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FIRST REPORT OF ENTERIC RED PLAGUE OF *Oreochromis niloticus* (Cichlidae) AND *Cyprinus carpio* (Cyprinidae) REARED IN CAMEROON: MORTALITY RATE, RISK FACTORS AND FINANCIAL LOSS

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ABSTRACT

Diseases are among the major constraints to sustainable aquaculture. Fish pathogens include bacteria responsible for devastating effects on the fish health and even that of consumers. In Cameroon, there is a dearth of quantitative data related to fish diseases and the economic impact. An epidemiological survey was carried out from April 22 to May 23, 2021 during a first epizootic of the enteric red plague in the fishes *Oreochromis niloticus* and *Cyprinus carpio* reared in ponds in the Monatélé Subdivision of the Centre Region of Cameroon. The objective was to assess clinical disorders and mortality rate, associated risk factors and economic losses in semi-intensive farms due to red plague in Cameroon. So, the standard epidemiological procedures were used to assess the mortality rates before and after antibiotic (Oxytetracyclin) treatment of the disease. Results showed that clinical signs recorded within three months of observing included lateral recumbency, breathing difficulties (dyspnea) and wide opening of mouths of affected fish. The overall mortality rate of 7.74% (294 dead fishes out of 3800) was recorded. The mortality rate was significantly higher ($p < 0.001$) in polyculture pond (11.33%) compared to monoculture pond (4.70%). *Cyprinus carpio* was significantly more affected than *Oreochromis niloticus.* The mortality rate was higher ($p < 0.01$) in younger fishes than older ones and was sex independent. The therapy was more effective in monoculture pond than in polyculture pond and in *Oreochromis niloticus* compared to *Cyprinus carpio.* Females were more sensitive to antibiotic treatment than males. The direct financial loss was $420.50. This study revealed that the main risk factors of the red plague disease were farming practice, species, age and size of fish**.** Rigorous epidemiological surveillance of fish diseases was suggested for improved productivity of fish farms in Cameroon.

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INTRODUCTION

Diseases are among the major constraints to fish production and should be taken into account for a sustainable aquaculture. In natural milieu, the pathogenic effects are attenuated because of the balance established during the evolution of fish and pathogen system (Fonkwa *et al.,* 2020). Though, cultured fish can have healthy status even in the continuous presence of pathogens, environmental stress has negative effects on the defense mechanisms of fishes and cause pathogens to thrive with shifting of the balance in favour of the disease. Severe outbreak of diseases may occur if the fish fail to adjust adequately or if timely corrective managerial measures are not carried out. The original balance between the fish and pathogens is restored when the environmental problems are resolved and effective therapeutics applied. In fishpond breeding systems, farming practices such as feeding, fertilization, pond emptying, level implementation of biosecurity measures, confinement of fish, muddy nature of vase, level of oxygenation, rate of water flow and depth of water can influence existing equilibrium between fish and pathogens. These conditions favour stress which weakens the immune system of fish and such pond water may harbour epizootics leading to high mortality rates and enormous economic losses fish (Boungou *et al.,* 2013).

Enterobacteria infections and gross economic losses due to Yersiniosis (*Yersinia ruckeri*) in fishes have been widely reported in coldwater fish farms in Iran (Zorriehzahra *et al*., 2012; Soltani *et al*., 2014). The mortalities rates ranging from 30 to 70% were affected by the fish size, stress condition, water temperature, individual susceptibility and strain virulence (Noga, 2010). Outbreak of similar disease conditions such as enteric redmouth disease in rainbow trout *Salmo gairdneira* in France (De Kinkelin-Pelletan and Michel, 2014), *Yersinia ruckeri* infection of cultured Nile tilapia (*Oreochromis niloticus*) in semi-intensive fish farm in Lower Egypt (Eissa *et al*., 2008) and *Cyprinus carpio* in a common carp farm in Germany (Böttcher *et al.*, 2021) have been recorded. The genus *Yersinia* is made up of eighteen (18) species of which three (3) are pathogenic in human namely *Yersinia pseudotuberculosis*, *Yersinia enterocolitica* and *Yersinia pestis*. *Yersinia pestis* causes red plague, a severe zoonotic disease of fishes characterized by clinical languor and purpura.

In Cameroon, there is a dearth of quantitative data related to fish diseases and their economic impact. It is therefore essential to investigate evidence for fish diseases such as red plague epizootic in farmed fishes in Cameroon and promote awareness against the disease for sustainable aquaculture and adequate epidemiological surveillance in the country.

This paper is a first scientific evidence of the red plague epizootic in farmed fishes namely Nile tilapia (*Oreochromis niloticus*) and common carp *(Cyprinus carpio*) in Cameroon. It intends to promote a sustainable aquaculture by raising awareness of stakeholders on the havoc that pathogens can induce over the fish production and the need of an adequate epidemiological surveillance. This study was carried out to assess clinical disorders and mortality rate**,** associated risk factors and economic losses in semi-intensive farms due to red plague in Cameroon.

MATERIAL AND METHODS

Geoclimatic characteristics of the study farm

A cross sectional study was conducted from April 22 to May 23, 2021 in a fish farm located in the administrative Monatele Subdivision, Lekie Division in the Centre Region of Cameroon (Figure 1). The geoclimatic characteristics of the study area are summarized in Table 1.

