E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2017; 5(2): 164-172

www.fisheriesjournal.com
Received: 23-01-2017
Accepted: 24-02-2017

T Olivier Amoussou
(A). Research Unit in Aquaculture and Aquatic Biodiversity, Polytechnic University of Bobo-Dioulasso, Bobo-Dioulasso 01, Burkina Faso
(B). Laboratory of Animal Sciences and Meat Technologies, Department of Animal Health and Production, University of Abomey-Calavi, Abomey-Calavi, Benin
(C). Centre International de Recherche-Développement sur l'élevage en zone Subhumide (CIRDES), Bobo-Dioulasso 01, Burkina Faso

Aboubacar Toguyeni
(A). Research Unit in Aquaculture and Aquatic Biodiversity, Polytechnic University of Bobo-Dioulasso, Bobo-Dioulasso 01, Burkina Faso
(B) Centre International de Recherche-Développement sur l'élevage en zone Subhumide (CIRDES), Bobo-Dioulasso 01, Burkina Faso

Ibrahim Imorou Toko
Research Unit in Aquaculture and Aquatic Ecotoxicology, Department of Animal Production, Faculty of Agronomy, University of Parakou, Parakou, Benin

Antoine Chikou
Laboratory of Hydrobiology and Aquaculture, Faculty of Agronomic Sciences, University of Abomey-Calavi, Abomey-Calavi, Benin

Thierry Akiti
Laboratory of Animal Sciences and Meat Technologies, Department of Animal Health and Production, University of Abomey-Calavi, Abomey-Calavi, Benin

Blaise M Enouheran
Laboratory of Animal Sciences and Meat Technologies, Department of Animal Health and Production, University of Abomey-Calavi, Abomey-Calavi, Benin

Camille F Bogninou
Laboratory of Animal Sciences and Meat Technologies, Department of Animal Health and Production, University of Abomey-Calavi, Abomey-Calavi, Benin

Issaka Youssao Abdou Karim
Laboratory of Animal Sciences and Meat Technologies, Department of Animal Health and Production, University of Abomey-Calavi, Abomey-Calavi, Benin

Correspondence
T Olivier Amoussou
(A). Research Unit in Aquaculture and Aquatic Biodiversity, Polytechnic University of Bobo-Dioulasso, Bobo-Dioulasso 01, Burkina Faso
(B). Laboratory of Animal Sciences and Meat Technologies, Department of Animal Health and Production, University of Abomey-Calavi, Abomey-Calavi, Benin
(C). Centre International de Recherche-Développement sur l'élevage en zone Subhumide (CIRDES), Bobo-Dioulasso 01, Burkina Faso

An overview of fish restocking into fresh and brackish inland waterways of Benin (West Africa)

T Olivier Amoussou, Aboubacar Toguyeni, Ibrahim Imorou Toko, Antoine Chikou, Thierry Akiti, Blaise M Enouheran, Camille F Bogninou and Issaka Youssao Abdou Karim

Abstract
The alien fish introduction into wild is done through restocking and escapes. The fish restocking can improve the productivity of waterways. However, it may cause some disruptions in aquatic ecosystems. In order to assess their impacts on the fisheries resources, this study reviewed the history of restocking programs made in Benin. A survey by prospective and retrospective interviews was led with fishermen and aquaculturists. The various introductions focused on both indigenous and non-native species. The most restocked hydrographic basin was Niger basin (779,555 fry) while the less stoked one was Mono basin (86,172 fry). The majority of stakeholders (98-100%) recognized that the various restocking programs were successful. Most of the actors have recognized that there has been until there no impact study of the different stocking campaigns (0-44.4%; $P<0.001$). The main problems linked to restocking programs and identified by the different actors, reside in their bad organization and evaluation.

Keywords: Stocking program, fishermen, aquaculturists, fisheries management, fisheries resources

1. Introduction

The issue of the rivers or lakes' restocking is to boost the dwindling fish stocks [1,2]. It will permit the reduction of the imports of frozen fish [3] and the restoration and protection of endangered species [4]. However, the promotion of restocking raises many questions regarding the species and the strains to use and arrangements to take for the sustainable management of aquatic resources. Restocking must be preceded by the construction of artificial spawning grounds [4] and should not be done without proper assessment of the land-use factors, catchment environmental degradation and possibilities for alien species invasion [5].

In many countries in Africa (Benin, Nigeria, South Africa, etc.), restocking showed negative impacts on the aquatic biodiversity and could be opposed by conservationists for possibility of polluting indigenous fish stocks [6,7]. Ecological imbalances, changes in community structure and loss of genetic integrity are potential risks bound to restocking [8], [9]. Similarly, fish restocking outside of their native geographic ranges for fishery enhancement or other management purposes has frequently resulted in hybridization between native and introduced species [6]. Of course, interspecific hybridization has been suggested to be an important evolutionary force that generates biological diversity by the recombination of genetic material among divergent lineages [10, 11]. The introgressive hybridization occurs not only at the time of the improvement of phenotypic traits, such as body colour, growth, but also when tolerating environmental conditions [11]. It can also be performed in cage aquaculture during length classification, when juveniles are added to the cages, by intentional releases, when fish are removed from the cages, due to cage damage, etc. [12]. Generally, restocking can be considered a success after efforts were done to remove alien fish species and improve land-use [5].

In Benin, from 2000 to nowadays, several restocking programs were led across the country by many actors such as (i) the National fisheries authority from 2000 to 2015; (ii) the Laboratory of Hydrobiology and Aquaculture of the University of Abomey-Calavi in 2002; (iii) the Program in Support for Participatory Development of Artisanal Fishing (PADPPA) in 2009 and 2013; (iv) the NGO Aquaculture and Sustainable Development (AquaDeD) in 2012; and (v) the Framework Programme in Support of Agricultural Diversification (ProCAD) in 2015. The majority of these restocking programs have not fulfilled "before" and "after" states studies in order to appraise their impacts especially in term of biodiversity and abundance of fishes stocked into the waterways. Therefore, the objective of the present study is to analyze the restocking programs made in Benin, assess their impacts on fisheries resources and propose some measures for a sustainable management of natural fishery resources before and after they are done.

2. Materials and Methods

The study has been conducted from July 2014 to October 2015 in Benin (6°30'-12°30' North latitude and 1°-30°40' East longitude). Benin has two types of climate. The first is an equatorial climate with high humidity presenting an alternation of dry seasons (November-March and mid-July to mid-September) and rainy seasons (April to mid-July and mid-September to October). The middle and north are characterized by a tropical climate with a dry season from November to April and a rainy season from June to September [13]. Temperatures have low amplitudes: the maximum vary from 28 to 32°C and the minimum from 23 to 26°C. The annual rainfall is between 999 mm and 1090 mm [13,14]. The Benin's relief is slightly uneven and consists of a coastal area, low and gritty limited by lagoons (i) a ferruginous clay plateau (ii) a silico-clayey plateau, strewed with some undergrowth (iii) the Atacora massif (800 m) in the northwest (iv) in the northeast, the silico-clayey and very fertile plains of Niger (v).

