

Relationship between the abundance and distribution of the endemic fish *Paretroplus dambabe* in the north-western wetland of Madagascar and the effect of environmental parameters and the presence of other fish species

Abstract

Paretroplus dambabe is a local endemic fish species only found in Kinkony Lake (in north-western wetland and protected area) and two surrounding small lakes, Andranobe and La Digue. The ecology of *P. dambabe* is threatened by the human activities that cause the erosion and decrease of reed vegetation surface. Also, the lake is undergoing rice-growing in the shore. In addition, the invasive fish species could affect the distribution of *P. dambabe*. This study aims to determine the influence of the physico-chemical parameters, reed vegetation and the other fish species on the abundance of *P. dambabe*. Three categories of variables were taken into account: (a) the physico-chemical parameters, (b) the distance from the reed vegetation, and (c) the number of fish species and the relative abundance per sampling station of each fish species. Environmental variables and the presence of the Tilapiinae cichlids do not yet affect the presence of *P. dambabe* in the Kinkony Lake. But, the abundance of this endemic fish is negatively and significantly influenced by the abundance of the common carp *Cyprinus carpio*, *Ambassis* sp., sleepy goby *Glossogobius biocelatus*, tank goby *G. giuris*, longfin tilapia *Oreochromis macrochir*, Nile tilapia *O. niloticus*, Mozambic tilapia *O. mossambicus*, redbreast tilapia *Tilapia rendalli* and redbelly tilapia *T. zillii*. Species within the genera *Oreochromis* and *Tilapia*, and *C. carpio* could eat the eggs of *P. dambabe* when they consume the aquatic plant in the lake. Species within the genus *Glossogobius* are carnivorous species and could eat the juvenile of *P. dambabe*. As *P. dambabe*, *A. sp.* is an omnivorous species and could be in competition with *P. dambabe*. Thus, the manager of this north-western protected area (Mahavavy-Kinkony Complex) should continue the ecological monitoring of the lake to observe the evolution of the physico-chemical parameters, the surface of the reed vegetation and the abundance of native and invasive species. Climate change can disturb the environmental parameters of Kinkony Lake and could affect native fish species compared to the invasive species.

Keywords: *Paretroplus dambabe*, abundance, environmental parameters, freshwater fishes, kinkony lake, north-western, wetland, Madagascar

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Introduction

The endemic Malagasy cichlid *Paretroplus dambabe* Sparks 2002 is a local endemic fish species located in Kinkony Lake (16°05'S, 45°52'E), in the north-western wetland and protected area of Madagascar, and two surrounding small lakes Andranobe (16°09'S, 45°42'E) and La Digue (16°09'S, 45°42'E). *Paretroplus dambabe* prefers deep freshwater and lives only in a habitat where the water is lukewarm and briny.¹ It is an omnivorous species and this species is more sensitive to any kind of disturbance in term of salinity compared to the other cichlids species.^{2,3} This last decade, Kinkony Lake ecosystem is disturbed by erosion and the conversion of the shore into rice-growing land. The lake is also threatened by sedimentation from the erosion of Mahavavy watershed and the other rivers that could increase the water salinity and pH. Furthermore, the invasive species especially the tilapiine cichlids could also disturb the ecology of the native species in the Lake.^{4,5} The tilapiine cichlids grow and breed quickly compared to the native fish species.³ Prior researches show

the capacity of tilapiine cichlids to live in water with temperature above 35°C.^{6,7} The member of this invasive subfamily is able to survive with 35‰ salinity, however the maximum lethal salinity for *P. dambabe* is 10‰.² Frei et al.⁸ state that combination of species within the tilapiine cichlids and the common carp *Cyprinus carpio* negatively impacts native macrophyte. This could impact native fish species ecology that uses macrophyte for spawning and foraging.^{9,10} Moreover, previous studies state that the main threat for *P. dambabe* could be the reduction of reed vegetation surface that was losing 80% of its surface since 1949 through 2008.^{11,12} *Paretroplus dambabe* could use the reed vegetation at Makary site to lay their eggs and this habitat also gives nutrients especially for fish that feeds on microorganisms and suspended matters.⁵ So, this study aims to determine the effect of the physico-chemical parameters spatial variation and the influence of the other fish species on the presence and abundance of *P. dambabe*. Also, it analyses if the distribution of *P. dambabe* is related to the reed vegetation. Therefore, the hypothesis of this study is that the spatial variation of the physico-chemical parameter, the presence of the

