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Climate Variability And Fish Hole Production In The Lower Oueme Valley

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Résumé – La présente recherche a été initiée pour étudier les incidences de la variabilité climatique sur la production des trous à poissons dans la basse vallée de l'Ouémé.
Pour atteindre cet objectif, l'analyse des donnée climatologiques de la période de 1986 à 2015, extraites des fichiers de l'ASECNA utilisant les paramètres de la statistique descriptive a permis de caractériser l'évolution du climat, ensuite les données de hauteurs d'eau et de débit extraites des fichiers de la DG-Eau puis les statistiques ichtyologiques obtenus à la Direction des Pêches ont permis d'analyser l'évolution des rendements halieutiques des trous à poissons dans le milieu d'étude. Le logiciel SPSS a permis de montrer les corrélations entre l'évolution des paramètres climatiques et de productions de trous à poissons avec le texte de la corrélation de Pearson à un seuil de 5 %.
Il ressort des analyses que l'évolution des rendements halieutique est positivement corrélé aux hauteurs de pluie tandis qu'il existe une corrélation négative entre les rendements halieutiques et le régie thermique.

Mots clés – Variabilité climatique, production de trous à poisson, vallée de l'Ouémé.

Abstract – This research was initiated to study the impacts of climate variability on the production of fish holes in the lower Ouémé valley. To achieve this objective, the analysis of the climatological data from the period 1986 to 2015, extracted from the ASECNA files using the parameters of the descriptive statistics allowed to characterize the evolution of the climate, Water and flow data extracted from the DG-Eau files and then the fish statistics obtained from the Fisheries Directorate made it possible to analyze the evolution of fish hatchery yields in the study environment. The SPSS software was used to show the correlations between the evolution of climatic parameters and the production of fish holes with the correlation text of the Pearson correlation at a threshold of 5%.
Analyzes show that changes in fish yields are positively correlated with rainfall, while there is a negative correlation between fishery yields and thermal management.

Keywords – Climate variability, production of fish holes, Oueme valley.

I. INTRODUCTION

The study of climate variability is of particular interest for scientific research, for water resources, for the economy of a region and for the populations themselves. Numerous studies on climate variability (Nicholson, 1994; Aka et al., 1996; Brou, 1997; Servat et al., 1998; Paturel et al., 1998; Ouédraogo, 2001; Ardoin et al., 2003; Ardoin, 2004), have been undertaken in several regions of non-Sahelian West and Central Africa. In recent years, for example, West Africa has been affected by climatic phenomena (Olivry, 1983; IPCC, 2007). This has affected many areas, particularly fishing.

Climate is the main factor determining the distribution of plant and animal species on a global scale (Rivierre, 2007). The vulnerability of fisheries to climate change depends on the nature of these changes, the type of fishery, the fish species and their habitats. Changes in climatic conditions such as air temperature and precipitation affect fisheries by altering the availability or

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quality of habitats. Specifically, fish habitats can be affected by changes in water temperature, the timing and duration of temperature extremes, the magnitude and pattern of annual flows, surface water elevation, and lake shorelines (Carpenter et al., 1992).

The Basse Vallée de l'Ouémé has enormous fishing potential due to the great variety of its ecology, which supports thousands of populations of diverse origins settled in its area (Lalèyè et al., 2007; Chikou, 2006). Despite these economic potentialities, it is increasingly faced with physical constraints, climatic hazards and risks of degradation of its resources (Villanueva, 2004; Sossou-agbo, 2012; Vissin, 2013; Houéssou, 2014). Studies on the general conditions of these ecosystems agree on the threats of various kinds that try to destroy in the short and medium term, their production capacities (FAO, 2006). In aquatic ecosystems, the production functions of fishing in general and the production of fish holes in particular are equally vulnerable to climate variability (PANA-Benin, 2008; IPCC, 2015).

Located in the department of Ouémé in the Republic of Benin, the Ouémé Valley (Figure 1).Thus, the Communes of Adjohoun, Aguégués, Bonou and Dangbo constituting the lower valley of the Ouémé, we have retained the wetland districts and especially in which the activity is much more developed.