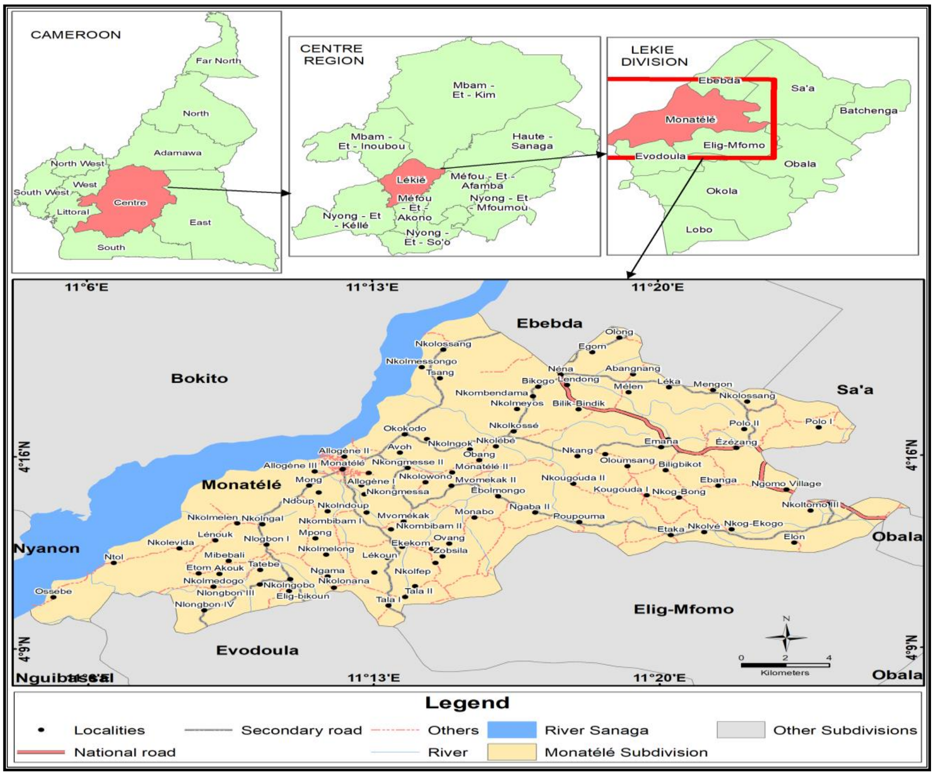

Figure 1. Map of Cameroon showing the geographical location of the administrative Monatélé Subdivision of Lékie Division in the Centre Region

Table 1. Geoclimatic characteristics of Monatélé Subdivision (Geotsy, 2022; Suchel, 1987)

Geoclimatic parameters	Characteristics
Coordinates	North Latitude : 4°10’- 4°18’
	East Longitude : 11°04’-11°26’
Average altitude	393 m above the sea level
Climate	Equatorial type
Average rainfall	Annual : 1743 mm; Lowest: 15 mm (January); Highest: 304 mm (October)
	Two dry seasons alternating with two rainy seasons
	Irregular short dry season: July-August
Seasons	Long rainy season: September - November
	Long dry season: December - mid-March
	Short rainy season: mid-March-June
Temperature	28°C (August) ; 31°C (February)
Average hygrometry	80%
Winds	Moist windblow direction : Southwest
	High windblow direction : Northwest
Sunstroke	1 200 - 800 hours / year
Soils	Mixture of clay and sand; pH : 5 - 8
Main river	Sanaga

Case report and diagnosis of the disease

An epidemiological investigation was therefore initiated following the notification on April 22, 2021 of unexplained massive mortality of fish in his farm. The affected ponds in the farm were seeded on January 29, 2021 with healthy fry [1000 *Oreochromis niloticus* (4g) and 2800 *Cyprinus carpio* (5g)]. The fish farming practices are summarized in Table 2.

Table 2. Some zootechnical characteristics of the affected farm

Variables	Characteristics
Production system	Semi-intensive[1]
Total number of ponds	9
Number of affected ponds	2 (Ponds 3 and pond 5)
Distance between infected ponds	15m
Pond 3	-Surface area: 72m^2
	-Depth: 1.20m
	-Monoculture: *Cyprinus carpio*
	-Integrated with pigs[2]
	-Stocking density: 23 fish/m^3
	- Fertilizer: pig dung
Pond 5	-Surface area : 40m^2
	-Depth : 1m
	- Polyculture : *Cyprinus carpio* + *Oreochromis niloticus*
	- Stocking density: 45 fishes/m^3
	-Stocking ratio: 56% (*Oreochromis niloticus*) : 44 % *Cyprinus carpio*
	- Fertilizer: chicken manure
Source of water supply	Groundwater
Manufactured feed	Le Gouessant brand

1: Relatively high number of fish fed both naturally and with industrial feed; 2: Pigs are reared together with fish; pigs dung from piggeries fertilize water