other fish species and the distance from the reed vegetation affect the presence and the relative abundance of *P. dambabe*.

Materials and methods

Preliminary study

Actually, sampling should cover all the part of the lake so that the modeling could have minimum of error. Also, the number of station in each site depended on the surface where fishing was feasible. So, map and shape file of Kinkony Lake from Asity Madagascar association were used to find some points that will represent stations of data sampling. The geographical coordinate of these points were imported into a Global Positioning System (GPS) to indicate automatically the station location in the field. Moreover, data regarding reed vegetation repartition and surface in Kinkony Lake were obtained from Asity Madagascar database as well.

Study site

Sampling was conducted in 10 September to 5 October 2014 in Kinkony Lake, Ramsar site located within the protected area of Mahavavy-Kinkony Wetland Complex, in the north-western area of Madagascar.¹³ As shown below (Figure 1), all sampling stations were spread over five sites in Kinkony Lake: (a) Bevoay (16°08'S, 45°45'E), (b) Tombomafana (16°10'S, 45°50'E), (c) Makary (16°09'S, 45°54'E), (d) Antongomenabe (16°08'S, 45°53'E) and (e) Marofandroboka (16°05'S, 45°51'E).

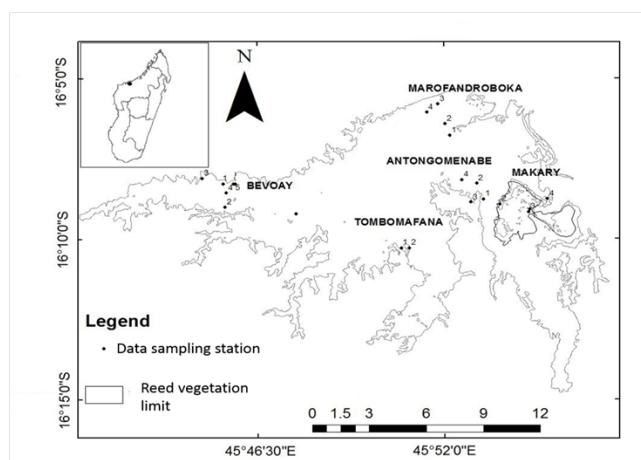


Figure 1 Data sampling stations in the Kinkony Lake. The site of Bevoay has six stations of data sampling (Bevoay1, Bevoay2, Bevoay3, Bevoay4, Bevoay5 and Bevoay6), Tombomafana has two stations (Tombomafana1 and Tombomafana2), Marofandroboka has four stations (Marofandroboka1, Marofandroboka2, Marofandroboka3 and Marofandroboka4), there are four data sampling stations in Antongomenabe (Antongomenabe1, Antongomenabe2, Antongomenabe3 and Antongomenabe4) and the site of Makary is constituted by four stations (Makary1, Makary2, Makary3 and Makary4).

Data sampling

Water parameter data such as the water temperature, turbidity,

pH, redox potential, dissolved oxygen and conductivity were taken at 6 hours in the morning. Water turbidity in Nephelometric Turbidity Unit (NTU) is measured by electronic turbidimeter (WGZ-1). Water temperature in Celsius degree (°C), pH, redox potential in millivolt (mV), dissolved oxygen in milligram per liter (mg l⁻¹) and conductivity in microsiemens (µS) were collected using an electronic device called SX736.