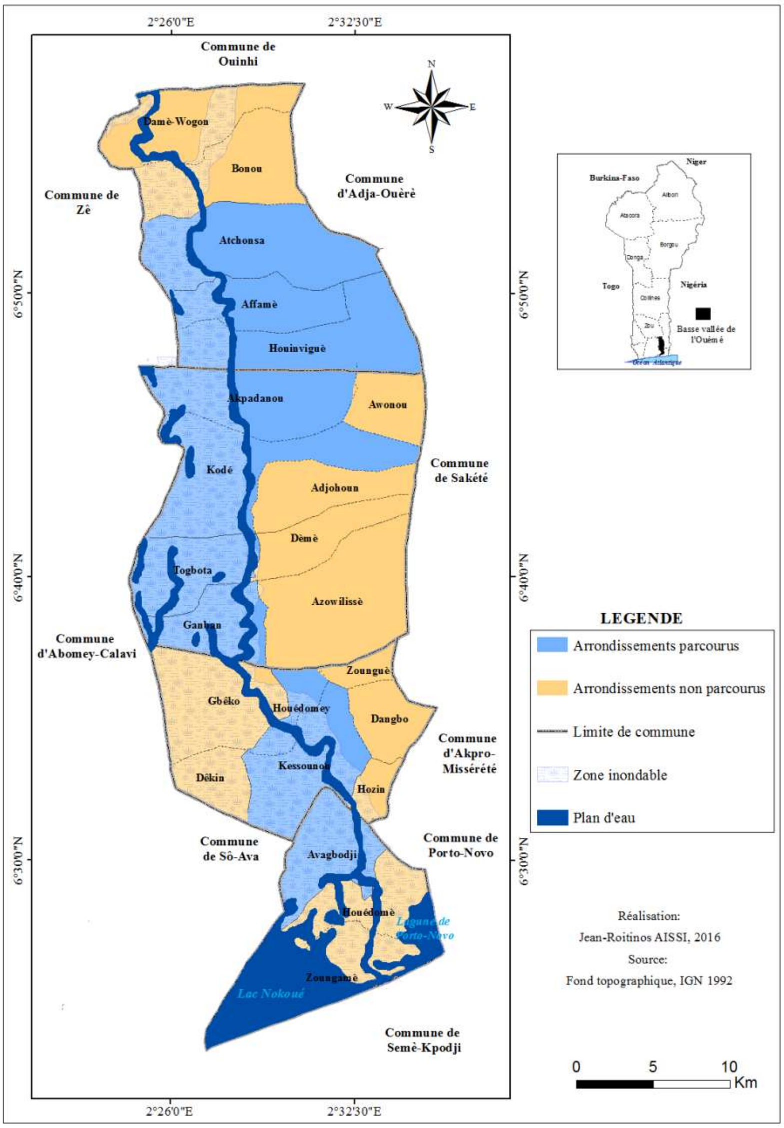

Figure 1: Location map of the districts selected and visited in the lower Ouémé valley

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II. MATERIALS AND METHODS

Sampling and collection techniques

The probabilistic method, which amounts to a selection of the sample by simple random drawing from the parent population, was adopted. Thus, the sample size (n) of respondents was determined by the formula of the binomial sampling law of Dagnelie (1998) which is expressed as follows :

$$n = \frac{U^2{}_{1-\propto/_2} \times P(1-P)}{d^2}$$

With n: sample size considered; U_(1-∝⁄2): value of the normal distribution at the probability value; 1-∝/2 with ∝ = 5% is 1.96; d: margin of error of the estimate set at a value of 5% ;

P: proportion of people to be surveyed in the ten districts selected with the technical agents for their greater production in the communes of the lower Ouémé valley for this study.

The sample size is then :

$$n = \frac{(1{,}96)^2 \times 0{,}39(1-0{,}39)}{(0{,}05)^2} = 365{,}57$$; 366 people to be surveyed

This size was distributed proportionally within the selected districts. The table below shows the number of respondents per district.

Production study in the context of climate change manifestations

The data collected for the realization of the present are:

- Climatic data; they consist of rainfall (monthly and annual rainfall); temperatures (maximum and minimum); taken from the ASECNA database over the period 1986-2015. Not all climatic data are available for the study area. Therefore, we also used data recorded in nearby localities (Porto-Novo and Cotonou City) located in the same climate zone.
- Hydrological data; these consist of the maximum monthly flows of the Ouémé River at the Bonou hydrometric station over the 1986-2015 series and extracted from the database of the General Directorate of Water.
- Statistical data on the productivity of fish holes. These data relate to fish production and yield over the period 2005-2015, given by the producers and justified by CARDER Ouémé/Plateau and also taken from the statistical compendia of the Directorate of Fisheries (average yields of the Communes of the lower Ouémé valley).

Data analysis

The assessment of the vulnerability of production was carried out in two stages, namely: the analysis of climatic variability and the influence of this variability on fishery production. The analysis of climatic variability required the calculation of the standardized precipitation index in order to characterize the degrees of humidity and drought at the scale of the Ouémé Valley. In addition, the break and trend texts were carried out in order to characterize the climatic variability at the level of the Ouémé valley.

With regard to the impact of climatic variability on fisheries production, statistical correlation tests were carried out in order to identify a statistically significant relationship between the hydroclimatic variables and fisheries production. The Pearson correlation coefficient gives the strength of the degree of relationship between two quantitative variables. This measure can demonstrate the

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existence of a relationship between independent and dependent variables. Correlation is a measure of linear relationship. The correlation coefficient takes values between -1 and +1; extreme values indicate a perfect or approximately perfect linear relationship between the two variables, while values near 0 indicate the absence of a linear relationship between the two variables. The positive or negative sign of the value indicates the direction of variation of one of the two variables when the other varies in a given direction. The null hypothesis in the test is that there is no relationship between the two variables (r = 0). The decision rule for the SPSS test is based on a statistical significance level of 5%, i.e., the p-value. If p is less than 0.05, H0 is rejected.

III. Results and Discussion

Interannual Variability of Rainfall

Rainfall amounts vary from year to year in the lower Ouémé valley. Figure 2 shows the interannual variability of rainfall amounts between 1986 and 2015.