There was increase in mortality and clinical signs recorded within three months of observing included lateral recumbency, breathing difficulties (dyspnea) and wide opening of mouths of affected fish (Goret *et al*., 1950; Zorriehzahra *et al*., 2012). The moribund fish were swimming (practically floating) near the water surface at the corners of ponds, moving sluggishly and showed no resistance to being captured. Macroscopic examination (Eissa *et al*., 2008) revealed darkening of the skin and hemorrhagic spots (dark red colored spots) particularly the of the integument of the flank and base and on the rays of the fins (Figure 2). There was extra-reddening of gills which were sometimes covered with plenty of grayish thick mucoid fluid while subcutaneous hemorrhages in and around parts of the mouth and throat (such as severe redness of the jaws) and anorexia were also observed. The abdominal structures (liver, pancreas, caeca, bladder, lateral muscles) showed multiple haematologic spots as well as enlarged darkish spleens.The affected fishes were bloated with dropsy abdomen due to opaque fluid accumulated in the intestine and some had protruded eyes while many showed evidence of decomposition within few minutes of death. The early signs of the disease are indicative of septicaemic bacteria disease (Kumar *et al*., 2015). However, the observed changes in fish behavior, subcutaneous hemorrhages of mouth parts, other clinical signs and pathological changes of gills, eyes and abdominal structures (internal and external) as well as increase mortality are characteristics of enteric redmouth disease of fish (Kumar *et al*., 2015; Zorriehzahra *et al*. 2017). Similar ethological, anatomical and patho-physiological symptoms typical of the red plague have been previously described by Goret *et al*. (1950). Though laboratory bacteriological examination is not a routine practice, enteric redmouth disesase due to Yersiniosis was suspected based on the clinical signs and high mortality observed.

The signs and symptoms observed in this study were associated to massive fish death due to enteric redmouth disease caused by *Yersinia ruckeri* in various species of cultured fishes (Zorriehzahra *et al*. 2012). Lethargic behavior and inactivity, swimming near the surface, anorexia, darkening and depigmentation of the skin (Carson and Wilson, 2002; Woo and Bruno, 2011), extensive lip, mouth, fin and skin hemorrhages and as well as hemorrhagic gastroenteritis and congestion of the internal organs (Eissa *et al*., 2008) of fishes suffering from enteric redmouth disease have been described. However, reddening and subcutaneous hemorrhages of the throat prolapse and hemorrhages in the anus were not noticed on the present study.

Figure 2. Distribution of some clinical signs recorded on the study. a: Reddening and hemorrhages in the gills (arrows) of *Cyprinus carpio*; b: *Oreochromis niloticus* showing hemorrhagic spots at the base of the dorsal fin (arrow) and operculum (arrow); c: *Cyprinus carpio* with bloated and soft abdomen (arrows); d: Sample of fishes showing evidence of decaying within minutes of death.

The biosecurity practice in the fish farm is presented in Table 3. A biosecurity measure was coded as 1 if that measure was implemented or 0 if the measure was absent or not implemented (Van *et al.,* 2011; Can and Altug, 2014; Sarrazin *et al.,* 2014). The linear scoring system was empirically calculated as previously described (Can and Altug, 2014; Gelaude *et al*., 2014; Maduka *et al*., 2016; Kouam and Moussala, 2018; Kouam *et al*., 2019). Indeed, the measures were weighted equally and any biosecurity measure estimated to be less efficient in the transmission and occurrence of a disease was also considered. Thus, fish may suffer from poor health due to lack of implementing biosecurity measures. The focus was on the importance of implementing biosecurity measures on the health of farmed fish and not the level of risk generated by each biosecurity measure as it is the case in disease transmission pathways (Ngueguim *et al.*, 2020). Gelaude *et al*. (2014) reported that the weighed scoring systems in the disease transmission pathways should not have the same efficiency given that direct contact is likely more risky than indirect contact with less efficiency for transmitting pathogens. Thus, of twenty-four (24) standard biosecurity measures recommended by Arthur *et al.* (2008), only nine (9) were implemented corresponding to 37.50% biosecurity compliance rate. The value is within the intermediate range (25-75%), indicating that the farm could be classified at the moderate risk level of contamination (Racicot and Vaillancourt, 2009).

Table 3. Scoring of biosecurity measures of the farm used in this study

N°	Biosecurity measures	Modalities	Score/24
1	Space for visitors	No	0
2	Use of footbaths	No	0
3	Special outfit for visitors (gloves, boots…)	No	0
4	Special outfit for staff	No	0
5	Visitors are allowed to have contact with fish in the pond	No	1
6	Farm is fenced	Yes	1
7	Others animals are present in the farm	Yes	0
8	Disinfection of breeding tools before use	No	0
9	Disinfection of breeding tools after use	No	0
10	Exchange of breeding tools between farms	No	1
11	Layout of fishponds	Derivation	1
12	Water circulation	Continuous	1
13	Sanitary lock	Yes	1
14	Analysis of water quality	No	0
15	Water supply tracks protected to trap debris and unwanted aquatic animals	Yes	1
16	Quarantine of new fish	No	0
17	Treatment of fish diseases	Yes	1
18	Awareness of fish diseases	Poor	0
19	Veterinary intervention	No	0
20	Diagnosis of fish diseases*	No	0
21	Cadaver management	Given to dogs	0
22	Captured fish put back into water	Yes	0
23	Awareness of biosecurity measures	Poor	0
24	Products used for the treatment of fish diseases	Antibiotics, vitamins, salt bath	1
Overall score			9

***:** Based on skills acquired by the farmer during fish training program

Treatment of the disease, collection and analysis of data

The treatment started on April 25, 2021 with changing of the water in the affected ponds followed by veterinary treatment using the antibiotic Oxytetracyclin 85 mg/ kg body weight associated with vitamins. The drug was mixed into feed and given to fish morning and evening for three days. Also, quick lime (25g/m^2) was equally evenly distributed over the pond water surface at the same periods.