Data collection covered 174 fishermen and 36 fish farmers spread across all the territorial departments of Benin. The material is composed of two survey forms. For fishermen, the survey forms contain the following information: profile of fishermen (i), fishermen' occupations (ii), species, category of individual used during the restocking programs and reasons of restocking (iii), preconditions, years of restocking and origins of fish used (iv), outcomes of restocking and the institutions having made it (v), difference between performances of the introduced fishes and those before or after introduction (vi), impacts of fish restocking on the fisheries resources and fishermen' incomes (vii), introduction of cage or enclosure aquaculture fish into wild (viii). For fish farmers, the survey collected information on the cage and enclosure aquaculturists, characteristics of each (voluntary or involuntary) restocking campaign and their impacts on the fisheries resources and stakeholders' incomes. The methodology used in the current study was the investigation by both prospective and retrospective interviews with the fishermen and fish farmers. Thus, the investigation also focused on the tabulation of the technical reports form the Fisheries Division (DPH) and those of the Program in Support for Participatory Development of Artisanal Fishing (PADPPA), the NGO Aquaculture and Sustainable Development (NGO AquaDeD), the Framework Programme in Support of Agricultural Diversification (ProCAD) and the Project in Support Agricultural Diversification (PADA).

The data collected during the survey were reviewed, coded and stored in a database designed using Excel software. The data collected were analysed using SPSS (Statistical Package for the Social Sciences) and R i386 3.2.1 (http://cran.r-project.org). Frequencies were calculated using the *crosstabs* procedure of SPSS. Frequencies were compared with the Chi-square test and the two-sided test of Z using the *chisq.test* and *prop.test* procedures of R software. For each frequency P, a confidence interval (CI) at 95% was calculated using the formula:

$$CI = 1.96\sqrt{\frac{[P(1-P)]}{N}}$$

Where: P is the relative frequency and N is the sample size.

3. Results

3.1 Profile of fishermen

In Benin, fishing is mainly practiced by men (95.4-100%) and in minority by women (0-4.6%). But proportions of men and women didn't vary significantly from a hydrographic basin to another (Figure 1). Actors of fishing are mainly represented by young people of age group 25 to 35 years old (11.1-35.3%) and those of 35 to 45 years old (21.5-33.3%). These groups are followed by the age groups of 45 to 55 years old (15.7-22.2%), 55 to 65 years old (11.8-22.2%), 15 to 25 years old (7.7-11.1%), 75 to 85 years old (0-4.6%) and 65 to 75 years old (0-2%) (Figure 1).

According to Table 1, 15 ethnic groups distributed across all the territorial departments, practice fishing: Bariba, Dendi, Ditamari, Fon, Goun, Idacha, Ifè, Lokpa, Mahi, Phéda, Sahouè, Tchabè, Wama, Wémè and Xwla. Bariba ethnic group is active respectively in Niger (28.6%) and Ouémé (3.1%) basins ($P<0.001$). Concerning Dendi ethnic group, it is present in 3 hydrographic basins: Niger (44.9%), Ouémé (13.8%) and Volta (23.5%). The proportion of fishermen from the following ethnic groups: Ditamari, Goun, Idacha, Ifè, Mahi and Xwla did not vary significantly according to the hydrographic basin ($p>0.05$). Fishermen from Fon's ethnic group were present only in Mono (11.1%) and Ouémé (7.7%) basins. The proportion of the fisheries actors speaking Lokpa and Wama is more important (13.7% and 23.5% respectively; $P<0.05$) in Volta basin than the 3 other basins. Fishermen speaking Phéda and Sahouè were active only in Mono basin. Both ethnic groups represent 11.1% of the fishermen of this basin. Tchabè ethnic group was active for fishing activity only in Ouémé basin (13.8%). Fishermen of Wémè ethnic group were active in the four hydrographic basins with respectively 44.4% in Mono basin, 15.7% in Volta basin and 10.2% in Niger basin ($P<0.05$). In addition, 27.7% of the fishermen from Ouémé basin were from the Wémè ethnic group. The questioned actors are mainly engaged in farming (0-46.9%; $P<0.05$) and fishing (44.9-100%; $P<0.05$). As secondary activities, the actors are farmer (32.2-55.6%; $p>0.05$), fisherman (0-55.1%; $P<0.05$) and fish farmer (4.1-44.4%; $P<0.01$) (Figure 1).

