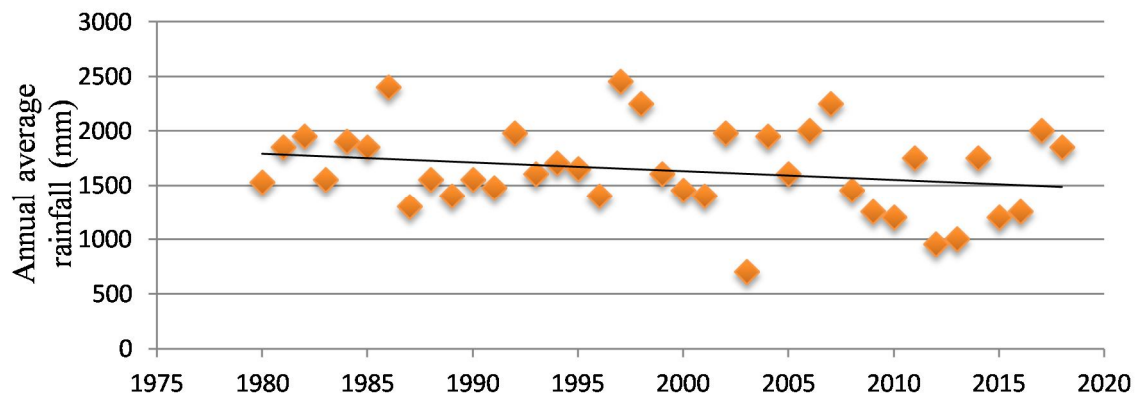


Figure 2. Trend of annual average rainfall (mm) of Unguja (Zanzibar airport) from 1980 to 2018. Source: Watkiss, 2012b, RGZ, 2010, 2019 and TMA (Zanzibar airport).

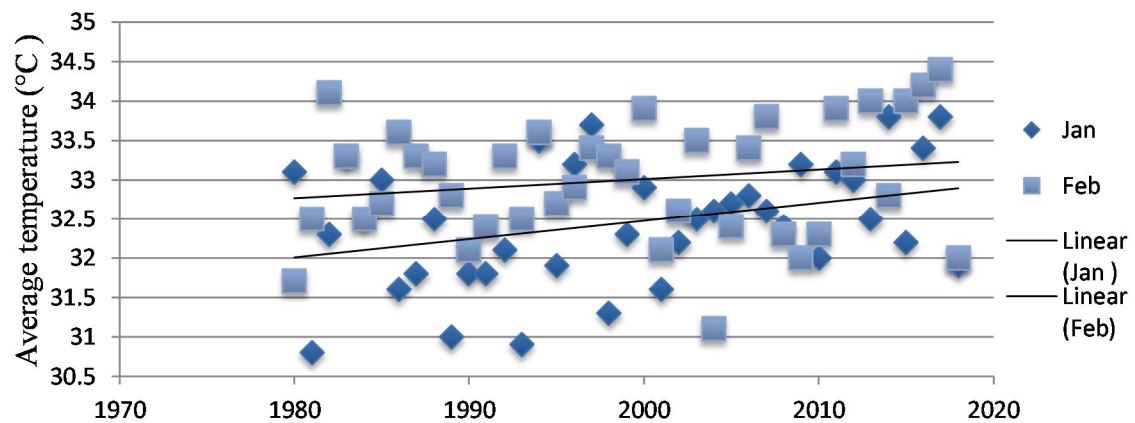


Figure 3. Trend of average monthly maximum Temperature (mm) of Unguja (Zanzibar airport) from 1980 to 2018. Source: Watkiss, 2012b, RGZ, 2010, 2019 and TMA (Zanzibar Airport).

image of February 2020). Tape measure used to take the other distance such as settlement dispersion from the pond. A floating objects and weighted cord/thick string/rope marked in feet are used to take depth (Masser and Jensen, 1991).

Secondary data collection

Literature review was conducted on different research reports from various projects and institutions worked in the area to reveal the past status of the pond in relation to current changes so as to make the primary data that was collected from respondents valuable. We found this useful because it provided background information of natural ponds and weather of study areas in the last five decades.