Fishes were monitored daily, the sex of dead fish determined and their standard length (SL) measured as previously described by Nack *et al*. (2022). The dead fishes were grouped into two size classes of 30 mm (80mm ≤ SL ≤ 110 mm and 110 mm < SL≤ 140 mm). A sample of 200 *Cyprinus carpio* was collected from each pond to determine the sex ratio and percentage of fish belonging to each size class. The extrapolation was done to compute the approximate total number of fish of each sex in the pond as well as the total number of fish from each size class. Only monosex (males) *Oreochromis niloticus* were reared. The mortality rate was calculated as follows:

$$\text{Mortality rate} = \frac{\text{Number of dead fish within a period of time}}{\text{Total number of fish in the population}} X\ 100$$

The chi-square test (X^2) was used to test significant levels of factors (farming practice, fish species, size and sex) on the mortality rate. The statistical significance was set at $p < 0.05$.

RESULTS

Mortality rate as a function of the farming practice and fish species

The mortality rate based on the farming practice and fish species is summarized in Table 4. The overall mortality rate of 7.74% (294 dead fish out of 3800) was observed irrespective of the type of pond and fish species. After treatment, the plague mortality rate dropped significantly (X^2 = 81.61; $p < 0.001$) from 8.25 to 1.77% corresponding to 72.73% treatment effectiveness. The highest mortality rate (X^2 = 52.07; $p < 0.001$) was recorded in polyculture pond (11.33%) compared to monoculture pond (4.70%). The treatment was more effective in monoculture pond since the mortality rate before and after treatment was respectively twice and 13.5 times higher ($p < 0.001$) in polyculture than monocultutre ponds.

For polyculture pond, the fish *C. carpio* was significantly (X^2 = 58.96; $p < 0.001$) affected more than *O. niloticus.* After treatment and regardless of the fish species, the mortality rate decreased (X^2 = 28.51; $p < 0.001$) from 8.11 to 3.51%. The mortality rate dropped significantly by 64.55% (13.75 to 5.65%; X^2 = 22.24; $p < 0.001$) and 51.28% (3.60 to 1.97%; X^2 = 3.96; p = 0.04) in *C. carpio* and *O. niloticus* respectively. Before and after antibiotic treatment, more *O. carpio* was affected ($p < 0.001$) compared to *O. niloticus* in polyculture pond. For the monoculture ponds, the treatment significantly reduced the mortality rate by 94.12% (X^2 = 64.55; $p < 0.001$).

Table 4. Distribution of mortality rate before and after treatment based on farming practice and fish species

Treatment	Polyculture pond			Monoculture pond	Overall
	C. carpio	*O. niloticus*	*C. carpio + O. niloticus*	*Cyprinus carpio*	
Before	110 (800)**13.75**^{aA}	36 (1000) **3.60** ^{aB}	146 (1800) **8.11**^{aA}	85 (2000) **4.25** ^{aB}	231 (3800) **8.25**^{a}
After	39 (690) **5.65**^{bA}	19 (964) **1.97** ^{bB}	58 (1654) **3.51**^{bA}	5 (1915) **0.26** ^{bB}	63 (3569) **1.77**^{b}
Overall	149 (800) **18.63**^{A}	55 (1000) **5.50**^{B}	204 (1800) **11.33**^{A}	90 (2000) **4.70**^{B}	294 (3800) **7.74**

Number of dead fish (number of fish in the ponds) mortality rate in %. a; b: values with different letters in the same column differ significantly ($p < 0.05$). A; B: values with different letters in the same row differ significantly ($p < 0.05$).

Daily mortality rate in *Cyprinus carpio* before treatment in relation to the farming practice

Before antibiotic treatment of the plague, a marked increase of the mortality rate (1.25 to 9.38%) in *Cyprinus carpio* was observed in polyculture pond (Figure 3) contrary to monoculture pond which experienced slight increase of the mortality rate (0.4 to 2.7%). The mortality rate was significantly higher (X^2= 65.49; $p < 0.001$) in polyculture pond than in monoculture one.