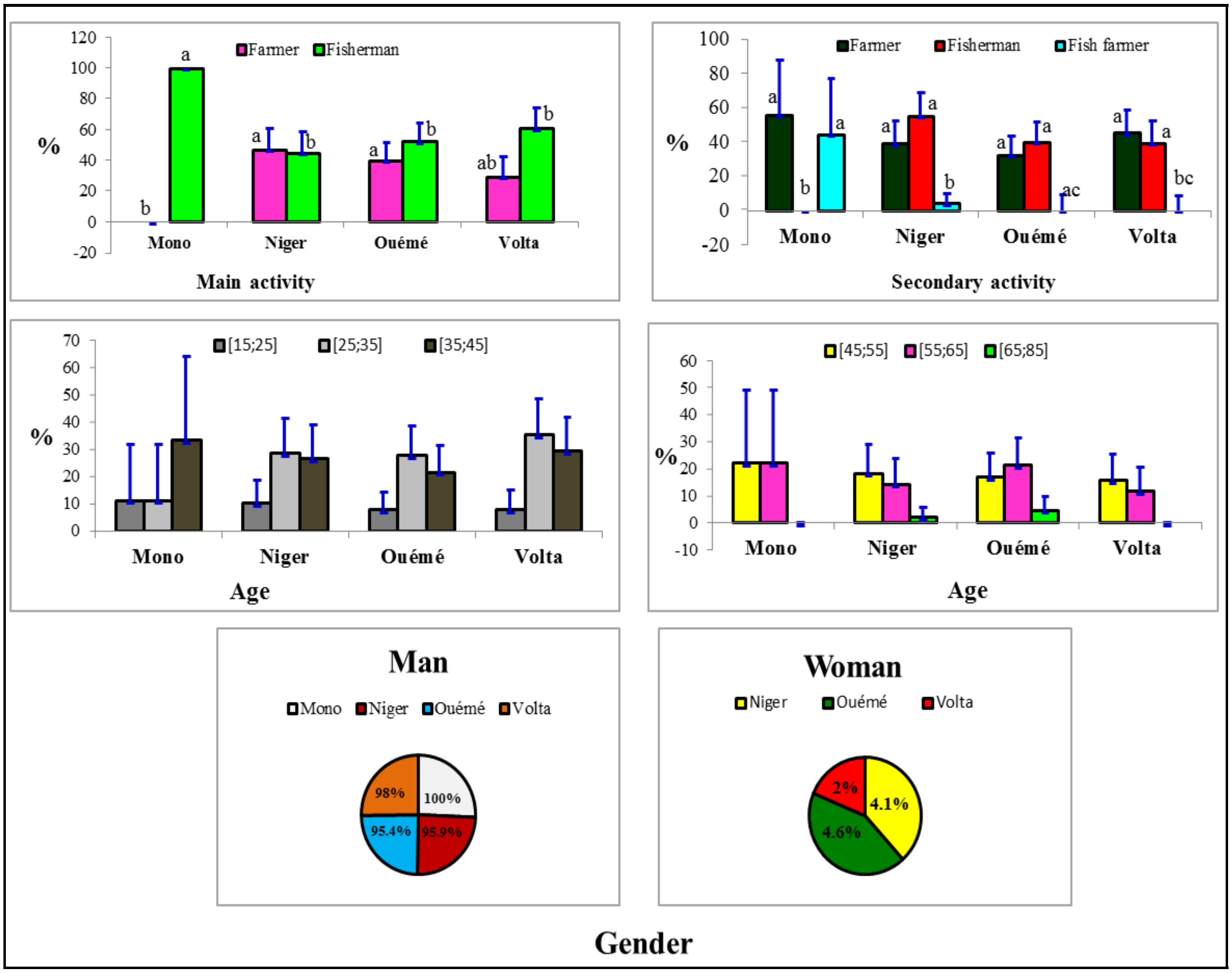

Fig 1: Profile of fishermen. Proportions in the same modality, followed by different letters, are significantly different with the threshold of 5%.

Table 1: Ethnic group of stakeholders

Variable	Mono basin (N=9)			Niger basin (N=49)			Ouémé basin (N=65)			Volta basin (N=51)			Chi-square test
	n	%	CI	n	%	CI	n	%	CI	n	%	CI	
Bariba	0	0ab	0	14	28.6a	12.65	2	3.1b	4.2	0	0b	0	***
Dendi	0	0b	0	22	44.9a	13.93	9	13.8b	8.4	12	23.5b	11.64	***
Ditamari	0	0a	0	0	0a	0	0	0a	0	4	7.8a	7.38	NS
Fon	1	11.1a	20.52	0	0b	0	5	7.7a	6.48	0	0b	0	*
Goun	0	0a	0	2	4.1a	5.55	4	6.2a	5.84	2	3.9a	5.33	NS
Idacha	0	0a	0	1	2a	3.95	6	9.2a	7.04	1	2a	3.81	NS
Ifè	0	0a	0	1	2a	3.95	2	3.1a	4.2	3	5.9a	6.46	NS
Lokpa	0	0ab	0	1	2b	3.95	2	3.1b	4.2	7	13.7a	9.44	*
Mahi	0	0a	0	1	2a	3.95	4	6.2a	5.84	0	0a	0	NS
Phéda	1	11.1a	20.52	0	0b	0	0	0b	0	0	0b	0	***
Sahouè	1	11.1a	20.52	0	0b	0	0	0b	0	0	0b	0	***
Tchabè	0	0ab	0	0	0b	0	9	13.8a	8.4	0	0b	0	***
Wama	0	0ab	0	0	0b	0	0	0b	0	12	23.5a	11.64	***
Wémè	4	44.4a	32.46	5	10.2b	8.48	18	27.7a	10.88	8	15.7ab	9.98	*
Xwla	2	22.2a	27.15	2	4.1a	5.55	4	6.2a	5.84	2	3.9a	5.33	NS

N = Sample size; n = observed individuals;% = Percentage, CI = Confidence interval; NS = Nonsignificant; *** = $P<0.001$; ** = $P<0.01$; * = $P<0.05$; Proportions in the same row, followed by different letters, are significantly different with the threshold of 5%.

3.2 Characteristics of the various restocking programs

Overall, the fish restocking campaigns included 13 waterways (Sô river, Couffo river, Mono river, Ouémé river, lake Azilin, lake Doukou, lake Hlan, lake Sré, lake Togbadji, lake Ahémé, lake Nokoué, Grand-Popo lagoon and Toho lagoon) and 69 reservoirs spread over a set of 4 hydrographic basins among the 5 hydrographic basins of the country. The fish species used during the various restocking programs are *Clarias (Clarias) gariepinus* (Burchell, 1822), *Heterobranchus longifilis* Valenciennes, 1840, *Oreochromis niloticus* (Linnaeus, 1758) and *Sarotherodon melanotheron* Rüppell, 1852 (Table 2). A part from *C. gariepinus*, the proportion the other fish species used during these restocking did not vary significantly from a hydrographic basin to another ($p>0.05$).

Moreover, *O. niloticus* and *C. gariepinus* were introduced together and at the same time in the Mono, Niger, Ouémé and Volta basins with respective percentages namely 11.1%, 8.2%, 10.8% and 2%. However, *H. longifilis* and *S. melanotheron* were used separately in the Ouémé basin only (3.1% vs 4.6%). Compared with fingerlings, fry were mostly used during the various restocking programs (Table 2). The depopulation of waterways, depopulation related to overfishing, declining of fish stocks and species in way of disappearance are the main reasons highlighted by fishermen and that justified the different restocking campaigns (Table 2). Before each restocking campaign, the different waterways and reservoirs showed: the declining of catches (56.9-100%; $P<0.05$), the decreasing in the species' abundance (0-28.6%; $p>0.05$) and the rarity of fish species (0-16.9%; $P<0.01$).

Most restocking campaigns were achieved in 2009 and 2015. In both two years, they covered all the 4 basins. In 2007, the repopulation programs were conducted solely in Mono and Ouémé basins. In 2002, 2012 and 2013, they have been led solely in Ouémé basin. In 2000, the restocking has been done in Volta basin only. However, in 2006, they were led solely in Mono basin. As institutions that provided the fry and fingerlings used during the different restocking programs, there are Songhaï Centre (fishes have been sent to Niger basin), Nursery Center of Tohonou (to Mono and Ouémé basins), artisanal fish farms (to all the 4 basins), Tonon Foundation (fishes have been sent to all the 4 basins), Laboratory of Hydrobiology and Aquaculture (to Ouéme basin only) and Royal Fish Benin Company (to Ouémé and Volta basins).