Gill net with 100m length, 1 m width and 20mm mesh is used to collect the quantitative and qualitative data regarding all fish species. The net was been setting up from 06 hours to 11 hours every day during two days per station. In this study, relative abundance (Ar) can be defined as the percentage of collected individuals of one species in relation to all collected individuals of all species in Kinkony Lake. Depending on the value of Ar,¹⁴ one species can be classified as dominant (Ar≥15%), influential (5%≤Ar≤15%), rare (1%≤Ar≤5%) and very rare (Ar≤1%). The relative abundance per station (Ars) which is defined as the number of collected individuals of one species per station divided to the number of all collected individuals of all species in this station, is also calculated to quantify the number of individuals of each fish species per station in the lake.

Data analysis

Factor analysis and Spearman bivariate correlation were used to outline the collinear independent variables. Only one of the collinear independent variables should be chosen to be included in the linear model. Then, the influence of retained independent variables on the presence and relative abundance of *P. dambabe*, were analyzed using the multiple linear regression (MLR). Akaike's information criterion (AIC) value of each model was employed to select the best model. Factor analysis and MLR were undertaken under the R 3.4 programme which is assessed with the help of RStudio.¹⁵⁻¹⁸ The model selection was possible thanks to the "car", "hier. part", "MASS", "MuMIn", "leaps" and "Hmisc" R packages. The Spearman bivariate correlation was performed using SPSS software.¹⁹

Results

Physical and chemical property of kinkony lake

The physical and chemical properties of all stations located in one site do not show any significant difference. Hence, physical and chemical variable value of one site is the average of the collected values of this variable in this site (Table 1). Marofandroboka is the site with the highest value of temperature. Moreover, the water is moderately saline throughout the lake. However, among the five sites, Tombomafana is less saline contrary to Makary. Regarding to all pH value, the water of the lake is basic. There are no significant differences between the pH of all sites and it is the same case for the dissolved oxygen rate. For the turbidity, the water at Makary and Antongomenabe are both slightly unclear and the three other sites are unclear. Makary has the lowest value of turbidity and Tombomafana has the most unclear water. All the redox potential values in Kinkony Lake are negative, i.e. the water of the lake is reducer. Bevoay has the lowest value of redox potential contrary to Makary.

Table 1 Characteristic of the water at each site according to the water physical and chemical property

site	Antongomenabe	Bevoay	Tombomafana	Makary	Marofandroboka
Number of stations	4	6	2	4	4
Temperature	25.44°C ±0°C	25.44°C ± 0°C	25.44°C ± 0°C	25.59°C ±0°C	27.05°C ±0°C
pH	8.84±0.06	8.82±0.16	8.76±0.12	8.20±0.29	8.82±0.04
Dissolved oxygen	16.41mg l ⁻¹ ±0.07mg l ⁻¹	16.72mg l ⁻¹ ±0.21mg l ⁻¹	16.51mg l ⁻¹ ± 0.01mg l ⁻¹	16.50mg l ⁻¹ ±0mg l ⁻¹	16.50mg l ⁻¹ ±0mg l ⁻¹
Turbidity	29.01NTU±8.81NTU	43.98NTU±15.98 NTU	53.54 NTU±1.73NTU	26.21NTU±8.18NTU	52.79NTU±13.79NTU
Redox potential	-109.85mV±3.97mV	-109.93mV±4.01mV	-104.74 mV±6.77mV	-70.24 mV±18.95mV	-108.00mV±3.24mV
Conductivity	296.40µS±20.89µS	260.11µS ±12.12µS	244.81µS ±1.17µS	347.15µS±24.20µS	263.50µS±5.58µS

Caught species and individuals and relative abundance

Makary and Antongomenabe have the highest value in term of number of caught fish species. Tombomafana, Bevoay and Marofandroboka have the highest number of captured individuals (Table 2). The long fin tilapia *Oreochromis macrochir*, the Nile tilapia *Oreochromis niloticus* and the Mozambique tilapia *Oreochromis*

mossambicus are the dominant species in Kinkony Lake (Table 2). The red belly tilapia *Tilapia zillii*, the redbreast tilapia *Tilapia rendalli*, *Ambassis* sp. and *P. dambabe* are influential. The tank goby *Glossogobius giuris* is a rare species and the sleepy globy *Glossogobius biocellatus* and *C. carpio* are very rare. There are actually two caught individuals of *C. carpio* in the lake but the relative abundance is really small and rounded off to 0%.