Data analysis

Both qualitative and quantitative methods for data analyses have been used to analyze data since the study involve both categorical data and numerical data. The qualitative data based on descriptive methods to be analyzed and quantitative data entered into the Statistical Package for Social Studies (SPSS) software (version 20) where t-test have been used and Microsoft excel for data storage, SPSS was used to give descriptive statistical results from which table and graphs were used to present the results.

RESULTS

Zanzibar has increased the intensity of extreme events of

temperature, wind and rainfall in last 20 years (Watkiss et al., 2012a, 2012b; ZCCS, 2013). The TMA data in Zanzibar airport show that there is decrease of monthly rainfall on the period of 2005 to 2018 (Figure 4) with average of 1305 mm compared to period of 1980 to 2000 of average of 1758 mm. There is the increasing of temperature (Figure 5) with high average of 31.09°C compared to 30.625°C average of 1980 to 2000. In January to December 1980 to 2000 shows that the temperature range between 28°C in July and 32°C in February, while the period of 2005 to 2018 the temperature range between 29.5°C in July and 33°C in February.

Changing in area coverage

Observation through measurement indicate that the area has been decrease about 31.4% from $796 \times 10^3 \text{ (m}^2\text{)}$ (100%) to $546 \times 10^3 \text{ (m}^2\text{)}$ (68.6%) (Table 1) of the all six water ponds study sites. The observation farther reveal the covering of non-pond trees such as *Casuarinas* (*Casuarinas equisetifolia*) and *Acacia* (*Acacia auriculiformis*), crops farming, settlements and path ways (human activities) in the earlier pond water covering area as the evidence that the area are no longer part of the ponds.

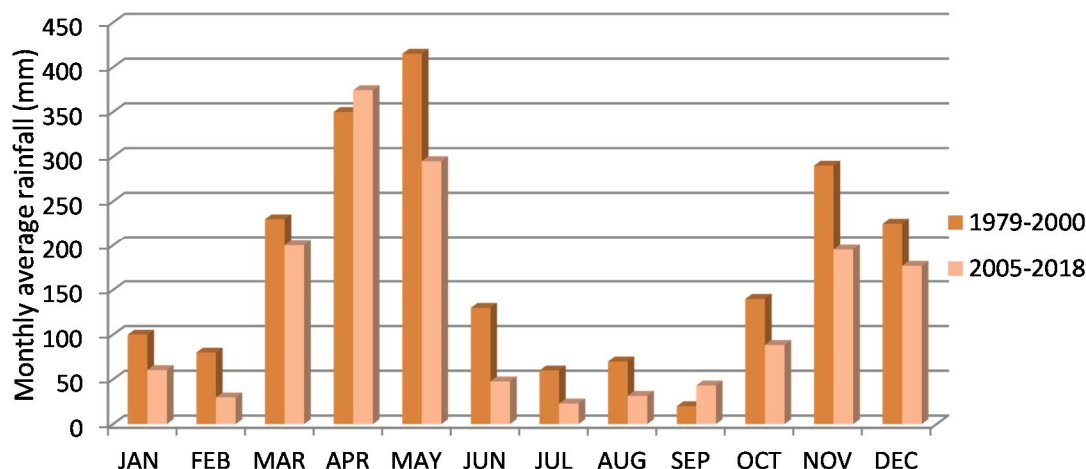


Figure 4. Average Monthly Rainfall (mm). Average of 1980-2000 and 2005-2018 Unguja. Source: Watkiss, 2012b, RGZ, 2010, 2019 and TMA (Zanzibar Airport).