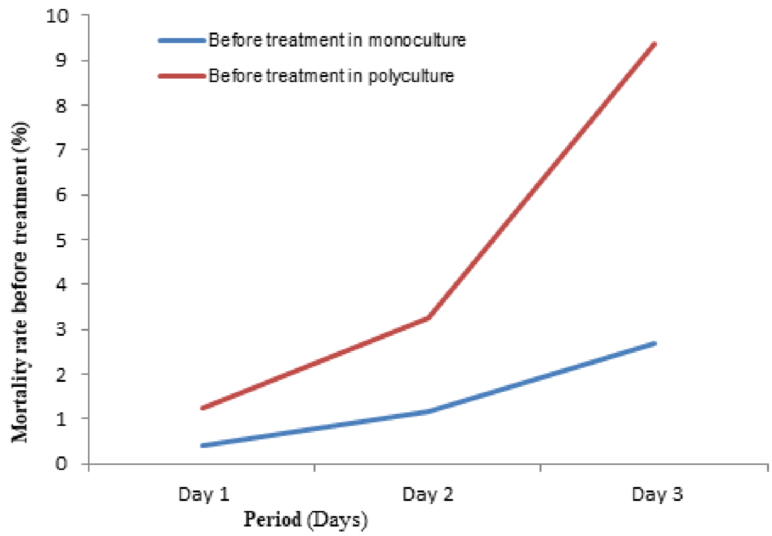

Figure 3. Daily mortality rate in *Cyprinus carpio* before antibiotic treatment in relation to the farming practice

Daily mortality rate based on fish species before antibiotic treatment in polyculture pond

The daily mortality rate as a function of fish species before treatment in polyculture pond is illustrated in figure 4. Irrespective of the fish species the highest ($X^2 = 60.73$; $p < 0.001$) mortality rate was recorded on day 1 (10.89%) followed by day 3 (5.11%) and day 2 (2.11%). The mortality rate in the fish *C. carpio* significantly ($X^2 = 59.39$; $p < 0.001$) doubled each day whereas in *O. niloticus,* there was a daily slight rise of the mortality rate ($X^2 = 5.11$; $p = 0.07$). Whatever the period, the mortality rate was higher in *C. carpio* than in *O. niloticus* with a significant difference on day 2 ($X^2 = 6.85$; $p = 0.03$) and day 3 ($X^2 = 48.40$; $p < 0.001$).

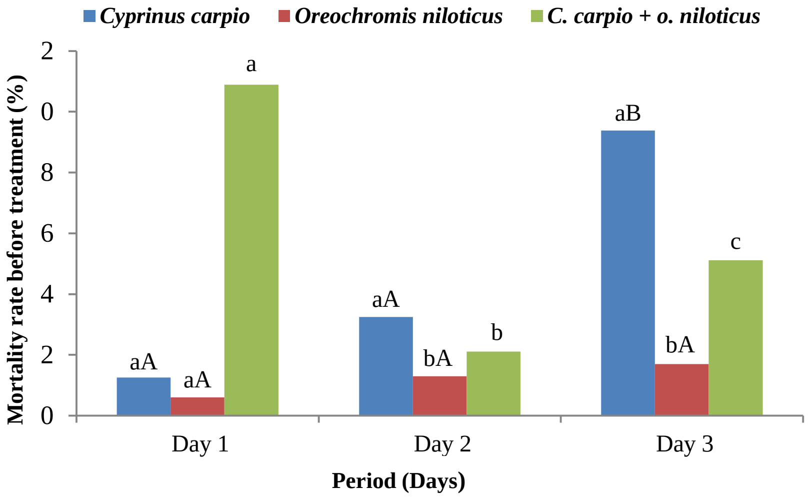

Figure 4. Day wise mortality rate based on fish species before antibiotic treatment in polyculture pond
a; b; c: for a given day, bars with different letters differ significantly (p< 0.05)
A; B; C: bars with different letters differ significantly (p< 0.05) for a given fish species
Green bars are only compared to each other during the three days.

Temporal distribution of the mortality rate after antibiotic treatment of the plague in polyculture pond

The temporal distribution of the mortality rate after antibiotic treatment of the plague in polyculture pond (Figure 5) showed an erratic fluctuation pattern two days post treatment. Overall, the mortality rate exhibited a synchronized pattern of distribution from day 6. The values increased and peaked on day 36 and dropped till 0% on day 37. The duration of full recovering of fish (0% mortality rate) was 33 days. The treatment effect was more effective among the *Oreochromis niloticus* than the *Cyprinus carpio* ($X^2 = 14.93$; $p < 0.001$).

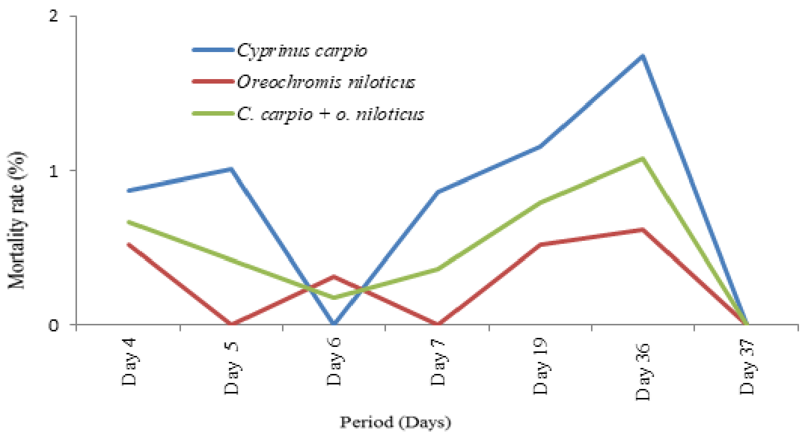

Figure 5. Temporal distribution of the mortality rate after antibiotic treatment of the plague in polyculture pond