The majority of stakeholders (98-100%; $p>0.05$) recognized that the various restocking programs were successful (Table 3). In their opinion, this was reflected by the abundance of the species in the waterways and reservoirs (55.6-79.6%; $p>0.05$), the improvement of the fish's availability (0-2%; $p>0.05$) and the species' availability in fishermen' catches (0-16.3%; $p>0.05$). However, for other fishermen, these restocking campaigns have not been successful as fish individuals have disappeared after some captures (Table 3). Furthermore, stakeholders from Mono (44.4%), Ouémé (16.9%) and Volta (9.8%) considered that there has been no impact study. Very highly significant ($P<0.001$) difference was observed between proportions of these last fishermen (Table 3). Six institutions namely the NGO Aquaculture and Sustainable Development (AquaDeD ONG), Fisheries Division of the Ministry of Agriculture, Livestock and Fisheries (DPH/MAEP), Laboratory of Hydrobiology and Aquaculture (LHA), Project in Support Agricultural Diversification (PADA), Program in Support for Participatory Development of Artisanal Fishing (PADPPA) and Framework Programme in Support of Agricultural Diversification (ProCAD) have done the various restocking campaigns.

A part of the stakeholders estimated that the introduced fish have better performances than those before restocking with regard to the weight at age-type (74.5-100%), length (80.4-100%), resistance to diseases (58.8-100%), mortality (56.9-100%), preferences of fishermen (64.7-100%) and preferences of consumers (66.7-100%). However, all the fishermen (100%) recognized that the introduced fishes have similar tastes to those before introduction (Table 3). Moreover, 74.5% to 100% of the fishermen have recognized that the introduced fish have better performance than those after introduction. It is the same for the length (74.5-100%), resistance to diseases (62.7-100%), mortality (56.9-100%), taste, preferences of fishermen and preferences of consumers (74.5-100%). Except for the mortality, no significant difference was observed between the six other appreciations (Table 3). The number of fishes used during the various stocking programs was as follow: 86,172 individuals in Mono basin, 779,555 individuals in Niger basin, 378,955 individuals in Ouémé basin and 342,265 individuals in Volta basin.

Table 2: Characteristics of the different restocking campaigns

Variable		Mono basin (N=9)			Niger basin (N=49)			Ouémé basin (N=65)			Volta basin (N=51)			Chi-square test
		n	%	CI	n	%	CI	n	%	CI	n	%	CI	
Species used during the restocking programs	*Clarias gariepinus*	0	0b	0.00	9	18.4ab	10.85	8	12.3b	7.99	16	31.4a	12.74	*
	Heterobranchus longifilis	0	0a	0.00	0	0a	0.00	2	3.1a	4.20	0	0a	0.00	NS
	Oreochromis niloticus + *Clarias gariepinus*	1	11.1a	20.53	4	8.2a	7.68	7	10.8a	7.54	1	2a	3.81	NS
	Oreochromis niloticus	8	88.9a	20.53	36	73.5a	12.36	45	69.2a	11.22	34	66.7a	12.94	NS
	Sarotherodon melanotheron	0	0a	0.00	0	0a	0.00	3	4.6a	5.10	0	0a	0.00	NS
Category of fish used during the restocking programs	Fry	9	100a	0.00	49	100a	0.00	63	96.9a	4.20	51	100a	0.00	NS
	Fingerling	0	0a	0.00	0	0a	0.00	2	3.1a	4.20	0	0a	0.00	NS
Reason of fish restocking	Depopulation of waterways	0	0a	0.00	0	0a	0.00	5	7.7a	6.48	4	7.8a	7.38	NS
	Depopulation related to overfishing	0	0a	0.00	2	4.1a	5.55	5	7.7a	6.48	4	7.8a	7.38	NS
	Declining of fish stocks	9	100a	0.00	33	67.3a	13.13	42	64.6a	11.63	28	54.9a	13.66	NS
	Species in way of disappearance	0	0a	0.00	14	28.6a	12.65	13	20a	9.72	15	29.4a	12.51	NS
Inventory before restocking	Declining catches in the inland waterways	9	100a	0.00	35	71.4ab	12.65	45	69.2ab	11.22	29	56.9b	13.59	*
	Decrease in the species' abundance	0	0a	0.00	14	28.6a	12.65	9	13.8a	8.40	14	27.5a	12.25	NS
	Rarity of species in water bodies	0	0a	0.00	0	0b	0.00	11	16.9a	9.12	8	15.7a	9.98	**

N = Sample size ; n = observed individuals;% = Percentage, CI = Confidence interval; NS = Nonsignificant; ** = $P<0.01$; * = $P<0.05$; Proportions in the same row, followed by different letters, are significantly different with the threshold of 5%.

Table 3: Outcomes of restocking and differences between performances of the introduced fish and those before or after introduction

Variable			Mono basin (N=9)			Niger basin (N=49)			Ouémé basin (N=65)			Volta basin (N=51)			Chi-square test
			n	%	CI	n	%	CI	n	%	CI	N	%	CI	
Success of the restocking	Yes		9	100a	0.00	47	95.9a	5.55	64	98.5a	2.99	50	98a	3.81	NS
	Justifi-cation	Abundance of the species in the waterways and reservoirs restocked	5	55.6a	32.46	39	79.6a	11.29	44	67.7a	11.37	36	70.6a	12.51	NS
		Improvement of the availability of fish	0	0a	0.00	0	0a	0.00	0	0a	0.00	1	2a	3.81	NS
		Disappearance of the species after some captures	0	0a	0.00	2	4.1a	5.55	1	1.5a	2.99	1	2a	3.81	NS
		Species recovered during fishing	0	0a	0.00	8	16.3a	10.35	9	13.8a	8.40	8	15.7a	9.98	NS
		No impact study	4	44.4a	32.46	0	0c	0.00	11	16.9ab	9.12	5	9.8b	8.16	***
Difference between performances of the introduced fish and those before restocking	Weight at age-type	Yes	9	100a	0.00	41	83.7a	10.35	54	83.1a	9.12	38	74.5a	11.96	NS
	Length	Yes	9	100a	0.00	43	87.8	9.18	54	83.1	9.12	41	80.4	10.9	NS
	Resistance to diseases	Yes	9	100a	0.00	35	71.4a	12.65	47	72.3a	10.88	30	58.8a	13.51	NS
	Mortality	Yes	9	100a	0.00	36	73.5ab	12.36	48	73.8ab	10.68	29	56.9b	13.59	*
	Fish taste	No	9	100a	0.00	49	100a	0.00	65	100a	0.00	51	100a	0.00	NS
	Preferences of fishermen	Yes	9	100a	0.00	36	73.5a	12.36	52	80a	9.72	33	64.7a	13.12	NS
	Preferences of consumers	Yes	9	100a	0.00	37	75.5a	12.04	51	78.5a	9.99	34	66.7a	12.94	NS
Difference between performances of the introduced fish and those after restocking	Weight at age-type	Yes	9	100a	0.00	41	83.7	10.35	57	87.7	7.99	38	74.5	11.96	NS
	Length	Yes	9	100a	0.00	42	85.7a	9.80	57	87.7a	7.99	38	74.5a	11.96	NS
	Resistance to diseases	Yes	9	100a	0.00	35	71.4a	12.65	48	73.8a	10.68	32	62.7a	13.27	NS
	Mortality	Yes	9	100a	0.00	35	71.4ab	12.65	47	72.3ab	10.88	29	56.9b	13.59	*
	Fish tatste	Yes	9	100a	0.00	42	85.7a	9.80	57	87.7a	7.99	38	74.5a	11.96	NS
	Preferences of fishermen	Yes	9	100a	0.00	42	85.7a	9.80	57	87.7a	7.99	38	74.5a	11.96	NS
	Preferences of consumers	Yes	9	100a	0.00	42	85.7a	9.80	57	87.7a	7.99	38	74.5a	11.96	NS