Changing in condition of water

Water as important element in pond life, has gone critical alteration as the study revealed. The amount and staying period of ponds water show dramatically change since the last two decades. They experienced frequency dry spells and some become seasonal. Decreased depth has been realized in all studied ponds due to the decreased amount of rainfall (56.63% of respondents). Direct

measurement of the depth based on observation checklist; also indicate the changing of both central and average depth of all ponds compared with last 20 years (Table 1). The study also indicate the decreased of water volume (Table 2) about 31.411% from $162.2 \times 10^4 \text{ (m}^3\text{)}$ (100%) before 2000 year to $111.25 \times 10^4 \text{ (m}^3\text{)}$ (68.588%) after 2000 year. However the statistical test, t-test reveal no significance difference of the volume between the periods ($t = 0.878$, $df = 15$, $p = 0.394$) (Table 3).

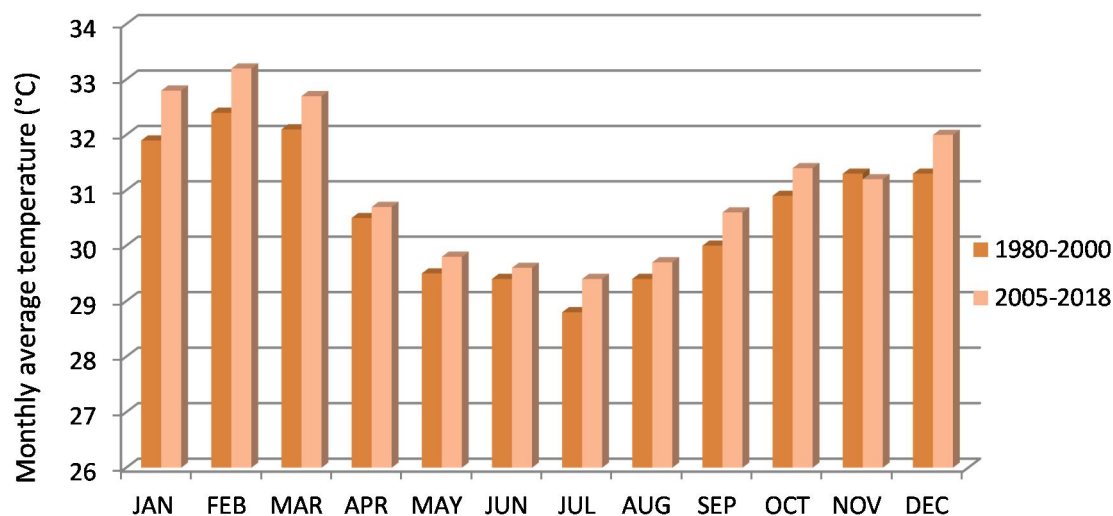


Figure 5. Average Monthly Maximum Temperatures (°C). Average of 1980-2000 and 2005-2018 Unguja. Source: Watkiss, 2012b, RGZ, 2010, 2019 and TMA (Zanzibar Airport).

Table 1. The water area coverage before and after 2000 year.

Pond name	Period of 1980 - 2000				Period of 2000 - 2019				
	Water coverage (m ²) × 10 ³	area	Depth (ft)		Settlement dispersion (m)	Water area coverage (m ²) × 10 ³	Depth (ft)		Settlement dispersion (m)
			Actual	Average			Actual	Mean	
Chaani ketwa	13.9		11.1	3.86	83.1	10.8	9.5	4.34	22.0
Donge Mbiji	209		14.5	4.75	30.8	158	12.6	5.47	-89.4
Donge Muwanda (Mwananyoto and Mzee Jumanne)	A= 181		A = 23.4	12.7	61.8	117	20.4	12.9	-4.8
	B= 59		B = 7.3	4.3		28.6	6.5	4	
Kinduni Kichungwani	A= 94.9		A=14.7	6.54	108	73	13.7	5.52	96.1
	B= 20.7		B=13.8	7.2		11.3	12.8	6. 2	
Kinyasini ziwani	115		7	3.15	38	88.9	5.5	3	-3.63
Vuga mkadini	102		17.2	5.78	38.6	A= 57.8	A=14.3	9.4	-13.6
total	796					546			
%	100					68.6			
Decrease	250					31.4%			

Table 2. The pond volume as the result of area times average depth.