Daily mortality rate of *Cyprinus carpio* before and after antibiotic treatment in the monoculture pond

The daily mortality rate of *Cyprinus carpio* of monoculture pond before treatment (Figure 6A) rose significantly (X^2 = 38.17; p < 0.001) from 0.4 (8 dead fish) to 2.7 (54 dead fsh) corresponding to 575% increase between days 1 and 3 respectively. After treatment (Figure 6B), 100% drop (X^2 = 2.80; p = 0.24) in mortality rate (0.15 to 0%) was recorded between days 4 to 6. Thus, three days were sufficient for the eradication of the illness and clinical signs. The treatment applied had a significant (X^2 = 66.27; p < 0.001) effect on the mortality rate.

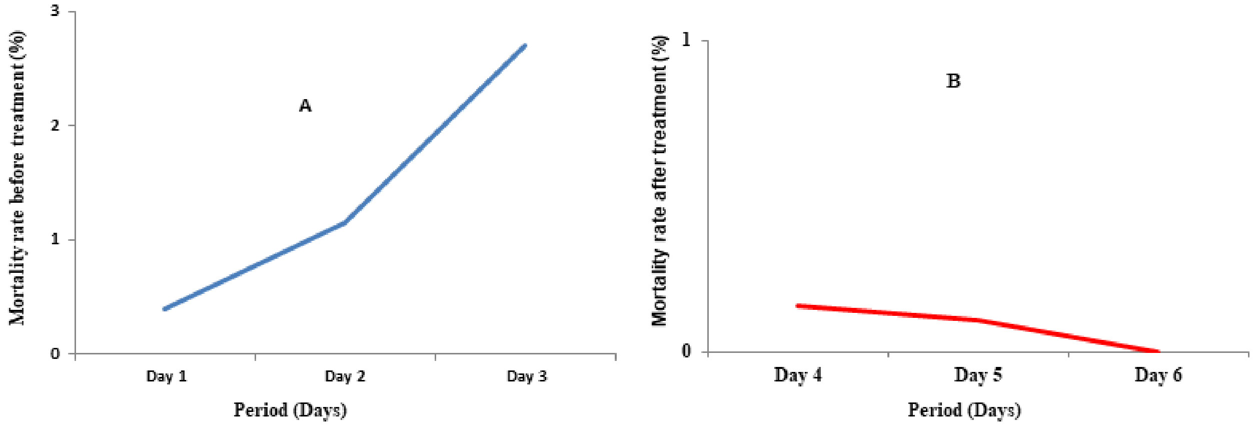

Figure 6A. Daily mortality rate in *Cyprinus carpio* before antibiotic treatment in the monoculture pond
Figure 6B. Daily mortality rate in *Cyprinus carpio* after antibiotic treatment in the monoculture pond

Mortality rate as a function of fish sex and antibiotic treatment

The mortality rate based on fish sex and antibiotic treatment is shown in figure 7. Fish were dead irrespective of the farming practice and species. As a whole, the mortality rate was non significantly higher in males than females (X^2 = 2.09; p=0.15) though, the treatment was more effective in females than in males (X^2 = 5.52; p = 0.01).

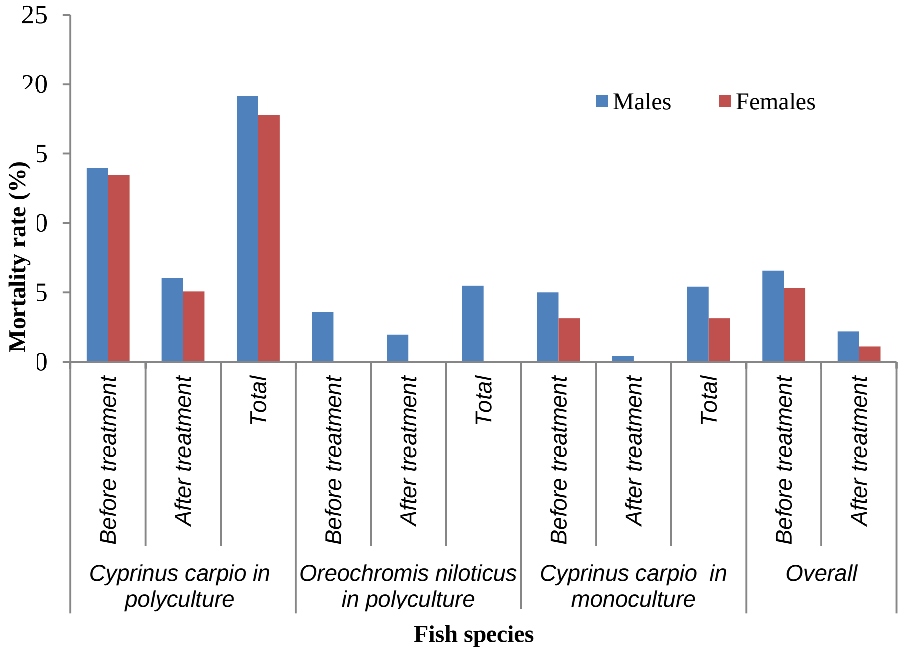

Figure 7. Mortality rate of *O. niloticus* and *Cyprinus carpio* as a function of fish sex and antibiotic treatment

Effect of the fish size classes on the mortality rate

The effect of the fish size classes on the mortality rate as highlighted in figure 8 suggested that fish size was a major factor. Unlike for *O. niloticus,* the overall mortality rate of *C. carpio* was about twice higher in younger fish (standard length ranging from 80 to 110mm) than in older ones. Irrespective of size class, the fish *C. carpio* recorded the highest mortality rate compared to *O. niloticus.* The mortality rate was significantly influenced by the size class ($p < 0.01$).