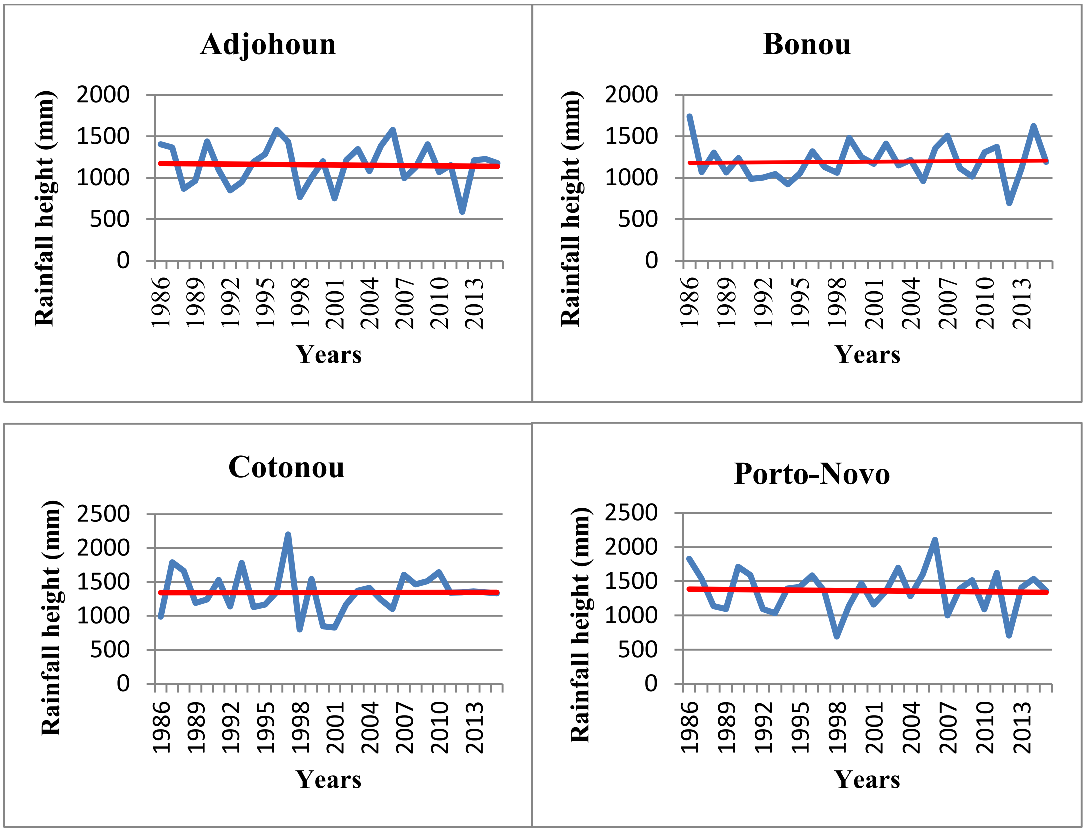

Figure 2 : Interannual variability of rainfall (1986 - 2015) in the lower Ouémé valley

Source : *Processing of the data ASECNA, 2016*

The analysis of Figure 2 shows the random nature of rainfall between 1986 and 2015 at the four (4) selected stations. Analysis of this figure shows a downward trend in rainfall at the Porto-Novo and Adjohoun stations. This rainfall variability is confirmed by the calculation of the standardized rainfall index for the four selected stations, which is also based on the fluctuations between wet and dry years (Figure 3).

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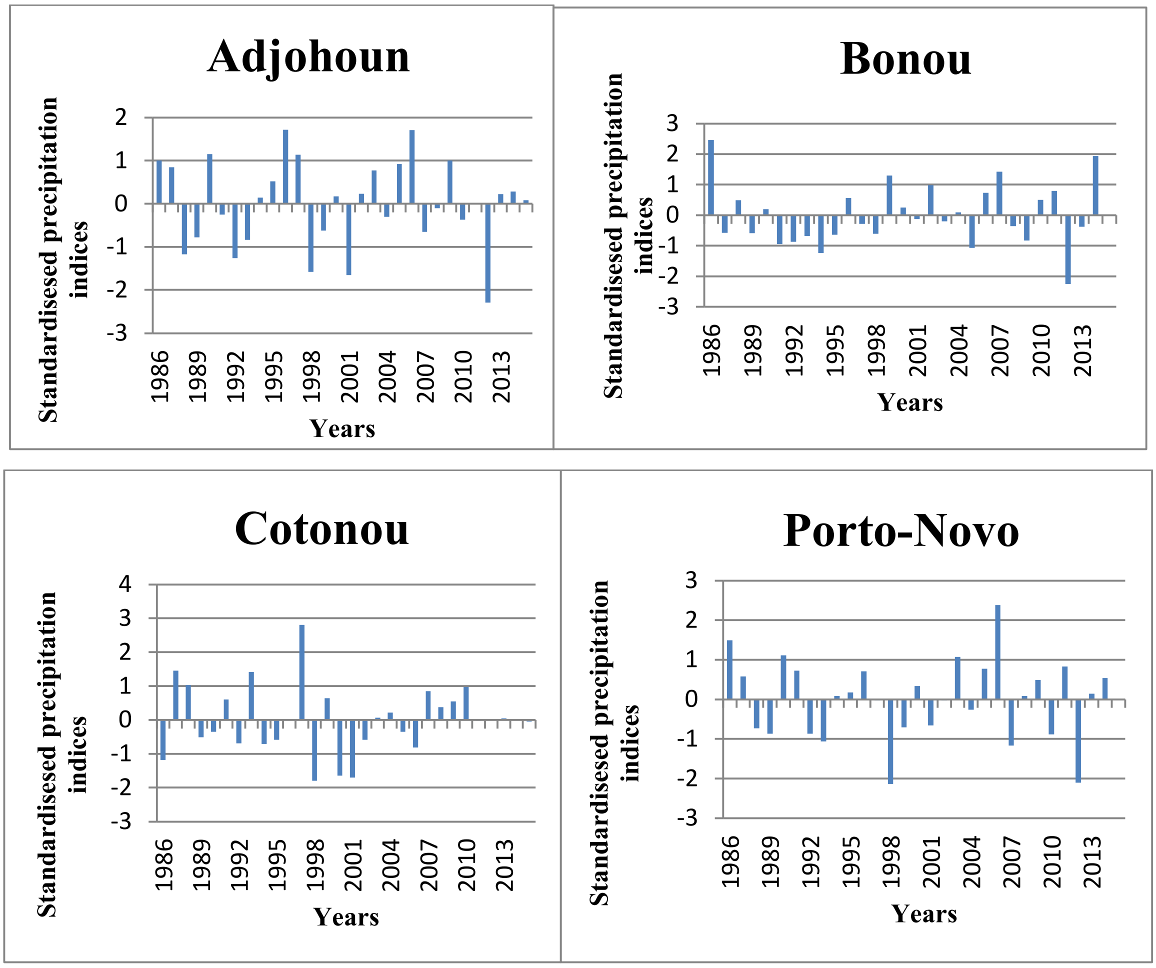