Table 2 Number of caught species and individuals per station

Stations	Caught individuals	Caught individuals	Species number	<i>P. dambabe</i>	<i>O. mossambicus</i>	<i>O. macrochir</i>	<i>O. niloticus</i>	<i>T. rendalli</i>	<i>T. zillii</i>	<i>C. carpio</i>	<i>A. sp.</i>	<i>G. giuris</i>	<i>G. biocellatus</i>
Bevoay1	27			4	8	6	0	0	9	0	0	0	0
Bevoay2	15			4	0	5	0	0	6	0	0	0	0
Bevoay3	26	106	8	0	5	5	6	0	10	0	0	0	0
Bevoay4	27			0	11	15	1	0	0	0	0	0	0
Bevoay5	6			1	0	0	1	0	2	0	2	0	0
Bevoay6	5			1	0	0	1	1	1	0	0	1	0
Tombomafana1	19	34	6	3	7	3	0	0	1	0	5	0	0
Tombomafana2	15			0	11	1	0	0	1	0	1	1	0
Makary1	34			1	13	0	7	9	2	0	0	0	2
Makary2	35	96	10	1	0	8	4	8	9	1	4	0	0
Makary3	18			3	1	3	2	5	2	0	1	0	1
Makary4	9			0	2	0	5	0	0	0	0	2	0
Antongomenabe1	9			0	0	3	2	2	0	0	0	0	2
Antongomenabe2	24	60	10	2	0	12	7	2	1	0	0	0	0
Antongomenabe3	1			0	0	0	0	1	0	0	0	0	0
Antongomenabe4	26			1	2	12	4	2	1	1	2	1	0
Marofandroboka1	20			0	0	1	9	2	0	0	7	1	0
Marofandroboka2	58	106	9	0	0	21	33	2	1	0	0	1	0
Marofandroboka3	5			1	0	3	0	0	0	0	0	0	1
Marofandroboka4	23			1	4	5	8	3	0	0	1	1	0
	402	402		23	64	103	90	37	46	2	23	8	6
		Ar (%)		6	16	26	22	9	11	0	6	2	1

At Bevoay, there are six stations of data sampling (Bevoay1, Bevoay2, Bevoay3, Bevoay4, Bevoay5 and Bevoay6), Tombomafana has two stations (Tombomafana1 and Tombomafana2), Marofandroboka has four stations (Marofandroboka1, Marofandroboka2, Marofandroboka3 and Marofandroboka4), there are four data sampling stations in Antongomenabe (Antongomenabe1, Antongomenabe2, Antongomenabe3 and Antongomenabe4) and the site of Makary contained four stations (Makary1, Makary2, Makary3 and Makary4). Relative abundances (Ar) are presented in the last row.

Influence of the physico-chemical and biological parameters

According to the factor analysis, the pH and redox potential have high loadings in Factor 1; and the distance from the reed vegetation and dissolved oxygen are both correlated to the Factor 2 [Factor analysis: $X^2(18)=19.37$, $P=0.37$, Table 3]. Moreover, there are significant correlation between pH and redox potential (Spearman correlation: $r_s = -0.918$, $P<0.001$), and between the distance from the reed vegetation and dissolved oxygen (Spearman correlation: $r_s=0.609$, $P=0.004$). Therefore, there are both collinearity between pH and redox potential, and between the distance from the reed vegetation and dissolved oxygen. Thus, the redox potential and distance from the reed vegetation are chosen to complete the others independent

variables for the next step of the analysis.