N = Sample size ;n = observed individuals;% = Percentage, CI = Confidence interval; NS = Nonsignificant; *** = $P<0.001$; * = $P<0.05$; Proportions in the same row, followed by different letters, are significantly different with the threshold of 5%.

3.3 Impacts of the restocking programs on fisheries resources

Most of the actors have recognized that there has been no impact study of the different stocking campaigns. However, other fishermen said that they observed environmental, genetic and economic impacts (Table 4). They also noted some reproductive, survival and fish sanitary impacts. The environmental impacts are ecological and demographic (87.8-100%). The destruction of the spawning-grounds and nests is the main ecological impact underlined by fishermen of Ouémé basin solely (3.1%). Similarly, up to 12.3% of stakeholders affirmed that the demographic impact is reflected in the increase in the species' abundance (Table 4). Most of the fishermen said that there is no genetic impact: 93.8% to 100% for introgression and 88.9% to 95.9% for inbreeding. The various repopulation campaigns have contributed to improve the incomes of fishermen from Niger basin (36.7%), Ouémé basin (30.8) and Volta basin (43.1%). These proportions did not differ significantly from a hydrographic basin to another ($p>0.05$). Several fishermen (74.5-100%) indicated that the restocking programs have contributed to the improvement of fish reproduction rate (Table 4). Some of them affirmed that the introduced fish have less vigorous reproduction behavior than wild species (0-6.2%). However, the improvement of the reproduction rate (29.2-47.1%) and normal reproductive behavior (27.5-55.6%) are the two arguments expressing the positive impact of restocking on the reproductive power of fish (Table 4). With regard to the survival rate, 96.9% to 100% of fishermen affirmed that very little fish died after the different campaigns.

Table 4: Impacts on fisheries resources and fishermen' incomes

Variable			Mono basin (N=9)			Niger basin (N=49)			Ouémé basin (N=65)			Volta basin (N=51)			Chi-square test
			n	%	CI	n	%	CI	n	%	CI	N	%	CI	
Environmental	Ecological	Yes	9	100a	0	43	87.8a	9.18	61	93.8a	5.84	46	90.2a	8.16	NS
		Destruction of the spawning-grounds and nests, reducing the reproductive performance	0	0a	0	0	0a	0	2	3.1a	4.2	0	0a	0	NS
		No impact study	9	100a	0	49	100a	0	63	96.9a	4.2	51	100a	0	NS
	Demographic	Yes	9	100a	0	43	87.8a	9.18	60	92.3a	6.48	46	90.2a	8.16	NS
		Increase in the species' abundance	0	0a	0	2	4.1a	5.55	8	12.3a	7.99	4	7.8a	7.38	NS
		No impact study	9	100a	0	47	95.9a	5.55	57	87.7a	7.99	47	92.2a	7.38	NS
Genetic	Introgression	No	9	100a	0	47	95.9a	5.55	61	93.8a	5.84	48	94.1a	6.46	NS
		Existence of hybrids	0	0a	0	2	4.1a	5.55	4	6.2a	5.84	3	5.9a	6.46	NS
		No hybrid	9	100a	0	47	95.9a	5.55	61	93.8a	5.84	48	94.1a	6.46	NS
	Inbreeding	No	8	88.9a	20.53	47	95.9a	5.55	61	93.8a	5.84	48	94.1a	6.46	NS
		Susceptibility to disease	1	11.1a	20.53	2	4.1a	5.55	4	6.2a	5.84	3	5.9a	6.46	NS
		No effect of inbreeding	8	88.9a	20.53	47	95.9a	5.55	61	93.8a	5.84	48	94.1a	6.46	NS
Economic		No	9	100a	0	31	63.3a	13.5	45	69.2a	11.22	29	56.9a	13.59	NS
		Improvement of the fishermen' incomes	0	0a	0	18	36.7a	13.5	20	30.8a	11.22	22	43.1a	13.59	NS
		No improvement	9	100a	0	31	63.3a	13.5	45	69.2a	11.22	29	56.9a	13.59	NS
Reproduction		Yes	9	100a	0	37	75.5a	12.04	53	81.5a	9.43	38	74.5a	11.96	NS
		Improvement of the reproduction rate	4	44.4a	32.46	17	34.7a	13.33	19	29.2a	11.06	24	47.1a	13.7	NS
		Less vigorous reproduction behavior than wild species	0	0a	0	0	0a	0	4	6.2a	5.84	0	0a	0	NS
		Normal reproductive behavior	5	55.6a	32.46	20	40.8a	13.76	31	47.7a	12.14	14	27.5a	12.25	NS
		No improvement	0	0a	0	12	24.5a	12.04	11	16.9a	9.12	13	25.5a	11.96	NS
Survival		Yes	9	100a	0	0	0b	0	2	3.1b	4.2	0	0b	0	***
		No mortality	9	100a	0	49	100a	0	63	96.9a	4.2	51	100a	0	NS
		Some dead fish observed	0	0a	0	0	0a	0	2	3.1a	4.2	0	0a	0	NS
Sanitary		Yes	9	100a	0	0	0b	0	0	0b	0	1	2b	3.81	***
		Fungus	0	0	0	0	0	0	0	0	0	1	2a	3.81	NS
		No disease	9	100a	0	49	100a	0	65	100a	0	50	98a	3.81	NS

N = Sample size ;n = observed individuals;% = Percentage, CI = Confidence interval; NS = Nonsignificant; *** = P<0.001; Proportions in the same row, followed by different letters, are significantly different with the threshold of 5%.