Figure 3 : Variation of the standardized precipitation index between 1986 and 2015.

Source : *Processing of the data ASECNA, 2016*

Fluctuations in the standardized rainfall index highlight the irregular nature of rainfall and a situation dominated by dry years at the Bonou station and moderately wet years at the Adjohoun, Porto-novo and Cotonou stations. Table I presents the frequency of years according to the classes of the standardized rainfall index.

Table I: Frequency of years according to the classes of the standardized precipitation index

	SE	SF	SM	HM	HF	HE	Total
Bonou	1	2	14	9	3	1	30
Adjohoun	1	4	9	10	6	0	30
Porto-Novo	2	2	10	12	3	1	30
Cotonou	0	4	11	11	3	1	30
Fréquence (%)	3	10	37	35	13	3	100

Source : *Processing of the data ASECNA, 2016*

HE: extreme humidity, HF: high humidity, HM: moderate humidity, SE: extreme drought, SF: high drought, SM: moderate drought.

In addition, it appears that the four weather stations studied, have overall more years of moderate drought than years of moderate humidity.

Thermal characteristics

Temperatures in the lower Ouémé valley vary according to the season. They are at their lowest in the month of August during the short dry season. Figure 4 shows the intermonthly evolution of temperatures from 1986 to 2015.

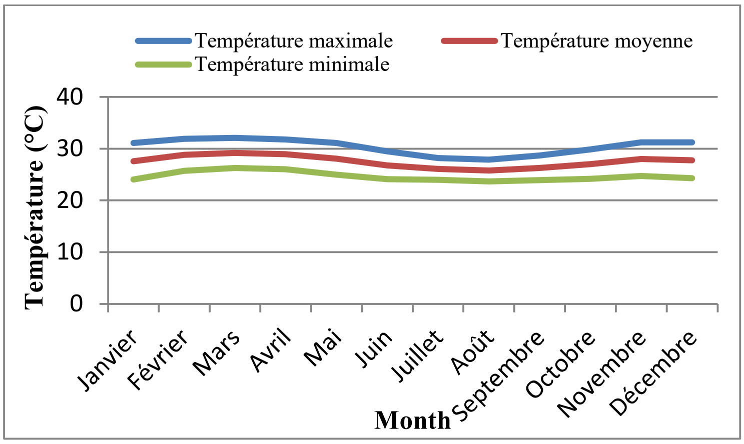

Figure 1: Average monthly thermal regime in the lower Ouémé valley (Cotonou synoptic station)

Data source : *ASECNA, 2016*

Examination of Figure 4 shows that the temperature pattern in the lower Ouémé valley has two periods of high temperatures, one of which is higher than the other. These periods correspond to the two dry seasons experienced in southern Benin. The main dry season covers the months of November to March. The increase in average temperature in February and March corresponds to the high intensity of solar radiation, during this period, fishing is unfruitful. However, the short dry season is confined between July and September. The hottest month of the year is March, in contrast to August, which records the lowest temperatures. During these periods of high intensity, fish migrate to the spawning grounds. The maximum and minimum temperatures in the lower Ouémé valley have decreasing trends. This remarkable downward trend in the months of June and July coincides with the onset of flooding, which favors the migration and reproduction of fish in the holes.

- ✓ **Interannual temperature trends**

Figure 5 shows the temperature trend between 1986 and 2015.