Regarding to the presence of *P. dambabe* and based on the MLR analysis, the effect of the Ars of *O. niloticus*, *T. zillii*, *O. mossambicus*, *T. rendalli*, *C. carpio* and redox potential on the presence of *P. dambabe*, is the best model (MLR: $F_{6,13}=1.72$, $r^2=0.186$, $P=0.194$). However, none of these predictors has a significant effect on the presence of *P. dambabe* (Table 4). Regarding to the Ars of *P. dambabe*, the effect of the Ars of *A. sp.*, *C. carpio*, *G. biocellatus*, *G. giuris*, *O. macrochir*, *O. niloticus*, *O. mossambicus*, *T. rendalli* and *T. zillii* on the Ars of *P. dambabe*, is the best model (MLR: $F_{6,13}=77.72$, $r^2=0.97$, $P<0.001$). The Ars of *P. dambabe* is significantly affected by all the predictors within this model (Table 4).

Table 3 Correlation between independent variables and generated factors obtained from factor analysis method

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10
n total	0.257		-0.205	0.411	0.284	0.174	0.560*	0.37	0.289	0.107
rs						0.937*				0.154
distance	-0.48	0.697*			0.201	-0.105	0.125	-0.213		-0.111
T	-0.124	-0.238						0.227	0.877*	
pH	0.980*							0.107		
DO	-0.151	0.672*			0.126	-0.176	0.119			-0.248
Turb	-0.382	0.334	0.501*		0.223				0.393	-0.203
E	0.966*									
C	0.824*	-0.206	-0.194		-0.207		-0.292	0.245	-0.216	
abomoss		-0.149			0.296	0.511*	0.391	-0.372	-0.22	-0.48
abomacr	-0.242	-0.166	-0.408	0.486	0.527*	-0.164	-0.194	-0.132	0.129	0.361
abonilo		-0.206		-0.273	0.101	-0.113	0.138	0.878*	0.244	
abtrend	0.156	-0.268	-0.139		0.910*	-0.203		-0.121		
abtzill		0.964*							-0.166	0.129
abccarp	0.15	-0.113				0.151	0.161		-0.105	0.804*
abasp			0.987*							
abggiur	-0.114			0.962*				0.18		
abgbioc		-0.231	-0.165	0.168			-0.785*		0.114	-0.122

The factors 1-10 are the created factors obtained from the factor analysis method. The null hypothesis that 10 factors are sufficient is not rejected [Factor analysis, $X^2(18) = 19.37$, $P = 0.37$]. * indicates significant correlation between variable and factor

X^2 , chi-squared; P, p-value; r, coefficient of correlation; n total, total number of caught individuals per station; rs, number of caught species per station; distance, distance to the reed vegetation; T, water temperature; pH, hydrogen potential; DO, dissolved oxygen; Turb, turbidity; E, redox potential; C, conductivity; abomoss, relative abundance per station (Ars) of *Oreochromis mossambicus*; abomacr, Ars of *O. macrochir*; abonilo, arsof *O. niloticus*; abtrend, ars of *Tilapia rendalli*; abtzill, arsof *T. zillii*; abccarp, Arsof *Cyprinus carpio*; abasp, arsof *Ambassis sp.*; abggiur, arsof *Glossogobius giuris*; abgbioc, arsof *G. biocellatus*

Table 4 Influence of independent variables on the presence and relative abundance per station (Ars) of *Paretroplus dambabe*

Presence				Relative abundance per station			
Predictors	Estimate	T	P	Predictors	Estimate	T	P
(Intercept)	1.971	2.53	0.025*	(Intercept)	83.204	15.33	< 0.001*
abtrend	-0.01	-1.68	0.117	abomoss	-0.874	-16.95	< 0.001*
abonilo	-0.014	-2.04	0.063	abomacr	-0.761	-11.08	< 0.001*
abtzill	0	0.03	0.979	abtrend	-0.839	-14.39	< 0.001*

Table continued...