3.4 Introduction of cage or enclosure's farmed fish into the wild

In southern Benin, cage aquaculture was conducted in the waterways of Mono (66.7%) and Ouémé basins (76.7%). However, enclosure aquaculture was also done both hydrographic basins (16.7% *vs* 23.3%). No significant difference was observed between proportions of these two systems. Pond aquaculture was also done but only on the lake Toho in Mono basin (16.7%) solely. The majority (66.7-93.3%) of fish farms has 1-5 cages or enclosures (Table 5). In Mono and Ouémé basins, fish farmers (16.7% *vs* 3.3%) exploited 5-10 cages or enclosures. In addition, in Ouémé and Mono basins, two fish farmers used respectively 10-50 and 50-100 cages or enclosures with respective proportions of 3.3% and 16.7% (Table 5). On the different investigated waterways, fish farming is practiced with various species, of which some fishes are exploited in association. Co-culture of *O. niloticus* and *C. gariepinus* in fish farming was done solely in Ouémé basin (43.3%). Then, *O. niloticus* solely farming is practiced on waterways of Mono and Ouémé basins (33.3% *vs* 26.7%, $p>0.05$). Furthermore, co-culture of *O. niloticus* and *S. melanotheron* in fish farming was done in the two hydrographic basins: 50% for Mono and 6.7% for Ouémé. In addition, 16.7% of fish farmers from Ouémé basin practiced *C. gariepinus* breeding solely (Table 5). *Porogobius schlegelii* was bred in two cages in Ouémé basin with a percentage of 6.7%. Finally, *Oreochromis mossambicus*, *O. niloticus* and *C. gariepinus* are in cages polyculture on Toho lagoon in Mono basin (16.7%). Aquaculture fish escape into wild environment during flooding (16.7%; $P<0.001$), during length classification (33.3-36.7%), when fish are added to cages/enclosures (26.7%-33.3%), when fish are removed from the cages/enclosures (33.3-36.7%) and due to cage or enclosure damage (40-50%). The single event of flooding is due to a rise in the water level in lake Toho (Mono basin) having flooded a waterside fish pond (Table 5). No fisherman evoked intentional releases.

Table 5: Introduction of cage or enclosure aquaculture fish into wild

Variable			Mono basin (N=6)			Ouémé basin (N=30)			Z test
			n	%	CI	n	%	CI	
Type of fish farmingoperated on the river	Cage	Yes	4	66.7a	37.72	23	76.7a	15.14	NS
	Enclosure	Yes	1	16.7a	29.82	7	23.3a	15.14	NS
	Pond	Yes	1	16.7a	29.82	0	0b	0.00	*
	Number of cages or enclosure	[1;5[	4	66.7a	37.72	28	93.3a	8.93	NS
		[5;10[	1	16.7a	29.82	1	3.3a	6.42	NS
		[10;50[	0	0a	0.00	1	3.3a	6.42	NS
		[50;100]	1	16.7a	29.82	0	0b	0.00	*
Fish species bred		Farming of *Clarias gariepinus* solely	0	0a	0.00	5	16.7a	13.34	NS
		Farming of *Porogobius schlegelii*	0	0a	0.00	2	6.7a	8.93	NS
		Co-culture of *Oreochromis mossambicus*, *Oreochromis niloticus* and *Clarias gariepinus*	1	16.7a	29.82	0	0b	0.00	*
		Farming of *Oreochromis niloticus* solely	2	33.3a	37.72	8	26.7a	15.83	NS
		Co-culture of *Oreochromis niloticus* and *Sarotherodon melanotheron*	3	50a	40.01	2	6.7b	8.93	**
		Co-culture of *Oreochromis niloticus* and *Clarias gariepinus*	0	0b	0.00	13	43.3a	17.73	*
Existence of escapes	Yes		4	66.7a	37.72	17	56.7a	17.73	NS
	During flooding	Yes	1	16.7a	29.82	0	0b	0.00	*
	During length classification	Yes	2	33.3a	37.72	11	36.7a	17.24	NS
	When fish are added to cages/enclosures	Yes	2	33.3a	37.72	8	26.7a	15.83	NS
	Intentional releases	No	6	100a	0.00	30	100a	0.00	NS
	When fish are removing from the cages/enclosures	Yes	2	33.3a	37.72	11	36.7a	17.24	NS
	Due to cage or enclosure damage	Yes	3	50a	40.01	12	40a	17.53	NS

N = Sample size ;n = observed individuals;% = Percentage, CI = Confidence interval; NS = Nonsignificant; ** = P<0.01 ; * = P<0.05; Proportions in the same row, followed by different letters, are significantly different with the threshold of 5%.

4. Discussion

The majority of the fishermen of the Beninese inland fisheries is the masculine sex [15, 16]. In the country, there are 14,674 men and 853 women involved in fishing activity full-time [17]. Similarly, the large majority (93%) of fish farms are managed by men [14]. The same observation was done in the present investigation. Illiteracy characterizes the fishermen community. In the inland fisheries, there are among others, 43,000 completely illiterate fishermen [15]. In northern Benin, fish farming is practiced by aged individuals from 20 to 65 years old. Furthermore, 3 ethnic groups are directly involved in fishing in this part of the country: Dendi (93.3%), Fulani (3.3%) and Fon (3.3%) [18].

In Benin, 243 reservoirs (mostly located in the northern's 4 departments) are built for irrigation, fish farming and water supplying for livestock [14]. The management of reservoirs is ensured by local committees. The source of incomes is the amount of fish selling and water for livestock [14]. In the country, 55.6% of cages are installed at the North in Borgou, Atacora and Collines departments while 44.4% are installed at the South in Mono, Atlantique and Ouémé departments. Enclosures are all (100%) exclusively installed in the South specifically in Atlantique and Ouémé departments [14]. The main reasons highlighted by the fishermen and that justified the different restocking campaigns are the depopulation of waterways, depopulation related to overfishing, declining of fish stocks and species in way of disappearance. These reasons corroborate with those evoked by Cowx (1998) [2]: mitigation, enhancement, restoration and creation of new fisheries. Many stocking programs are carried out without definition of objectives or evaluation of the potential or actual success of the exercise [2]. In Benin, no restocking campaigns carried out had impact study as well have highlighted the different stakeholders. Even though there has been no impact study, some fishermen estimated that many restocking campaigns have been successful. However, in developing countries, successful stocking programs seem to be associated with reservoir fisheries that have been heavily stocked to increase yield [2, 19]. Most of the fish farmers reported a weak number of cage or enclosure (from 1 to 5). However, in Brazil, De Azevedo-Santos *et al*. (2011) [12] recorded a large number of cages (upper to 40). This reflects the level of cage aquaculture development in this country. Unlike in Brazil where only *O. niloticus* is raised in cage [12], in Benin, a diversity of species is observed in cage or enclosure aquaculture (*O. niloticus*, *C. gariepinus*, *S. melanotheron*, *P. schlegelii* and *O. mossambicus*). They are raised either in monoculture or in polyculture. Otherwise, for aquaculture reason, several fish species have been introduced in the country's water bodies from various countries throughout the world: *O. niloticus* in 1979, *Oreochromis urolepis hornorum* in 1983, *Oreochromis aureus* in 1983, *O. mossambicus* in 1985 and *Oreochromis spilurus* in 1986 [20]. Cage and enclosure aquacultures constitute an important vector for fish introductions in the wild [12]. The same remark was done in this survey. In Benin, aquaculture fish escape into the wild environment through five manners: during flooding, during length classification, when fish are added to cages/enclosures, when fish are removed from the cages/enclosures and due to cage or enclosure damage (33.3-100%). Ansah *et al*. (2014) [21] have recorded that African countries currently lack the capacity to prevent the escape of selectively-bred fish from aquaculture facilities or to prevent the intentional release of these fish into wild. Likewise, De Azevedo-Santos *et al*.