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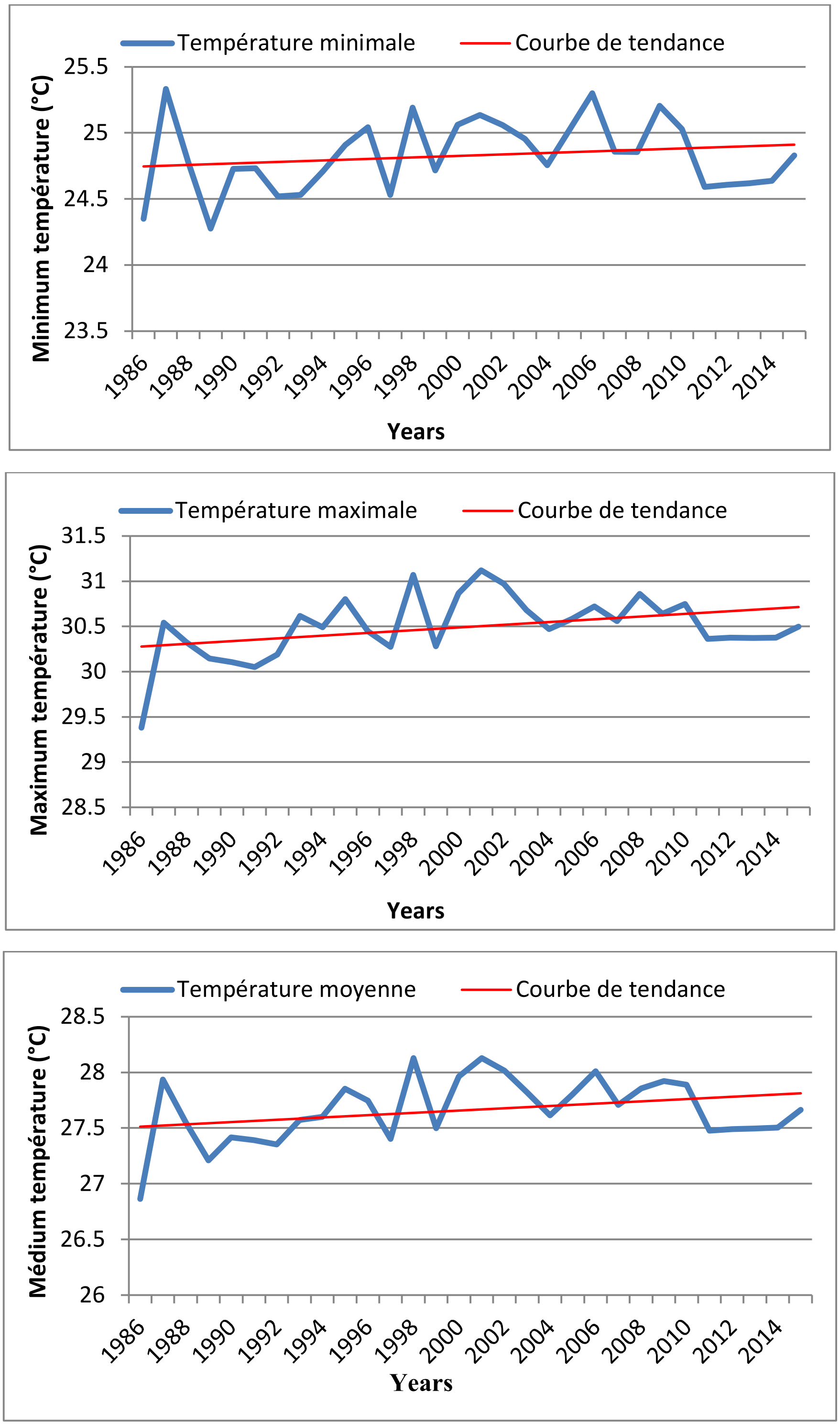

Figure 5: Interannual evolution of temperatures

(Cotonou synoptic station)

Data source : ASECNA, 2016

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Figure 5 shows an inter-annual variability in temperatures, reflected in an upward trend in their variation. This shows that the Communes of the lower Ouémé Valley are not immune to the global warming that is being observed worldwide.

Minimum temperatures vary between 24.34°C in 1986 and 24.82°C in 2015 with a peak of 25.33°C recorded in 1987 and a minimum value of 24.27°C in 1989.

As for the maximum temperatures, they have evolved from 29.38 °C in 1986 to 30.49 °C in 2015. These maximum temperatures peaked in 2001 with a value reaching 31.12 °C. On the other hand, the decade 2000 records the highest values of temperature.

The annual thermal averages recorded over thirty (30) years have evolved from 26.86 °C in 1986 to 27.66 °C in 2015. The average temperatures have experienced an average increase of 1°C between 1986 and 2010, with the maximum in 1998 or 28.13°C and the minimum in 1986 or 26.86°C. This is not without effect on aquatic ecosystems.

Interannual evolution of the average water level

The average water level in the study area evolves according to the amount of rainfall in the region, but especially in the northern part of the country. Figure 6 shows the interannual variation of the water level.