Presence				Relative abundance per station			
Predictors	Estimate	T	P	Predictors	Estimate	T	P
E	0.008	1.3	0.218	abccarp	-1.329	-3.63	0.005*
abccarp	0.036	0.35	0.731	abasp	-0.74	-9.81	< 0.001*
				abggiur	-0.568	-5.09	< 0.001*
				abgbioc	-0.885	-9.93	< 0.001*
				abonilo	-0.927	-19.13	< 0.001*

Each effect of the independent variable is quantified by the estimate, T value (T) and P value (P). *(above P) indicates that the null hypothesis accordingly the response variable and predictor are independent, is rejected.

Abtrend, relative abundance per station (Ars) of *Tilapia rendalli*; abonilo, ars *Oreochromis niloticus*; abtzill, ars of *Tilapia zillii*; abomoss, ars of *O. mossambicus*; E, redox potential; abccarp, ars of *Cyprinus carpio*; abomacr, ars of *O. macrochir*; abasp, ars of *Ambassis* sp.; abggiur, ars of *Glossogobius giuris*; abgbioc, ars of *G. biocellatus*

Discussion

Water temperature of freshwater lake influences the other water physic-chemical parameters such as conductivity, turbidity, pH, redox potential and dissolved oxygen.^{20–23} During the fieldwork, the water temperature in Marofandroboka is higher compared to the other sites (Table 1). The cause of this variation could be the erosion of the Mahavavy River. This latter is poured out and brings sediment to the lake mainly at the east part of Marofandroboka and decreases both the lake depth and the temperature variation between the deep and the surface water.¹² According to the water classification of Bhatnagar & Devi,²³ the water conductivity and pH of the lake are acceptable for freshwater fish. Conferring to the water redox potential at all data sampling stations, the water of the lake is categorized as reducer and water tends to be reducer when its pHvalue is greater than 7.²⁰ During this study, the spatial variation of the redox potential and pH were collinear (Table 3). The collected data on pH by the SX736 is not really relevant; so, it is preferable to use the redox potential for the analysis. Otherwise, the dissolved oxygen rate is approximately constant throughout the lake and livable for freshwater fish (dissolved oxygen rate greater than 7 mg l⁻¹) conforming to the findings of Rodier et al.²⁴ The dissolved oxygen rate and the distance from the reed vegetation are collinear variables. The reed vegetation influences the dissolved oxygen rate; so, only the reed vegetation is retained for the modelling among these last collinear variables. According to the turbidity, data sampling sites are either slightly unclear or unclear. Marofandroboka, Tombomafana and Bevoay that have the highest value of turbidity, are directly linked to some watersheds especially the Mahavavy watershed (Figure 2) which is undergoing erosion.¹² Nevertheless, the spatial variation of the physic-chemical parameters of the lake during the fieldwork did not affect neither the presence nor the abundance of *P. dambabe*.