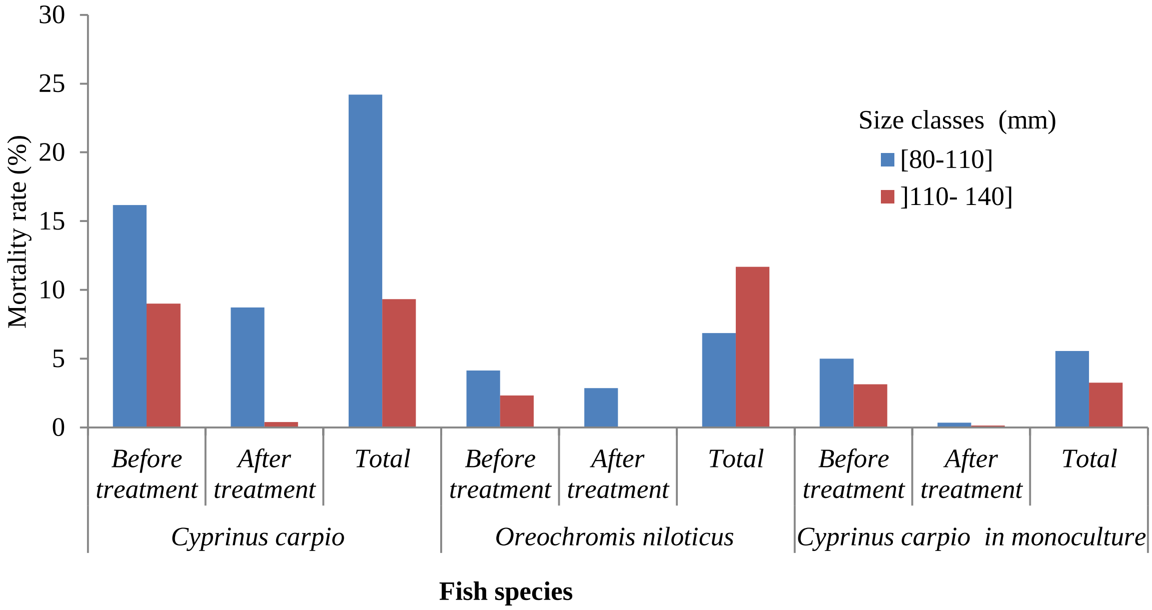

Figure 8. Effect of the fish size classes on the mortality rate

Economic impact caused by the red plague

Overall, 294 with an average weight of about 0.150 kg of 3800 fish examined died equivalent to about 7.74% production loss. This corresponded to a direct financial loss of $420.50 based on cost of $5.00 per fish and total disease treatment cost of $ 200.

DISCUSSION

The assessment of the mortality rate caused by the red plague due to Yersiniosis in grower pond fishes at a semi-intensive farm fish in Cameroon, associated risk factors, effectiveness of the antibiotic treatment and direct financial losses revealed a low (< 10%) overall mortality rate of 7.74%. A mortality rate in the range of 30 to 70% was expected since muddy vase, low oxygenation and low water depth which enhance the transmission of pathogens (Barassa *et al.,* 2003) were observed in the study. The overall mortality rate was low probably because fishes were infected from an advance stage of development i.e. fingerlings. The higher values of the mortality rate would have been recorded if bacteria had infected fishes at the early stage (fry) since the immune system response is likely to increase with the age of the fish. The mortality rate could be reduced if the farmer used the fastanks or concrete tanks instead of earthen fishponds. In fact, the water quality control and the observance of biosecurity measures seem easier in out-ground rearing infrastructures. The red plague in the present study was water borne disease due to the failure of biosecurity practice in the farm. Wild animals such as birds, invertebrates and even humans could have served as vectors of *Yersini*a *spp*. primarily, horizontal transmission of *Yersini*a *spp* from fish to fish through the water has been described (Eissa *et al*., 2008). The Yersinia bacterial species may remain for up to 2 months in ponds mud and have been recovered from the aquatic environment including water, faeces and sewage sludge and from human bile (Coquet *et al*., 2002; Tinsley, 2010).