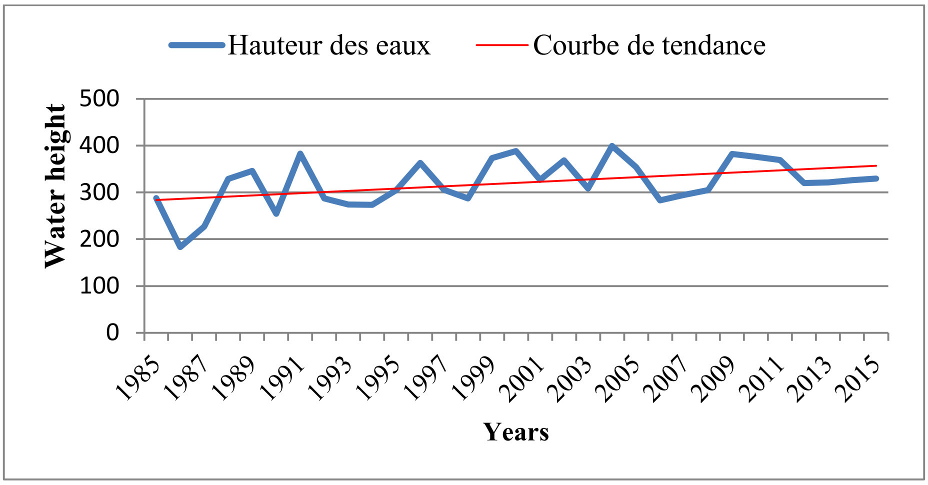

Figure 6: Evolution of the water level

Source des données : *DG-Eau, 2016*

Analysis of Figure 6 shows that interannual water levels in the lower Ouémé valley have shown a sawtooth pattern between 1986 and 2015. In addition, there is an upward trend in the interannual evolution of water levels in the lower Ouémé valley. Thus, from 1986 to 2015, the water level increased by an average of 246.42 ± 46.18cm.

The Pearson correlation coefficient is 0.58. This coefficient reflects a strong positive correlation between time and water level. But the threshold of significance = 0.05 or = 5% at which the correlation coefficient was read allows us to conclude that there is a strong positive correlation and significant at the threshold of 5% between time and water level.

Interannual evolution of the flow

Along with water levels, flow variation in the study area has impacts on fisheries production (Figure 7).

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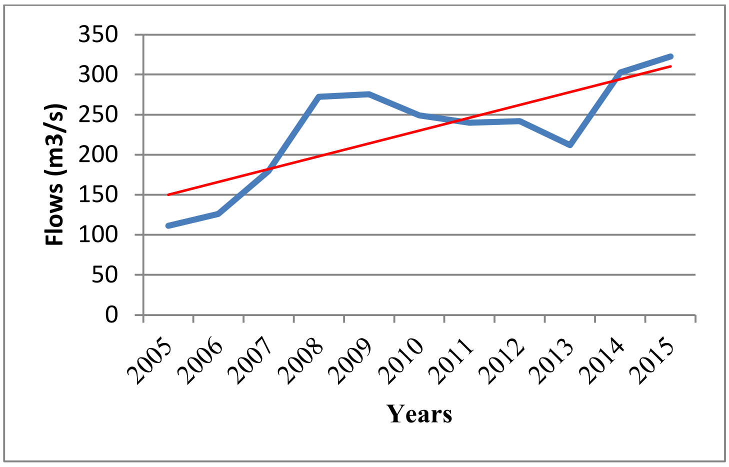

Figure 7: Interannual evolution of the flow in

the lower valley of the Ouémé at Bonou (2005 -2015)

Sources des données : *DGE, 2016*

The analysis of Figure 7 shows an interannual variability of the Ouémé River flows from 2005 to 2015. There is a noticeable upward trend with a sawtooth evolution from one year to the next (111.21 m3/s to 322.86 m3/s). In 2005, the lowest flow was observed (111.21 m3/s), and the peak (322.86 m3/s) was reached in 2015.

Effects of climate variability on production

Thermal factors and fish hole production

The analysis of thermal data of the study area shows that the thermal averages are increasing in the lower Ouémé valley.

The analysis in Figure 8 shows the interrelationship between thermal factors and fish production.

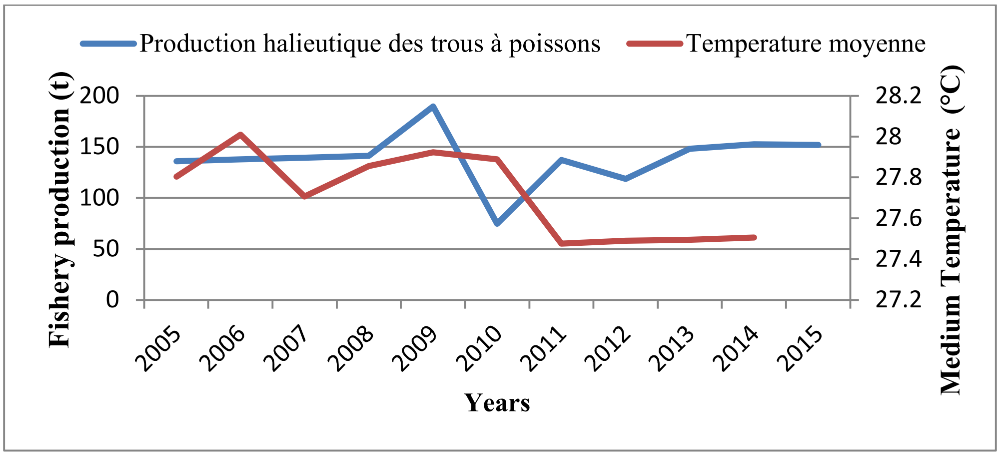

Figure 8: Temperature and interannual production

Source des données : *ASECNA/DP/CARDER-OP, 2016*

The analysis of Figure 8 reveals an evolution in opposite directions of the two curves showing the evolution of fish production and temperature. Between 2009 and 2015, temperatures showed an upward trend in contrast to fish production in fish holes. The fish production recorded from 2009 onwards is relatively important and coincides with the significant decrease in temperature during

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this period. Indeed, the high production observed in 2009 and 2013 corresponds to a thermal average of 27.6 °C. However, the ichthyological fauna requires a range of temperature to its physiological functions that reproductive. Thus, the period from 2009 to 2015 is a period where climatic conditions are favorable to the productivity of fish holes. This allows us to conclude that the fishery production of fish holes in the lower Ouémé valley is a function of thermal conditions.