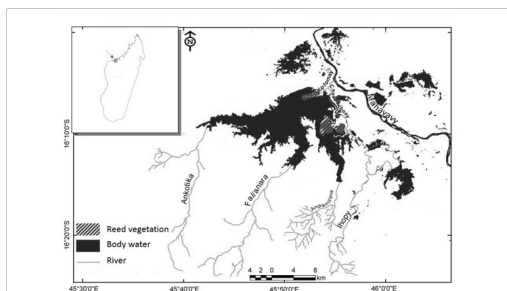


Figure 2 Hydrography of the Kinkony Lake. Reproduced with permission from.12

The reed vegetation of Makary which is not directly affected by the erosion, gives suitable condition for fish especially those which use the reed to lay eggs like *P. dambabe*. However, this variable is not kept within the best MLR models neither with the model related to the presence of *P. dambabe* nor the one related to its Ars. Distance to the reed vegetation does not influence neither the presence nor the abundance of the target species. Actually, all sites have little discontinuous reed vegetation that *P. dambabe* can use and individuals of *P. dambabe* could not be obliged to go to Makary. Species number seems to be higher at Makary and Antongomenabe which are not directly threatened by the erosion and the rice-growing. Plus, the reed vegetation is located at Makary. Caught individual number is higher in Marofandroboka, Bevoay and Makary. Even if Makary gives appropriate condition for fish survival, dominant and influential species such as the member of the tilapiine sub family which are mostly the invasive species, could adapt themselves to the areas that are directly affected by erosion such as Marofandroboka and Bevoay. Nevertheless, neither species number per station nor total number of caught individuals per station do not show any relation to neither the presence nor the Ars of *P. dambabe*.

On the one hand, none of the predictors have a significant effect on the presence of *P. dambabe*. *Paretroplus dambabe* could be present in all sampling station. The pressure from human activities and from the invasive species especially the tilapiine cichlids which are either dominant or influential, do not yet affect the presence of *P. dambabe* in Kinkony Lake. On the other hand, the Ars of *P. dambabe* is negatively and significantly influenced by the Ars of all the other caught fish species. The effect of *C. carpio* which is classified as a very rare species, has the highest estimate followed by the effect of *O. niloticus* which is in turn a dominant species (Table 4). Actually, *C. carpio* is essentially an omnivorous fish like *P. dambabe*²⁵ and could be in competition with *P. dambabe*. Like the tilapiine cichlids, *C. carpio* are known to have negative impact on the aquatic plant that could be used as support for the eggs of *P. dambabe*. Species within the genera *Oreochromis* and *Tilapia* are herbivorous.^{26–33} The member of these last genera could eat the eggs of *P. dambabe* when they consume the aquatic plant. Moreover, the fact that *Oreochromis* genus are mouth brooder,^{34,35} makes them a competitive groups compared to *P. dambabe*. Previous study found that when the resource is restricted, *O. mossambicus* feed on both small size fish and fish eggs.^{3,36,37} Species of the genus *Glossogobius* are carnivorous and the two species of *Glossogobius* in Kinkony Lake are bottom-feeding fishes.³⁸ *Glossogobius biocellatus* which is classified as very rare species and *G. giuris* which is a rare species, could prey on the juvenile of

P. dambabe. The negative effect of *A. sp.* on *P. dambabe* could be explain by the fact that like all the species within the genus *Ambassis*, *A. sp.* could be probably omnivorous with carnivorous tendency.³ So, *A. sp.* could be both in competition and predator of *P. dambabe*.

Thus, the manager of the protected area of the Mahavavy-Kinkony Complex should continue the ecological monitoring of the lake and sample data on the evolution of each physic-chemical and biological parameters especially the ones that influence the abundance of *P. dambabe*. Climate change can perturb the environmental parameters of Kinkony Lake and could disturb native fish species compared to the invasive species. The absence of data from the far south of the lake limited the conclusion of this study. In addition, collected temperature during this study represents only the temperature of the water in the surface. Furthermore, data on the lake depth and salinity are useful to measure the effect of the watershed erosion and the rice-growing in the shore. Then, nets used during the field do not reach the bottom of the lake and could affect the probability of capture of bottom-feeding fish compared to pelagic fish. Also, used nets during this study can only catch individual that is between 4 and 25 cm in length. So, it cannot capture any individual of Madagascar round herring *Pellonulops madagascariensis* which is a small size species. *Paretroplus dambabe* is also threatened by *Pe. Madagascariensis* fishing. During the fieldwork, *P. dambabe* was seen captured by the seine for *Pe. madagascariensis* but *P. dambabe* is not targeted by any fishermen. Finally, data sampling was performed at the end of the austral winter and before the closure of the fishing period. It will be interesting to compare the findings of this study to the collected data in the end of austral summer or in the beginning of the fishing period.

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Conflict of interest

Authors declare there is no conflict of interest in publishing the article.

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