Pond name	Before 2000 year (2 decades)			After 2000 year to Present time		
	Area coverage (m ²) × 10 ⁴	Average depth (m)	Volume (m ³) × 10 ⁴	Area coverage (m ²) × 10 ⁴	Average depth(m)	Volume (m ³) × 10 ⁴
Chaani ketwa	1.39	1.18	1.63	1.08	1.32	1.43
Donge Mbiji	20.9	1.45	30.3	15.8	1.67	26.4
Muwanda A	18.1	3.88	70.1	11.7	3.92	46.0
Muwanda B	5.91	1.31	7.74	2.86	1.22	3.48
Kinduni A	9.49	1.99	18.9	7.3	1.68	12.3
Kinduni B	2.07	2.19	4.54	1.13	1.89	2.13
Kinyasini	11.5	0.960	11.0	8.89	0.914	8.13
Vuga mkadini	10.2	1.76	18.0	A=5.78	1.520	8.78
Vuga B				B= 2.11	1.23	2.60

Table 3. Independent samples test.

		Levene's test for equality of variances		T-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
									Lower	Upper
Volume	Equal variances assumed	.508	.487	.878	15	.394	79317.780	90344.615	-113247.209	271882.770
	Equal variances not assumed			.857	12.018	.408	79317.780	92535.249	-122265.984	280901.545

Changing in settlement encroachment

The establishment of settlement in pond area is another alteration that the ponds face. The four ponds among the six studied, the houses are within the pond areas with different distance. Before last two decades, houses were 30.75, 61.79, 11.58 and 38.58 m far away from the pond at Donge Mbiji, Donge Muwanda, Kinyasini ziwani and Vuga mkadini respectively. Due to the encroachment, settlements at these ponds are within the pond area to 89.35 m - Donge Mbiji, 4.8 m - Donge Muwanda, 3.63 m - Kinyasini ziwani

and 13.60 m - Vuga mkadini at presence time (Table 1). The average distance of the settlements from the ponds were 60.05 m before 2000 to 1.111 m average from the ponds after 2000. The t-test reveal statistical significance differences of settlement dispersion between the periods T-test ($t = 2.150$, $df = 10$, $p = 0.05$) (Table 4).

Changing in vegetation cover

The most changes are the decrease of natural

trees and plant (the decrease of native spices of plants), and notable increased of planted trees which are not natives at the areas. The respondents by 89.38% said the natural vegetations which are native at pond areas, decreased in large extent due to the combination of climate change, 61.06% of respondents, and human activities by 50.44% of the respondents. As the water reduced due to short rainfall and long sun period (climate change) people increased their farms by cutting the pond vegetation. "As water decrease, we extent our farms so all vegetation slashed and uprooted

Table 4. Independent samples test.

		Levene's test for equality of variances		T-test for equality of means					
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference
									Lower Upper
Settlement	Equal variances assumed	.606	.454	2.150	10	.057	59.001	27.445	-2.150 120.154
	Equal variances not assumed			2.150	7.449	.066	59.001	27.445	-5.111 123.114

away and they became reachable by firewood cutter that why they reduced and disappeared (extinct)" this was the statement by respondents from all pond.

The planted trees increased with high rate by 41.59% of respondents. The observation done around the pond, found the presence of plantations of Casuarinas (*Casuarinas equisetifolia*) and Acacia (*Acacia auriculiformis*) which according to respondents historical not grow around the pond.

DISCUSSION

The result shows that the increasing temperature and decrease of rainfall, with the increase of anthropogenic activities are associated with alterations (changes) upon the natural ponds. The study by Brönmark and Hansson (2002) in Sweden stated that changes in the abiotic frame of ponds induced by global warming, such as changes in nutrient input and heat loading, may have strong effects on the biota, altering the species composition of phytoplankton, zooplankton, benthic invertebrates and fish. Continued increases in air temperatures and changing precipitation regimes associated with climate change can have profound impacts on pond biota and water quality (Fox and Smith,

2016 study done at Cape Cod) such as alterations to freshwater biogeochemical processes, primary and secondary productivity, food-web structure, population dynamics and species interactions, species ranges, and large-scale patterns of freshwater biodiversity (Wrona et al., 2006). Anthropogenically induced fragmentation constitutes a major threat to biodiversity (Berger-Tal and Saltz, 2019; Primack, 2014 and Noss, 1991). Human disturbances may have strong effects on the biodiversity of ponds and thereby affect their processes and function. Different disturbances change the quality and thereby give different compositions of the resulting pond community (Brönmark and Hansson, 2002).