In addition, there is a weak negative correlation (-0.158) not significant at the 5% threshold between temperature and fish production in fish holes.

Rainfall factors and fish production

Rainfall variations have effects on the living environment of the halieutic species.

Figure 9 shows the inter-annual evolution of rainfall and production in the lower Ouémé valley.

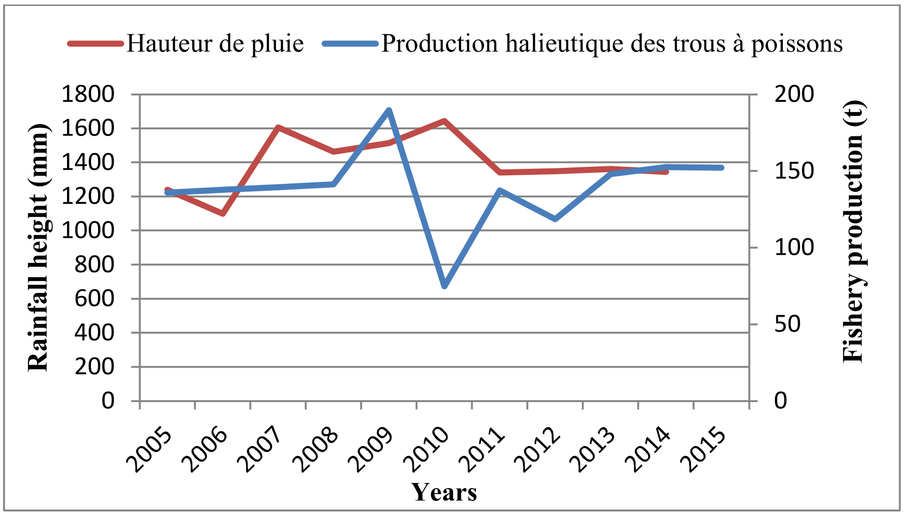

Figure 9: Rainfall and interannual production

***Source des données :** ASECNA, 2016 ; DP, 2016*

Examination of Figure 9 shows that the period 2005-2015 shows an upward trend in rainfall with a peak recorded in 2010. The two curves showing the evolution of fishery production and rainfall show the same relatively increasing trend between 2005 and 2015. On the other hand, from 2006 to 2008 and from 2010 to 2013, fishery production showed a decreasing trend with rainfall. In contrast, between 2013 and 2014, both trends are increasing. The very low production observed in 2010 is subsequent to the floods recorded in that year in the lower Ouémé valley. This flood, which is still remembered, destroyed a number of holes and washed away fish from the holes. This has caused a drop in production this year. However, there is a weak negative correlation (r=-0.204 and p > 0.5) between rainfall and fish production (Table II).

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Table II : Correlation matrix between fisheries production and rainfall

Corrélations

		Rainfall height	Fishery production
Rainfall height	Corrélation de Pearson	1	-0,204
	Sig. (bilatérale)		0,572
	N	10	10
Fishery production	Corrélation de Pearson	-0,204	1
	Sig. (bilatérale)	0,572	
	N	10	11

Source des données : *ASECNA, 2016 ; CARDER/ DP, 2016*

Hydrological factors and fishery production

The hydrological dynamics give rhythm to the seasonality of its fishery production and cause the migration of species. The Communes benefit not only from the rains in the area, but also from large quantities of water from the upper reaches of the Ouémé River located in the northern part of the country.

Water levels and interannual fish production

The variation in water level in the study area affects the fishery production of the fish holes. Figure 10 shows the interannual evolution of water levels and production in the lower Ouémé valley.

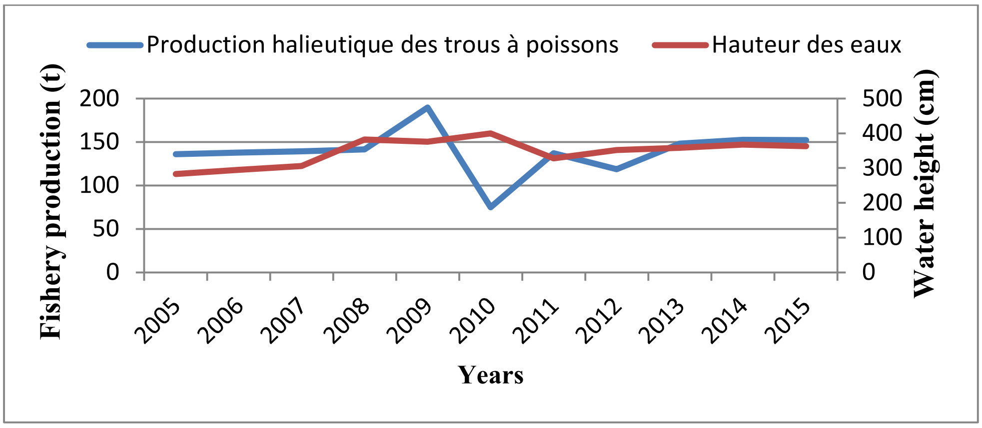

Figure 10: Water levels and interannual production

Source des données *: DGE, DP et CARDER-OP, november 2016*

The analysis of figure 10 reveals a variation of the fish production of the fish holes according to the annual water level. The two curves showing the evolution of the water level and the fishery production have a more or less uniform movement in time except for the year 2010 where we note a significant phase shift. The hydrological constraints have effects on the aquatic ecosystem and consequently influence the fishery yield of the waters. The higher the water level, the higher the fishery production in the period. However, we note the drop in production in 2008 and 2010 despite the high water level.