(2011) [12] observed that releases were mainly accidental and occur during some management procedures (length classification, fish capture and juvenile stocking) or due to cage damage and deliberate releases. *O. niloticus* and *O. mossambicus* are non-natives, so they may disturb native populations or ecosystems processes.

According to the fishermen, most restocking campaigns were a success and this has resulted in: the increasing in the species' abundance, the improvement of the fish availability and the recovering of species during fishing. Species introductions are a valid means to improve production and economic benefit from fisheries and aquaculture [7, 22, 23]. Approximately 17% of the world's finfish production is due to alien species [7, 24]. The production of the African cichlid tilapia is much higher in Asia (>700,000 tonnes) than in most areas of Africa (about 40,000 tonnes) [25]. The introduced salmonids in Chile support a thriving aquaculture industry that is responsible for approximately 20% of the world's farmed salmon and directly employs approximately 30,000 people [25, 26]. Most species introductions are without ecological effect but the socioeconomic impacts are more frequently beneficial [25].

However, escapes of aquaculture stocks are common and these fish can have negative effects on resident indigenous forms [27]. Many fish strains like GIFT/GST may have the potential to be highly damaging for African receiving ecosystems [21]. Ecological imbalances, changes in community structure, pathogens and diseases transmission and loss of genetic integrity are potential risks bound to restocking [9, 28, 29]. The Beninese fishermen observed the ecological and demographic environmental impacts, and this is consistent with those evoked by [29]. Furthermore, in the present study, some fishermen claimed to have seen some cases of fish diseases. Indeed, inbreeding of natural fish populations with introduced fish is the biggest direct effect of restocking [21]. The other genetic impact is the reduction in genetically effective population size due the decrease in fish abundance [30]. Released cultured stock may reduce the fish abundance through competition, predation, habitat alteration, or changes in community trophic structure or food webs [21,32]. In Thailand, using allozymes and microsatellites, Senanan *et al*. (2004) [32] demonstrated that gene introgression of African catfish *C. gariepinus* in the native catfish *Clarias macrocephalus* intervened in 4 natural populations and 2 breeding populations. The use of selectively bred individuals into the wild populations may result in offspring that exhibit low fitness, posing the risk of outbreeding depression at a local scale [27, 33, 34]. It corroborates with the findings of this study where some fishermen recognized that the introduced fish have better performances than those after introduction.

The main problem of the restocking programs resides in their bad organization and evaluation (prefeasibility and impact studies) [2, 21]. A strategy for evaluating a stocking program to minimise the potential risks and maximise the potential benefits has been proposed by Cowx (1998) [2]. However, the assessment of the restocking impacts remains largely approximate and more objective and performance indicators remain to be invented [29]. Likewise, the Cartagena Protocol on Biosafety addressed management of genetic resources [35]. Convention articles 15, 16, and 22 outline guidelines on risk assessment, risk management and capacity building with regards to living modified organisms (LMOs). In Brazil, De Azevedo-Santos *et al*. (2011) [12] recommend prudence and responsibility in cage aquaculture programs while encouraging the cultivation of native species. To be sustainable, the species used for restocking must be specific or relate to the type of waterway [24]. A stable community is one whose structure and function return to their initial conditions after a perturbation [36]. The objectives of restocking must find a compromise firstly between conservation and protection of the ecosystem and secondly between positive economic return and food security or employment [2]. Restocking cannot succeed without a reduction in overfishing, environmental degradation and without an improved management strategy [24, 27]. Likewise, it is imperious to lead actions encouraging the natural recruitment such as fertilisation of the water and supplementary feeding [9]. Furthermore, political and economic instability, changes in fisheries sector objectives, shifts in environmental awareness and changes in aquatic resource use may affect the long-term success of restocking [2]. In addition, cooperative or community-based management initiatives have to be encouraged in order to ensure the durability of the activity [37, 38]. Generally, incomes do not cover the costs of the stocking program. To this end, it is necessary to encourage the sport fisheries where people pay high fees to guarantee to catch fish [2].

5. Conclusion

Throughout Benin, the various introductions were focused on both indigenous and non-native species (*C. gariepinus*, *H. longifilis*, *P. schlegelii*, *S. melanotheron vs O. niloticus*, *O. urolepis hornorum*, *O. aureus*, *O. mossambicus*, *O. spilurus*). Most of the actors have recognized that there has been no impact study of the various stocking campaigns. However, environmental, genetic, reproductive, survival, sanitary and economic impacts were noted by some stakeholders after the restocking campaigns are done. Cage and enclosure aquaculture's fishes escape into wild environment during flooding, length classification, when fish are added to cages/enclosures, when fish are removed from the cages/enclosures and due to cage or enclosure damage. No fisherman evoked intentional releases. Prefeasibility and impact studies have to be led to ensure the durability of the restocking programs.

6. Acknowledgements

This study was financially supported by the EU "European Union" through the HAAGRIM project (INTRA-ACP ACADEMIC MOBILITY SCHEME). The authors also wish to thank the UEMOA "Union Economique et Monétaire Ouest Africaine" for its financial support through the PAES/Tilapia project. This research was also supported by the International Foundation for Science, Stockholm, Sweden, through a grant to T.O. Amoussou. T.O. Amoussou would like to thank the Government of France for providing a PhD scholarship through the SCAC "Service de Coopération et d'Action Culturelle" of the France embassy in Cotonou, Benin. The authors thank the authorities of Fisheries Division (DPH/MAEP) and those of the other programs for providing their technical reports.