It is as happened to Mediterranean temporary ponds, that there is decreasing in most of their distribution area due to human activities (Ruiz, 2008). Also the work of climate such as reduction in flows or water levels within an ecosystem could reduce the area of freshwater habitat (Jones, 2013) and as supported by Kumar and Padhy (2015) that alteration in precipitation patterns, which include timing, intensity and quantity of rainwater the reason for the decreased of the areas of the ponds. The respondents reveal that "*nowadays the amount of rain we are receiving does not fulfill the ponds, so the water coverage does not reach the point that we experienced previous 10-20 years*". Habitat fragmentation due

to human activities associated with a consequent reduction in the total amount of area, as well as with changes to the habitat's spatial configuration (Primack, 2014; Noss, 1991).

As the result demonstrated, other studies on ponds indicated that climate change would probably alter the hydrological regime of freshwater inland water bodies (Ruiz, 2008). In ponds, hydrologic variation may appear dramatic, for example drying out completely in summer (Jones, 2013). The structure and function of ponds are determined by factors such as water clarity and water depth (Hoverman and Johnson, 2012). Ponds depend on the availability of fresh water and this availability varies over time and space (Jones, 2013). Alterations in precipitation patterns, which include timing, intensity and quantity of rainwater, combined with rise in temperature alter the water cycle within catchments (Kumar and Padhy, 2015; Brönmark and Hansson, 2002); thereby causing a decrease in water column in small water bodies (Brönmark and Hansson, 2002). Similarly, ponds were vulnerable to dry spells, as water level reduced and some become seasonal (Balama et al., 2013). The same as the study of Ruiz (2008) show the impact of climate change (frequency and intensity of rainfall) modify the flooding patterns of Mediterranean temporary ponds. These changes could prolong inundation periods after intense

rainfall and shorten these periods after prolonged droughts, or even prevent pond inundation during several years. The study of Jones (2013) from Britain show that the impact of inundation on ponds largely depends on the length of time the water is retained; many ponds dry out intermittently or regularly.

Regard to other studies, the case is greater where the encroachment lead to the extinction of the complete pond. The studies of Rajasekaran (2012) and Kumar and Pandhy (2015) show that the ponds in India are under threat due to various factors including encroachments thus lead to their extinctions

A significant amount of shoreline vegetation has vanished due to human trampling around beach and swimming areas, diminishing its protective capacity. Climate change is another threat" (Jones, 2013). This is also found by Fox and Smith (2016), on their study of Kettle Ponds and Climate Change, as quoted "Recreational use is a threat to pond vegetation. Indeed certain rare species are associated with ponds are naturally prone to drying (Jones, 2013). It is as the study of Hoverman and Johnson (2012) which stated that introduction of exotic species of plants is challenging problem to pond ecosystem. Native plants are plants that have evolved over thousands of years to be successful in a particular region, and are thus ideal when creating habitat for native species (Wolinsky and Bourassa, 2006).

CONCLUSION

The observation indicate the covering of non-pond trees (such as Casuarinas and acacia), crops farming, settlements and path ways in the earlier pond water covering area as the evidence that the area are no longer part of the ponds. The amount and staying period of ponds water reduced since the last two decades. They experienced dry spells, as water level reduced and some become seasonal which lead the construction of houses within the pond area. There is decreased of natural trees and plants (the decrease of native spices of plants), and notable increased of planted trees which are not natives at the ponds areas. The study highlighted that climate change and variability has a greater influence on pond size, flora and fauna in all study sites. We strongly call upon all conservationist and other practitioners to raise their voice to serve the nature.

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