Table III presents the correlation matrix between fisheries production and water level.

Table III: Correlation matrix between fishery production and water level

Correlations, reveals a variation in fish production from fish holes as a function of annual water depths. The two curves showing the evolution of the water level and the fishery production have a more or less uniform movement over time, except for the year 2010 where we note a consequent phase shift. The hydrological constraints have effects on the aquatic ecosystem and consequently influence the fishery yield of the waters. The higher the water level, the higher the fishery production in the period. However, we note the drop in production in 2008 and 2010 despite the high water level.

Table III presents the correlation matrix between fisheries production and water level.

Table III: Correlation matrix between fishery production and water leve

Corrélations

		Height of water	Fishery production
Height of water	Pearson correlation	1	-0,103
	Sig. (bilatérale)		0,762
	N	11	11
Fishery production	Pearson correlation	-0,103	1
	Sig. (bilatérale)	0,762	
	N	11	11

Source des données : *ASECNA, 2016 ; CARDER/DP, 2016*

Analysis of this Table III reveals that there is a weak non-significant negative correlation (r=-0.103 and $p > 0.5$) between water depths and fish production.

Flows and fishery production of fish hole

During floods, fish retreat to the wetlands and populate the holes. In effect, they find refuge in sloughs, spawning grounds, and holes in the major river beds. Figure 11 shows the interannual evolution of flows and fish production in the lower Ouémé valley.

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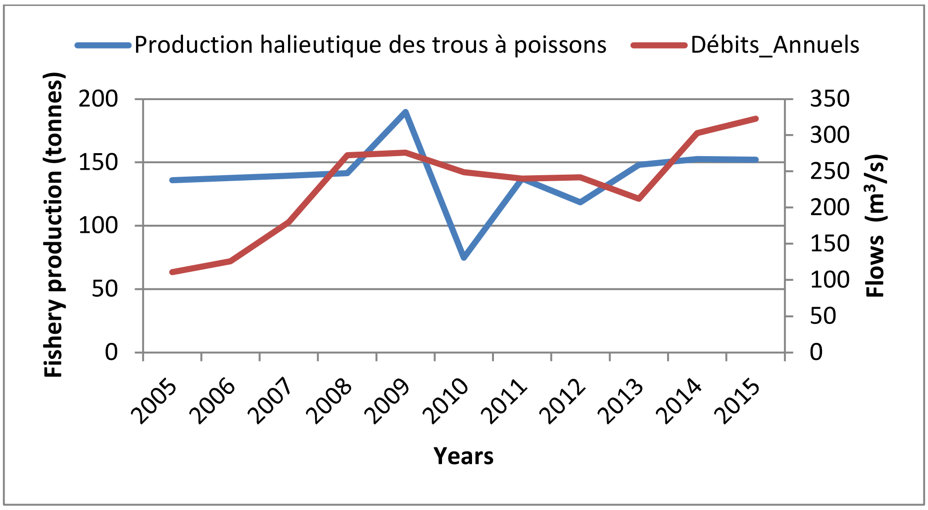

Figure 11 : Flows and fishery production of fish hole

Source des données : *ASECNA, 2016 ; CARDER/DP, 2016*

The analysis of Figure 11, reveals a variation in fish hole production in phase with the variation in annual flow. Thus, from 2005 to 2008, and from 2013 to 2015, fish hole production showed a slight upward trend in relation to the increase in flow.

However, there is a weak non-significant positive correlation ($r=0.186$ and $p > 0.5$) between annual flows and fish hole production (Table IV).

Table IV: Correlation matrix between fisheries production and rainfall

Corrélations

		Annual flows	Fishery production
Annual flows	Pearson correlation	1	0,186
	Sig. (bilatérale)		0,585
	N	11	11
Fishery production	Pearson correlation	0,186	1
	Sig. (bilatérale)	0,585	
	N	11	11

IV. Conclusion

The lower Ouémé valley is vulnerable to climatic variations and thus the production of fish holes is dependent on hydrological constraints. These hydrological constraints are not the only factors limiting the abundance of ichthyological species in the waters of the main fish hole production area in southern Benin. Temperature variation influences the abundance of aquatic animal species in the water bodies of the study area. Thermal factors have impacts on aquatic fauna depending on the variation of water temperature.

The Pearson correlation matrices between fish hole production and rainfall, temperature, water level and flow rate showed that climatic parameters do not significantly influence fish hole production at the 5% threshold.

In view of the results obtained, climatic variability is a reality in the study area. The trends obtained in the thermal chronicles prove that global warming is unequivocal in the Lower Ouémé Valley and remains a potential threat to fish survival.

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