The polyculture (11.33%) system exhibited a higher mortality rate compared to the monoculture (4.70%) suggesting that polyculture practice was likely to increase the transmissibility of the pathology. This may be due to the interspecific competition for space and feed between fishes in the polyculture. Thus, the fishes were stressed and their immune system weakened causing them to be more vulnerable to infections (Boungou *et al.,* 2013). The interspecific competition and higher than recommended stocking densities of the fish (25 fish /m3) and interspecies stocking (67% *Oreochromis niloticus*: 37% *Cyprinus carpio*) was observed in polyculture pond in the present study. In addition, the chicken manure used in the farm as fertilizer in the polyculture pond might have influenced the transmissibility, infectivity and virulence of the bacterial agents and morbidity of fishes by negatively modifying the water physico-chemical quality contrary to pig dung applied in monoculture pond.

The effectiveness of antibiotic treatment was farm practice dependent with better treatment effects noted in monoculture pond. In the polyculture pond, the mortality rate was higher in *Cyprinus carpio* (18.63 %) than *Oreochromis niloticus* (5.50%). Interspecies characters of defense mechanisms or immune systems could have been responsible for the difference recorded. The outbreak of the red plague described in the present study was associated with the rainy season. Indeed, Eissa *et al*. (2008) reported that the pre-acute to acute redmouth disease took place in Lower Egypt during the spring and beginning of summer which are periods of rising water temperatures. Although the mortality rate was not evaluated by Eissa *et al*. (2008), the prevalence was 66.6% and mortality rate linked to fluctuation in water temperature, predation due to migratory birds that ‘stopover’ at that site, and overstocking of ponds. Acute to subacute infections usually appeared in yearling fish in the fall and early winter with declining water temperatures. Acute redmouth disease has resulted in huge economic losses and 30-70% mortalities depending on the fish size, stress condition, water temperature, individual susceptibility and strain virulence (Noga, 2010).

Böttcher *et al.* (2021) noticed that enteric redmouth disease in *Cyprinus carpio* in Germany was related to season and farm practices. They observed an over-wintering mortalities rates (October 2017 – April 2018) of 3.6 % in the hibernation pond of a high stocking density (5.2 tons/ hectare). That mortality rate was below the normal expected value meaning that fish were in a good health state despite the overcrowding. Within 48 hours period after harvest, a mortality rate of 2.7 % was recorded (450 fish dead). After putting fish in production ponds with low densities (136 – 251 kg/ hectare) and optimal environmental conditions without any drug treatment, the mortality rate rose to 9.0%. This value was still acceptable because of being below average and gave no indication of any underlying health problems. It was in autumn 2018 that clinical signs of the enteric red mouth disease were clearly observed in almost 100% of examined common carps. Thus, the mortality rate recorded by Böttcher *et al.* (2021) in *Cyprinus carpio* could not be compared to that of the present survey because of the dissimilarities on the farming practice and the environmental conditions. Likewise, the causative agent of both diseases i.e. enteric redmouth and red plague though closer were different.

No mortality was noted only after thirty three (33) days in polyculture pond unlike three (3) days recorded in monoculture one post treatment. In polyculture pond fishes, bacteria would have developed antibiotic resistance rendering the treatment more complicated. Rodgers (2001) reported that by exposing *Yersinia ruckeri* to inadequate or variable dosage, failure to complete the recommended course or by repeated short term treatment will probably lead to selection for drug resistance.

The mortality rate was statistically not affected by the fish sex suggesting that sex is not a risk factor. The findings of the present study agree with Noga (2010) who reported that, the mortality rates of *Yersinia ruckeri* infections were only related to fish size, stress condition, water temperature, individual susceptibility and strain virulence. The active ingredient of Oxytetracyclin used for treatment in the study would be better potentiated by female fish. The use of the synthetic antibiotic in aquaculture should be discouraged for ecological and public health reasons. On the other hand, medicinal plants should be strongly prescribed for disease prevention, control and treatment. The mortality rate was significantly influenced by age and size. Indeed, the highest mortality rate was noted with the younger and smaller fishes than older and bigger ones. This can be explained by the fact that, the immune system response is better developed in the older fish.

There is no data relevant to the economic loss caused by fish pathogens in Cameroon. The 7.74% production loss corresponding to a direct financial loss of $420.50 in a single small holder farm is very significant. It would have increased if measures had not been taken to limit the spread and occurrence of the disease in other fish farms. There are concerns about increasing economic losses in fish farms due to diseases In China, which is world’s largest aquaculture producer. Economic losses estimated at $ 5.3 billion in 2017 had an increase of $ 1.2 on 2016 estimated value. Over 96 diseases have been linked to losses in production of 62 breeding fish species including tilapia which is ranked top at 33.3% losses ($ 450 millions) (FAO, 2019).

CONCLUSIONS

The present study reported the first outbreak of red plague in pond fishes and revealed that mortality rate was significantly influenced by farming practice, species, age and size of fish**.** The direct financial loss caused by the red plague was significant and likely to increase on a large scale. Rigorous epidemiological surveillance of fish diseases is vital for improved productivity of fish farms. Determine of the genotype and biochemical characteristics of the fish disease causative agents should be emphasized.

COMPETING INTEREST

The authors have no conflict of interest declare

ETHICAL CLEARANCE

The investigation followed a protocol approved and authorized by the Institutional Animal Care and Use Committee at the Department of Aquaculture, Institute of Fisheries and Aquatic Sciences, University of Douala-Cameroon.

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