7. References

1. McNease L, Joanen T, Richard D, Shepard J, Nesbitt S. The brown pelican restocking program in Louisiana. In Proc. Annu. Conf. Southeast. Assoc. Fish an Wilddl. Agencies. 1984; 38:165-173.
2. Cowx IG. An appraisal of stocking strategies in the light

of developing country constraints. FAO Fisheries Technical Paper. 1998; 374:21-34.
3. DPH. Le Bénin repeuple les plans d'eau avec un million d'alevins pour restaurer les stocks halieutiques. Direction de la Prodution Halieutique, Cotonou, Bénin, 2015, 1.
4. Aqua DeD. Restaurer et conserver la biodiversité aquatique du delta de l'Ouémé au Bénin. AquaDeD ONG, Abomey-Calavi, Benin, 2010, 27.
5. De Groot SJ. A review of the past and present status of anadromous fish species in the Netherlands: Is restocking the Rhine feasible? Hydrobiologia. 2002; 478:205-218.
6. De Silva CD. Genetic variation in tilapia populations in man-made reservoirs in Sri Lanka. Aquac. Int. 1997; 5: 339-349.
7. Vitule JRS, Freire CA, Simberloff D. Introduction of non-native freshwater fish can certainly be bad. Fish Fisheries. 2009; 10(1):98-108.
8. Peterson MS, Slack WT, Brown-Peterson NJ, McDonald JL. Reproduction in nonnative environments: Establishment of Nile Tilapia, *Oreochromis niloticus*, in Coastal Mississippi Watersheds. Copeia. 2004; 4:842-849.
9. Petersson E. Impact écologique des repeuplements par des poissons d' élevage sur les espèces sauvages. Aquac. Environ. 2009; 26:36-47.
10. Mallet J. Hybridization as an invasion of the genome. Trends Ecol. Evol. 2005; 20(5):229-237.
11. Bezault E, Rognon X, Clota F, Gharbi K, Baroiller JF, Chevassus B. Analysis of the meiotic segregation in intergeneric hybrids of tilapias. Int. J Evol. Biol. 2012, 1-10.
12. De Azevedo-Santos VM, Rigolin-Sá O, Pelicice FM. Growing, losing or introducing? Cage aquaculture as a vector for the introduction of non-native fish in Furnas reservoir, Minas Gerais, Brazil. Neotrop. Ichthyol. 2011; 9(4):915-919.
13. Boko M, Kosmowski F, Vissin EW. Les Enjeux du changement climatique au Bénin. Konrad-Adenauer-Stiftung Programme, Cotonou, Bénin, 2012, 72.
14. MAEP/JICA. Etude de la promotion de l'aquaculture continentale pour le developpement rural en Republique du Benin: rapport final. Direction de la Production Halieutique, Cotonou, Bénin, 2009, 109.
15. FAO. Vue générale du secteur des pêches national de la République du Bénin. FAO, Rome, Italie, 2008, 42.
16. FAO. Inventaire national de collecte des données sur la pêche. FAO, Cotonou, Bénin, 2009, 8.
17. Country Stat. Base de données statistiques de la FAO. FAO, Rome, Italie, 2016.
18. Imorou-Toko I, Attakpa EY, Baco MN, Gouda AI. Analyse des systèmes piscicoles dans la Vallée du Niger (Nord Bénin). Int. J. Biol. Chem. Sci. 2011; 5(5):1993-2003.
19. Barbosa FI, Hartmann WD. Participatory management of reservoir fisheries in North-Eastern Brazil. FAO Fish. Tech. Pap. 1998; 374:1-15.
20. Lazard J. Transferts de poissons et développement de la production piscicole: Exemple de trois pays d'Afrique subsaharienne. Rev. Hydrobiol. Trop. 1990; 23(3):251-265.
21. Ansah YB, Frimpong EA, Hallerman EM. Genetically-improved tilapia strains in Africa: Potential benefits and negative impacts. Sustainability. 2014; 6(6):3697-3721.
22. Ali L, Islam Z. An assessment of the economic benefits from stocking seasonal floodplains in Bangladesh. FAO Fisheries Technical Paper, Rome, Italy, 1998, 19.
23. Lazard J. Aquaculture et espèces introduites: Exemple de la domestication ex situ des tilapias. Académie de l'Agriculture de France. 2006, 1-2.
24. Hung LT, Luong VC, Hoa NP, Diana J. Impacts of the introduction of alien tilapias (*Oreochromis spp.*) on the fisheries and biodiversity of indigenous species in Tri an reservoir, Vietnam. Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, 2011, 88-100.
25. Bartley D, Casal CV. Impacts of introductions on the conservation and sustainable use of aquatic biodiversity. FAO Aquaculture Newsletter, Lisbon, Portugal, 1998, 15-19.
26. Garibaldi L, Bartley DM. The database on introductions of aquatic species (DIAS): The web site. FAO Aquaculture Newsletter, Lisbon, Portugal, 1998, 20-24.
27. Cross TF. Genetic implications of translocation and stocking of fish species, with particular reference to Western Australia. Aquac. Res. 2000; 31(1):83-94.
28. Daszak P, Cunningham AA, Hyatt AD. Anthropogenic environmental change and the emergence of infectious diseases in wildlife. Acta Trop. 2001; 78:103-116.
29. Lazard J. Les paradoxes et les questionnements soulevés par l'exploitation de la biodiversité (autochtone et introduite) en aquaculture. Potentiels la Sci. pour l'avenir l'agriculture, l'alimentation l'environnement. 2013, 1-13.
30. Nikolic N. Diversité génétique et taille efficace chez les populations de poissons sauvages: le cas du saumon atlantique un poisson migrateur amphihalin menacé.Université de Toulouse III – Paul Sabatier, Toulouse, France, 2009, 308.
31. Senanan W, Kapuscinski AR, Na-Nakorn U, Miller LM. Genetic impacts of hybrid catfish farming (*Clarias macrocephalus* x *C. gariepinus*) on native catfish populations in central Thailand. Aquaculture. 2004; 235(1-4):167-184.
32. Hudson AG, Vonlanthen P, Bezault E, Seehausen O. Genomic signatures of relaxed disruptive selection associated with speciation reversal in whitefish. BMC Evol. Biol. 2013; 13(1):1-17.
33. Neraas LP, Spruell P. Fragmentation of riverine systems: the genetic effects of dams on bull trout (*Salvelinus confluentus*) in the Clark Fork River system. Mol. Ecol. 2001; 10(5):1153-1164.
34. Hutchings JA, Fraser DJ. The nature of fisheries- and farming-induced evolution. Mol. Ecol. 2008; 17(1):294-313.
35. Secrétariat de la Convention sur la diversité biologique. Protocole de Cartagena sur la prévention des risques biotechnologiques relatif à la convention sur la diversité biologique. Québec, Canada, 2000, 19.
36. Isumbisho Mwapu P. Ecologie du zooplancton du lac Kivu (Afrique de l'Est). Facultés Universitaires Notre-Dame de la Paix, Namur, Belgique, 2006, 180.
37. Siri PA, Born AF. Inland fisheries enhancement implementation criteria : Are common measures attainable ? a consultation retrospective. FAO Fish. Tech. Pap. 1998; 374:1-8.
38. Ahmad I, Bland SJR, Price CR, Kershaw R. Open water stocking in Bangladesh: experiences from the third fisheries project. FAO Fisheries Technical Paper. 1998; 374:337-350.